100 – AGN I: Low Luminosity AGN and the Galactic Center
Oral Session – Great Lakes Grand Ballroom – 18 Aug 2014 08:30 am to 10:00 am
Chair(s):
Keith Arnaud (CRESST/UMd/GSFC)

100.01 – Black Holes and Galaxies: An “Active” Field
Tight scaling relations between supermassive black holes (BHs) and galaxies suggest that BHs play an active role in galaxy formation. I will focus on recent results involving actively accreting BHs that probe BH-galaxy coevolution. Specifically, I will focus on recent results in BH demographics and AGN feedback. I will finish with a forecast for exciting new directions opened by facilities like ALMA, NuSTAR, and 30m telescopes.

Author(s): Jenny E. Greene

Institution(s): 1. Princeton University, Princeton, NJ.

100.02 – Hunting for the Variable Iron Line in NGC 4258
Aside from our own Galaxy, NGC 4258 hosts the supermassive black hole with the most precisely known mass and distance. Furthermore, we are viewing a nearly perfectly Keplerian, thin, warped accretion disk nearly edge-on, with our nuclear line of sight passing through the disk. The measured column in this source may be directly probing the disk's accretion rate. NGC 4258 is also important in that it is emitting at only a small fraction of the Eddington luminosity, lying in logarithmic steps half way between bright Seyferts and the extremely low luminosity of Sgr A*. The former exhibit well-formed disk spectra and relativistically broadened Fe lines. The latter, such as M81* (which lies at lower fractional Eddington luminosity than NCG 4258) shows line structure revealed by Chandra-HETG observations which may be indicative of an advective flow. Here we shall discuss the variable, narrow line Fe structure revealed by a series of observations with Chandra-HETGS, XMM, and Suzaku. We compare these results to previous studies of M81* and the recent Chandra-HETGS observations of Sgr A*.

Author(s): Michael Nowak, Christopher S. Reynolds, Sera Markoff, Joern Wilms, Andrew J. Young, John C. Houck

Institution(s): 1. MIT Kavli Institute, Methuen, MA. 2. University of Maryland, College Park, MD. 3. Astronomical Institute Anton Pannekoek, Amsterdam, Netherlands. 4. Dr. Karl Remeis-Sternwarte and ECAP, Bamberg, Germany. 5. University of Bristol, Bristol, United Kingdom. 6. Center for Astrophysics, Cambridge, MA.

100.03 – The 3 Megasecond Chandra Campaign on Sgr A*: A Census of X-ray Flaring Activity from the Galactic Center
Over the last decade, X-ray observations of Sgr A* have revealed a black hole in a deep sleep, punctuated roughly once per day by brief ares. The extreme X-ray faintness of this
supermassive black hole has been a long-standing puzzle in black hole accretion. To study the accretion processes in the Galactic Center, Chandra (in concert with numerous ground- and space-based observatories) undertook a 3 Ms campaign on Sgr A* in 2012. With its excellent observing cadence, sensitivity, and spectral resolution, this Chandra X-ray Visionary Project (XVP) provides an unprecedented opportunity to study the behavior of our closest supermassive black hole. We present a progress report from our ongoing study of X-ray flares, including one of the brightest flares ever seen from Sgr A*. Focusing on the statistics of the flares, the quiescent emission, and the relationship between the X-ray and the infrared, we discuss the physical implications of X-ray variability in the Galactic Center.

**Author(s): Joseph Neilsen**1, 2, Michael Nowak2, Charles F. Gammie3, Jason Dexter4, Sera Markoff5, Daryl Haggard6, Sergei Nayakshin7, Q. D. Wang8, N. Grosso9, D. Porquet9, John Tomsick10, 4, Nathalie Degenaar11, P. C. Fragile12, John C. Houck2, Rudy Wijnands5, Jon M. Miller11, Frederick K. Baganoff2


**100.04 – Update on the Sgr A*/G2 Collison from Chandra and VLA**

The enigmatic object G2 (is it a gas cloud or a star?) has passed pericenter in its encounter with Sgr A*. G2’s highly eccentric orbit brought it within 150 AU of Sgr A*, and IR monitoring has revealed signs of tidal disruption by the black hole. High-energy emission from the Sgr A*/G2 encounter was expected to rise toward pericenter (Spring 2014) and continue over several years as the material circularized, but no clear changes in Sgr A*’s X-ray or radio emission have yet been detected. Continued multiwavelength monitoring will determine the nature of the G2 object. These ambitious campaigns are also poised to distinguish the physical processes that underlie rapid flares originating near the black hole’s event horizon — we have detected the brightest X-ray flare yet recorded in recent Chandra and VLA observations. The appearance of a new magnetar (SGR J174540.2-290029, 2.4” from Sgr A*) and an outburst from a very faint X-ray binary (CXO J174540.0-290005) are also yielding new Galactic Center science. I will present an update on our intensive multiwavelength campaigns and discuss the constraints these data place on theoretical models for the Sgr A*/G2 encounter and Sgr A*’s X-ray flares.

**Author(s): Daryl Haggard**1, Frederick K. Baganoff2, Gabriele Ponti3, Craig O. Heinke4, Nanda Rea5, Joseph Neilsen7, Michael Nowak2, Sera Markoff5, Farhad Yusef-Zadeh1, Douglas A. Roberts1, Christaan Brinkerink8, Casey J. Law9, William D. Cotton6, Stefan Gillessen3, Norbert S. Schulz2, Riley Connors5

**Institution(s):** 1. Northwestern University/CIERA, Evanston, IL. 2. MIT/Kavli Institute, Cambridge, MA. 3. Max-Planck-Institut für extraterrestrische Physik, Garching, Bavaria, Germany. 4. University of Alberta, Edmonton, AB, Canada. 5. University of Amsterdam, Amsterdam, North Holland, Netherlands. 6. NRAO, Charlottesville, VA. 7. Boston University,
100.05 – The Characterization of the Gamma-Ray Signal from the Central Milky Way: A Compelling Case for Annihilating Dark Matter

In scenarios where dark matter particles can annihilate to produce standard model, the galactic center of the Milky Way is expected to provide the highest flux from dark matter in the sky. Recently, we have worked on gamma-ray observations from the Fermi-LAT telescope, and have detected a significant extended excess, which is spherically symmetric around the position of the galactic center, and does not trace any known astrophysical emission profile. In this talk, I will summarize the current status of these observations and discuss dark matter and astrophysical interpretations of the data. I will show results which strongly constrain the properties and the possible interpretations of the observed excess. Finally, I will posit upcoming tests which will strongly suggest, or rule out, a dark matter interpretation.

Author(s): Tim Linden
Institution(s): 1. Astrophysics / KICP, U Chicago / KICP, Chicago, IL.

101 – HEAD Dissertation Prize Talk

101.01 – Particle Acceleration in Merging Galaxy Clusters

Merging galaxy clusters are excellent laboratories to study particle acceleration in dilute cosmic plasmas, to explore the nature of dark matter, and to investigate galaxy cluster growth. In a few dozen merging galaxy clusters diffuse extended radio emission has been found, implying the presence of relativistic particles and magnetic fields in the intracluster medium. A major question is how these particles are accelerated up to such extreme energies. I will present X-ray and radio observations of merging clusters, providing new clues about the acceleration mechanism and extending radio studies to higher redshifts. I will also show the latest results from the new revolutionary low-frequency telescope LOFAR and the upgraded JVLA. These telescopes enable studies of diffuse cluster emission with unprecedented resolution and sensitivity.

Author(s): Reinout J. Van Weeren
Institution(s): 1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

102 – Galaxy Clusters

102.01 – Sunyaev Zel’dovich Cluster Surveys

The Sunyaev Zel’dovich (SZ) effect is the inverse Compton scattering of cosmic microwave background photons off of hot gas, most often associated with clusters of galaxies. The surface brightness of the SZ effect is redshift independent, making it a useful tool to find the most-distant, massive clusters in the Universe. In 2008, the first clusters were found via the SZ effect, and since then, more than 1000 have been identified in SZ surveys, in particular by the Planck satellite, the South Pole Telescope (SPT), and the Atacama Cosmology Telescope (ACT). I will
give an overview of recent results from SZ surveys, describing their cosmological constraints and some of the more spectacular newly discovered clusters. I will also discuss the complimentary of SZ surveys with other multi-wavelength surveys, and the projected improvements for next-generation SZ surveys.

Author(s): Bradford Benson²,¹

Institution(s): 1. University of Chicago, Chicago, IL. 2. Fermilab, Batavia, IL.

102.02 – Weighing the Giants: Galaxy Cluster Cosmology Anchored by Weak Gravitational Lensing

The gas mass fractions and the distribution in mass and redshift of the galaxy cluster population provide powerful probes of cosmology, constraining the cosmic matter density ($\Omega_m$), the amplitude of the matter power spectrum ($\sigma_8$), properties of dark energy, and the mass of neutrinos, among other parameters. Historically, these tests have been limited by the *absolute accuracy* of cluster mass determinations. Here, mass measurements from weak lensing (made in the right way) have an advantage over estimates based on observations of the intracluster medium (ICM), because the former are nearly unbiased and can be straightforwardly tested against simulations. I will report new cosmological constraints obtained from an analysis of X-ray selected cluster samples, incorporating extensive gravitational lensing data from the Weighing the Giants project -- the first cluster cosmology study to consistently integrate a lensing mass calibration, including a rigorous quantification of all systematic uncertainties. Compared with earlier work, which had to incorporate larger systematic allowances associated with an ICM-based mass calibration, our joint constraints on $\Omega_m$ and $\sigma_8$ are improved by a factor of 2. Including Cosmic Microwave Background and other cosmological probes in the analysis, we find no evidence for non-zero neutrino mass in the current data. This result is directly dependent on the absolute cluster mass calibration, and conflicts with some recent cluster results using ICM-based masses, highlighting the need for an accurate mass calibration (such as lensing provides). We also obtain tight constraints on dark energy models; for flat models with a constant equation of state ($w$), the cluster data alone yield $w=-0.98\pm0.15$. Our data, and their combination with other leading cosmological data sets, remain consistent with the concordance model of cosmology, with zero global curvature, dark energy as a non-evolving cosmological constant ($w=-1$), minimal neutrino mass, and gravity described by General Relativity.

Author(s): Adam Mantz¹, Anja Von Der Linden²,³, Steven W. Allen³,⁴, Douglas Applegate⁵, Patrick Kelly⁶, Glenn Morris⁴, David Rapetti², Robert Schmidt⁷, Harald Ebeling⁸


102.03 – Detection of an Unexplained Emission Line at 3.56 keV

We recently detected a weak unidentified emission line at $\sim$3.56 keV in the stacked XMM spectra of 73 galaxy clusters spanning a redshift range 0.01 ? 0.35. The line is seen at $>3\sigma$ statistical significance in all three independent samples of XMM-Newton MOS and the full sample of the PN. The line is also detected at the same energy and consistent flux in the Chandra ACIS-S and ACIS-I spectra of the Perseus cluster, although it is not seen in the ACIS-I
spectrum of Virgo. I will discuss why there should be no atomic transitions in thermal plasma at this energy, leaving the possibility that this line is a signature of decaying of sterile neutrinos.

**Author(s):** Esra Bulbul¹, Maxim L. Markevitch², Adam Foster¹, Randall K. Smith¹, Michael Loewenstein², Scott W. Randall¹

**Institution(s):** 1. Center for Astrophysics, Cambridge, MA. 2. NASA Goddard Space Flight Center, Greenbelt, MD.

102.04 – What do density fluctuations tell us about physics of the ICM?

X-ray images of galaxy clusters show rich substructure on top of global unperturbed surface brightness. The truly spectacular statistics accumulated by X-ray observatories on nearby clusters allows us probe surface brightness and density fluctuations at a range of spatial scales from few 100 kpc down to scales close to a mean free path. Focusing mainly on the nearby clusters, I will address questions on driving mechanisms and properties of observed fluctuations, ICM turbulence and heating of plasma.

**Author(s):** Irina Zhuravleva¹

**Institution(s):** 1. KIPAC/Stanford University, Stanford, CA.

103 – Stellar Clusters and Star Formation

**Special Session – Huron – 18 Aug 2014 02:00 pm to 03:30 pm**

**Chair(s):**

Eric Feigelson (Penn State Univ.)

103.01 – X-ray Insights into the Origin of Star Clusters

Most stars form in clusters of ~100-10,000 stars, often dominated by massive OB stars. Yet the formation process of clusters is poorly understood: Do they form rapidly as a monolithic structure, or slowly over time? Is the merger of subclusters from filaments in a turbulent molecular cloud important? What is the cause of mass segregation where the OB stars concentrate in cluster cores? What are the mechanisms by which most clusters quickly dissipate, releasing their stars into the Galaxy? Progress on these issues has been hampered by the poor census of pre-main sequence (PMS) stars in molecular clouds. Commonly used optical and infrared selection methods are often restricted to subpopulation of PMS stars with accretion from dusty protoplanetary disks. Cloud obscuration and contamination by nebular emission and unrelated Galactic field stars can be severe. X-ray surveys with the high-resolution Chandra X-ray Observatory provide a powerful complement to long-waveband surveys, as PMS stars have greatly enhanced X-ray emission from magnetic reconnection flaring compared to MS stars. Chandra images penetrate through $A_v > 100$ mag and identify disk-free PMS stars with sub-arcsecond precision. This session provides a few of the recent findings based on combined X-ray/infrared surveys of giant molecular clouds and the rich star clusters they produce. In addition to improved samples, new insights are emerging on the formation process of clusters and their early dynamical evolution that improve our understanding of both Galactic and extragalactic star formation.

**Author(s):** Eric Feigelson¹

**Institution(s):** 1. Penn State Univ., University Park, PA.

103.02 – INTER- AND INTRA-CLUSTER AGE GRADIENTS IN MASSIVE STAR FORMING REGIONS AND INDIVIDUAL NEARBY STELLAR CLUSTERS REVEALED BY MYStIX
The MYStIX (Massive Young Star-Forming Complex Study in Infrared and X-ray) project seeks to characterize 20 OB-dominated young star forming regions (SFRs) at distances <4 kpc using photometric catalogs from the Chandra X-ray Observatory, Spitzer Space Telescope, UKIRT and 2MASS surveys. As part of the MYStIX project, we developed a new stellar chronometer that employs near-infrared and X-ray photometry data, AgeJX. Computing AgeJX averaged over MYStIX (sub)clusters reveals previously unknown age gradients across most of the MYStIX regions as well as within some individual rich clusters. Within the SFRs, the inferred AgeJX ages are youngest in obscured locations in molecular clouds, intermediate in revealed stellar clusters, and oldest in distributed stellar populations. Noticeable intra-cluster gradients are seen in the NGC 2024 (Flame Nebula) star cluster and the Orion Nebula Cluster (ONC): stars in cluster cores appear younger and thus were formed later than stars in cluster halos. The latter result has two important implications for the formation of young stellar clusters. Clusters likely form slowly: they do not arise from a single nearly-instantaneous burst of star formation. The simple models where clusters form inside-out are likely incorrect, and more complex models are needed. We provide several star formation scenarios that alone or in combination may lead to the observed core-halo age gradients.

Author(s): Konstantin V. Getman1, Eric Feigelson1, Michael A. Kuhn1, Patrick S. Broos1, Leisa K. Townsley1, Tim Naylor2, Matthew S. Povich3, Kevin Luhman1, Gordon Garmire4


103.03 – MYStIX: Dynamical evolution of young clusters

The spatial structure of young stellar clusters in Galactic star-forming regions provides insight into these clusters’ dynamical evolution—a topic with implications for open questions in star-formation and cluster survival. The Massive Young Star-Forming Complex Study in Infrared and X-ray (MYStIX) provides a sample of >30,000 young stars in star-forming regions (d<3.6 kpc) that contain at least one O-type star. We use the finite mixture model analysis to identify subclusters of stars and determine their properties: including subcluster radii, intrinsic numbers of stars, central density, ellipticity, obscuration, and age. In 17 MYStIX regions we find 142 subclusters, with a diverse radii and densities and age spreads of up to ~1 Myr in a region. There is a strong negative correlation between subcluster radius and density, which indicates that embedded subclusters expand but also gain stars as they age. Subcluster expansion is also shown by a positive radius--age correlation, which indicates that subclusters are expanding at <1 km/s. The subcluster ellipticity distribution and number--density relation show signs of a hierarchical merger scenario, whereby young stellar clusters are built up through mergers of smaller clumps, causing evolution from a clumpy spatial distribution of stars (seen in some regions) to a simpler distribution of stars (seen in other regions). Many of the simple young stellar clusters show signs of dynamically relaxation, even though they are not old enough for this to have occurred through two-body interactions. However, this apparent contradiction might be explained if small subcluster, which have shorter dynamical relaxation times, can produce dynamically relaxed clusters through hierarchical mergers.

Author(s): Michael A. Kuhn1

Institution(s): 1. Pennsylvania State University, University Park, PA.
103.04 – X-ray and IR Surveys of the Orion Molecular Clouds and the Cepheus OB3b Cluster

X-ray and IR surveys of molecular clouds between 400 and 700 pc provide complementary means to map the spatial distribution of young low mass stars associated with the clouds. We overview an XMM survey of the Orion Molecular Clouds, at a distance of 400 pc. By using the fraction of X-ray sources with disks as a proxy for age, this survey has revealed three older clusters rich in diskless X-ray sources. Two are smaller clusters found at the northern and southern edges of the Orion A molecular cloud. The third cluster surrounds the O-star Iota Ori (the point of Orion's sword) and is in the foreground to the Orion molecular cloud. In addition, we present a Chandra and Spitzer survey of the Cep OB3b cluster at 700 pc. These data show a spatially variable disk fraction indicative of age variations within the cluster. We discuss the implication of these results for understanding the spread of ages in young clusters and the star formation histories of molecular clouds.

Author(s): S. Thomas Megeath1, Scott J. Wolk2, Ignazio Pillitteri3, Tom Allen1

103.05 – Cygnus OB2: Star Formation Ugly Duckling Causes a Flap

Cygnus OB2 is one of the largest known OB associations in our Galaxy, with a total stellar mass of 3x10^4 Msun and boasting an estimated 65O-type stars and hundreds of OB stars. At a distance of only 1.4kpc, it is also the closest truly massive star forming region and provides a valuable testbed for star and planet formation theories. Chandra's megasecond 1 square degree survey of the association revealed about 8000 X-ray point sources, approximately 5750 of which have been identified with objects in optical and infrared surveys. The stellar census has enabled studies of sub-structuring, mass segregation and dynamics, while infrared data reveal a story of protoplanetary disk attrition in an extremely harsh radiation environment. We will discuss how Cygnus OB2 challenges the idea that stars must form in dense, compact clusters, and demonstrates that stars as massive as 100 Msun can form in relatively low-density environments. Convincing evidence of disk photoevaporation poses a potential problem for planet formation and growth in starburst environments.

Author(s): Jeremy J. Drake1, Mario G. Guarcello2, 1, Nicholas J. Wright3, 1

Contributing team(s): Chandra Cygnus OB2 Team

104 – Ballooning & Sounding Rockets

Special Session – Great Lakes Grand Ballroom – 18 Aug 2014 02:00 pm to 03:30 pm
Chair(s):
Henric Krawczynski (Washington Univ, St. Louis)

104.01 – Overview of the NASA Suborbital Program

The NASA Suborbital Program consists of Sounding Rocket and Balloon Projects managed, respectively, by the Heliophysics and Astrophysics Divisions of the Science Mission Directorate, which maintains “Program” Offices at the NASA Wallops Flight Facility. Suborbital missions have
for several decades enabled investigations with significant results from relatively modest investments. Some have been competitive with orbital missions, while others have enabled orbital missions. NASA launches suborbital missions from sites established in the U.S. and around the world to meet investigators’ needs. A sea change in scientific ballooning occurred with the inauguration of 8 - 20 day flights around Antarctica in the early 1990’s. The U.S. National Science Foundation supports these circumpolar flights, which have been spectacularly successful with many investigations utilizing multiple flights of payloads that are recovered, refurbished, and reused to minimize life-cycle costs. The attainment of 25 - 32 day and 35 - 55 day flights in two and three circumnavigations, respectively, of the Antarctic continent has greatly increased expectations of scientific users. The 55-day Super-TIGER flight over Antarctica during the 2012-13 season broke the 42-day CREAM record during the 2004-05 season, as well as the 54-day super pressure balloon test flight in 2008-09. Qualification of super pressure flights to support 1000 kg science instruments for up to 100 days at 33 km have proceeded in parallel with plans to increase the altitude for less massive instruments requiring less atmospheric overburden. The nearly constant volume of super-pressure balloons allows stable altitude flights at non-polar latitudes. Long-duration flights in both polar and non-polar regions will confirm the important contributions that ballooning can make in traditional Astrophysics, Solar and Heliophysics, and Earth Science disciplines. With two comets approaching the sun in 2013-14, the Planetary Science community has shown increased interest in remote observations of comets, planets, and other objects in the Solar System.

Author(s): W. Vernon Jones
Institution(s): 1. NASA Headquarters, Washington, DC.

104.02 – Observing Star Formation with the Next Generation BLASTPol Experiment

Despite the significant progress astronomers have made in recent decades, we do not yet fully understand the process of star formation. One of the key uncertainties concerns the role of Galactic magnetic fields. Submillimeter polarimetry of the thermal emission from interstellar dust grains provides a method for mapping the magnetic fields of star forming clouds. After its three successful flights as a total intensity experiment (in 2003, 2005, and 2006), the Balloon-borne Large Aperture Submillimeter Telescope (BLAST) was converted into a polarimetric experiment, BLASTPol, which was flown in Antarctica in 2010 and 2012. With its approx. 2 meter diameter primary mirror and its large-format detector arrays operating at 250, 350, and 500 microns, BLASTPol obtains sub-arcminute diffraction limited resolution over degree-scale fields, making it ideal for linking all-sky, five arcminute resolution dust emission polarization maps from ESA's Planck satellite to sub-arcsecond interferometric polarization maps made using the Atacama Large Millimeter-submillimeter Array (ALMA). We will describe science results from our 2010 and 2012 flights, and present our plans for the next generation BLASTPol experiment, which will contain three arrays of microwave kinetic inductance detectors (MKIDs) allowing a 16-fold increase in mapping speed. The first flight of this new experiment is scheduled for 2016. We anticipate collecting approximately 500,000 individual polarization measurements (a.k.a. "vectors") across our three spectral bands. We will make one quarter of the flight (150 hours) available to the community for "shared risk" observing.

Author(s): Giles Novak
Institution(s): 1. Northwestern Univ., Evanston, IL.
Contributing team(s): The BLAST collaboration

104.03 – Studying the Hot ISM with the X-ray Quantum Calorimeter Sounding Rocket
The X-ray Quantum Calorimeter sounding rocket instrument is a 36-pixel microcalorimeter array with a 1 sr field of view and 8-10 eV FWHM resolution in the 0.1-1.5 keV energy range. XQC has made 6 flights from White Sands Missile Range between 1995 and 2013 to obtain high resolution spectra of the soft diffuse X-ray background. With these spectra we have gained insight into some of the key open questions about the hot interstellar medium in our Galaxy, such as the contribution of Solar Wind Charge Exchange to the observed diffuse background and the extent of iron depletion in the Local Cavity, and even placed constraints on certain types of dark matter. I will present results from previous flights, discuss the current state of data analysis from our most recent flight, and share our outlook for future rocket missions.

Author(s): Kelsey Morgan1, Felix Jaeckel1, Dan McCammon1, Dallas Wulf1, Andrew E. Szymkowiak2, Gabrielle Betancourt-Martinez3, Youaraj Uprety4


104.04 – The Off-plane Grating Rocket Experiment (OGRE)
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.

Author(s): Randall L. McEntaffer1, Casey DeRoo1, James Tutt1, Ted Schultz1, William Zhang2, Ryan McClelland2, Neil Murray3, Andrew Holland3

Institution(s): 1. University of Iowa, Iowa City, IA. 2. NASA Goddard Space Flight Center, Greenbelt, MD. 3. Open University, Milton Keynes, United Kingdom.

104.05 – The Micro-X High-Energy-Resolution Microcalorimeter X-ray Imaging Rocket
The 2015 flight of the Micro-X Sounding Rocket Payload will obtain the first broad-band high-resolution X-ray spectrum of the diffuse emission from a supernova remnant. Its 128-pixel Transition-Edge-Sensor array is coupled to a 300 cm^2 grazing-incidence optic with a bandpass between 0.2-3 keV. An energy resolution between 2-4 eV will provide the unprecedented ability to measure plasma properties on an element-by-element basis. Measurements of the temperature, bulk velocity, turbulence, and ionization equilibrium can be individually done for O, Ne, Fe, Mg, Si, and S. Spatial correlations in our 11.8 arcmin field of view can be made with our 2.4 arcmin imaging resolution. Our first target is the Bright Eastern Knot, a complex cloud-shock interaction region in the Puppis A supernova remnant. Other targets for future flights include a Si-rich ejecta region in Puppis A as well as the Cas A supernova remnant. We overview the science and present results from the integration tests of the payload as we prepare for our first flight.

Author(s): Enectali Figueroa-Feliciano1

Institution(s): 1. Massachusetts Institute of Technology, Cambridge, MA.
Contributing team(s): Micro-X Collaboration

104.06 – The hard X-ray polarimeter X-Calibur

X-ray polarimetry promises to give qualitatively new information about high-energy astrophysical sources, such as binary black hole systems, micro-quasars, active galactic nuclei, and gamma-ray bursts. We designed, built and tested a hard X-ray polarimeter, X-Calibur, to be used in the focal plane of the balloon-borne InFOCuS grazing incidence hard X-ray telescope. X-Calibur combines a low-Z Compton scatterer with a CZT detector assembly to measure the polarization of 20-60 keV X-rays making use of the fact that polarized photons Compton scatter preferentially perpendicular to the electric field orientation. The X-Calibur detector assembly is completed, tested, and calibrated. X-Calibur achieves a high detection efficiency of order unity. The results of the performance studies will be presented. A first flight is scheduled from Ft.Sumner, NM, in fall 2014. In principal, a similar space-borne experiment could be operated in the 5-100 keV regime.

Author(s): Matthias Beilicke

Institution(s): 1. Washington University of ST.LOUIS, ST.LOUIS, MO.

Contributing team(s): X-Calibur collaboration

104.07 – The Compton Spectrometer and Imager (COSI) Superpressure Balloon Payload

The Compton Spectrometer and Image (COSI) is a ULDB-borne soft gamma-ray telescope (0.2-5 MeV) designed to probe the origins of Galactic positrons, uncover sites of nucleosynthesis in the Galaxy, and perform pioneering studies of gamma-ray polarization in a number of source classes. COSI uses a compact Compton telescope design, resulting from a decade of development under NASA’s ROSES program – a modern take on techniques successfully pioneered by COMPTEL on CGRO. COSI performs groundbreaking science by combining improvements in sensitivity, spectral resolution, and sky coverage. The COSI instrument and flight systems have been designed for flight on NASA’s 18 MCF superpressure balloon (SPB). We are now beginning a series science flights to fulfill the COSI science goals: a SPB in 2014 from Antarctica, followed by two 100-day ULDB flights from New Zealand. COSI is a wide-field survey telescope designed to perform imaging, spectroscopy, and polarization measurements. It employs a novel Compton telescope design utilizing a compact array of cross-strip germanium detectors (GeDs) to resolve individual gamma-ray interactions with high spectral and spatial resolution. The COSI array is housed in a common vacuum cryostat cooled by a mechanical cryocooler. An active CsI Shield encloses the cryostat on the sides and bottom. The FoV of the instrument covers 25% of the full sky at a given moment. The COSI instrument builds upon considerable heritage from the previous Nuclear Compton Telescope (NCT) balloon instrument that underwent a successful technology demonstration flight in June 2005 from Fort Sumner, NM, a successful “first light” science flight from Fort Sumner in May 2009, and a launch campaign from Alice Springs, Australia in June 2010, where it unfortunately suffered a launch mishap. COSI has been upgraded from the previous NCT instrument by conversion to a detector configuration optimized for polarization sensitivity and addition of a cryocooler to remove consumables (LN2) for ULDB flights. In this talk, we will present the redesign of the COSI instrument and payload, as well as the overall flight program and science goals of our ULDB science flight program.

Author(s): Steven E. Boggs
105 – X-ray Binaries I

Oral Session – Great Lakes Grand Ballroom – 18 Aug 2014 04:00 pm to 05:30 pm

Chair(s):
Paolo Coppi (Yale Univ.)

105.02 – A Deep Chandra Survey of One of the Nearest Star-Forming Low-Metallicity Galaxies: First Results

The production rate of neutron stars and black holes remains poorly known because single objects are dim and most binaries are weakly interacting, yielding only faint signatures from the compact object. We won a 1.1Ms Chandra Cycle 14 Visionary Project (PI A. Zezas) to address this using the Small Magellanic Cloud (SMC) as a laboratory to find all the weakly interacting X-ray binaries and determine the compact object production rate as a function of star formation history. This deep survey aims to identify the nature of X-ray sources detected down to few times $10^{32}$ erg/s in fields with young ($<$100 Myr) stellar populations of different ages. These data will provide the deepest X-ray luminosity functions for X-ray binaries (XRBs) in a low metallicity (0.2Z$_{\odot}$) star-forming galaxy. They will allow the study of the formation and evolution of accreting XRBs and will provide observational constraints on mass-transfer mechanisms. We detect 50-100 sources per field and measure their X-ray photometric and spectroscopic parameters. Lightcurve analysis is used to identify accreting pulsars and flaring objects. Based on source multi-wavelength properties, we will identify high-mass XRBs and study their clustering with star-forming regions.

Author(s): Vallia Antoniou$^{1}$, Andreas Zezas$^{1}$, Jeremy J. Drake$^{1}$, Paul P. Plucinsky$^{1}$

Institution(s):
1. Smithsonian Astrophysical Observatory, Cambridge, MA.

Contributing team(s): SMC XVP Collaboration

105.03 – Simultaneous Chandra and NuSTAR View of the Bursting Pulsar

The LMXB GRO J1744-28 entered a new episode of activity at the beginning of 2014, after nearly 18 years of quiescence. During outburst, the luminosity of this unique source reaches the Eddington luminosity, and, aside from the rapid burster, it is the only source showing type II bursts, followed by a dip in the persistent emission intensity. We will discuss here nearly three hours of simultaneous Chandra HETG and NuSTAR observations. The high spectral resolution of Chandra gratings and the broad energy coverage of NuSTAR allowed for an unprecedented look at the source bursts, dips, and persistent emission spectra during outburst.

Author(s): George A. Younes$^{1}$, Chryssa Kouveliotou$^{2}$, Jamie A. Kennea$^{3}$, Brian Grefenstette$^{4}$, Jon M. Miller$^{5}$, John Tomsett$^{6}$, Fiona Harrison$^{4}$

Institution(s):

105.04 – NuSTAR detection of an absorption line in the Type I burst spectrum of GRS 1741.9-2853

We report on two NuSTAR observations of GRS 1741.9-2853, a faint neutron star LMXB burster located 10? away from the Galactic center. We caught the source serendipitously as it emerged
from quiescence (since July 2010). A bright H-triggered mixed H/He thermonuclear Type I burst with mild photospheric radius expansion (PRE) is present during the second observation. Assuming an H mass fraction $X = 0.7$ in the atmosphere and a neutron star mass $M = 1.4M_\odot$, we determine a new distance for this source at $6.3 \pm 0.5$ kpc, but we note that it should be regarded as a lower limit. We searched for oscillations during the burst and the outburst but found none. A narrow absorption line at $5.49 \pm 0.08 \pm 0.10$ keV is detected during the PRE phase of the burst at the 99.5% confidence level, which most likely formed in the wind above the photosphere of the neutron star. We speculate that the line is formed by resonant Kα transition from H-like Cr gravitationally redshifted by a factor $1 + z = 1.08$, corresponding to a radius range of 29.0 – 41.4 km for a mass range of 1.4 – 2.0 $M_\odot$.

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**105.05 – Discovery of a Neutron Star Oscillation Mode During a Superburst**

Neutron stars are among the most compact objects in the universe and provide a unique laboratory for the study of cold ultra-dense matter. Asteroseismology can provide a powerful probe of the interiors of stars. For example, helioseismology has provided unprecedented insights about the interior of the Sun, but comparable capabilities for neutron star seismology have not yet been achieved. Here we report the discovery of a coherent X-ray modulation from the neutron star 4U 1636-536 during the February 22, 2001 thermonuclear superburst seen with NASA’s Rossi X-ray Timing Explorer (RXTE) that is very likely a global oscillation mode. The observed frequency is $835.6440 \pm 0.0002$ Hz (1.43546 times the stellar spin frequency of 582.14323 Hz) and the modulation is well described by a sinusoid with an amplitude of 0.19 ± 0.04 %. The observed frequency is consistent with the expected inertial frame frequency of an $m=2$ rotationally-modified g-mode or perhaps an r-mode, where $m$ is the mode's azimuthal wavenumber. Interestingly, this frequency is within 1.5 % of the candidate oscillation frequency recently identified in the accreting millisecond X-ray pulsar XTE J1751-305 assuming that the relevant mode has $m=2$, and the observed frequency is indeed the mode's inertial frame frequency. If this is correct, it is conceivable that the same oscillation mode is detected in both 4U 1636-536 and XTE J1751-305, but we observe the mode's inertial frame frequency in the former, and the co-rotating frame frequency in the latter. Our results provide further strong evidence that global oscillation modes can indeed produce observable modulations in the X-ray flux from neutron stars.

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**106 – AGNs**

**106.01 – The origin of the soft excess emission in Ark 120, and the importance of taking the broad view**

We present results of a simultaneous NuSTAR and XMM-Newton observation of the bright radio-quiet Seyfert 1 galaxy, Ark 120. The broad band coverage allowed us to disentagle the various spectral components, and in particular the soft X-ray emission. For the latter component, we found that Comptonization by a population of warm electrons is the most likely explanation.

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**Contribution team(s):** NuSTAR AGN Physics WG

**106.02 – The AGN of NGC 4151 as revealed by NuSTAR and Suzaku**

Through X-ray timing and spectral analyses of simultaneous, 150 ks Nuclear Spectroscopic Telescope Array (NuSTAR) and Suzaku X-ray observations of the Seyfert 1.5 galaxy NGC 4151, we determine the properties of the innermost regions of the active galactic nucleus (AGN). Despite spectral complexity added by a possible Compton-thin eclipse, we constrain the dimensionless spin of the supermassive black hole (SMBH) in NGC 4151 for the first time through a spectral analysis. Applying a “lamp post” model for the innermost regions of the accretion disk, we find evidence that the corona is compact. To investigate time-variability of the inner accretion disk emission during an eclipse, we develop a library of time-dependent spectra and light curves covering a large range of disk, black hole, and absorber parameters. This library, when applied to an observation of a Compton-thick eclipse of the inner disk, will enable specific tests of inner accretion disk reflection models. We make these simulations available to the community in the form of table models useable in standard X-ray data analysis software.

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**Contribution team(s):** The NuSTAR Team

**106.03 – NuSTAR and XMM-Newton Observations of NGC 1365: Extreme Absorption Variability and a Constant Inner Disk**

Measurement of black hole spin in active galactic nuclei has the potential to enhance our understanding of how the black holes powering these sources grew to be so massive. To date, the best methods for measuring AGN spin are anchored in X-ray spectroscopy, and primarily involve studying relativistic reflection features from the inner accretion disk. However, there
has been a long-standing debate surrounding such measurements, with models dominated by absorption and reprocessing in distant structures proposed as alternative interpretations of the observed X-ray spectra. We present the results from a series of four coordinated NuSTAR+XMM-Newton observations of the Seyfert galaxy NGC 1365, which has recently become central to this debate. Despite exhibiting an extreme range of absorption states, each of the observations displays the same characteristic signatures of relativistic reflection from the inner accretion disk. Through time-resolved spectroscopy, we find a clear link between the broad iron emission and the Compton reflection hump, and that each of the observations independently gives consistent parameters for the inner disk. These results strongly support the view that such regions are both observationally accessible and influence the observed spectra, and confirm that NGC 1365 hosts a rapidly rotating black hole.

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**Contributing team(s):** The NuSTAR Team

**106.04 – NuSTAR Reveals the Comptonizing Corona of the Broad-Line Radio Galaxy 3C 382**

Broad-line radio galaxies (BLRGs) are active galactic nuclei that produce powerful, large-scale radio jets, but appear as Seyfert 1 galaxies in their optical spectra. In the X-ray band, BLRGs also appear like Seyfert galaxies, but with flatter spectra and significantly weaker reflection features. One possible explanation for these properties is that the X-ray continuum is diluted by emission from the jet. Here, we present two *NuSTAR* observations of the BLRG 3C 382 that show clear evidence that the continuum of this source is dominated by thermal Comptonization, as in Seyfert 1 galaxies. The two observations were separated by over a year and found 3C 382 in different states separated by a factor of 1.7 in flux. The lower flux spectrum has a photon-index of $\gamma = 1.68_{-0.02}^{+0.03}$, while the photon-index of the higher flux spectrum is $\gamma = 1.78_{-0.03}^{+0.02}$. Thermal and anisotropic Comptonization models provide an excellent fit to both spectra and show that the coronal plasma cooled from $kT_e = 228 \pm 19$ keV in the low flux data to $158_{-76}^{+35}$ keV in the high flux observation (assuming a slab geometry). These are precisely the characteristics of a Comptonizing corona, and are distinct from those found in jet-dominated sources. 3C 382 exhibits very weak reflection features, which may be best explained by an outflowing corona combined with an ionized inner accretion disk.

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106.05 – NuSTAR measurement of the high spin of the supermassive black hole in NGC 4051

We present the results of a NuSTAR campaign consisting of three 50 ks long observations of the AGN in NGC 4051, one of the local, bright AGN displaying the most extreme X-ray variability. The very hard >10 keV spectrum, with a strong 30 keV peak present even in the highest flux states, can be formally reproduced either by a reflection-dominated component, or by Compton-thick absorption of an intrinsic continuum at least an order of magnitude brighter than observed, or by a combination of the two. The absorption-only interpretation would imply a highly super-Eddington luminosity, and/or an X-ray dominated SED. The high relative flux of the reflected component in the other two cases requires an X-ray source within a few gravitational radii from a maximally rotating black hole.

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106.06 – NuSTAR View of the Nearby Obscured AGN

The first focusing hard X-ray telescope, NuSTAR, is about to take the studies of obscured AGN to a new level by enabling deep extragalactic surveys with unprecedented spatial resolution and two orders of magnitude higher sensitivity than any other instrument operating in the same bandpass. With its sensitivity at energies above 10 keV, NuSTAR enables us to directly probe the population of obscured AGN both locally and up to z~2. In order to better understand the high-redshift counterparts, we are conducting a hard X-ray spectroscopic survey of nearby obscured AGN selected from the Swift/BAT catalog. This will ultimately provide the largest collection of high-quality hard X-ray spectra to date and enable studies of the unresolved geometry of the obscuring and reprocessing material in the local AGN population. In this talk I will present some of the first results from spectral modeling of Compton-thick AGN observed in this survey, the challenges they pose for the currently available spectral models, and the importance of the multi-wavelength approach in constraining the unresolved structure of obscured AGN. I will also briefly present a preliminary analysis of the survey sample, which is nearing completion at the end of 2014.

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Contributing team(s): NuSTAR Extragalactic Science Team

106.07 – Hot Flow Model for Low Luminosity AGNs and Black Hole Binaries: the Role and Origin of Non-thermal Electrons

Optically thin, two-temperature accretion flows are widely considered as a relevant accretion mode below ~0.01 L_eedd in AGNs as well as in X-ray binaries. We study spectral formation in such flows using a refined model with a fully general relativistic description of both the radiative (leptonic and hadronic) and hydrodynamic processes, and with an exact treatment of global Comptonization. We point out that basic properties of two-temperature flows determine the relative strengths of the synchrotron radiation of thermal electrons and non-thermal electrons from charged-pion decay, in a manner consistent with observations. In AGNs, the non-thermal synchrotron dominates the seed photon input down to ~10^{-5} L_eedd and it allows to explain the X-
ray spectral index–Eddington ratio relation as well as the cut-off energies measured in the best-studied AGNs; the (standard) model with the thermal synchrotron being the main source of seed photons does not agree with these observations. For stellar-mass black holes, non-thermal electrons from hadronic processes become important only above \ (~0.01 L_{Edd}) (and may be relevant for the non-thermal tails observed in luminous hard states of Cyg X-1 and GX 339-4) and we find that the thermal synchrotron provides a sufficient seed photon flux to explain observations of black hole transients below \ (~0.01 L_{Edd}). We also note that non-thermal acceleration processes in hot flows are constrained by comparisons of the predicted gamma-ray fluxes (from neutral pion decay) with Fermi-LAT upper limits. For NGC 4151, it limits the energy content in the non-thermal component of proton distribution to at most 1 per cent.

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**106.08 – The Parsec-scale Structure and Kinematics of Radio-Loud Narrow-Line Seyfert 1 Galaxies**

We have begun a campaign to monitor a sample of 15 radio-loud narrow-line Seyfert 1 galaxies (NLS1s) with the Very Long Baseline Array (VLBA). Here, we present early results from this program, which includes total intensity and polarimetric observations at 1, 2, 4, and 6cm wavelengths. NLS1s are a class of active galactic nuclei that share many observational properties with the much more powerful blazar classes. Despite their low black hole masses and near- or super-Eddington accretion rates, a small minority are radio loud. A growing number of these have been detected in GeV gamma rays, indicating that a relativistic jet has formed in at least some of these sources. This presents a challenge to jet models, but may provide a link between jets found at the small scales of galactic binaries and the large scales of giant quasars. In addition to our VLBA program, we are carrying out complementary fast-cadence single dish 2cm radio monitoring with the Owens Valley Radio Observatory 40m telescope and an optical spectroscopic monitoring campaign using the Guillermo Haro Astrophysics Observatory 2m-class telescope in Cananea, Mexico. Using data from this program, we will expand the currently limited knowledge of the parsec-scale properties and kinematics of this class of sources. Among our first epoch results, we find significant parsec-scale extension in about two thirds of our sample, many of which are excellent candidates for jet kinematics analysis.

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**106.09 – Gamma-ray flares in blazars accompanied by synchrotron polarization angle swings**

We present a detailed analysis of time- and energy-dependent synchrotron polarization signatures in a shock-in-jet model for gamma-ray blazars. Our calculations employ a full 3D radiation transfer code, considering synchrotron emission from a helical magnetic field, and
taking into account all light-travel-time and other relevant geometric effects, while the relevant synchrotron self-Compton and external Compton effects are handled with a 2D Monte-Carlo/Fokker-Planck code. We find that a scenario in which a relativistic shock propagating through the jet leads to a compression of the magnetic field, increasing the toroidal field component, can lead to correlated synchrotron + SSC flaring, associated with substantial variability in the synchrotron polarization percentage and position angle (PA). Most importantly, this scenario naturally explains large PA rotations by ?180 deg, as observed in connection with gamma-ray flares in several blazars, without the need for bent or helical jet trajectories or other non-axisymmetric jet features.

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106.10 – Very High Energy Blazars and the Potential for Cosmological Insight

Gamma-ray blazars are among the most extreme astrophysical sources, harboring phenomena far more energetic than those attainable by terrestrial accelerators. These galaxies are understood to be active galactic nuclei that are powered by accretion onto supermassive black holes and have relativistic jets pointed along the Earth line of sight. The emission displayed is variable at all wavelengths and timescales probed thus far, necessitating contemporaneous broadband observations to disentangle the details of the emission processes within the relativistic jets. The very high energy (VHE; E> 100 GeV) photons emitted by these sources are detectable with ground based imaging atmospheric Cherenkov telescopes such as VERITAS. As these photons propagate extragalactic distances, the interaction with the diffuse starlight that pervades the entire Universe results in a distance and energy dependent gamma-ray opacity, offering a unique method for probing photon densities on cosmological scales. These galaxies have also been postulated to be potential sources of ultra-high-energy cosmic rays, a theory which can be examined through the deep gamma-ray observations of sources which probe moderate gamma-ray opacities. Within this talk, I will highlight ongoing research regarding the broadband emission from VERITAS-observed VHE blazars, as well as the potential to use them for cosmological insight.

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Contributing team(s): VERITAS

106.11 – Bright gamma-ray flares of the quasars 3C 279 and PKS 1222+216 observed at the highest energies with Fermi-LAT and VERITAS

Flat spectrum radio quasars (FSRQs) are the most powerful sources continuously detected at gamma-ray energies, with luminosities exceeding $10^{48}$ erg s\(^{-1}\). The high-energy emission of quasars peaks in the MeV-GeV band, and only a few episodic detections have been reported at very high energies (VHE, E>100 GeV). We will present the first results from an observing campaign on the FSRQ 3C 279 in April 2014 during the brightest gamma-ray outburst ever recorded for this object, with flux exceeding the historic 1991 flare seen by EGRET. Observations include simultaneous coverage with the Fermi-LAT satellite and the VERITAS ground-based array spanning four decades in energy from 100 MeV to 1 TeV with
unprecedented sensitivity. We will also report on the detection of persistent VHE emission from the quasar PKS 1222+216 over a week-long period in March 2014. These observations present strong challenges to current models of energy dissipation in relativistic jets. The implications of the absence/presence of VHE emission in connection with flaring activity in the MeV-GeV regime will be discussed, especially concerning the role of ambient photon fields in the radiation mechanisms, and the size and location of the gamma-ray emission region.

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Contributing team(s): VERITAS Collaboration

106.12 – Fermi GBM observations of the hard x-ray spectrum of Mrk 421
The Gamma-ray Burst Monitor (GBM) on Fermi uses the Earth Occultation technique for long-term monitoring of the hard X-ray/low energy gamma-ray sky. GBM produces multi-band light curves and spectra for known sources and transient outbursts in the 8 keV to 1 MeV energy range with its NaI detectors and up to 40 MeV with its BGO detectors. Mrk 421, one of the brightest and closest (z=0.031) established TeV blazars, is listed as a marginal detection in the GBM 3 year catalog. In this work, we report on five years of monitoring results for Mrk 421. Mrk421 was active between 2009 and 2010. The spectrum from the joint MAXI and GBM data in the range of 2-60 keV show clearly a curved spectrum fitted by a Log Polynomial function.

Author(s): Ching-Cheng Hsu, Ching-Cheng Hsu, Valerie Connaughton, Michael L. Cherry, James Rodi, Narayana P. Bhat, Mark H. Finger, Peter Jenke, Colleen Wilson-Hodge


106.13 – First-Epoch VLBA Images of Twenty Fainter TeV Blazars
Ground-based TeV gamma-ray telescopes have now detected over 40 high-frequency peaked BL Lac objects (HBLs), making them by far the most common type of TeV source. However, except for the brightest few, these TeV HBLs have not yet been well studied in the radio with VLBI imaging. Such VLBI imaging is the only way to reveal the parsec-scale jet structure and kinematics of these sources, which in turn constrains the Lorentz factor, viewing angle, and Doppler factor of their jets. Here we present first-epoch VLBA images of 20 recently announced and radio-fainter TeV HBLs, obtained with the sensitivity-upgraded VLBA during 2013. We discuss the parsec-scale jet morphologies, the radio-core brightness temperatures, and correlations between VLBI properties and properties measured at other wavebands.

Author(s): B. G. Piner, Philip Edwards


106.14 – Simultaneous X-ray and gamma-ray observations of Mrk 421 during a strong flaring episode
We will present results from a multiwavelength campaign on Mrk 421 during a strong flaring episode at TeV gamma-ray energies. Mrk 421 is a nearby BL Lac object and is one of the brightest AGN in very high energy (VHE; E>100 GeV) gamma-ray band. Significant flux variation of the source on a wide range of timescales, months down to minutes, has been observed in the past in both X-ray and TeV energies where its spectral energy distribution peaks. Therefore, it is essential to observe the source simultaneously in different wavebands, in order to
accurately and reliably study its time-dependent multiwavelength behavior. However, such data are severely lacking, especially for studies of rapid variability on sub-hour timescales. On 2014 April 25, Mrk 421 flared up to about 7 times of the Crab Nebula flux at TeV energies, as observed by MAGIC. We triggered a long-standing XMM ToO program and carried out simultaneous X-ray/gamma-ray observations of the source with XMM and VERITAS, with contemporaneous support from MAGIC and a number of radio and optical facilities. Due to XMM visibility constraints, the observations occurred in three separate orbits, with each lasting continuously for over 4.5 hours. Results from detailed temporal, spectral, and correlative studies will be described and discussed.

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Contributing team(s): a large MWL collaboration

106.15 – Probing Fast X-ray Variability of Blazars with a Large Data Set from Swift
The Swift X-ray Telescope has obtained 0.2-10 keV x-ray data on numerous blazars over timescales ranging from seconds to more than 8 years. Much of these data come from intense target of opportunity observations that can be analyzed in a multiwavelength context and used to model jet parameters, particularly during flare states. Another large component of these data comes from monitoring that was obtained during a variety of flux states. By looking at this broad data set, one can evaluate variability timescales and limit the emission mechanisms and associated parameters. Some of these blazars are known to exhibit variability timescales on the order of minutes in the gamma-ray band and tens of minutes in the x-ray band. We report on our search for short timescale x-ray variability that could limit the size and nature of the emission region/s in blazar jets.

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106.16 – SMARTScience Tools: Interacting With Blazar Data In The Web Browser
The Yale-SMARTS blazar group has accumulated 6 years of optical-IR photometry of more than 70 blazars, mostly bright enough in gamma-rays to be detected with Fermi. Observations were done with the ANDICAM instrument on the SMARTS 1.3 m telescope at the Cerro Tololo Inter-American Observatory. As a result of this long-term, multiwavelength monitoring, we have produced a calibrated, publicly available data set (see www.astro.yale.edu/smarts/glast/home.php), which we have used to find that (i) optical-IR and gamma-ray light curves are well correlated, supporting inverse-Compton models for gamma-ray production (Bonning et al. 2009, 2012), (ii) at their brightest, blazar jets can contribute significantly to the photoionization of the broad-emission-line region, indicating that gamma-rays are produced within 0.1 pc of the black hole in at least some cases (Isler et al. 2014), and (iii) optical-IR and gamma-ray flares are symmetric, implying the time scales are dominated by light-travel-time effects rather than acceleration or cooling (Chatterjee et al. 2012). The volume of data and diversity of projects for which it is used calls out for an efficient means of visualization. To this end, we have developed a suite of visualization tools called SMARTScience Tools, which allow users to interact dynamically with our dataset. The SMARTScience Tools is publicly available via our webpage and can be used to customize multiwavelength light curves and color magnitude diagrams quickly and intuitively. Users can choose specific bands to
construct plots, and the plots include features such as band-by-band panning, dynamic zooming, and direct mouse interaction with individual data points. Human and machine readable tables of the plotted data can be directly printed for the user’s convenience and for further independent study. The SMARTSScience Tools significantly improves the public’s ability to interact with the Yale-SMARTS 6-year data base of blazar photometry, and should make multiwavelength studies of blazars even more accessible, efficient, and community driven.

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**106.17 – What can we learn from the Fourier analysis of blazar light curves?**

Blazars display strong variability on multiple timescales and in multiple radiation bands. Their variability can be characterized by power spectral densities (PSDs) and time lags as a function of Fourier frequency. We develop a new theoretical model based on analysis of the electron continuity equation carried out in the Fourier domain. This model predicts features in the synchrotron, synchrotron self-Compton (SSC), and external Compton (EC) PSDs and time lags associated with electron cooling, escape, and light travel time effects across the electromagnetic spectrum, from sub-mm to gamma-rays. We also find that FSRQs should have steeper PSD power-law indices than BL Lac objects at low Fourier frequencies if FSRQs produce gamma-rays by EC and BL Lac objects by SSC emission, in qualitative agreement with reported observations by the Fermi Large Area Telescope.

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**106.18 – Eddington-class flares and their distance from the central black hole in blazars**

The distance from the central engine at which the bright gamma-ray flares of blazars take place is an open question with implications on our understanding of jet formation and collimation. In some cases, pair opacity arguments suggest that the detection of sub-TeV photons points to the emission taking place beyond the ~0.1 pc size broad line region. Here we show that for bright flares having beaming-corrected luminosity comparable to the Eddington luminosity (Eddington-class flares), strong deceleration due to Compton drag is expected if the flare takes place inside the 1-few pc molecular torus region. This is incompatible with the highly superluminal speeds these sources exhibit, requiring that Eddington-class flares take place beyond the molecular torus. We demonstrate this in the case of the MAGIC-detected source PKS 1222+21 (Aleksic et al. 2011), a source that exhibited Eddington-class flares in 2010 (Tanaka 11).

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**106.19 – Sneaky Gamma-Rays: Using Gravitational Lensing to Avoid Gamma-Gamma-Absorption**

It has recently been suggested that gravitational lensing studies of gamma-ray blazars might be a promising avenue to probe the location of the gamma-ray emitting region in blazars. Motivated by these prospects, we have investigated potential gamma-gamma absorption
signatures of intervening lenses in the very-high-energy gamma-ray emission from lensed blazars. We considered intervening galaxies and individual stars within these galaxies. We find that the collective radiation field of galaxies acting as sources of macrolensing are not expected to lead to significant gamma-gamma absorption. Individual stars within intervening galaxies could, in principle, cause a significant opacity to gamma-gamma absorption for VHE gamma-rays if the impact parameter (the distance of closest approach of the gamma-ray to the center of the star) is small enough. However, we find that the curvature of the photon path due to gravitational lensing will cause gamma-ray photons to maintain a sufficiently large distance from such stars to avoid significant gamma-gamma absorption. This re-inforces the prospect of gravitational-lensing studies of gamma-ray blazars without interference due to gamma-gamma absorption due to the lensing objects.

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### 106.20 – Blazar Observations with the Space-Borne X-Calibur X-Ray Polarimeter

Blazars are an excellent science topic for X-ray polarimetry as the emission is non-thermal and highly polarized. We explore the scientific return from spectropolarimetric observations of blazars - Active Galactic Nuclei (AGNs) with jets aligned with the line of sight. We discuss three different science investigations: (i) probing the structure and role of magnetic fields in AGN jets, (ii) deciding on the origin of the high-energy emission component, (iii) probing Lorentz Invariance Violations (LIVs). We discuss new theoretical results and outline a possible observation program.

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### 106.21 – Quasar Jets on the kpc scale: Fast and Super-Eddington or Slow and Multi-TeV Accelerators?

A long-standing debate exists around the nature of the anomalously high X-ray emission from the kpc-scale resolved quasar jet emission, which is related to the question of their speeds on the kpc scale. Are they fast (Lorentz factors ~10-20) and powerful (in many cases super-Eddington) or slow, sub-Eddington, and multi-TeV particle accelerators? This question has direct bearing on the physics of cluster heating by powerful jets. Also, the slow jet case implies that the beaming-corrected radiated power of the jet on kpc scales may be comparable to, or even exceed that of the blazar (core) emission, with important implications for the GeV background radiation and the heating of intergalactic gas by TeV photons. The widely accepted model for producing the high X-ray emission has been a highly-relativistic kpc-scale jet producing inverse Compton emission by up-scattering the cosmic microwave background (IC/CMB), though the X-rays could also be synchrotron emission from a multi-TeV electron population accelerated in situ, as both models can reproduce the observed radio to X-ray spectra. We present very recent work by our group, showing that IC/CMB model is ruled out in
at least two cases. In both 3C 273 PKS 0637-752, the uniquely determined GeV flux predicted by the IC/CMB model overproduces the 99.9% flux limits obtained from recent Fermi gamma-ray observations.

Author(s): Eileen T. Meyer¹, Markos Georganopoulos², William B. Sparks¹

106.22 – Stability of Astrophysical Jets
Compared to their terrestrial and laboratory counterparts, the astrophysical jets appear to be very stable - for example, the extragalactic jets cross the distances that are up to one billion times larger than their initial radius. Many years after their discovery and numerous theoretical and numerical studies, there is still no consensus as to what is behind this remarkable stability. We argue that this must be a very robust reason, not sensitive to the details of internal jet structure and composition, but rather reflecting their environment. In particular, the astrophysical jets propagate through "atmospheres" with rapidly declining pressure (and density), which results in their rapid sideways expansion - e.g. the radius of the M87 jet increases by the factor close to one million. Such a rapid expansion renders the causal connectivity across jets ineffective and can even suppress it altogether, resulting in free expansion of the jets. When the connectivity is lacking, the jets cannot develop coherent large scale displacements, which otherwise would threaten their integrity and survival. We present the results of new 3D numerical simulations of expanding magnetized relativistic jets, designed to test this idea.

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Contributing team(s): Porth, O.

106.23 – Time Dependent Leptonic Modeling of Fermi II Processes in the Jets of Flat Spectrum Radio Quasars.
We discuss the results of the fitting of a time dependent leptonic model to the blazar 3C 273, in order to investigate different flaring scenarios between different bandpasses. We use a general set of input parameters to model the spectral energy distribution of the blazar 3C 273. We then apply perturbations to a set of the input parameters (magnetic field, injection luminosity, acceleration time scale) and investigate the lightcurves and correlations/anti-correlations between different bandpasses produced by these perturbations. We find that an increase in the acceleration efficiency causes a distinct correlation between the optical and gamma ray bandpasses. We also observe an anti-correlation between the radio and x-ray bandpasses with the flare in the x-rays lagging behind the other flare components by a few hours. This anti-correlation between the radio and the x-rays could represent an observational signature of a flare produced by Fermi II acceleration.

Author(s): Chris S. Diltz¹, Markus Boettcher¹,²
Institution(s): 1. Physics and Astronomy, Ohio University, Athens, OH. 2. North Western University, Potchefstroom, South Africa.

106.24 – Radiation from accelerated particles in relativistic jets with shocks and shear-flow
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. Kinetic Kelvin-Helmholtz instability (KKHI) is also responsible to create strong DC and AC magnetic fields. The velocity shears in core-sheath jets create strong magnetic field perpendicular to the jet. We examine how the Lorentz factors of jets affect the growth rates of KKHI. We have calculated, self-consistently, the radiation from electrons accelerated in these turbulent magnetic fields in the shocks. 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 will investigate synthetic spectra from accelerated electrons in strong magnetic fields generated by KKHI. 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.

Author(s): Ken-Ichi Nishikawa¹, Phil Hardee², Ioana Dutan³, Jacek Niemiec⁴, Mikhail Medvedev⁵, Athina Meli⁶, Yosuke Mizuno⁷, Aake Nordlund⁸, Jacob Trier Frederiksen⁹, Helene Sol⁹, Bing Zhang¹², Martin Pohl¹⁰,¹³, Dieter Hartmann¹¹

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106.25 – Particle Diffusion and Localized Acceleration in Inhomogeneous AGN Jets

We present an inhomogeneous AGN jet model built on our time-dependent multi-zone radiation code that permits studying how particle acceleration and spatial diffusion complicate the energy-dependent jet inhomogeneity. In the code, a Fokker-Planck equation is used to describe the electrons accelerated through a second-order Fermi process. A Monte Carlo method is used for the radiative transfer, so that light travel time effects are taken into account. To account for inhomogeneity, we use a 2D axi-symmetric cylindrical geometry for both relativistic electrons and magnetic field. We found that small isolated acceleration regions in a much larger emission volume are sufficient to generate high energy particles needed for the X-ray and gamma-ray emission. Diffusive escape from these regions provides a natural explanation for the spectral form of the jet emission. Characteristic spectral hardening can be identified at high energies if diffusive escape is relatively inefficient. Various possible geometries and locations of the acceleration region are evaluated to further assess the structure of the relativistic jets and the energy dissipation processes in them. If the acceleration region is not located at the center of the emission region, the electron spectrum is an atypical broken power-law. The change in the power-law index, which is a result of both particle cooling and escape, is less than 1, the traditionally assumed value.

Author(s): Xuhui Chen¹,², Martin Pohl¹,², Markus Boettcher³,⁴

Institution(s): 1. University of Potsdam, Potsdam, Brandenburg, Germany. 2. DESY, Zeuthen, Brandenburg, Germany. 3. North-West University, Potchefstroom, South Africa. 4. Ohio University, Athens, OH.

106.26 – Cosmic Collisions: Galaxy Mergers and Evolution
Over the years evidence has mounted for a significant mode of galaxy evolution via mergers. This process links gas-rich, spiral galaxies; starbursting galaxies; active galactic nuclei (AGN); post-starburst galaxies; and gas-poor, elliptical galaxies, as objects representing different phases of major galaxy mergers. The post-starburst phase is particularly interesting because nearly every galaxy that evolves from star-forming to quiescent must pass through it. In essence, this phase is a sort of galaxy evolution “bottleneck” that indicates that a galaxy is actively evolving through important physical transitions. In this talk I will present the results from the ‘Galaxy Zoo Quench’ project – using post-starburst galaxies to place observational constraints on the role of mergers and AGN activity in quenching star formation. ‘Quench’ is the first fully collaborative research project with Zooniverse citizen scientists online; engaging the public in all phases of research, from classification to data analysis and discussion to writing the article and submission to a refereed journal.

Author(s): Laura Trouille\textsuperscript{1, 3}, Kyle Willett\textsuperscript{2}, Karen Masters\textsuperscript{4}, Christopher Lintott\textsuperscript{4}, Laura Whyte\textsuperscript{3}, Stuart Lynn\textsuperscript{3}, Christina A. Tremonti\textsuperscript{5}


Contributing team(s): Zooniverse Team

107 – Astroparticles, Cosmic Rays, and Neutrinos
107.01 – Probing Efficient Cosmic-Ray Acceleration in Young Supernovae using the Cherenkov Telescope Array

It is widely accepted that supernova (SN) shocks can accelerate particles to very high energies, although the maximum energies are still unclear. These accelerated particles can interact with other particles to produce gamma-ray emission. Details of the process are not well characterized, including the dynamics and kinematics of the SN shock wave, the nature and magnitude of the magnetic field, and the details of the particle acceleration process. The properties of the SN shock itself are regulated by the surrounding medium, which in a massive star is formed by mass-loss from the pre-SN progenitor during its lifetime. Thus the spectra of accelerated particles, and the resultant gamma-ray emission, depend on the evolution of the SN progenitor before it explodes. Herein we explore in detail aspects of SN evolution, particle acceleration, and the non-thermal emission, for young SNe right after outburst. We use these calculations to predict and constrain the detectability of young SNe of various types with the next generation gamma-ray telescope, the Cherenkov Telescope Array.

Author(s): Vikram Dwarkadas\textsuperscript{1}, Matthieu Renaud\textsuperscript{2}, Alexandre Marcowith\textsuperscript{2}, Vincent Tatischeff\textsuperscript{3}

Institution(s): 1. Univ. of Chicago, Chicago, IL. 2. Universite Montpellier 2, Montpellier, France. 3. Universite Paris-Sud, Orsay, France.

107.02 – High Energy Astrophysics with the HAWC Observatory

The High Altitude Water Cherenkov (HAWC) Observatory detects astrophysical gamma rays and cosmic rays in the energy range from 100 GeV to 100 TeV. Located at an elevation of 4100 meters on the slopes of Sierra Negra in the Mexican state of Puebla, HAWC comprises an array of 300 water Cherenkov tanks covering an area of 22000 square meters and is scheduled for completion in 2014. Using 1200 upward-facing photomultiplier tubes distributed throughout
the tanks, HAWC measures the Cherenkov radiation generated by air-shower particles, from which the direction and energy of the primary particle may be determined. The detector has been taking data as a partial array for more than a year. I will highlight cosmic-ray and gamma-ray observations from this initial data set, including measurements of the cosmic-ray anisotropy and searches for transient sources. I will also discuss the expected contributions of HAWC to gamma-ray science as the detector enters full operation in the coming year.

Author(s): Thomas Weisgarber

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Contributing team(s): the HAWC Collaboration

107.03 – Proton Calorimetry and Gamma-Rays in Arp 220

Until recently, it was thought that starburst galaxies were both electron and proton calorimeters, making them especially bright in gamma-rays. However, with detections of starburst galaxies M82 and NGC 253 by Fermi, HESS, and VERITAS, we find that such galaxies are only partial proton calorimeters due to significant advection by galactic winds. Thus, to find cosmic-ray proton calorimeters, we must look for much denser systems. Previous models of the cosmic ray interactions in Arp 220 (e.g. Torres 2004) suggest it is a proton calorimeter and that it should already be detectable by Fermi. The Torres model suggests that if Arp 220 is a calorimeter, then it should have been detected in gamma-rays by Fermi at levels above current upper limits. We therefore must question. whether Arp 220 is a true proton calorimeter, and if so what other properties could be responsible for its low gamma ray flux. Here, we further explore the observed ranges on environmental properties and model the central nuclei to predict both the radio and gamma-ray spectra. We test the proton calorimetry hypothesis and estimate the observation time needed for a detection by Fermi for a range of assumptions about conditions in Arp 220.

Author(s): Tova Yoast-Hull, John S. Gallagher, Ellen G. Zweibel

Institution(s): 1. University of Wisconsin-Madison, Madison, WI.

107.04 – Ultra-High Energy Neutrino Astrophysics from Greenland; In situ measurements of the Radio Attenuation Length at the proposed Greenland Neutrino Observatory Site

Neutrino astrophysics allows us to explore the ultra-high energy universe from a unique perspective and to test our understanding of particle physics at energies greater than those achievable at particle colliders. The future of ultra-high energy neutrino detection lies with ground-based radio arrays with the sensitivity required to reach even the most pessimistic models of neutrino production. The Greenland Neutrino Observatory (GNO) is a proposed ground-based radio array located at Summit Station in Greenland. We present an in situ measurement of the radio attenuation length of the ice from 50 - 200 MHz at the Summit Station site taken in June 2013, and show that Summit Station is a world-class location for a next-generation radio detector of ultra-high energy neutrinos.

Author(s): Jessica Avva, Abigail Vieregg

Institution(s): 1. University of Chicago, Chicago, IL.

Contributing team(s): Greenland Neutrino Observatory

107.05 – Indirect Dark Matter Detection in Dwarf Spheroidal Galaxies at VERITAS

Recent data and cosmological models point to a significant fraction of the Universe comprised of Cold Dark Matter (DM), though little is known about it directly. The most likely explanation
for Dark Matter is a Weakly Interacting Massive Particle (WIMP) having a mass as low as 10 GeV to as high as 10 TeV. Many direct and indirect detection schemes have been proposed to search for the elusive particle. Dwarf Spheroidal Galaxies (dSphs) orbiting the Milky Way Galaxy are suitable targets for indirect DM detection via gamma-rays because the ratio of their gravitational mass to luminous mass is high and their gamma-ray background from other astrophysical sources is low. We present preliminary results on the VERITAS observations of five dSphs. The thermally-averaged DM annihilation velocity-weighted cross-section can then be computed from the gamma-ray flux upper limit.

**Author(s):** James Tucci¹, John P. Finley¹, Ben Zitzer²

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**Contributing team(s):** The VERITAS Collaboration

107.06 – Constraints on Axions and Axion-Like Particles from Fermi-LAT Observations of Neutron Stars

We present constraints on the nature of axions and axion–like particles (ALPs) by analyzing gamma–ray data from neutron stars using the Fermi Large Area Telescope. In addition to solving the strong CP problem of particle physics, axions and ALPs are also possible dark matter candidates. We investigate axions and ALPs produced by nucleon–nucleon bremsstrahlung within neutron stars. We derive a realistic spectral model for the gamma–ray spectrum arising from axion decays, taking into account the effect of axion to photon conversion. By analyzing a sample of 4 nearby neutron stars, we obtain a combined 95% confidence level upper limit on the axion mass $m_a$ of 3.98 eV, which corresponds to a lower limit for the Peccei-Quinn scale $f_a$ of $1.51 \times 10^6$ GeV. Our constraints are more stringent than previous results probing the same physical process, and are competitive with results probing axions and ALPs by different mechanisms.

**Author(s):** Bijan Berenji¹, 2, Jennifer M. Siegal-Gaskins³


**Contributing team(s):** Fermi LAT Collaboration

108 – Cosmic Backgrounds and Deep Surveys

108.01 – The VERITAS Survey of the Cygnus Region of the Galaxy

VERITAS (Very Energetic Radiation Imaging Telescope Array System) is an array of four 12 m diameter Imaging Atmospheric Cherenkov Telescopes (IACTs) located at Mt Hopkins, AZ. From 2007 to 2009 VERITAS undertook an extensive survey of the Cygnus region from 67 to 82 degrees Galactic longitude and from -1 to 4 degrees in Galactic latitude. This is a region with many promising Very High Energy (VHE) gamma-ray candidates such as supernova remnants, pulsar wind nebulae, high mass X-ray binaries and massive star clusters including previously detected VHE gamma-ray sources and dozens of GeV gamma-ray sources (detected by the Fermi-LAT). Along with the initial 140 hours of observations, there are over 150 hrs (a total of 294 hours after cuts for bad weather) of follow-up pointed VERITAS observations in the region that we are analyzing with updated analysis techniques. Here we present the current status of this analysis, and of an analysis of over five years of Fermi-LAT data in the region. Using a cross
correlation of these results we can motivate continued observations in this active region of the Galaxy, and will incorporate multi-wavelength perspectives into a future results paper.

**Author(s):** Alexis Popkow\(^1\), Taylor Aune\(^1\), Rene A. Ong\(^1\), John E. Ward\(^2\)

**Institution(s):** 1. UCLA, Santa Monica, CA. 2. Washington University in St. Louis, St. Louis, MO.

**Contributing team(s):** for the VERITAS Collaboration

108.02 – The ChIcAGO Survey: Multi-wavelength Identification of Galactic Plane X-ray Sources

I present the Chasing the Identification of ASCA Galactic Objects (ChIcAGO) survey, which is designed to identify the unknown X-ray sources discovered during the ASCA Galactic Plane Survey (AGPS). Little is known about most of the AGPS sources, especially those that emit primarily in hard X-rays (2-10 keV) within the \(F_x \approx 10^{-13}\) to \(10^{-11}\) erg cm\(^{-2}\)s\(^{-1}\) X-ray flux range. In ChIcAGO, the subarcsecond localization capabilities of Chandra have been combined with a multi-wavelength follow-up program, with the ultimate goal of classifying the unidentified sources in the AGPS. Overall to date, 93 unidentified AGPS sources have been observed with Chandra as part of the ChIcAGO survey. A total of 253 X-ray point sources have been detected in these Chandra observations within 3\(^\prime\) of the original ASCA positions, the majority of which have optical and infrared counterparts. Using these multi-wavelength follow-up results I have developed a new statistical diagnostic for identifying likely populations of X-ray emitting sources. These studies have revealed that the primary populations of Galactic plane X-ray sources that emit in the \(F_x \approx 10^{-13}\) to \(10^{-11}\) erg cm\(^{-2}\)s\(^{-1}\) flux range are active stellar coronae, massive stars that are possibly in colliding-wind binaries, X-ray binaries, and magnetars. There is also another primary population that is still unidentified but, on the basis of its X-ray and infrared properties, likely comprise partly of Galactic sources and partly AGN.

**Author(s):** Gemma Anderson\(^1\), Bryan M. Gaensler\(^2\), Patrick O. Slane\(^3\), David L. Kaplan\(^4\), Bettina Posselt\(^5\)

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**Contributing team(s):** The ChIcAGO Team

108.03 – X-ray Scattering through the Intergalactic Medium: Time Variability and Ghost Halos

Dust grains polluting the intergalactic medium (IGM) have a chance of being detected through the phenomenon of X-ray scattering, which produces a diffuse arcminute-scale halo around bright X-ray point sources. We present follow up work to Corrales & Paerels (2012) by calculating the expected intensity of intergalactic dust scattering halos using the more exact Mie scattering treatment. This adjustment is necessary to check for large 0.1-1 micron sized dust grains that would interfere with the photometry needed for high precision measurements of cosmological constants. Even with the supreme focusing power of Chandra, we find that the dust scattering halo intensity is much dimmer than the Chandra PSF wings. However, scattered light takes a longer path to reach the observer, causing intergalactic scattering halos to be delayed ~10,000 years. I investigate the possibility of detecting a scattering halo around a quasar that has recently become dim, or ghost halos from quasars that are no longer visible.

**Author(s):** Lia Corrales\(^1\),\(^2\)

**Institution(s):** 1. Columbia University, New York, NY. 2. MIT Kavli Institute, Boston, MA.
108.04 – Intensity of the Isotropic Diffuse Gamma-ray Background from 100 MeV to 820 GeV

The gamma-ray sky can be decomposed into individually detected sources, diffuse emission attributed to the interactions of cosmic rays with gas and radiation fields in our Galaxy, and a residual all-sky emission component commonly called the isotropic diffuse gamma-ray background (IGRB). The IGRB comprises all extragalactic emissions too faint or too diffuse to be resolved in a given survey, as well as any residual Galactic foregrounds that are indistinguishable from isotropic. The sum of the IGRB and individually resolved extragalactic sources represents our best estimate of the total extragalactic gamma-ray background. The first IGRB measurement with the Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope used 10 months of sky-survey data and considered an energy range between 200 MeV and 100 GeV. Improvements in event selection and characterization of particle backgrounds, better understanding of the diffuse Galactic emission, updated emission models for the Earth atmosphere, Sun, and Moon, as well as a longer data accumulation of 50 months, allow for a refinement and extension of the IGRB measurement with the LAT, now covering the energy range from 100 MeV to 820 GeV. We discuss the possible presence of a high-energy cutoff (>100 GeV) in the IGRB, as well as systematic uncertainties that impact the shape and normalization of the measured spectrum.

Author(s): Keith Bechtol

Institution(s): 1. University of Chicago, Chicago, IL.

Contribution team(s): Fermi-LAT Collaboration

108.05 – Detecting the Missing Baryons in X-rays with a Statistical Approach

The Warm Hot Intergalactic Medium (WHIM) (non-virialized, filamentary gas at temperatures between $10^5$ and $10^7$ K, density $<1000 \, \rho_h$ and size of several Mpc) has been proposed as the major reservoir for the baryons that are detected in the distant Universe but are missing at low redshift ($z<1$). We analyzed the 3 Ms XMM-Newton observations of the Chandra Deep Field South in order to characterize the Angular Autocorrelation Function (AcF) from the WHIM. We removed all known virialized structures to obtain a fair map of the Diffuse X-ray Background (DXB) for the bands [0.4-0.6] keV ad [0.7-0.9] keV where the WHIM contribution is expected to be the highest. We detected a signal significantly different from zero for both energy bands, in good agreement with theoretical predictions. As the contribution from other sources has been removed, this is strong evidence of the WHIM contribution to the DXB and possibly the best claim so far of WHIM detection in X-rays. Furthermore, by comparing the contributions of the two bands we have also been able to estimate the average physical properties of the gas responsible of the AcF signal, namely average temperature and density. In particular, the derived density can be used to explain the missing baryons.

Author(s): Eugenio Ursino, Massimiliano Galeazzi, Wenhao Liu, Tomykkutty Velliyyedathu

Institution(s): 1. University of Miami, Miami, FL.

108.06 – The Chandra COSMOS Legacy Survey: first results

The COSMOS field is the only large (2 sq. deg.) field for which complete, deep, panchromatic data exist and which all large telescopes can observe due to its equatorial location. In 2013, the COSMOS survey was greatly extended, thanks to the Chandra COSMOS Legacy Survey, the second largest extragalactic Chandra project ever approved. This survey is aimed at studying the formation of the structures in the high redshift Universe and understanding the role active
super massive black holes played in their evolution. With 56 overlapping ACIS-I pointings of 50-ksec depth each, the Chandra COSMOS-Legacy survey uniformly covers the 1.7 sq. deg. COSMOS/HST field to ~160 ksec depth, with a total of 2.8 Ms exposure time. This triples the area of the earlier deep C-COSMOS survey (limiting flux ~3e-16 ergs/cm2/s in the 0.5-2 keV band), and together these two projects cover a total area of 2.2 sq. deg., yielding a sample of ~4200 X-ray sources. We present the survey properties, the procedure adopted to obtain our final catalog and the first scientific highlights, focusing on the high redshift (z>3) sample.

Author(s): Stefano Marchesi¹ ³, Francesca M. Civano¹ ², Martin Elvis², C. M. Urry¹, Andrea Comastri⁴

Institution(s): 1. Yale University, New Haven, CT. 2. SAO - Smithsonian Astrophysical Observatory, Cambridge, MA. 3. Università di Bologna, Bologna, Italy. 4. INAF-OABO, Bologna, Italy.

109 – Galactic Black Holes
109.01 – A Global Look at Reflection in Black-Hole X-ray Binaries Using RXTE
Spectral reflection is ubiquitous in black-hole X-ray binaries, and is produced by the coronal hard X-ray emission illuminating the cooler accretion disk. The observed interplay between coronal and reflection spectral components provides insight into the geometry of the corona - an attribute which is presently only weakly constrained We present first results from a new campaign analyzing all RXTE PCU-2 spectra of accreting stellar-mass black holes. A simple but self-consistent treatment of disk, coronal, and reflection emission highlights changes evident in the coronal geometry between soft and hard spectral states.

Author(s): James F. Steiner¹, Javier Garcia¹, Ruben C. Reis², Jeffrey E. McClintock¹

Institution(s): 1. Smithsonian Astrophysical Observatory, Cambridge, MA. 2. University of Michigan, Ann Arbor, MI.

109.02 – LMXB X-ray Transients: Revealing Basic Accretion Parameters in Non-stationary Regimes
X-ray observations of low mass X-ray binaries(LMXBs), especially those black hole transient systems, have been very important in shaping up our understanding of black hole accretion and testing accretion theory in a broad range of accretion regimes. We show strong evidence for non-stationary accretion regimes in the X-ray observations of spectral states and multi-wavelength observations of disk-jet coupling in more than 100 outbursts of 36 black hole and neutron star transients in the past decade or so. The occurrence of spectral state transitions and the peak episodic jet power during the rising phase of transient outbursts are found correlated with rate-of-increase of the X-ray luminosity, indicating the rate-of-change of the mass accretion rate, in addition to the mass accretion rate, must be considered when interpreting observations of spectral state transitions and disk-jet coupling in these X-ray transients. This is supported by observations since the increase of the mass accretion rate due to its rate-of-change on the observational time scale of interest is significant during outbursts.

Author(s): Wenfei Yu¹, Zhen Yan¹, Hui Zhang¹, Wenda Zhang¹

Institution(s): 1. Shanghai Astronomical Observatory, Shanghai, China.

109.03 – Swift Observations of the 2014 Outburst of the X-ray Nova/Black Hole Candidate GRS 1739-278
The bright X-ray transient and black hole candidate GRS 1739-278 is currently undergoing its second outburst since its discovery in 1996 (Vargas 1997). The 1996 outburst lasted nearly 300 days and showed rapid X-ray variability early in the outburst when the source was in the high and very high states (Borozdin 2000), and a strong 5-Hz quasi-periodic oscillation (QPO) was discovered in a single Rossi X-ray Timing Explorer observation during the very high state (Borozdin 2000; Wijnands 2001). Based on these variations and spectral state changes, Borozdin (2000) proposed that GRS 1739-278 contains a black hole candidate. The current outburst began in early March 2014 and continues through mid-May, reaching a peak of ~300 mCrab in the 15-50 keV band, a factor of ~3 lower than the peak in 1996. The source has exhibited a complicated light curve in Swift observations, both in the Burst Alert Telescope (BAT) where it shows flux variations of a factor of two on time scales as short as five days, and in the X-Ray Telescope (XRT), which is more sparsely sampled, but shows strong variability in intensity and hardness ratio both on long (multi-day) and short (~minute) time scales. This is suggestive of an outburst that has remained in the hard state. The long series of Swift observations enables us to track the evolution of spectral parameters with fine temporal resolution through a series of spectral states. We also search the XRT data for evidence of QPOs or other timing features. These spectral and timing studies and the 18-year gap between outbursts give new insight into the nature of this system and its evolution, and will help to confirm the black hole nature of the compact source. We will also compare this system to other X-ray novae black-hole binary systems in outburst like V404 Cyg.

Author(s): Hans A. Krimm2, 1, Jamie A. Kennea3, Nikolai Shaposhnikov5, 1, John Tomsick4


110 – Galaxies & ISM

110.01 – The origin of the “local” $\frac{1}{2}$ keV X-ray flux

The Solar Wind interacts with interstellar neutrals via charge exchange producing a spatially and temporally varying x-ray flux difficult to separate from other diffuse sources. The Diffuse X-rays from the Local Galaxy (DXL) mission measured the spatial signature of Solar Wind Charge eXchange (SWCX) emission using 2 large-area proportional counters. DXL was able to separate the SWCX contribution from the more dominant flux originating in the Local Hot Bubble. The data from the mission provide a robust estimate of the SWCX contribution to the RASS data in the $\frac{1}{2}$ keV band, showing that the total SWCX contribution is 40%±5% (stat) ±5% (sys) of the minimal $\frac{1}{2}$ keV flux in the Galactic plane. This result implies that the measured fluxes are dominated by interstellar emission, strengthening the idea of a hot bubble filling the cavity in the local interstellar medium extending ~50-150 pc from the Sun. Combined with recent three-dimensional maps of the local interstellar medium and Voyager measurements of the magnetic field outside the heliosphere, it also leads to a consistent picture of the local interstellar environment.

Author(s): Youaraj Uprety1, Meng Chiao2, Michael Collier2, Thomas Cravens3, Massimiliano Galeazzi1, Dimitra Koutroumpa4, K. D. Kuntz5, Rosine Lallement6, Susan T. Lepri7, Wenhao Liu1,
Shadowing Observations of the Soft X-ray Background with XMM-Newton and Suzaku

Shadows in the soft X-ray background allow one to separate the Galactic halo’s X-ray emission from the local foreground emission due to the Local Bubble and/or solar wind charge exchange. Accurate measurements of the foreground emission and of the halo emission are needed to test models of solar wind charge exchange and of the origin of the hot halo gas, respectively.

We present results from XMM-Newton and Suzaku observations of six shadowing interstellar clouds. While results for some of these shadows have previously been published, this is the first uniform analysis of a sample of CCD-resolution shadowing observations. Our sample includes two shadows in the northern Galactic hemisphere, for which there are no published CCD-resolution shadowing observations, and a compact shadowing cloud that fits into a single XMM-Newton field. For each shadow, we fit spectral models to the on- and off-shadow spectra in order to separate the Galactic halo emission from the foreground emission. For this purpose, we explore different foreground spectral models, including a thermal plasma (Local Bubble) model, and solar wind charge exchange models. We can therefore examine the sensitivity of the inferred halo parameters to the assumed foreground model. In addition, two of our shadows have been observed with both XMM-Newton and Suzaku - we can use these shadows to test whether or not a given foreground model yields consistent halo measurements from two observations separated in time.

Author(s): David Henley¹, Robin L. Shelton¹, Renata Cumbee¹, Phillip C. Stancil¹

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

It is well-known that most galaxies are missing most of their baryonic mass. Perhaps more surprisingly, they also seem to be missing most of their metals. I will present Chandra, XMM-Newton and Suzaku observations probing our Milky Way halo in absorption and emission. Our results show that the Milky Way halo contains a huge reservoir of warm-hot gas that may account for a large fraction of missing baryons and metals. I'll review current status of this field, discuss implications of our results to models of galaxy formation and evolution and outline paths for future progress.

Author(s): Smita Mathur¹, Anjali Gupta¹, Yair Krongold²

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Author(s): Smita Mathur¹, Anjali Gupta¹, Yair Krongold²

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**110.04 – Filamentary star formation in a unique environment**

The most spectacular examples of star formation outside of galactic disks occur in the vicinities of some brightest cluster galaxies (BCGs) in rich, X-ray bright ‘cool core’ galaxy clusters. We present the results of HST optical and UV photometry of massive star formation that is occurring at large projected distances (~20 kpc) from the centre of the BCG NGC 1275 in the Perseus cluster. The star formation is occurring in situ in an extensive filamentary nebulosity which engulfs the host galaxy. Powerful AGN feedback is responsible for distributing the cool gas to large radii which then sits in the hot, high pressure intra-cluster medium. We model the ages and masses of the young star clusters and determine that the star-forming filaments switched on ~50 Myrs ago and are currently feeding the growth of the NGC 1275 stellar halo at a rate of 2-3 solar masses per year. Star formation in filamentary nebulae surrounding BCGs could lead to dynamically hot, spatially extended stellar halos and globular cluster systems. This mode of star-formation may also be important in early galaxy formation where powerful AGN are common and the pressurised external atmospheres in these systems may be supplied by the in-falling intergalactic medium.

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**110.05 – Faint X-Ray Binaries and Their Optical Counterparts in M31**

To investigate the XRB population in M31, we utilized all 121 publicly available observations of M31 totalling over 1 Ms from the Chandra X-Ray Observatory’s ACIS instrument. Of 83 star clusters in the bulge identified in the year 1 star cluster catalog from the Panchromatic Hubble Andromeda Treasury Survey, we found 15 unique star clusters that matched to 17 X-ray point sources within 1? (3.8 pc). This population is composed predominantly of globular cluster low-mass XRBs, with one previously unidentified star cluster X-ray source. Logistic regression showed that the F475W magnitude was the most important predictor of the probability a cluster hosted an X-ray source, followed by the effective radius, while color (F475W-F814W) was not a statistically significant predictor of whether a cluster hosted an X-ray source. The lack of dependence on color is likely due to our sample being restricted to metal-rich bulge star clusters. We also matched X-ray sources to 1566 H II regions in the disk and found 10 unique matches to 9 X-ray point sources within 3? (11 pc). Logistic regression showed that neither the radius nor H? luminosity were significant predictors of an H II region hosting an X-ray source. Four matches have no previous classification and thus are high-mass XRB candidates. A stacking analysis of both star clusters and H II regions resulted in non-detections, giving typical upper limits of \(?10^{32}\) erg s\(^{-1}\), which probes the quiescent XRB regime. We are now using the Chandra ACIS observations to compile a new X-ray point source catalog. In some regions of M31 the exposure time reaches ~500 ks, ~2.5 times deeper than any previous work. This allows us to reach limiting luminosities of \(\sim10^{33}\) erg s\(^{-1}\). We report preliminary results (e.g. source characteristics, X-ray luminosity functions) from this work.

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**110.06 – A diagnostic tool for compact objects and accretion states of X-ray binaries**

Classification of X-ray binaries on the basis of their compact object and/or accretion state is one of the key components for understanding their populations. We present the first results from
an effort to develop a diagnostic scheme that can be used to distinguish between different
types of accreting objects and accretion states based on their X-ray colours and/or luminosity.
This diagnostic scheme is based on the analysis of RXTE spectra of Galactic X-ray binaries for
which we have characterized the spectral state of each RXTE observation. Based on these
observations and extensive simulations we have defined the locus of accreting pulsars and
black-hole X-ray binaries of different states in X-ray colour-colour and colour-intensity
diagnostics. We compare these diagnostics with data from Chandra and NuSTAR observations
in order to test them and characterize the X-ray binaries in nearby galaxies. We also present
correction factors that can be used to estimate the bolometric accretion luminosity of an X-ray
binary based on its observed luminosity and accretion state.

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**110.07 – The discrete X-ray source population of M51**

We present results on the discrete X-ray source population of the nearby interacting galaxy
system M51 from new and archival observations by the Chandra X-ray Observatory with total
exposure time of nearly 1 Ms. This dataset allows us to study the spectral and temporal
variability of the X-ray source population on timescales ranging from tens of seconds to years. In
addition to the X-ray data, we utilize deep observations from the Hubble Space Telescope
legacy archive to examine unique source counterparts and optical environments of X-ray
sources. We also present, for the first time for any galaxy in the Chandra era, an image
reconstruction in which the point sources are treated as true point sources, removing the
smoothing artifacts that cause off-axis sources to appear blurred and elongated with greatly
exaggerated flux. For this analysis, we have developed a code to model the 2D point spread
function for each source in each observation, then synthesize an on-axis point source with the
correct spectral properties. The synthesized point sources are then re-added to an image of the
diffuse emission. The 2D PSF modeling also provides extremely accurate regions for source
extraction, allowing us to recover the true flux and X-ray colors for faint, off-axis sources.

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**110.08 – The Ultraviolet Halos of Nearby Spiral Galaxies**

We developed a new method to study cool gas in spiral galaxy halos by measuring the light
scattered by dust grains embedded in halo gas using GALEX and Swift. These halos are faint (a
few percent of the galaxy luminosity) but ubiquitous and extend 10-20 kpc above the midplane
of highly inclined galaxies, and their luminosities and spectral energy distributions tell us about
the mass and metal content of the cool gas near the disk. Our ability to image the halos in
nearby galaxies allows us to examine how these quantities change as a function of position
around the galaxy. I will present a brief overview of the method and its potential as applied to
several nearby edge-on galaxies with high quality data.
**Author(s):** Edmund J. Hodges-Kluck, Joel N. Bregman, Julian Cafmeyer

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**110.09 – Implications of Ultraviolet Halos in Spiral Galaxies**

We have detected ultraviolet halos out to about 10-20 kpc around numerous galaxies by measuring light scattered by dust in the halo. The properties of these halos may give insight into the properties of halo gas (such as mass or metal content) and help explain why galaxies are missing most of their baryonic matter. We will present correlations between the halo luminosity and several galaxy properties for several sub-samples of spiral galaxies, and discuss the implications for galaxy growth.

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**110.10 – NuSTAR observations of the starburst galaxy NGC 253: constraints on diffuse inverse Compton emission**

The nearby starburst galaxy NGC 253 has been detected at GeV and TeV energies, however, the dominant emission mechanism responsible for the gamma-ray luminosity is challenging to determine from the Fermi-LAT and H.E.S.S. data alone. Understanding what fraction of the gamma-ray signal comes from hadronic processes has implications for the non-thermal energy density in actively star-forming regions in both cosmic rays and magnetic fields. The focusing hard X-ray optics of NuSTAR have enabled the most sensitive search to date for diffuse inverse Compton emission in the 10-30 keV energy range in a starburst galaxy. We discuss NuSTAR upper limits on the diffuse inverse Compton component in the context of broadband spectral models.

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**Contributing team(s):** NuSTAR

**110.11 – In Search of AGN in Starburst Galaxies with NuSTAR**

The coeval growth of supermassive black holes (SMBH) and their stellar halo hosts provides evidence that star formation and AGN activity must be closely associated, but it is not clear to what extent they must always be coordinated. A prime test of this coordination is the search for AGN activity in starburst galaxies, which by definition have high star-formation rates but whose SMBH can be illusive due to low luminosities and obscuration. NuSTAR offers a unique opportunity to detect AGN activity in starbursts because of its high-sensitivity X-ray imaging above 10 keV. We present the preliminary results of searching for X-ray emission in the starburst galaxies in the NuSTAR starburst program. To date three starbursts have been observed, Arp 299, M83, and NGC 253. Of these, only the nucleus of the western galaxy in the Arp 299 pair has been detected strongly above 20 keV, suggesting that this is the only galaxy harboring an obscured AGN. Evidence from combined Chandra and NuSTAR monitoring indicate that the SMBH in NGC 253 was nearly dormant in 2012 (L/LEdd < 10^-4); however, Chandra data from 2003 indicates that a low-luminosity AGN may have been more active a decade ago. The AGN in the western nucleus of Arp 299 is Compton-thick (N_H ~ 2 x 10^24 cm^-2) and also exhibits neutral Fe-K emission. We will discuss the implications of these results as well as prospects for detecting AGN in the remainder of the NuSTAR starburst sample.
Author(s): Andrew Ptak\textsuperscript{1,2}, Ann E. Hornschemeier\textsuperscript{1,2}, Andreas Zezas\textsuperscript{3}, Vallia Antoniou\textsuperscript{4}, Meg Argo\textsuperscript{5}, Keith Bechtol\textsuperscript{6}, Fiona Harrison\textsuperscript{6}, Roman Krivonos\textsuperscript{7}, Bret Lehmer\textsuperscript{1,2}, Thomas J. Maccarone\textsuperscript{8}, Daniel Stern\textsuperscript{9}, Tonia M. Venters\textsuperscript{1}, Daniel R. Wik\textsuperscript{1,2}, Mihoko Yukita\textsuperscript{1,2}, William Zhang\textsuperscript{1}, Malachi Tatum\textsuperscript{1,10}


110.12 – What's important at z>5? X-ray Emission from Starbursts!

There has recently been quite a bit of excitement on the role of X-ray emission from galaxies in reionization. It turns out that the X-ray output from X-ray binaries and hot gas are both likely important and may rival the ionizing output of AGN at z>5, particularly for Hydrogen reionization. Here we present our research on constraining the X-ray SED of high-redshift galaxies using an important local universe analog population, the Lyman Break Galaxy Analogs. We have established a 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=1.5-4) to Lyman break analogs (LBAs) in the present-day Universe (z~0.1). We present results from the 4Ms Chandra Deep Field South (CDF-S) observations of ~4000 z=1.5-4 LBGs as well as in-depth studies of a sample of six nearby GALEX-selected z~0.1 LBAs, which are individually X-ray detected. Both populations may yield a larger output in collective HMXB luminosity per unit SFR than that observed in local (z=0) star-forming galaxies. We also discuss the properties of the hot gas in these galaxies, particularly what we hope to learn with next generation facilities such as the Athena calorimeter.

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111 – Galaxy Clusters

111.01 – Improving our knowledge of the distant X-ray Universe via gravitational lensing: RCS2 032327-132623, a case study

We report on our X-ray analysis of the field of RCS2 032727-132623 (J0327 for short, z = 0.564, lensed galaxy z =1.5) The analysis has yielded three phenomena that are on one hand interesting and on the other hand require follow up to determination of their precise origin. The primary effect we discovered is a 1.47 keV line whose origin could be diffuse or point-like. If point-like the line is most likely due to Fe emission from a highly magnified AGN. If instead the line is coming from diffuse emission, then again Fe line emission from magnified background cluster is most likely, with sterile neutrino decay being a distant third explanation. In any regard, a key point is for any background (a foreground is excluded as this should produce a Fe line between 4.3 and 6.7 keV) object, the reason we are able to detect the line is only because it has been highly magnified by gravitational lensing of the foreground cluster. In our...
presentation we give details about the line and then discuss two other ancillary effects we want of followup. The results demonstrate the value of searching rich clusters of galaxies with high magnification for otherwise impossible-to-detect distant X-ray emitting objects.

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**111.02 – Exploring the Outskirts of Galaxy Clusters**

A number of recent studies have traced the hot intracluster medium (ICM) to the virial radius in a sizeable sample of galaxy clusters. These results have begun to clarify the thermodynamic conditions at the edge of clusters, constraining models of cluster growth and evolution, yet the observations are challenging and bedeviled by a host of systematic issues due to the very low ICM surface brightness in the cluster outskirts. We are currently embarked on a program to observe a sample of about ten relaxed clusters with Suzaku, fully imaging each cluster to beyond $R_{200}$, and leveraging complementary data from XMM-Newton and Chandra. Our results support the idea that the ICM is not in hydrostatic equilibrium in the cluster outskirts, where we see indications of low-entropy substructures and some evidence for azimuthal variations in temperature and surface brightness. I will present the latest results from this project, explore the possible sources of systematic error, and discuss the remarkable “universality” of thermodynamic profiles to the outer limits of galaxy clusters.

**Author(s):** Eric D. Miller¹, Jithin V. George², Richard Mushotzky², Mark W. Bautz¹, David S. Davis³,⁴, J. P. Henry⁵


**111.03 – The ACCEPT 2.0 database of galaxy cluster properties**

The current public ACCEPT database of cluster properties includes radial profiles of temperature, electron density, entropy, and cooling time. With the new ACCEPT2 project we are currently doubling the number of clusters in ACCEPT and expanding the current suite of properties to include uniformly measured profiles of gas mass and hydrostatic equilibrium mass along with signatures of dynamical relaxation (centroid shift, power ratios, surface brightness concentration, temperature ratios) and global quantities such as core-excised temperatures, X-ray luminosities, and metallicities. We are presenting the first results obtained on the relationship between cool cores and dynamical relaxation, the reliability of hydrostatic mass profiles, and the dependence of the gas mass fraction on halo mass, redshift, and the degree of relaxation.

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**111.04 – Constraining SNe Models Using Galaxy Clusters**

Since the X-ray emitting gas is in (near) thermal equilibrium and the plasma is optically thin the observed metal line fluxes can be straightforwardly converted into elemental abundances. This allows us to analyze the processes of metal enrichment in the ICM and their evolution in z.
However, this study has been limited by the uncertainties on SN Type metal yields models. While theoretical models have been advancing at a fast pace, uncertainties can reach factors of two or more for the yields of specific elements for different explosion mechanisms. One can invert the problem and use robustly measured metal abundances to provide useful constraints to SN models. Here, we use metal abundance ratios in a cluster analysis clusters and groups, of different temperatures spanning a wide range of values, using ASCA, Chandra and XMM to analyze the SN models that best fit the data.

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111.05 – Development of a hot intergalactic medium in spiral-rich galaxy groups: the example of HCG 16

Galaxy groups provide the environment in which the majority of galaxies evolve, with low velocity dispersions and small galaxy separations that are conducive to tidal interactions and mergers between group members. X-ray observations reveal the frequent presence of hot gas in groups, with larger quantities linked to early-type galaxies, whereas cold gas is common in spiral-dominated groups. Clarification of the origin and role of the hot medium is central to the understanding of the evolution of the galaxy population and of all phases of the IGM. We here report on the nuclear activity, star formation and the high luminosity X-ray binary populations of the spiral-dominated, likely not yet virialized, group HCG 16, as well as on its intra-group medium, based principally on deep (150 ks) Chandra X-ray observations of the group, as well as new Giant Metrewave Radio Telescope (GMRT) 610 MHz radio data. We confirm the presence of obscured active nuclei in NGC 833 and NGC 835, and identify what may be a previously unrecognized nuclear source in NGC 838; all are variable. NGC 838 and NGC 839 are both starburst-dominated systems, with galactic superwinds that show X-ray and radio evidence of IGM interaction, but only weak nuclear activity; NGC 848 is also dominated by emission from its starburst. We confirm the existence of a faint, extended low-temperature (0.3 keV) intra-group medium, a subject of some uncertainty in earlier studies. The diffuse emission is strongest in a ridge linking the four principal galaxies, and is at least partly coincident with a large-scale HI tidal filament, indicating that the IGM in the inner part of the group is highly multi-phase. We conclude that starburst winds and shock-heating of stripped HI may play an important role in the early stages of IGM formation, with galactic winds contributing 20-40% of the observed hot gas in the system.

Author(s): Jan M. Vrtilek¹, Ewan O'Sullivan¹, Laurence P. David¹, Simona Giacintucci², Andreas Zezas³, Gary Mamon⁴, Trevor J. Ponman⁵, Somak Raychaudhury⁵

111.06 – Distributed heating and disruption of a cool core through gas sloshing: Abell 3581

We present results of joint Chandra, JVLA, HST and narrow-band imaging of the nearby galaxy group Abell 3581. Galaxy groups have shallower potential wells compared with rich galaxy clusters. An important implication of this is that the mechanical output from an active galactic
nucleus outburst is of the same order as the group binding energy. The effect of feedback may well be more devastating to the group atmosphere than on the cluster scale. We find evidence in the X-ray and Radio of a series of AGN outbursts which have changed rise direction over time dragging with them cool gas from the centre of the galaxy. The observed bubbles are not powerful enough to offset the radiative cooling within the cooling radius, however, sloshing motions of the core, probably responsible for the changing direction of the bubbles, are stripping the cool core and distributing this high metallicity, low entropy gas over the inner 50 kpc. These bulk motions are capable of destroying the core within 1-2 Gyrs and are likely contributing to the distributed heating and cooling in the cluster.

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**111.07 – X-ray Observations of the Outskirts of the Nearest Non-Cool Core Cluster: the Antlia Cluster**

Recent Suzaku X-ray observations have revealed hot gas properties of a number of clusters of galaxies out to their virial radii, allowing us to explore regions that was not possible in the past. We will present results of our Suzaku mosaic observations of the nearest non-cool core cluster, the Antlia Cluster, out to its degree-scale virial radius in the East direction. Together with Chandra and XMM-Newton observations, systematic uncertainty caused by background point sources is greatly reduced. Physical properties such as surface brightness and temperature profiles will be presented and compared to theoretical models and other clusters. Implications of our results will be discussed.

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**111.08 – X-ray and Weak Lensing Masses for a Sample of 50 Relaxed and Non-Relaxed Clusters of Galaxies**

We present an updated, recalibrated, multiwavelength, X-ray + weak lensing measurement of the mass profiles for 50 rich systems of galaxies. We find that our weak gravitational lensing masses, calibrated with state-of-the-art shear testing simulations, are 18% +/- 4% higher than those found for the clusters in the Planck satellite sample. Using the Joint Analysis of Cluster Observations codebase, we simultaneously model the baryonic and nonbaryonic matter profiles in these systems, deriving joint constraints on the gas entropy, pressure, metallicity, and dark matter distributions. Simultaneous analysis of Chandra and XMM-Newton data where both are available allows us to constrain these profiles over nearly two decades in radius. We
find clusters with low BCG-to-X-ray center offsets form a remarkably regular sample, with NFW dark matter profiles and gas fraction values that are consistent with the cosmological value. Clusters with low central gas entropy exhibit a similar trend, and do so with an intrinsic scatter that is consistent with zero. Non-relaxed clusters, on the other hand---those with offset BCGs and high central entropies---exhibit significant scatter and have mass profiles inconsistent with the NFW value (most likely due to strong violations of spherical symmetry).

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**111.09 – Characterizing Planck-detected Clusters of Galaxies with Chandra**

Through a Chandra XVP program, we are completing observations of all Planck ESZ clusters of galaxies at z<0.35. The Chandra observations of this mass limited cluster sample enable detailed studies of key cluster scaling relations and comparisons of SZ and X-ray selected cluster samples. In particular, from the Chandra observations, we have determined each cluster's dynamical state, as well as the properties of the X-ray gas. We compare the fractions of clusters with particular cluster morphologies, ranging from cool core relaxed clusters to clusters undergoing major mergers, in the Planck SZ sample with the percentages of similar clusters in X-ray selected samples. We also show comparisons of the distributions of X-ray luminosities for X-ray and SZ selected cluster samples. Finally we determine the fraction of Planck ESZ clusters with AGN-produced cavities and compare these results with those derived from X-ray selected cluster samples.

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**Contributing team(s):** Members of the Planck Collaboration

**111.10 – 3C28 in Abell 115- A Radio Source With a Twist: Tracing Gas Vortices in a Merging Subcluster Core**

Abell 115 is one of the “bimodal” clusters, first identified from Einstein Observatory X-ray images. The X-ray image is dominated by emission from two subclusters, separated by about 900 kpc, that are in the process of merging. The northern subcluster (A115-N) contains a bright central galaxy that hosts the radio source 3C28. 3C28 has a remarkable morphology. Although there is no evidence of a presently active nucleus, there are two prominent jets connected to a pair of radio lobes, each of which exhibits a radio tail. A115-N shows a classic cold front, the remarkable phenomenon first studied from Chandra cluster observations. We describe the overall structure of the cluster from detailed Chandra observations. We review the gravitational lensing observations and radio observations of the relic and discuss the overall state of the cluster merger. In addition, we exploit the Chandra data and the cold front phenomenon to study the gas motions in and around A115-N that hosts 3C28. The subcluster motion of A115-N through the cluster induces counter-rotating vortices in the subcluster gas that give rise to the unique radio morphology of 3C28 with its two radio tails pointing in the direction of motion of A115-N. Thus, the radio emitting plasma acts as a dye in a fluid tracing the vortices in the X-ray emitting gas, resembling text book pictures of fluid motions.
112 – Gamma-Ray Bursts

112.01 – Pair-dominated GeV-optical flash in GRB 130427A

The double GeV+optical flash of GRB 130427A provides a unique opportunity to probe the blast wave physics starting from the time when the prompt emission is still going on. The onset in both bands was delayed by \( \sim 10 \) s with respect to the burst trigger, the light curves peaked almost simultaneously and thereafter exhibited an extended monotonic decline. We show that the light curves of the double flash are consistent with radiation from the blast wave in a wind-type medium with density parameter \( \rho \approx 5 \times 10^{10} \) g/cm³. The peak of the flash is emitted by copious electron-positron pairs created and heated in the blast wave; our first-principle calculation determines the pair-loading factor and temperature of the shocked plasma. Using detailed radiative transfer simulations we reconstruct the observed double flash. The optical flash is dominated by synchrotron emission from the thermal plasma behind the forward shock, and the GeV flash is produced via inverse Compton scattering by the same plasma. No non-thermal population of electrons is required and would weakly affect the predicted flash. We find that the blast wave Lorentz factor at the peak of the flash is \( \gamma \sim 200 \), and the forward shock magnetization is \( \chi_B \sim 2 \times 10^{-4} \).

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112.02 – Probing the Cosmic Gamma-Ray Burst Rate with Trigger Simulations of the Swift Burst Alert Telescope

The gamma-ray burst (GRB) rate is essential for revealing the connection between GRBs, supernovae and stellar evolution. Additionally, the long GRB rate at high redshift provides a strong probe of star formation history in the early universe. While hundreds of GRBs are observed by Swift, it remains difficult to determine the intrinsic GRB rate due to Swift’s complex trigger algorithm. Current studies usually approximate the Swift trigger algorithm by a single detection threshold. However, unlike the previously flown GRB instruments, Swift has over 500 trigger criteria based on photon count rate and additional image threshold for localization. To investigate possible systematic biases and explore the intrinsic GRB properties, we developed a program that is capable of simulating all the rate trigger criteria and mimicking the image trigger threshold. We use this program to search for the intrinsic GRB rate. Our simulations show that adopting the Swift’s complex trigger algorithm increases the detection rate of dim bursts. Therefore, GRBs need to be intrinsically dimmer than previously expected to avoid overproducing the number of detections and to match with Swift observations. As a result, we find that either the GRB rate is much higher at large redshift than previous expectations, or the luminosity evolution is non-negligible.

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112.03 – Towards a New Model for GRB Prompt Emission and a New Hardness-Luminosity Relation for Cosmology

GRB prompt emission spectra are usually considered as adequately fitted with the so-called Band function. Although purely empirical, the Band function has usually a non-thermal shape, but incompatible with the most popular synchrotron emission scenarios. Despite decades of use, the Band function clearly shows its limitations for interpreting the initial phase of the GRB phenomenon. Recent observations of bright GRBs with Fermi reveal significant spectral deviations to the Band function: a thermal-like component adequately approximated with a black body (BB) spectral shape and interpreted as the jet photospheric emission, and/or an additional power law (PL). In this presentation, I show a sample of famous bright Fermi GRBs exhibiting the presence of the three components simultaneously. This new model completely changes the view that we had on those GRBs previously. While the fit of a Band function alone to the data results in dramatic changes of its parameter values on very short time scales - difficult to interpret - the three components of our new models vary much smoother. More importantly, in our new model, the Band function shape becomes (more) compatible with synchrotron model predictions. In addition, despite the presence of three distinct components, we succeed in reducing the complexity of this new model in making it statistically very competitive with a single Band function with only one additional degree of freedom. Through the presentation, we will see how the various components evolve with time and how this new model leads to an hardness-intensity relation which could eventually be used as a tool for cosmology. Finally, we will see that the validity of this new model is supported by observations with other instruments such as CGRO/BATSE, Swift and WIND/Konus.

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112.04 – UNCOVERING THE INTRINSIC VARIABILITY OF GAMMA-RAY BURSTS

We develop a robust technique to determine the minimum variability timescale for gamma-ray burst (GRB) light curves, utilizing Haar wavelets. Our approach averages over the data for a given GRB, providing an aggregate measure of signal variation while also retaining sensitivity to narrow pulses within complicated time series. In contrast to previous studies using wavelets, which simply define the minimum timescale in reference to the measurement noise floor, our approach identifies the signature of temporally smooth features in the wavelet scaleogram and then additionally identifies a break in the scaleogram on longer timescales as a signature of a true, temporally unsmooth light curve feature or features. We apply our technique to the large sample of Swift GRB gamma-ray light curves and for the first time—due to the presence of a large number of GRBs with measured redshift—determine the distribution of minimum variability timescales in the source frame. We find a median minimum timescale for long-duration GRBs in the source frame of $t_{\text{min}} = 0.5$ s, with the shortest timescale found being on the order of 10 ms. This short timescale suggests a compact central engine (3000 km). We discuss further implications for the GRB fireball model and present a tantalizing correlation between the minimum timescale and redshift, which may in part be due to cosmological time dilation.
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112.05 – A Comprehensive Analysis of GRB Afterglows with Deep Chandra Follow-up: Implications for Off-Axis Jets

We present a sample of 27 GRBs with detailed Swift light curves supplemented by late time Chandra observations. By fitting to empirical mathematical functions, we find a higher fraction of jet-break candidates (56%) than previous studies using Swift-only samples and different analysis techniques (12%). To answer the missing jet-break problem in general, we further develop a numerical simulation-based model which can be directly fit to the data using Monte Carlo methods. Our numerical model takes into account all the factors that can shape a jet break: (i) lateral expansion (ii) edge effects and (iii) off-axis effects. Comparing to the empirical function fit, our results provide improved fits to the light curves and better constraints on physical parameters. More importantly, our results suggest that off-axis effects are important and must be included in interpretations of GRB jet breaks.

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112.06 – Non-Thermal Gamma-Ray Emission from Delayed Pair Breakdown in Magnetized and Photon-Rich Outflows

We consider delayed, volumetric heating in a magnetized outflow that has broken out of a confining medium and expanded to a high Lorentz factor (\(\gamma \approx 10^2 \text{ to } 10^3\)) and low optical depth to scattering (\(\tau \approx 10^{-2} \text{ to } 10^{-1}\)). The energy flux at breakout is dominated by the magnetic field, with a modest contribution from quasi-thermal gamma rays. We focus on the case of extreme baryon depletion in the magnetized material, but allow for a separate baryonic component that is entrained from a confining medium. Dissipation is driven by relativistic motion between these two components, which develops once the photon compactness drops below \(4 \times 10^3 (Y_e /0.5)^{-1}\). The pair and photon distributions are evolved self-consistently using a one-zone kinetic code that incorporates an exact treatment of Compton scattering, pair production and annihilation, and Coulomb scattering. Heating leads to a surge in pair creation, and the scattering depth saturates at \(?\approx 1-4\). High-energy power-law spectra with photon indices in the range observed in GRBs (\(\gamma_3 < \gamma < 3/2\)) are obtained by varying the ratio of heat input to the seed energy in quasi-thermal photons. We contrast our results with those for continuous heating across an expanding photosphere, and show that the latter model produces soft-hard evolution that is inconsistent with observations of GRBs.

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113 – Gravitational Waves
113.01 – The First Two Years of Electromagnetic Follow-Up with Advanced LIGO and Virgo

We anticipate the first direct detections of gravitational waves with Advanced LIGO and Virgo later this decade. Though this groundbreaking technical achievement will be its own reward, a still greater prize could be observations of compact binary mergers in both gravitational and electromagnetic channels simultaneously. During Advanced LIGO and Virgo's first two years of operation, 2015 through 2016, we expect the global gravitational-wave detector array to improve in sensitivity and livetime and expand from two to three detectors. We model the detection rate and the sky localization accuracy for binary neutron star mergers across this transition. We have analyzed a large, astrophysically motivated source population using real-time detection and sky localization codes and higher-latency parameter estimation codes that have been expressly built for operation in the Advanced LIGO/Virgo era. We show that for most binary neutron star events the rapid sky localization, available about a minute after a detection, is as accurate as the full parameter estimation. We demonstrate that Advanced Virgo will play an important role in sky localization, even though it is anticipated to come online with only 1/3 as much sensitivity as the Advanced LIGO detectors. We find that the median 90% confidence region shrinks from ~500 square degrees in 2015 to ~200 square degrees in 2016. From hundreds of simulated events unfold some likely detection scenarios.

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113.02 – Formation and Dynamics of Binary Black Holes in Globular Clusters

We study the dynamics of black holes within dense globular clusters. To improve upon previous results, we have developed a new technique that combines the precision of N-body codes with the speed of the Monte Carlo technique. Our hybrid Monte Carlo code models two-body relaxation between stars and binaries while the orbits of the black holes are integrated directly. This allows us to consider the dynamics of the black holes in a realistic globular cluster environment. We consider the number of black holes retained over the lifetime of the cluster, as well as the formation and properties of dynamically formed binary black holes. We explore the population of synthesized binary black holes and the implications for advanced gravitational-wave detectors.

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113.03 – Searches for gravitational waves associated with gamma-ray bursts

Gamma-ray bursts are likely related to several processes linked to catastrophic stellar events. The progenitor scenarios of gamma-ray bursts include mergers of binary systems composed of neutron stars or a neutron star and a stellar-mass black hole, core collapse of massive stars, and
perturbed neutron stars. Gravitational-wave emission is expected to accompany such events. We discuss the strategies developed to search for gravitational waves associated with these events and the search results from the initial LIGO and Virgo detectors. We also discuss the prospects for such searches with advanced LIGO and Virgo detectors. In order to provide quick feedback, we are developing promptly launched gravitational-wave data analyses for the gamma-ray bursts observed by the Swift and Fermi satellites.

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**Contributing team(s):** For the LIGO Scientific Collaboration and the Virgo Collaboration

113.04 – Following Up Gravitational Wave Transients with the Cherenkov Telescope Array

Detections of the electromagnetic counterparts to gravitational wave (GW) observations will be critical to understanding the astrophysical phenomena involved. However, in many cases—especially early in the advanced LIGO/Virgo era—the localization of GW transients will be poor, and follow-up observations will be required to rapidly search hundreds to thousands of square degrees of the sky. Relatively few telescopes are capable of such searches with the required sensitivity. We show that the Cherenkov Telescope Array (CTA) has the sensitivity needed to detect short gamma-ray bursts (GRBs) over the detection volume of advanced LIGO/Virgo (a range of hundreds of megaparsecs); short GRBs are thought to originate in compact-binary mergers, which are also considered to likely be the first class of sources detected in GWs. Thus, CTA can make an invaluable contribution to understanding the first GW detections.

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113.05 – A Numerical Calculation of the Gravitational Wave Signal in the Low Frequency Regime Produced by Binary Supermassive Black Holes

We model the population of binary supermassive black holes at z < 4 using recent large-scale numerical simulations. We relate galaxies to the dark matter halos using calibrated relations between the halo and stellar mass functions. Galaxies are populated with supermassive black holes according to recent correlations between galaxy bulge mass and black hole mass, and the distribution of binary supermassive black holes is calculated from this population and the galaxy merger rate inferred from the simulations. We calculate the expected gravitational wave signal available to pulsar timing arrays by performing monte-carlo selection from this distribution.

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114 – Isolated NSs

114.01 – X-ray emission mechanism in magnetars

In the magnetar model, the observed persistent luminosity and outbursts are both powered by dissipation of magnetic energy. The emission mechanisms of persistent and burst emission will
be discussed and compared. Observations suggest the presence of hot spots on magnetars. They may result from internal (subsurface) or external (magnetospheric) heating. Both mechanisms appear to be needed to explain the data.

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114.02 – Phase Resolved Observations of Magnetar 4U 0142+61 with NuSTAR

We report ongoing spectral and temporal analysis of new 167 ks, 3-79 keV NuSTAR observations of magnetar 4U 0142+61. With contemporaneous Swift-XRT observations, the low energy phase-averaged spectra are well fit by T_eff = 0.461±0.006 keV blackbody and a soft (0.35±0.04) power law and the high-energy spectra are well explained by a hard power law (0.38±0.03). We detect pulsations at all energies in the Swift-XRT and NuSTAR observations. The fractional RMS variation in the 3-79 keV band is 14%. We detect increasing fractional RMS variation as a function of energy (9% at 3-10 keV; 17% at 10-20 keV; 20% at 20-35 keV). The pulse morphology changes from single peaked at low energies to a double peaked structure at ~35 keV. We fit the X-ray data using the electron-positron outflow model developed by Beloborodov for explaining magnetar hard X-ray spectra.

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Contributing team(s): NuSTAR Science Team

114.03 – Latest efforts in the hunt for Black Widow and Redback pulsars with Fermi-LAT

Since its launch ~6 years ago, the Large Area Telescope (LAT) on Fermi has been extremely successful at discovering new pulsars, both directly in the gamma-ray band and through dedicated radio searches of LAT gamma-ray sources with pulsar-like qualities. Among the most interesting pulsars found by the LAT are members of the so-called Black-Widow (BW) and Redback (RB) families. These systems consist of a millisecond pulsar in a tight circular orbit around a small mass companion (from ~0.01 to ~0.1 of a solar mass, for BWs and RBs respectively) that is being "eaten" away by the high-energy radiation from the pulsar. To date, most BW and RB pulsars have been discovered in radio searches of Fermi-LAT unassociated sources. Radio searches, however, are often severely hampered by the absorption and scattering in the material ablated from the companion. Blind searches for BW/RB pulsars in gamma rays are not subject to such issues but instead are complicated by the long integration times necessary, requiring dedicated multi-wavelength (optical and X-ray) campaigns to severely constrain the orbital parameters of the system. We will describe our latest efforts in the search for these extreme systems and discuss the prospects for finding more of them in the future.

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Contributing team(s): Fermi-LAT Collaboration

**114.04 – Revisiting the Magnetic and Spin Evolution of Two Young X-ray Pulsars**

We present results from timing analysis of two young X-ray pulsars found in the large Magellanic Cloud: the Crab-like energetic pulsar PSR B0540-69 and the so-called "big glitcher", PSR J0537-6910. In both cases, we analyze data taken with the Rossi X-ray Timing Explorer. This work extends the published data sets for these pulsars by approximately doubling their respective data spans. We revisit the glitching activity of these neutron stars, particularly that of PSR J0537-6910, determine more precise glitch and spin parameters, and discuss the implications for the spin and magnetospheric evolution of these interesting pulsars.

**Author(s): Robert Ferdman¹, Victoria M. Kaspi¹, Robert F. Archibald¹**

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**114.05 – High Spatial Resolution X-Ray Spectroscopy of the IC443 Pulsar Wind Nebula**

Deep Chandra ACIS observations of the region around the putative pulsar CXOU J061705.3+222127, in the supernova remnant IC443, reveal a ~5" radius ring-like morphology surrounding the pulsar and a jet-like structure oriented roughly north-south across the ring and through the pulsar's location. The observations further confirm that (1) the spectrum and flux of the central object are consistent with a rotation-powered pulsar, (2) the non-thermal spectrum and morphology of the surrounding nebula are consistent with a pulsar wind, and (3) the spectrum at greater distances is consistent with thermal emission from the supernova remnant. 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 is not distorted by motion through the ambient medium. Comparing this observation with historical observations of the same target we set a 99-% confidence upper limit to the proper motion of CXOU J061705.3+222127 to be less than 310 km/s, with the best-fit (but not statistically significant) direction toward the west.

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**114.06 – PSR J1640-4631: a Young, Energetic Pulsar Powering the Gamma-ray Source HESS J1640-465**

The discovery of a young, energetic X-ray pulsar associated with HESS J1640-465 provided important new constraints on possible emission models for this Galactic TeV source, the most luminous known. The 206 ms pulsar PSR J1640-4631 and its surrounding PWN lie within SNR G338.3-0.0 and are co-located with the gamma-ray source HESS J1640-465 and possibly 1FHL J1640.5-4634. The NuSTAR discovery and subsequent spin-down measurements imply Edot = 4.4E36 erg/s, Bs = 1.4E13 G, tau = 3350 yrs. The origin of the gamma-ray emission is difficult to discern given the complex local environment, both leptonic and hadronic models have been proposed. We present an evolutionary SNR/PWN model fit to the spectral energy distribution of HESS J1640-465 using updated spectral data and input parameters. The pulsar energetics
predict an initial spin period < 15 ms and a braking index less than or equal to 2. A NuSTAR program to measure the pulsar's braking index is underway to better constrain its true age.

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**Contributing team(s):** The NuSTAR Observatory Team

**114.07 – Discovery of X-ray Pulsations from the INTEGRAL Source IGR J11014?6103**

IGR J11014?6103 is an X-ray source with a cometary tail that strongly suggests it is a pulsar moving away from the center of the SNR MSH 11?61A at high velocity, at greater than 1000 km s⁻¹. It also has a very long X-ray jet that is misaligned from the tail. The jet direction could indicate the rotation axis of the pulsar. We performed an observation of IGR J11014?6103 with the XMM-Newton EPIC pn in small window mode that resulted in the discovery of 62.8 ms pulsations from the point-like component in this system. The X-rays from PSR J1101?6101 have a pulsed fraction of 0.5, and a pulse shape that is largely independent of energy from 0.5?10 keV, similar to the non-thermal pulsations from most other rotation-powered pulsars detected by INTEGRAL. A second observation with XMM-Newton is planned to measure the spin-down rate of PSR J1101?6101. This will determine its age, and establish whether it is consistent with originating in SNR MSH 11?61A.

**Author(s):** Jules P. Halpern¹, John Tomsick², Eric V. Gotthelf¹, Fernando Camilo³, Chi-Yung Ng³, Arash Bodaghee⁴, Jerome Rodriguez⁵, Sylvain Chaty⁵, Farid Rahoui⁶


**114.08 – A Search for X-ray Counterparts of Radio Pulsars**

Cross-correlating the radio timing positions of all known radio pulsars with archival X-ray observations, we identified 24 new X-ray counterparts of radio pulsars. In most cases the archival data are too sparse to support a detailed spectral and timing analysis. About one-third of these detections are millisecond-pulsars. The others belong to the group of Vela-like and middle-aged pulsars. Furthermore, we deduced upper limits of the X-ray flux for more than 200 other radio pulsars. This large sample enables us to study the X-ray efficiency of those sources and to put further constrains on models which describe the thermal evolution of neutron stars.

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**Contributing team(s):** Tobias Prinz

**114.09 – The dynamics of Bow-shock Pulsar Wind Nebula: Reconstruction of multi-bubbles**

Bow-shock pulsar wind nebulae (PWNe) exhibit a characteristic cometary shape due to the supersonic motion of the pulsar interacting with the interstellar medium (ISM). One of the spectacular bow-shock is the Guitar Nebula, which is produced by the fast pulsar PSR B2224+65 (vpsr > 1000 km s⁻¹), and consists of a bright head, a faint neck, a two larger bubbles. We present that the peculiar morphology arises from variations in the interstellar medium density. We perform 3-D hydrodynamic simulation to understand the evolution of the pulsar as its moves through the density discontinuity. We found that when the pulsar encounters the low-
density medium, the pressure balance at the head of the bow shock begins to collapse, producing the second bubble. The expansion rate of the bubble is related to the properties of both the pulsar and the ambient medium. Assuming that the pulsar's properties, including spin-down energy, are constant, we conclude that the ambient density around the second bubble should be 4.46 times larger than around the first bubble in the Guitar body. We further found that when the pulsar encounters the inclined density discontinuity, it can produce the asymmetric shape of the bow shock observed in a subset of bow-shock PWNe including J2124-3358.

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**114.10 – Timing Noise in Pulsars and Magnetars and the Magnetospheric Moment of Inertia**

We examine timing noise in both magnetars and regular pulsars, and find that there exists a component of the timing noise ($\sigma_{TN}$) with strong magnetic field dependence ($\sigma_{TN} \sim B_o^{2} \Omega T^{3/2}$) above $B_o \sim 1012.5$ G. The dependence of the timing noise floor on the magnetic field is also reflected in the smallest observable glitch size. We find that magnetospheric torque variation cannot explain this component of timing noise. We calculate the moment of inertia of the magnetic field outside of a neutron star and show that this timing noise component may be due to variation of this moment of inertia, and could be evidence of rapid global magnetospheric variability.

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**114.11 – Investigating bright Fermi-LAT pulsar-like unassociated sources**

The past five years have been a bonanza for millisecond pulsar searchers, with the number of known field MSPs tripling in that time. A major driver of these discoveries has been the availability of accurate positions and spectra of gamma-ray sources from the Fermi Large Area Telescope. However, nineteen bright, high-latitude sources with pulsar-like spectra have been observed five or more times in the radio by the Fermi Pulsar Search Consortium with no clear detection of pulsations. We look in depth at the spectral properties of several of these sources, comparing three spectral models (PowerLaw, LogParabola, and PExpCutoff) to see how strongly the gamma-ray emission supports the pulsar hypothesis.

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**Contributing team(s):** The Fermi-LAT Collaboration

**114.12 – The Central Compact Object in Kesteven 79: A Strongly Magnetized Neutron Star**

I present modeling of the X-rays from the central compact object (CCO) PSR J1852+0040 in Kesteven 79. A conventional polar cap model can reproduce the broad, large-amplitude X-ray pulse only with a "pencil plus fan" beam emission pattern, which is characteristic of neutron star atmospheres with $>10^{12}$ Gauss, substantially greater than the $\sim 10^{10}$ Gauss surface dipole field inferred from the pulsar spin-down rate. This discrepancy can be explained by an axially displaced dipole. For other beaming patterns, it is necessary to invoke high-aspect-ratio emitting regions that are greatly longitudinally elongated, possibly due to an extremely offset dipole. For all assumed emission models, the existence of strong internal magnetic fields ($>10^{14}$ Gauss) that preferentially channel internal heat to only a portion of the exterior is
required to account for the implied high-temperature contrast across the stellar surface. This lends observational evidence in support of the "hidden" strong magnetic field scenario, in which CCOs possess submerged magnetic fields that are much stronger than the surface dipole field.

Author(s): Slavko Bogdanov

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114.13 – An Exploration of X-ray Based Distance Estimates to Pulsars

It is often desirable to estimate a distance to a pulsar using X-ray emission. Sometimes, it is because the dispersion measure distance is suspect for some reason. Sometimes, there are no radio pulsations and so alternate distance estimates are required. Methods people have used include the L_X/Edot relation, X-ray absorption, and thermal emission from a presumed neutron star surface area. However, none have been calibrated against robustly determined distances. Here we present a study of X-ray emission from pulsars with well determined parallax distances in order to determine the feasibility of using X-rays to estimate distances. We separately consider millisecond pulsars and young pulsars.

Author(s): Mallory Roberts1, 2, Kristof Bognar2, Shami Chatterjee3


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

Various telescopes including RXTE, INTEGRAL, Suzaku and Fermi have detected steady non-thermal X-ray emission in the 10 ~ 200 keV band from strongly magnetic neutron stars known as magnetars. Magnetic inverse Compton scattering is believed to be a leading candidate for the production of this intense X-ray radiation. Generated by electrons possessing ultra-relativistic energies, this leads to attractive simplifications of the magnetic Compton cross section. We have recently addressed such a case by developing compact analytic expressions using correct spin-dependent widths acquired through the implementation of Sokolov & Ternov (ST) basis states, focusing specifically on ground state-to-ground state scattering. Such scattering in magnetar magnetospheres can cool electrons down to mildly-relativistic energies. Moreover, soft gamma-ray flaring in magnetars may well involve strong Comptonization in expanding clouds of mildly-relativistic pairs. These situations necessitate the development of more general magnetic scattering cross sections, where the incoming photons acquire substantial incident angles relative to the field in the rest frame of the electron, and the intermediate state can be excited to arbitrary Landau levels. Here, we highlight results from such a generalization using ST formalism. The cross sections treat the plethora of harmonic resonances associated with various cyclotron transitions between Landau states. Polarization dependence of the cross section for the four scattering modes is illustrated and compared with the non-relativistic Thompson cross section with classical widths. Results will find application to various neutron star problems, including computation of Eddington luminosities and polarization mode-switching rates in transient magnetar fireballs. We express our gratitude for the generous support of Michigan Space Grant Consortium, the National Science Foundation (grants AST-0607651, AST-1009725, AST-1009731 and PHY/DMR-1004811), and the NASA Astrophysics Theory Program through grants NNX06AI32G, NNX09AQ71G and NNX10AC59A.
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**114.15 – The Surprising High-Energy Pulsations of PSR J1813-1246**

The launch of Fermi has revolutionized our understanding of high-energy emission from pulsar magnetospheres. The comparison between radio and gamma-ray light curves has provided important information and constraints on emission geometry. On the other hand, only a few pulsars have long, dedicated observations in the X-ray band. We have obtained new, deep XMM-Newton and Chandra observations of the energetic, radio-quiet PSR J1813-1246 discovered in gamma rays by Fermi. Extending the Fermi ephemeris to five years, we found two glitches. The detected X-ray pulsations of J1813-1246 have a nearly 100% pulsed fraction, with very sharp, non-thermal peaks separated by 0.5 in phase. The X-ray spectrum is unusual and very hard, with photon index of 0.85. The Fermi gamma-ray light curve also shows two peaks with 0.5 phase separation, that lag the X-ray peaks by 0.25 in phase. The unusual X-ray and gamma-ray phasing cannot be easily explained by current outer magnetosphere emission models. We explore an alternative geometrical model where the gamma-ray emission is from the outer magnetosphere while the X-ray emission comes from the polar cap pair cascades.

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**Contributing team(s):** Fermi LAT

**114.16 – Gamma-Ray Activity from the Binary System PSR B1259-63/SS 2283 Near its 2014 Periastron**

The Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope observed brightening of the binary system PSR B1259-63/SS 2883 in the GeV energy range during the period following the periastron of 2014 May 4. Observed variability is consistent with repetition of the GeV light curve observed at the previous 2010-2011 periastron (binary period 3.4 yr). In the 2014 cycle the Fermi spacecraft was operated in pointed mode for part of the time after periastron to enhance exposure in the LAT. The onset of detectable gamma-ray emission occurred around 2014 June 6, which was 33 days after periastron. We summarize gamma-ray behavior of the source through this cycle and also discuss the broader multi-wavelength context, comparing with the previous cycle. A discussion of the full radio-to-TeV picture of the preceding cycle is available in Chernyakova et al. (2014, MNRAS 439,432). Fermi LAT analysis is supported by NASA.

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**Contributing team(s):** Fermi LAT Collaboration
115 – Laboratory Astrophysics and Data Analysis

115.01 – Electron Impact Excitation Collision Strengths for Extreme Ultraviolet Lines of Fe VII and Fe IX

Extensive calculations are performed for electron excitation collision strengths and transitions probabilities for a wide range of ultraviolet lines in Fe VII and Fe IX. The collision strengths are calculated in the close-coupling approximation using the B-spline Breit-Pauli R-matrix method. The multiconfiguration Hartree-Fock method in conjunction with B-spline expansions is employed for an accurate representation of the target wave-functions. The close-coupling expansions include 189 and 370 fine-structure levels of Fe VII and Fe IX respectively. We have included levels of the 3p6, 3p53d, 4l, 5s, 3s3p63d, 4s, 4p, 3p43d2, 3s3p53d2 configurations and some low-lying levels of the 3p3d3 configuration for Fe IX. The effective collision strengths are obtained by averaging the electron collision strengths over a Maxwellian distribution of velocities at electron temperatures in the range from 104 to 107 K. There is a good agreement with the previous R-matrix calculation for transitions between first 17 levels of the 3p6, 3p53d, and 3s3p63d configurations in Fe IX. We were able to generate more accurate target states than those in the previous calculations. We included all 3p43d3nl correlation configurations and 3p-4f promotion for Fe VII which were found very important for accurate representation of 3dnl states. The present results considerably expand the existing data sets for Fe IX, allowing a more detailed treatment of the available measured spectra from different space observatories. This research work is supported by NASA grant NNX11AB62G from the Solar and Heliophysics program.

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115.02 – Laboratory-based standards for interpreting X-ray spectra from celestial sources

High sensitivity, high resolution instrumentation flown on the Chandra, XMM-Newton, and Suzaku X-ray observatories have provided X-ray astrophysicists with relatively straightforward access to powerful line diagnostics that tightly constrain the physical parameters of celestial sources. Accurate measurements of transition energies, line shapes, and intensities provide, for example, quantitative measures of velocity fields, electron densities, and temperatures. X-ray measurements probe sources unattainable by any other wavelength bands, such as the regions of accretion disks near black holes, and the hot intracluster medium in clusters of galaxies. Thus, X-ray astronomy in the age of Chandra, XMM-Newton, and Suzaku provides important information necessary to understand the formation and evolution of galaxies, stars, the phenomena near black holes, and the evolution of the universe as a whole. Beginning in 2015 with the launch of the Astro-H X-ray Observatory, high throughput, high resolution X-ray spectroscopy of extended sources in the Fe K band will be available for the first time, making it possible to unravel the mysteries of some of the most energetic objects in our Universe. Accurate, unambiguous interpretation of high quality, high resolution spectra from these premier observatories requires laboratory-tested spectral models. Starting over twenty years ago, the electron beam ion trap facility at Lawrence Livermore National Laboratory has produced a plethora of highly accurate data to satisfy this requirement, and has also addressed specific problems found to be beyond any modeling capability. As part of this work, a variety of new measurement techniques and instruments, including the NASA/GSFC ECS calorimeter,
have been developed. More recently, the portable FLASH-EBIT, built and maintained at the Max Planck Institute for Nuclear Physics and coupled to third and fourth generation light sources has opened new measurement regimes, i.e., the ability to probe the atomic structure of highly charged ions using high resolution, high intensity photon beams. Selected results will be presented. Work performed under auspices of U.S. D.o.E. by DE-AC52-07NA27344 and supported by NASA grants to LLNL and GSFC.

Author(s): Gregory V. Brown

Institution(s): 1. LLNL, Livermore, CA.

Contributing team(s): Hi-Lite Collaboration, NASA/GSFC Calorimeter Group

115.03 – Measurement of the Radiative Decay of the Longest-Lived Level in the Fe XVII Spectrum

The Fe XVII emission spectrum comprises several very prominent X-ray lines that play an important role in the study of many astrophysical objects. Among the Fe XVII X-ray lines, those emanating from a 3s level, i.e., lines 3F, 3G, and M2, invariably appear too strong compared to the lines emanating from a 3d level, i.e., lines 3C and 3D, when compared to theory. Two of the four 3s levels are metastable, which means they have a rather long radiative decay time compared to collisional processes. The decay rate of the 2p^53s J=2 level has recently been measured at the Livermore EBIT facility [J. R. Crespo López-Urrutia and P. Beiersdorfer, ApJ 721, 576 (2010)], and the scatter of predictions by a factor of 1.7 has been reduced to a measurement uncertainty of merely a few percent. Even longer-lived is the J=0 level of the same 2p^53s configuration. Theory predicts an exclusive magnetic dipole decay to the lowest J=1 level of the same 2p^53s configuration, i.e. to the upper level of line 3G. There appear to be fewer predictions for this rate than for the rates associated with the other Fe XVII levels. Various calculations yield a decay rate near 16 000 s\(^{-1}\) for this level (or a level lifetime near 63 \(\mu\)s). If this value is correct, electron-impact collisions affect line ratios tied to this level at densities between about 10^{10} cm\(^{-3}\) and 10^{13} cm\(^{-3}\), that is, exactly at many coronal densities of present interest. We have used the Livermore EBIT facility to measure the M1 decay rate of the 2p^53s J=0 level. We find a value commensurate with the value predicted by the Flexible Atomic Code. Work performed under auspices of U.S. D.o.E. by DE-AC52-07NA27344 and supported by NASA's APRA program under Interagency Agreement NNG13WF991.

Author(s): Gregory V. Brown\(^1\), Peter Beiersdorfer\(^1\), Elmar Träbert\(^1\)

Institution(s): 1. LLNL, Livermore, CA.

115.04 – XSPEC: Progress and Plans

I will summarize recent progress on XSPEC and describe some of the improvements planned for the near future.

Author(s): Keith A. Arnaud

Institution(s): 1. CRESST/UMd/GSFC, Greenbelt, MD.

115.05 – X-ray Line Diagnostics and Non-equilibrium Ionization Applications based on AtomDB v3.0

Based on newly updated AtomDB v3.0, we will present our theoretical investigations of X-ray line Diagnostics and a couple of applications for some typical non-equilibrium ionization(NEI) plasmas in massive star binaries, stellar cluster winds and supernova remnants.
Author(s): Li Ji$^1$, Adam Foster$^2$, Randall K. Smith$^2$, Shuinai Zhang$^1$, Xin Zhou$^1$, Yu Cheng$^3$, Zhiyuan Ji$^3$

Institution(s): 1. Purple Mountain Observatory, CAS, Nanjing, China. 2. Harvard Smithsonian Center for Astrophysics, Boston, MA. 3. Astronomy and Space School of Nanjing University, Nanjing, Jiangsu, China.

115.06 – Using the new AtomDB 3.0: Non-Equilibrium Plasma Analysis.
The AtomDB project (www.atomdb.org) consists of a large collection of atomic data relevant to modeling X-ray emission from collisionally ionized astrophysical plasmas. This data is coupled with a range of different software programs to produce the resulting spectrum and to connect it to analysis packages. With the release of AtomDB 3.0.0 we have completed a long-term project to update the models to accurately handle atomic data for plasmas outside of collisional ionization equilibrium. We have assembled this data from a combination of new and existing theoretical calculations and existing experimental data. We discuss here the differences between our new data and the data from the literature, identifying the causes behind the significant differences in Auger yields which this revised data gives rise to due to truncated autoionization channels in the existing data. We then present the results of fitting both low resolution (recombining SNR W49B Suzaku spectra) and high resolution (WR 140) analysis using the new model. We highlight both the ease of use of these models and the significant changes in abundance which they give rise to.

Author(s): Adam Foster$^1$, Randall K. Smith$^1$, Nancy S. Brickhouse$^1$, Timothy R. Kallman$^3$, Li Ji$^2$, Shuinai Zhang$^2$, Xin Zhou$^2$, Joern Wilms$^4$, Natalie Hell$^4$


116 – Missions & Instruments
116.01 – Animating Fermi - Science Outreach through Art
Animation students at the Maryland Institute College of Art working with scientists in the Fermi team at the NASA Goddard Space Flight Center produced five short animations (and an associated game) related to science discoveries and operations of the Fermi satellite. The topics animated were the Fermi bubbles, dark matter, binary stars, the discovery of cosmic rays, and space debris. We describe the process, show examples of the animations, and discuss the potential of art/science collaborations for public outreach and education.

Author(s): Robin Corbet$^{1,2}$, Laurence Arcadias$^3$

Institution(s): 1. UMBC, Greenbelt, MD. 2. NASA GSFC, Greenbelt, MD. 3. Maryland Institute College of Art, Baltimore, MD.

Contribution team(s): MICA/Fermi Animation Collaboration

116.02 – Autonomous Spacecraft Navigation With Pulsars
An external reference system suitable for deep space navigation can be defined by fast spinning and strongly magnetized neutron stars, called pulsars. Their beamed periodic signals have timing stabilities comparable to atomic clocks and provide characteristic temporal signatures that can be used as natural navigation beacons, quite similar to the use of GPS satellites for navigation on Earth. By comparing pulse arrival times measured on-board a spacecraft with
predicted pulse arrivals at a reference location, the spacecraft position can be determined autonomously and with high accuracy everywhere in the solar system and beyond. The unique properties of pulsars make clear already today that such a navigation system will have its application in future astronautics. We will describe the basic principle of spacecraft navigation using pulsars and report on the current development status of this novel technology.

Author(s): Werner Becker¹,²
Institution(s): 1. Max Planck Institute for extraterr. Physics, Garching, Bavaria, Germany. 2. Max-Planck Institut für Radioastronomie, Bonn, NRW, Germany.

Contributing team(s): Mike G. Bernhardt, Tobias Prinz

116.03 – The Effects of Orbital Environment on X-ray CCD Performance
X-ray telescopes, such as NASA's Chandra X-ray Observatory and Japan's Suzaku, have flown in space for several decades, however the effects of this hostile environment on sensitive astrophysics instruments are still not completely documented. Both observatories use CCD cameras for imaging spectroscopy of the X-ray sky. The CCDs themselves are similar in design, being fabricated at MIT's Lincoln Laboratory. We compare the on-orbit performance evolution of the Chandra ACIS and Suzuki XIS, to better understand the effect of the radiation environment in low- and high-Earth orbit. After more than a combined twenty years in space, both instruments have suffered performance degradation due to radiation damage, but comparison must take into consideration the operational differences, such as the presence of charge injection and the warmer focal plane temperature of the XIS. The low-Earth orbit of Suzuki has the advantage of a lower and stable particle background during observations, while the Chandra particle background during observations is higher and subject to variations due to the solar cycle and solar storms. This is in contrast to the rate of radiation damage accumulation, which is about four times higher for Suzuki, even after correcting for operational differences. We present models of the particle environments for both Suzaku and Chandra which can explain the apparent discrepancy. While the choice of orbit for future missions is obviously dependent on many factors beyond radiation environment, we hope this study will be useful for better informing that choice.

Author(s): Catherine E. Grant¹, Beverly LaMarr¹, Eric D. Miller¹, Mark W. Bautz¹
Institution(s): 1. MIT, Cambridge, MA.

116.04 – New prospects for Laue lenses made of self-focusing Si Laue Components (SiLCs)
A Laue lens telescope (LLT) could efficiently complement wide field of view instruments in the soft gamma-ray domain by providing enhanced sensitivity and angular resolution in a selection of energy bands. The observation of nuclear decay lines from supernovae, novae, and supernovae remnants, and the study of the hard tails from compact objects (enabling the detection of polarization) are areas for which a LLT would provide unmatched performance. We present a new concept of Laue lens using self-focusing elements, the SiLCs, a new technology derived from Silicon Pore Optics. A Laue lens made of SiLCs can produce a point-spread function of a few hundred microns in diameter, enabling previously unthinkable sensitivity and imaging capabilities, vastly improving the performances with respect to ‘classical’ Laue lenses. The first SiLCs were produced and tested in 2013, confirming the potential of this revolutionary technique.
Author(s): Nicolas M. Barrière¹, Marcel Ackermann², Colin Wade³, Steven E. Boggs¹, Lorraine Hanlon³, John Tomsick¹, Peter von Ballmoos⁴

Institution(s): 1. Space Sciences Laboratory, UC Berkeley, Berkeley, CA. 2. cosine Research B.V, Leiden, Netherlands. 3. School of Physics, University College Dublin, Dublin, Ireland. 4. Institut de Recherche en Astrophysique et Planétologie, UMR 5277, Toulouse, France.

116.05 – The Speedster-EXD - A New Event-Triggered Hybrid CMOS X-ray Detector

We present the characterization of a new event driven x-ray hybrid CMOS detector developed by Teledyne imaging Sensors in collaboration with Penn State University. Hybrid CMOS detectors currently have many advantages over CCD’s including lower susceptibility to radiation damage, lower power consumption, and faster read-out time to avoid pile-up. The Speedster-EXD includes an in-pixel comparator that enables read out of only the pixels with signal from an x-ray event. The comparator threshold can be set by the user and only pixels with signal above this threshold are read out. This event-driven readout feature can increase effective frame rates by orders of magnitude, enabling future x-ray missions. The Speedster-EXD hybrid CMOS detector also has additional features that improve upon our previous generation of detectors including: (1) a low-noise, high-gain CTIA amplifier to eliminate interpixel capacitance crosstalk, (2) four different gain modes to optimize either full well capacity or energy resolution, and (3) in-pixel CDS subtraction to reduce read noise. We present the read noise, dark current, interpixel capacitance, energy resolution, and gain variation measurements of the Speedster-EXD detector.

Author(s): Christopher Griffith¹, Abraham Falcone¹, Zachary Prieskorn¹, David N. Burrows¹

Institution(s): 1. Penn State, University Park, PA.

116.06 – In-Flight Calibration Plans for Astro-H

We present a preliminary list of candidate sources that will be used as performance verification targets for the four instruments on the Astro-H observatory, slated for launch in November 2015. Target viability is being assessed with spectral simulations in order to determine the optimal exposure time necessary to achieve the uncertainty requirement and goal on each parameter of interest.

Author(s): Laura Brenneman¹, Randall K. Smith¹, Robert Petre², Matteo Guainazzi³


116.07 – A Future NICER Observation of Pulsar J0437-4715 from the Perspective of the X-ray Concentrators’ Performance

While on-board the International Space Station, the Neutron Star Interior Composition ExploreR (NICER) will perform high accuracy X-ray timing measurements of neutron stars. The X-ray Timing Instrument (XTI), consisting of 56, high effective area, X-ray Concentrators (XRCs) co-aligned with silicon drift detectors, provides absolute GPS-based photon time-tagging. This allows for high-quality lightcurves from long exposures compiled over many brief observation segments. Through energy-dependent lightcurve analysis of millisecond pulsar observations we can infer neutron star radii within 5% and further constrain the equations of state. One of NICER’s key targets to perform a radius measurement is PSR J0437-4715, the closest known MSP. However, the observation of this pulsar will not be as straight forward as pointing the XTI in the pulsar’s direction. One of the main reasons the XRCs have such a high effective area is...
the same reason this observation poses a unique challenge, concentrators cannot discriminate photons from different sources. With the XRCs’ field of view of 6 arcminutes and a bright AGN (RX J0437.4-4711) located less than 4.3’ from PSR J0437-4715, we must minimize the AGN photon contribution in order to minimize the uncertainty in the radius measurement. Even though the AGN is approximately one order of magnitude brighter than the pulsar, the XRCs’ effective area depends greatly on the photons’ incident angles. The fact that the efficiency of a source observed off-axis is much lower than one observed on-axis can be used to our advantage. Using a comprehensive analysis and thorough understanding of the XRC performance from X-ray testing at NASA Goddard’s beamlines and NICER’s raytrace code, I am developing a method for observing PSR J0437-4715. The simulations for this work include considering NICER’s pointing budget and the timing and spectral properties of these sources from previous research found in the literature.

**Author(s): Erin Balsamo\(^1,4\), Keith Gendreau\(^2\), Zaven Arzoumanian\(^3,2\)**


**Contribution team(s):** NICER

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**116.08 – Cross-calibration of the X-ray Instruments onboard the Chandra, Suzaku, Swift, & XMM-Newton Observatories using 1E 0102.2-7219**

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

**Author(s):** Paul P. Plucinsky\(^1\), Andrew P. Beardmore\(^2\), Daniel Dewey\(^3\), Adam Foster\(^1\), Frank Haberl\(^5\), Eric D. Miller\(^3\), Andrew Pollock\(^4\), Steve Sembay\(^2\), Randall K. Smith\(^1\)

116.09 – Chandra Optical Axis, Aimpoint and Their Drifts
Chandra X-ray Observatory revolutionized the X-ray astronomy as being the first, and so far the only, X-ray telescope achieving sub-arcsecond resolution. Chandra comprises of three principal elements: the High Resolution Mirror Assembly (HRMA), Pointing Control and Aspect Determination (PCAD) system, and the Science Instrument Module (SIM). To achieve and retain the unprecedented imaging quality, it is critical that these three principal elements stay rigid and stable for the entire life time of the Chandra operation. Measuring and tracking the telescope optical axis and aimpoint positions are the key to understand the stability of the telescope and to maintain the optimal Chandra operation. The study shows that both the optical axis and the aimpoint has been drifting since Chandra launch. I will review the history and current status of these drift and their impact to the Chandra operation, as well as the steps we took to ensure the Chandra science returns.

Author(s): Ping Zhao
Institution(s): 1. Harvard-Smithsonian, CfA, Cambridge, MA.

116.10 – Ongoing and Planned Space Missions for High Energy Astrophysics in China: How to Reduce the Cost?
In this talk, I will introduce the ongoing and planned space missions, dedicated to high energy astrophysics in China, including X-ray missions e.g. HXMT, POLAR, and Einstein Probe, and gamma-ray missions e.g. DAMPE and HERD. I will briefly talk about the budget situation and possible ways to reduce the cost of space mission learned from the limited experience out of these space missions.

Author(s): Meng Su
Institution(s): 1. MIT, Cambridge, MA.

116.11 – BurstCube: A Gamma-ray Burst Detecting Swarm of CubeSats
The study of gamma-ray bursts (GRBs) has seen major advances in the past decade based on the results of several highly successful missions like Swift and Fermi. These prolific GRB detectors have enabled multi-wavelength follow-up of hundreds of GRBs and have allowed us to answer some of the outstanding questions in this field as well as prompted research in many new directions. It is critical to continue GRB detection, especially with gravitational wave detectors coming online in the next few years, e.g. advanced LIGO/Virgo, and the continued operation of multi-messenger observatories such as IceCube. Without the detection and study of counterparts to these future non-photon detections, the full characterization of a GRB would be difficult. The current GRB detection technology is at a mature level such that small, inexpensive detectors on CubeSats could perform as well or better than the current generation of GRB scintillator detectors. This paper will detail the design parameters and performance of small, GRB detecting CubeSats operating in a swarm that can detect, localize, and characterize GRBs via the high energy photon signatures.

Author(s): Jeremy S. Perkins, Judith L. Racusin, John F. Krizmanic, Julie E. McEnery
Institution(s): 1. NASA/GSFC, Greenbelt, MD. 2. USRA/CRESST/GSFC, Greenbelt, MD.

116.12 – Detection of ultra-high energy neutrino interactions in ice: comparing radio detector array designs
Ultra-high energy (UHE, >10\(^{18}\) eV) cosmic neutrinos are anticipated to reveal the most distant, most obscured, and highest energy particle accelerators in the Universe. An almost guaranteed
flux of UHE neutrinos is predicted from the interactions of UHE cosmic rays with the cosmic microwave background, and additional contributions may arise from prompt emission at individual sources. The spectrum of UHE neutrinos is a sensitive discriminator of the cosmological evolution of UHE sources, as well as the composition of UHE cosmic rays. At the same time, UHE neutrinos will enable several tests of fundamental physics, including constraints on the neutrino-nucleon interaction cross section at center-of-momentum energies $\sim$100 TeV, and searches for Lorentz invariance violation. Theoretical predictions and subsequent laboratory measurements of coherent radio emission from showers initiated by neutrino interactions in dielectric media (e.g., ice, sand, salt, lunar regolith) have motivated diverse experimental approaches involving "detectors" comprised of up to millions of cubic kilometers of natural materials. I will discuss simulation results comparing the expected performance of several proposed radio detector array designs with subterranean, ice shelf, and above ice configurations.

**Author(s):** Keith Bechtol\textsuperscript{1}, Abigail Vieregg\textsuperscript{1}

**Institution(s):** 1. University of Chicago, Chicago, IL.

**116.13 – Tests of General Relativity in the Strong Gravity Regime With the Space-Borne X-Calibur X-ray Polarimeter**

Broadband spectropolarimetric observations of black holes in X-ray binaries with X-Calibur will allow us to test General Relativity in the yet untested strong gravity regime. We study the spectral and polarimetric signatures with two models. First we model a hot spot in the accretion disk of a black hole. This is then used to explain the position and amplitude of the high frequency quasi periodic oscillations (HFQPO) peaks. These HFQPOs have been repeatedly observed at near constant frequencies however their origin is still unknown. The second model uses a lamp-post to illuminate the accretion disk with high-energy photons. Photons acquire a polarization when scattering in the disk. We have developed a code that parallel transports the photon wave and polarization vectors through the Kerr spacetime or alternative spacetimes. Furthermore, it models the polarization changes from photon reflections off the accretion disk with the formalism of Chandrasekhar (1950). The numerical simulations allow us to evaluate how well X-Calibur can constrain the black hole spin and the accretion disk inclination. Furthermore, we are able to assess the impact of alternative spacetimes on the observable flux and polarization energy spectra.

**Author(s):** Janie Hoormann\textsuperscript{1}, Banafsheh Beheshtipour\textsuperscript{1}, Nathan Walsh\textsuperscript{1}, Henric Krawczynski\textsuperscript{1}

**Institution(s):** 1. Physics Department, Washington University in St. Louis, St. Louis, MO.


Since the launch of AGILE and FERMI, the scientific progress in high-energy ($E_g > 200$ MeV) gamma-ray science has been, and will continue to be dramatic. Both of these telescopes cover a broad energy range from $\sim$20 MeV to $>$10 GeV. However, neither instrument is optimized for observations below $\sim$200 MeV where many astrophysical objects exhibit unique, transitory behavior, such as spectral breaks, bursts, and flares. Hence, while significant progress from current observations is expected, a significant sensitivity gap will remain in the medium-energy regime ($0.75 – 200$ MeV) that has been explored only by COMPTEL and EGRET on CGRO. Tapping into this unexplored regime requires development of a telescope with significant
improvement in sensitivity. Our mission concept, covering ~5 to ~200 MeV, is the Advanced Energetic Pair Telescope (AdEPT). The AdEPT telescope will achieve angular resolution of ~0.6 deg at 70 MeV, similar to the angular resolution of Fermi/LAT at ~1 GeV that brought tremendous success in identifying new sources. AdEPT will also provide unprecedented polarization sensitivity, ~1% for a 1 Crab source. The enabling technology for AdEPT is the Three-Dimensional Track Imager (3-DTI) a low-density, large volume, gas time-projection chamber with a 2-dimensional readout. The 3-DTI provides high-resolution three-dimensional electron tracking with minimal Coulomb scattering that is essential to achieve high angular resolution and polarization sensitivity. We describe the design, fabrication, and performance of the 3-DTI detector, describe the development of a 50x50x100 cm3 AdEPT prototype, and highlight a few of the key science questions that AdEPT will address.

Author(s): Stanley D. Hunter¹, Georgia De Nolfo¹, Andrei R. Hanu¹, John F. Krizmanic¹, Floyd W. Stecker¹, Andrey Timokhin¹, Tonia M. Venters¹

Institution(s): 1. Code 661, NASA/GSFC, Greenbelt, MD.

116.15 – Transforming Our Understanding of the X-ray Universe: The Imaging X-ray Polarimeter Explorer (IXPE)

Accurate X-ray polarimetry can provide unique information on high-energy-astrophysical processes and sources. As there have been no meaningful X-ray polarization measurements of cosmic sources since our pioneering work in the 1970’s, the time is ripe to explore this new parameter space in X-ray astronomy. To accomplish this requires a well-calibrated and well-understood system that—particularly for an Explorer mission—has technical, cost, and schedule credibility. The system that we shall present satisfies these conditions, being based upon completely calibrated imaging- and polarization-sensitive detectors and proven X-ray-telescope technology.

Author(s): Martin C. Weisskopf¹, Ronaldo Bellazzini², Enrico Costa³, Giorgio Matt⁴, Herman L. Marshall⁵, Stephen L. O’Dell¹, George G. Pavlov⁶, Brian Ramsey¹, Roger W. Romani⁷

Institution(s): 1. NASA/MSFC, Huntsville, AL. 2. INFN, Pisa, Italy. 3. IAPS-INAF, Rome, Italy. 4. Universita Roma Tre, Rome, Italy. 5. MIT, Cambridge, MA. 6. PSU, Happy Valley, PA. 7. Stanford University, Palo Alto, CA.

Contributing team(s): The IXPE Collaboration

116.16 – The Athena X-ray Observatory: observing luminous extragalactic transients

The ESA Athena X-ray observatory will combine exceptionally high throughout with high spectral-energy resolution. Athena will revolutionize many aspects of high-energy astrophysics. Here we concentrate on the subject of time-domain astronomy. Many of the most powerful transient sources, including gamma-ray bursts and tidal disruptions events, are bright X-ray sources. Athena will be designed to have a fast-response capability, permitting efficient observations of many transients. We will summarize the proposed capability of the mission and illustrate science programs to study transients ranging from the most distant GRBs to nuclear activity in nearby galaxies.

Author(s): P. T. O’Brien¹, Peter G. Jonker²


116.17 – PANGU: A High Resolution Gamma-Ray Space Telescope
We propose a high angular resolution telescope dedicated to the sub-GeV gamma-ray astronomy as a candidate for the CAS-ESA joint small mission. This mission, called PANGU (PAir-poductionN Gamma-ray Unit), will open up a unique window of electromagnetic spectrum that has never been explored with great precision. A wide range of topics of both astronomy and fundamental physics can be attacked with a telescope that has an angular resolution about one order of magnitude better than the currently operating Fermi Gamma-ray Space Telescope (Fermi) in the sub-GeV range, covering galactic and extragalactic cosmic-ray physics, extreme physics of a variety of extended (e.g. supernova remnants, galaxies, galaxy clusters) and compact (e.g. black holes, pulsars, gamma-ray bursts) objects, solar and terrestrial gamma-ray phenomena, and searching for Dark Matter (DM) decay and/or annihilation signature etc. The unprecedented resolution can be achieved with a pair-production telescope that, instead of the high-Z converter commonly used, relies on a large number of thin active tracking layers to increase the photon conversion probability, and to precisely reconstruct the pair-produced electron and positron tracks. Scintillating fibers or thin silicon micro-strip detectors are suitable technology for such a tracker. The energy measurement is achieved by measuring the momentum of the electrons and positrons through a magnetic field. The innovated spectrometer approach provides superior photon conversion identification and photon pointing resolution, and is particular suitable in the sub-GeV range, where the opening angle between the electron and positron is relatively large. The level of tracking precision makes it possible to measure the polarization of gamma rays, which would open up a new frontier in gamma-ray astronomy. The sub-GeV full sky survey by PANGU would provides crucial link with GeV to TeV maps from current/future missions including Fermi, DAMPE, HERD, and CTA.

Author(s): Meng Su
Institution(s): 1. MIT, Cambridge, MA.

116.18 – Arcus: A Low Cost and High Capability X-ray Grating Spectrometer on the ISS

We present the scientific motivation for Arcus, a proposed X-ray grating spectrometer SMEX mission to be deployed on the International Space Station. The primary goals of this mission are to understand structure formation via the imprint it leaves on hot gas in and around galaxies and clusters, to characterize feedback from supermassive black holes by observing highly ionized material coming from these sources, and to study the stellar life cycle from formation through death. The mission parameters are similar to those of the IXO X-ray Grating Spectrometer, with of R>2500 and > 600 sq. cm around the crucial O VII and O VIII lines, and a bandpass from 8-52 A (0.25-1.5 keV).

Author(s): Randall K. Smith
Institution(s): 1. Smithsonian Astrophysical Observatory, Cambridge, MA.

Contributing team(s): The Arcus Collaboration

116.19 – Arcus: An X-ray Grating Spectrometer on the ISS: Mission Overview

Arcus is an X-ray grating spectrometer mission to be deployed on the International Space Station in response to NASA’s Astrophysics Division plan to announce a SMEX call in Fall 2014 with a cost cap of $125M (FY15). The baseline design uses sub-apertured X-ray silicon pore optics feeding into off-plane gratings to achieve both high spectral resolution with a large effective area. The detector focal plane uses Suzaku-type CCDs. The mission would be ready to be launched and mounted on the ISS in 2020. The mission parameters are R=2800 and ~800 sq.
cm at the critical O VII wavelength near 21Å (~0.5 keV), with an overall bandpass from 8-52Å (0.25-1.5 keV), enabling a wide range of science objectives. These values are similar to those of the grating spectrometers considered as part of the proposed Constellation-X and IXO missions, which were highly ranked by two Decadal surveys.

Author(s): Jay A. Bookbinder¹
Institution(s): 1. Smithsonian Astrophysical Obs., Cambridge, MA.

Contributing team(s): the Arcus Team

116.20 – GEMS Instrument Performance and Science

The Gravity and Extreme Magnetism Small Explorer (GEMS) will realize its scientific objectives through high sensitivity linear X-ray polarization measurements in the 2-10 keV band. The GEMS X-ray polarimeters, based on the photoelectric effect, provide a strong polarization response with high quantum efficiency over a broad band-pass using a time projection chamber. This poster will provide an update on the performance of the GEMS flight polarimeters. We will present measurements of the detector response to X-rays and measures of the level of systematic errors. We will also summarize and update the science goals for X-ray polarimetry missions.

Author(s): Timothy R. Kallman¹, Kevin Black¹, Joanne E. Hill¹, Keith Jahoda¹
Institution(s): 1. NASA’s GSFC, Greenbelt, MD.

116.21 – HaloSat – A CubeSat to Study the Hot Galactic Halo

Observations fail to locate about half of the baryons required in cosmology. One possible reservoir of missing baryons associated with our Milky Way galaxy is an extended halo of X-ray emitting gas at temperatures of several million degrees. We describe a CubeSat capable of measuring the oxygen line emission from the hot, Galactic halo. HaloSat will provide an unprecedented, all sky map of the emission lines of O VII and O VIII. This will improve our understanding of the quantity and distribution of hot gas in the Milky Way and also of solar wind charge exchange interactions within the solar system. The mission can be accomplished at modest cost.

Author(s): Philip Kaaret¹, Keith Jahoda², Brenda Dingwall³
Institution(s): 1. Univ. of Iowa, Iowa City, IA. 2. NASA/GSFC, Greenbelt, MD. 3. NASA/WFF, Wallops Island, VA.

116.22 – Thin fused silica optics for a high angular resolution and large collecting area X Ray telescope after Chandra

The implementation of an X-ray mission with high imaging capabilities, similar to those achieved with Chandra (<1 arcsec Half Energy Width, HEW), but with a much larger throughput is very attractive, even if challenging. For such a mission the scientific opportunities, in particular for the study of the early Universe, would remain at the state of the art for the next decades. Initially the ESA-led XEUS mission was proposed, with an effective area of several m² and an angular resolution better than 2 arcsec HEW. Unfortunately, this mission was not implemented, mainly due to the costs and the low level of technology readiness. Currently the most advanced proposal for such a mission is the SMART-X project, led by CfA together with other US institutes. This project is based on adjustable segments of thin foil mirrors with piezo-electric actuators, aiming to achieve an effective area >2 m² at 1 keV and an angular resolution better than 1 arcsec HEW. Another attractive technology to realize an X-ray telescope with
similar characteristics is being developed at NASA/Goddard. In this case the mirrors are based on Si substrates that are super-polished and figured starting from a bulky Si ingot, from which they are properly cut. Here we propose an alternative method based on precise direct grinding, figuring and polishing of thin (a few mm) glass shells with innovative deterministic polishing methods. This is followed by a final correction via ion figuring to obtain the desired accuracy. For this purpose, a temporary stiffening structure is used to support the shell from the polishing operations up to its integration in the telescope supporting structure. This paper deals with the technological process under development, the results achieved so far and some mission scenarios based on this kind of optics, aiming to achieve an effective area more than 10 times larger than Chandra and an angular resolution of 1 arcsec HEW on axis and of a few arcsec off-axis across a large field of view (10 in diameter).

Author(s): Giovanni Pareschi¹, Oberto Citterio², Marta M. Civitani¹, Stefano Basso¹, Sergio Campana¹, Paolo Conconi¹, Mauro Ghigo¹, Enrico Mattaini³, Alberto Moretti¹, Giancarlo Parodi⁴, Gianpiero Tagliaferri⁵

Institution(s): 1. INAF-Osservatorio Astronomico di Brera, Merate, Italy. 2. Media Lario Technologies, Bosisio Parini (LC), Italy. 3. INAF-IASF Milano, Milano, Italy. 4. BCV Progetti, Milano, Italy.

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

Every conceivable future x-ray astronomical mission would require x-ray optics. These optics must meet the three-fold requirements of angular resolution, effective area, and cost. 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.

Author(s): William Zhang¹

Institution(s): 1. NASA's GSFC, Greenbelt, MD.

116.24 – Development Status of Adjustable X-ray Optics with 0.5 Arcsecond Resolution

We report on the continuing development of adjustable, grazing incidence X-ray optics for 0.5 arcsec telescopes. 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 piezoelectric 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 cell yield to ~ 100 per cent, measurements of hysteresis and stability, comparisons of modeled and measured behavior, simulations of mirror performance, and the development and testing of conical Wolter-I mirror segments. We also present our plans going forward toward the eventual goal of achieving TRL 6 prior to the 2020 Decadal Review.

Author(s): Paul B. Reid¹, Thomas Aldcroft¹, Ryan Allured¹, Vincenzo Cotroneo¹, Raegan L. Johnson-Wilke², Vanessa Marquez¹, Stuart McMuldroch¹, Daniel A. Schwartz¹, Susan Trolier-
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 small-size telescope (SST) of the Cherenkov Telescope Array, CTA, sensitive in the energy band from a few TeV up to hundreds TeV. The ASTRI telescope is based on a dual-mirror Schwarzschild-Couder (ASTRI SST-2M) optical design, with a compact (F# = 0.5) optical configuration named ASTRI SST-2M telescope. This allows us to adopt an innovative modular focal plane camera based on silicon photo-multipliers, with a logical pixel size of 6.2mm x 6.2mm. Moreover, planned, and already being developed, an SST mini-array based on 7 identical telescopes represents an evolution of the ASTRI SST-2M telescope. The ASTRI/CTA mini-array will be part of the CTA array, representing a precursor that will be included into the final array. With the mini-array, in addition to a technical assessment studies in the perspective of the full CTA implementation, it will be possible to perform an early scientific program. In particular we wish to start investigating the poorly known energy range between a few and 100 TeV, thus exploring e.g. the cut-off regime of cosmic accelerators. Apart from INAF, other international institutes will directly participate in the mini-array implementation, as the North-West University in South Africa and the University of Sao Paulo in Brazil. An interest about it has been expressed also by other international groups. In this talk we will report on the development status of the ASTRI prototype and ASTRI/CTA mini-array.
116.26 – Development of a Schwarzschild-Couder Optical System for the Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is the next-generation ground-based observatory for very high energy (E > 100 GeV) gamma-ray astronomy. It will integrate several tens of imaging atmospheric Cherenkov telescopes (IACTs) with different apertures into a single astronomical instrument. The US constituent of the CTA Consortium has proposed and is developing a novel IACT design with a Schwarzschild-Couder (SC) aplanatic two-mirror optical system. We report on the status of the development of the SC optical system, part of the effort to build and test a full-scale prototype telescope of this design at the Fred Lawrence Whipple Observatory in southern Arizona.

Author(s): Brian Humensky¹, Valerie Connaughton², Manel Errando³, Reshmi Mukherjee³, Daniel Nieto¹, Akira Okumura⁴, Julien Rousselle⁵, Vladimir Vassiliev⁵


Contributing team(s): CTA Consortium

116.27 – Cherenkov Telescope Array Technologies

The Cherenkov Telescope Array (CTA) will feature innovative technologies to achieve an order of magnitude greater sensitivity than the current generation of ground-based imaging atmospheric Cherenkov telescopes (IACTs). Several telescope designs of various sizes are currently in the prototyping stage. In addition to the traditional single-mirror Davies-Cotton design used for IACTs to date, a dual-mirror Schwarzschild-Couder design is being prototyped for both the small (4 m diameter) and medium (9.5 m diameter) telescopes. The dual-mirror designs feature compact focal planes that enable Cherenkov photon detection with innovative photo-detectors including silicon photomultipliers. The prototype telescopes are also testing several designs for readout electronics to capture the fast (~10 ns) Cherenkov light pulses from hundreds of thousands of channels across the array. Finally, the CTA prototype telescopes are testing technologies for telescope mounts and mirrors that meet the unique needs of a large array of IACTs.

Author(s): Justin Vandenbroucke¹

Institution(s): 1. University of Wisconsin, Madison, WI.

116.28 – Cherenkov Telescope Array Sensitivity
The Cherenkov Telescope Array (CTA) will provide unprecedented capabilities in the gamma-ray regime, from a few tens of GeV up to at least 100 TeV. The goal of CTA is to improve the sensitivity over the whole energy range covered by current ground-based telescopes by a factor of between 5 and 10, depending on the energy, to extend the range of energies observed, with significantly improved energy and angular resolution over previous instruments. Plans for the layout of the array and the estimated sensitivity, derived from Monte Carlo, will be presented.

**Author(s):** Brian Humensky\textsuperscript{1}, Jeff Grube\textsuperscript{2,3}


**Contributing team(s):** CTA Consortium

116.29 – Cherenkov Telescope Array Site Search

The Cherenkov Telescope Array (CTA) will be built on two sites, one placed in the Southern Hemisphere and another in the Northern Hemisphere, in order to achieve full sky coverage. The sites in the Northern Hemisphere under consideration include San Pedro Martir in Mexico (Baja California), a site near Izana on the island of Tenerife in Spain (Canary Islands), and two sites in the USA (Northern Arizona). In the South, negotiations are under way with Namibia (a site on the farm Aar near Aus) and Chile (a site near Paranal), while Argentina is considered as a third option. The data collection efforts for site evaluation and the key site specifications will be summarized.

**Author(s):** Brian Humensky\textsuperscript{1}, Jeff Grube\textsuperscript{2,3}


**Contributing team(s):** CTA Consortium

116.30 – Science with the Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is the next-generation ground-based observatory with an unprecedented sensitivity to gamma-rays with energies from a few tens of GeV to more than 100 TeV. CTA will address a wide range of scientific questions, which can be grouped into three broad themes of cosmic particle acceleration and propagation, probing extreme environments, and physics frontiers. The first and second themes include improving our understanding of the sites of particle acceleration in our galaxy, in the jets and lobes of active galaxies, and in many other extreme regions. The physics frontier theme includes the search for the nature and distribution of Dark Matter, and investigating if the speed of light is constant for high-energy photons. CTA observations will address these science themes with deep surveys and monitoring observations to build source populations and study transient phenomena.

**Author(s):** Jeff Grube\textsuperscript{1}

**Institution(s):** 1. Adler Planetarium for the CTA Consortium, Chicago, IL.

117 – NuSTAR

117.01 – NuSTAR Observations of the Norma Arm Region

One of the Galactic regions being surveyed by NuSTAR covers a 2 degree x 0.8 degree region of the Norma Arm that was observed with Chandra in 2011. This region was selected because its recent star formation and large number of OB associations make it a good place to search for and study X-ray sources associated with massive stars, such as high-mass X-ray binaries.
(HMXBs) and colliding wind binaries (CWBs). For the vast majority of sources in this region, the Chandra data are insufficient for constraining their individual spectral parameters and identifying their physical nature, but combining NuSTAR and Chandra data provides strong constraints on their X-ray properties. Roughly a third of the area surveyed by Chandra has been observed with NuSTAR to date, and we present preliminary results identifying the hard X-ray sources observed by both telescopes. We have obtained near-infrared spectra of the counterparts of some of these X-ray sources, which also facilitate their identifications. Although our analysis is ongoing, a significant fraction of sources appear to be intermediate polars, some are likely CWBs and HMXBs, and one may be a black hole binary.

Author(s): Francesca Fornasini, John Tomsick, Arash Bodaghee, Roman Krivonos, Farid Rahoui, Franz E. Bauer, Jesus Corral-Santana, Daniel Stern


117.02 – NuSTAR observations of SMC X-1 at two different superorbital phases

SMC X-1 is a Roche-lobe accreting 0.71 s X-ray pulsar with a supergiant companion. The system has a 3.9 day orbital period and is eclipsing. Its X-ray lightcurve also shows a superorbital cycle, on a varying timescale of 40 to 70 d. This variability is thought to be due to a precessing, warped accretion disk which leads to varying obscuration. NuSTAR observed SMC X-1 twice in 2012, once during a minimum of its superorbital cycle and once during the decline of the following peak. The fluxes of the two observations differ by a factor of 10. We present a detailed broadband spectral analysis and comparison of the two spectra. They are well described by empirical cutoff power law models as well as by thermal Comptonization. The previously reported soft excess from the accretion disk is also tentatively detected. One spectral difference between the two superorbital phases is that the low flux spectrum shows additional absorption as well as a higher equivalent width iron line. This confirms the warped disk picture and refines sparse earlier broadband results obtained with BeppoSax and RXTE. Above 3 keV the pulse profile is only mildly energy dependent. For the high flux observation we perform a detailed pulse phase resolved analysis. No strong changes in spectral shape are detected. To our knowledge this is the first such spectral study extending to above 10 keV reported for SMC X-1.

Author(s): Katja Pottschmidt, Matteo Bachetti, Felix Fuerst, Jean-Christophe Leyder, Steven E. Boggs, Deepto Chakrabarty, Finn Christensen, William W. Craig, Brian Grefenstette, Charles J. Hailey, Fiona Harrison, Ann E. Hornschemeier, Kristin Madsen, Craig Markwardt, Daniel Stern, Rebecca Tang, John Tomsick, Joern Wilms, William Zhang

117.03 – Supernova Remnants with NuSTAR: Highlights and new discoveries
Young supernova remnants represent a unique laboratory for the study of supernova explosion dynamics and particle acceleration in the local universe. In the hard X-ray band probed by NuSTAR (3-79 keV), the continuum emission is thought to be dominated by synchrotron radiation from ~TeV electrons, while line emission at 68 and 78 keV is produced by the decay of radioactive 44Ti synthesized in the supernova explosion. Here we present highlights of the supernova remnant science from the first two years of the NuSTAR mission.

Author(s): Brian Grefenstette
Institution(s): 1. Caltech, Pasadena, CA.
Contributing team(s): The NuSTAR Team

117.04 – Observations of the Magnetar 1E 2259+586 with NuSTAR
We present new spectral and temporal observations of the magnetar 1E 2259+586 located in the supernova remnant CTB 109. Our analysis covers the energy range from 0.5-79 keV and is based on data acquired simultaneously with the Nuclear Spectroscopic Telescope Array (NuSTAR) and Swift. Double-peaked pulse profiles in various energy bands are shown and we compare them to previously published RXTE results. With NuSTAR, pulsations above 20 keV are observed for the first time and we report evidence that one of the pulses in the double-peaked pulse profile shifts position with energy. We found the pulsed fraction of the magnetar increases strongly with energy and our spectral analysis reveals that the soft X-ray spectrum is well characterized by an absorbed double-blackbody or blackbody plus power-law model in agreement with previous reports. Our new hard X-ray data, however, suggests that an additional component, such as a power-law, is needed to describe the NuSTAR and Swift spectrum. We also fit the data with the recently developed coronal outflow model by Beloborodov for hard X-ray emission from magnetars and show that the outflow from a ring on the magnetar surface is statistically preferred over outflow from a polar cap. Part of this work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 (LLNL-ABS-654716).

Author(s): Julia K. Vogel1, Romain Hascoet2, Victoria M. Kaspi3, Hongjun An3, Robert F. Archibald3, Andrei M. Beloborodov2, Steven E. Boggs4, Finn Christensen5, William W. Craig4, Eric V. Gotthelf2, Brian Grefenstette6, Charles J. Hailey2, Fiona Harrison6, Jamie A. Kennea7, Kristin Madsen6, Michael Pivovaroff1, Daniel Stern6, William Zhang9
Contributing team(s): NuSTAR Magnetar/RPP Team, NuSTAR Team

117.05 – A NuSTAR Survey of Nearby Ultraluminous Infrared Galaxies
Ultraluminous infrared galaxies (ULIRGs) are typically weak in the X-rays based on previous surveys of ULIRGs at energies below 10 keV. It is thought that the poor detection statistics is a result of either the low luminosity nature of their central engines or the purported Compton-thick columns that obscure their nuclei. This is consistent with the idea that ULIRGs are part of an evolutionary paradigm where gas-rich galaxies collide, rapidly form stars and feed a buried active nucleus. The nucleus then shines as an unobscured quasar once the obscuring material is
removed through galactic-scale winds. The ULIRG phase occurs during the most obscured period when the central black hole is growing most rapidly. Taking advantage of NuSTAR's sensitivity at energies above 10 keV, we conducted a survey of nine of the nearest ULIRGs. Here, we present the results from our imaging and spectral analysis of these data.

**Author(s):** Stacy H. Teng

**Institution(s):** 1. NASA/GSFC, Greenbelt, MD.

**Contributing team(s):** the NuSTAR team

118 – SMBH

118.01 – Flaring Activity of Sgr A* During the Passage of the G2 Cloud

Preliminary results of our monitoring of Sgr A* in coordination with Chandra, XMM and HST will be presented. The main focus will be on the cross correlation analysis of radio and X-ray flare emission on September 12, 2013 when a luminous X-ray flare was detected by Chandra. The peak of flare emission at 3.5cm was found to be delayed by more than 130 minutes when compared to the peak of the X-ray emission. The cross correlation of the peak emission at radio and X-rays is consistent with an adiabatic expansion model of flare emission.

**Author(s):** Farhad Yusef-Zadeh, Howard A. Bushouse, William D. Cotton, N. Grosso, Daryl Haggard, Craig O. Heinke, E. Mossoux, D. Porquet, Douglas A. Roberts, M. Wardle


118.02 – New and Recurring Galactic Center X-ray Transients from Chandra, Swift, and XMM

Intensive X-ray monitoring campaigns have revealed a wealth of new and unusual transient phenomena in the Galactic Center. The magnetar SGR J174540.2-290029, discovered in April 2013, remains bright in Chandra observations, with a spectrum still consistent with a ~0.8keV blackbody, and a 1-10keV absorbed flux of ~2.6x10^-12 erg/s/cm^2, only marginally decayed in recent months. An outburst from CXO J174540.0-290005 in 2013 marks it as one of the best-studied very faint X-ray binaries (peak LX < 10^{36} erg/s) yet recorded, with detections in 173 ks of X-ray observations over 50 days. Three XMM Newton observations from August-September 2013 caught the eclipsing neutron star low mass X-ray binary, AXJ1745.6-2901 in outburst at a 3-10 keV flux level of 11.5, 17.0 and 16.4x10^-11 erg/s/cm^2 --- showing very interesting spectral variability. Daily Swift and ~monthly monitoring from Chandra over the last several years have also offered a unique view of the long-term X-ray behavior of Sgr A*, in particular of its X-ray flaring properties. We highlight these and other recent Galactic Center findings from current state-of-the-art X-ray observatories.

**Author(s):** Daryl Haggard, Nanda Rea, Francesco Coti Zelati, Craig O. Heinke, Eric Koch, Arash Bahramian, Kaya Mori, Nathalie Degenaar, Gabriele Ponti, Frederick K. Baganoff

**118.03 – Modelling Pericenter Passage near a Supermassive Black Hole**

On an eccentric trajectory toward a supermassive black hole, a core-less cloud is expected to produce distinct observational signatures from a star embedded in an extended dusty/gaseous envelope (Eckart et al. 2013; Zajacek et al. 2014). We model the pericenter passage of such a star that plunges as close as \( \sim 10^3 \) gravitational radii. As an example, we show predictions for the G2/DSO object in the Galactic center (Sgr A*) for which the stellar origin seems to be supported by observations. An encounter of a core-less cloud with a supermassive black hole would have been, most likely, a non-repeating event, whereas in the case of a star a part of the extended atmosphere can survive the pericenter passage. We also examine an interesting possibility of a binary system within a common envelope that becomes dispersed at the pericenter passage.

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**Institution(s):**
1. Astronomical Institute, Academy of Sciences, Prague, Czech Republic.
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3. Max-Planck-Institut für Radioastronomie (MPIfR), Bonn, Germany.

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**118.04 – Two-phase medium of the Galactic centre mini-spiral as the origin of activity of Sgr A* supermassive black hole at different level of accretion rate**

The thermal instability can enhance the process of capture of gaseous clouds from the Galactic centre mini-spiral onto the supermassive black hole (Sgr A*). This mechanism operates on the sub-parsec scale in a certain range of temperature and density, depending on the level of external irradiation. The instability is switched off in the present quiescent state of the Milky Way's nucleus, but it could have operated during the recent luminous episode of Sgr A* activity, when the accretion rate was probably higher. The combined effect of the central luminosity and the stellar radiation field determine the range of masses and sizes of clumps that can plunge from the mini-spiral and trigger the enhanced activity of the black hole.

**Author(s):** Devaky Kunneriath\(^1\), Agata Rozanska\(^2\), Bozena Czerny\(^2\), Tek P. Adhikari\(^2\), Vladimir Karas\(^1\), Monika Moscibrodzka\(^3\)

**Institution(s):**
1. Astronomical Institute, Prague, Czech Republic.
2. Nicolaus Copernicus Astronomical Center, Warsaw, Poland.
3. Department of Astrophysics, IMAPP, Nijmegen, Netherlands.

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**118.05 – VERITAS Observations of The Galactic Center Ridge**

The Galactic Center Ridge is perhaps the most local, busy environment for high-energy particle acceleration, harboring as it does many relativistic particle accelerators such as pulsar wind nebulae, supernova remnants, and the central supermassive black hole SgrA*. Observations with very high energy (VHE, >100 GeV) gamma-ray telescopes of the region have revealed multiple point sources associated with well-known objects, as well as regions of extended emission not directly associated with sources at other wavelengths. More importantly, the detection of a large, diffuse component of >300 GeV gamma-ray emission by the HESS collaboration is strongly believed to be the result of accelerated cosmic rays interacting with molecular-cloud regions, thus providing insight into high-energy cosmic ray acceleration. Here we present the VERITAS observations of the Galactic Center Ridge taken from 2008-2014 in the >2 TeV regime. We will focus on the VERITAS results on the known HESS sources in the region,
as well as the diffuse component of TeV emission along the plane. Due to the much higher energy threshold of the VERITAS observations, our data provide a new window into some of the highest energy particle acceleration occurring in the center of our galaxy.

Author(s): Andrew W. Smith

Institution(s): 1. Physics and Astronomy, University of Utah, Salt Lake City, UT.

Contributing team(s): VERITAS

118.06 – A Rapidly Spinning Black hole in the Lensed Quasar RX J1131-1231 at z=0.658

The co-evolution of a super-massive black hole with its host galaxy through cosmic time is encoded in its spin. We will report on a recent analysis of archival Chandra data together with a new XMM-Newton observation of the gravitationally lensed quasar RX J1131-1231 at a redshift of z=0.658. The boost in S/N provided by the gravitational lens allows us to place strict constraints on the spin of the SMBH in a moderate redshift quasar for the first time, with implications for the growth of SMBHs.

Author(s): Mark Reynolds, Ruben C. Reis, Jon M. Miller, Dom Walton

Institution(s): 1. University of Michigan, Ann Arbor, MI. 2. California Institute of technology, Pasadena, CA.

119 – Solar and Stellar

119.01 – Swift Observations of Proxima Cen

Swift observed Proxima Cen (dM5.5e) for more than 40 segments (roughly 100 separate exposures) from 2009 to 2012, including several UV grism observations. We present analyses of variability in the optical, UV, and X-ray bands on time scales covering individual flares to a possible multiyear stellar cycle, and show moderate-resolution spectra covering 2300-6000 Angstroms.

Author(s): Bradford J. Wargelin, Steven H. Saar, Jeremy J. Drake, Vinay Kashyap

Institution(s): 1. Harvard-Smithsonian, CfA, Cambridge, MA.

119.02 – X-ray Evidence for a Pole-Dominated Corona on AB Dor

Fine analysis of spectral line widths and Doppler shifts employing Fourier transform and cross-correlation techniques has been applied to the Chandra HETG spectra of the rapidly rotating young star AB Doradus in order to investigate its coronal topology. We find no significant Doppler shifts that could be attributed to rotation of dominant coronal structures. Individual spectral line widths are statistically consistent with thermal broadening and formally require no rotational broadening, while the 1σ limit to rotational broadening corresponds to a compact corona restricted to latitudes > 30 deg. Fourier analysis suggests a small amount of additional rotational broadening is present consistent with a corona restricted to the poles, and excludes models with surface rotational broadening or greater. These results present direct spectroscopic evidence that the dominant coronal activity on rapidly-rotating active stars is associated with the dark polar spots commonly seen in photospheric Doppler images, and support models in which these spots are of mixed magnetic polarity.

Author(s): Jeremy J. Drake, Sun Mi Chung, Vinay Kashyap, David Garcia-Alvarez

119.03 – Benchmarking abundance determinations of massive stars with X-ray spectroscopy

Nitrogen surface abundances of OB stars have recently emerged as a key test of evolutionary models. The correlation of nitrogen enrichment with stellar rotation in B stars and the many exceptions found by Hunter et al. (2008) provide intriguing clues about rotational mixing, magnetic fields, and binarity. Much less is known about O stars. Traditional abundance determinations rely on sophisticated, but also notoriously complex NLTE models of photospheric and wind lines in the optical and UV. X-ray observations have several advantages over traditional methods for abundance determination: line formation is greatly simplified, and emission line strength scales linearly with elemental abundance; and the temperature distribution and ionization balance are much easier to constrain, since the strongest lines of every dominant charge state of N and O are in the bandpass of the XMM-Newton Reflection Grating Spectrometer (RGS). We have developed a simple method for separating the modeling of the partially optically thick wind absorption from the multi-temperature emission, allowing fast and accurate extraction of elemental abundances. I will show preliminary results from the application of our method to a sample of archival RGS spectra of nearby O stars.

Author(s): Maurice A. Leutenegger\textsuperscript{1}, Jake Neely\textsuperscript{2}, David H. Cohen\textsuperscript{2}, Stan Owocki\textsuperscript{3}, Jon Sundqvist\textsuperscript{3,5}, Janos Zsargo\textsuperscript{4}


119.04 – An Isolated Forming Star in the Galactic Bulge Survey

We present photometry and spectroscopy of a candidate new FU Orionis object in the Galactic Bulge Survey (GBS). The GBS is an X-ray survey of the Galactic Bulge region targeted at identifying new Low Mass X-ray Binaries in quiescence. It is a wide field survey, covering 12 square degrees above and below the Galactic Plane, and as such we have many different types of X-ray sources with implications for a broad cross-section of astronomy. One such object undergoes an optical and infrared outburst of at least 6 magnitudes which lasts for at least 4 years. It has a strong infrared excess, indicating the presence of a cloud of dust around it. We propose that this object is a protostar undergoing an FU Orionis outburst, despite being in a region far from molecular clouds or large star forming regions. We discuss implications of this isolation for models of star formation in the Galaxy.

Author(s): Christopher Britt\textsuperscript{1}, Thomas J. Maccarone\textsuperscript{1}, Joel D. Green\textsuperscript{2}

Institution(s): 1. Texas Tech University, Lubbock, TX. 2. UT Austin, Austin, TX.

Contributing team(s): Chandra Galactic Bulge Survey Collaboration

119.05 – Tanagra: Timing Analysis of Grating Data

We describe the Tanagra dataset, which now contains the complete set of cool stars observed with the Chandra gratings thus far. We have analyzed the datasets to produce a catalog of light curves, flare-like events, measures of spectral variability, evaluations of variability for strong spectral lines, correlations of intensity between high- and low-temperature lines, and other useful observational summaries. We will describe the analysis methods used and the data products obtained, and highlight some special cases. This work has been supported by the Chandra archival grant AR0-11001X.
**Author(s):** Vinay Kashyap¹, Jennifer Posson-Brown¹, Jeremy J. Drake¹, Steven H. Saar¹, Jeffrey D. Scargle², Alanna Connors³


**Contributing team(s):** CHASC AstroStatistics Collaboration

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**120 – Supernovae and Supernova Remnants**

**120.01 – Chandra Observations of RCW 103**

We present analysis of Chandra observations of RCW103 with a combined exposure time of 99 ks, based on X-ray and equivalent width images, plus spectral analysis of 28 regions. We find strong variations in absorption across the remnant, with stronger absorption in the north and west. The electron temperature is fairly uniform at 0.58 keV. Metal abundances are inhomogeneous and vary from 0.3 - 1.4 solar from region to region, but likely include significant contributions from both the CSM, with subsolar abundances, and ejecta, with abundances that are above solar. Preliminary comparison with predictions for core-collapse nucleosynthesis models suggest a low progenitor mass of 13-15 solar masses.

**Author(s):** David N. Burrows¹, Kari A. Frank¹

**Institution(s):** 1. Penn State Univ., University Park, PA.

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**120.02 – X-ray Emission From Young Supernovae as a Probe of their Progenitor Stars**

After several decades of study, the progenitor stars of supernovae (SNe) have still proven difficult to identify. The identification of progenitors has generally been the purview of optical astronomy, aided by stellar evolution models. But observations at other wavelengths can provide strong clues about the progenitors. We have aggregated together data available in the literature, or analysed by us, to compute the X-ray lightcurves of almost all young SNe. We use these, coupled with analytical and numerical simulations, to explore the various SN types, investigate SN expansion, explore the characteristics of the medium into which SNe are expanding, and examine the implications for their progenitors. We show that the low X-ray luminosity of IIPs sets a limit on the mass-loss rate, and thereby constrains the maximum initial mass of a red supergiant star which can become a Type IIP progenitor to be lower than 19 solar masses. We discuss how current stellar evolution models relate to the X-ray emission from various types of SNe, and where discrepancies appear to arise between observations and theory.

**Author(s):** Vikram Dwarkadas¹

**Institution(s):** 1. Univ. of Chicago, Chicago, IL.

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**120.03 – Nonuniform Expansion of the Youngest Galactic Supernova Remnant G1.9+0.3**

G1.9+0.3 is the youngest known Galactic supernova remnant (SNR), about 100 yr old from global expansion measurements, and most likely the result of an asymmetric Type Ia supernova explosion. We smoothed a Chandra image from a 1 Ms observation in 2011 and fit the resulting model to unsmoothed images from 2007 and 2009, allowing for expansion and image shifts. The measured expansion rates strongly deviate from uniform expansion, increasing inward by about 60% along the X-ray bright SE-NW axis, from 0.52% +/- 0.03% per yr to 0.84% +/- 0.06% per yr. This corresponds to undecelerated ages of 120 - 190 yr, confirming the young age of G1.9 +0.3, and implying a significant (deceleration parameter m < 0.6) deceleration of the blast
wave. The spatially-integrated X-ray flux, strongly dominated by synchrotron emission, increases at a rate of 1.9% ± 0.7% per year, in agreement with previous measurements. G1.9+0.3 is the only Galactic SNR brightening at X-ray and radio wavelengths. We identify the inner rims with the reverse shock and more slowly-expanding rims farther out with the blast wave. The large spread in expansion ages between the reverse shock and the blast wave requires abrupt density gradients in either the ejecta or the ambient medium, to suddenly decelerate the reverse shock or the blast wave. The blast wave could have been decelerated recently by an encounter with a modest (factor of several) density discontinuity in the ambient medium, such as found at a wind termination shock, implying a strong presupernova wind from the progenitor system. Alternatively, the reverse shock might have encountered a larger (factor of 10 or more) density discontinuity within the SN ejecta, such as found in pulsating delayed-detonation Type Ia SN models. Through 1D hydrodynamical simulations, we demonstrate that the blast wave is much more decelerated than the reverse shock in these models for remnants at ages similar to G1.9+0.3. The presence of strong density gradients in the outer ejecta of Type Ia SNe has significant implications for the interpretation of their early-time spectra and for understanding how white dwarfs explode.

Author(s): Stephen P. Reynolds¹, Kazimierz J. Borkowski¹, David Green², Una Hwang³, Robert Petre⁴


120.04 – High Spatial Resolution Spectral Analysis of the SW Limb in RCW 86

Despite intensive study in recent years, the nature of the progenitor system and explosion type of the galactic supernova remnant RCW 86 remains uncertain. We present preliminary results from a high spatial resolution imaging spectroscopic analysis of archival Chandra data of the southwestern limb of RCW 86. We report the detection of a small, previously undiscovered knot of ejecta with super-solar abundances of O, Mg, Ne, and Si, and present maps detailing the variation of temperature and abundance on small spatial scales in this limb. Based on elemental abundances within the ejecta knot and physical conditions at the limb, we suggest that RCW 86 is the result of a core-collapse supernova, with a progenitor of around 18 solar masses, and that the southwestern shock is encountering a dense, clumpy cavity wall.

Author(s): Thomas Brantseg¹, Randall L. McEntaffer¹, Natalie Butterfield¹, Allison H. Savage¹

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120.05 – CHANDRA VIEW OF G340.6+0.3

We present the refined analysis results of the Chandra ACIS GTO observation of the faint, distant (~15 kpc) and small (~6') diameter shell type Galactic Supernova Remnant G340.6+0.3. With its ~69 ks exposure, the Chandra observation is the deepest available X-ray observation of the remnant, and allows us to resolve the northern part of the shell, which is the brightest, as well as the southern part. Spectra of the whole remnant and of the two partial shells show strong emission lines from Si, S, Ar, and Ca in a ionized plasma at temperatures kT ~ 0.8-1.5 keV. Abundances of these elements are significantly higher than solar in the northern shell arc, and consistent with solar in the southern, indicating that metal enriched ejecta from the progenitor star are still dominating in the north while shocked interstellar medium is likely responsible for
the emission from the south. We discuss our findings in the context of the Supernova nucleosynthesis models.

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**120.06 – The X-ray and Radio Evolution of Supernova 1993J**

Supernova 1993J in the nearby galaxy M81 is one of the best observed supernovae (SNe) at radio and X-ray wavelengths, with better long-term time-sampling than almost any other SN except 1987A. In this project we explore the X-ray and radio light curves of SN 1993J over more than 20 years of evolution, the evolution of the X-ray spectrum, the kinematics of the SN shock wave, and the implications for the structure of the medium into which it is expanding.

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**120.07 – Complexities of a Mid-Life Crush: A Study of the Vela X Pulsar Wind Nebula**

The Vela supernova remnant is a canonical example of a middle-aged composite system in which the SNR reverse shock has disrupted the central pulsar wind nebula, Vela X. Due to a non-uniform ambient medium, the shock has propagated asymmetrically, crushing the northern part of the PWN. The result is a complex structure characterized by nonthermal X-rays from the pulsar wind, thermal X-rays from ejecta mixed into the nebula, and gamma-ray emission in both the GeV and TeV bands, for which the morphology shows striking differences.

Here we report on an XMM Large Project to study Vela X. We study variations in the spectral index of the nonthermal X-ray emission, along with the distribution and thermal properties of the shocked ejecta, and correlate these with the gamma-ray properties of the PWN. We evaluate these properties in the context of the evolution of PWNe in composite SNRs, with a view to the ultimate fate of the relativistic particles produced in these systems.

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**Institution(s):** 1. Harvard-Smithsonian, CfA, Cambridge, MA.

**Contributing team(s):** XMM Vela X Large Project Team

**120.08 – New Chandra ACIS Observations of SN 1987A**

We present results from the latest Chandra ACIS observations of SN 1987A and compare them to past observations. The soft X-ray light curve is updated and examined for evidence of a break which would indicate the forward shock has passed through the equatorial ring. We also calculate the expansion rate and investigate evolution in the radial expansion of the remnant.

**Author(s): Kari A. Frank, David N. Burrows**

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**120.09 – Spitzer Observations of the Type Ia Supernova Remnant N103B: A Type Ia with CSM Interaction?**

A small but growing subclass of Type Ia supernovae show signs of interaction with material in a circumstellar medium (CSM), likely the result of significant pre-supernova mass loss from the progenitor system. Among Type Ia supernova remnants (SNRs), only the remnant of Kepler's supernova has been shown to be interacting with a dense CSM. We report results from Spitzer
observations of SNR 0509-68.7, also known as N103B, a young Type Ia supernova remnant in the Large Magellanic Cloud that shows interaction with a dense medium in its western hemisphere. Our images show that N103B has strong IR emission from warm dust in the post-shock environment. The post-shock gas density we derive, \(45 \text{ cm}^{-3}\), is much higher than in other Type Ia remnants in the LMC, though a lack of spatial resolution may bias measurements towards regions of higher than average density. This density is similar to that in Kepler’s SNR. Optical images show H\(\alpha\) emission along the entire periphery of the western portion of the shock, with [O III] and [S II] lines emitted from a few dense clumps of material where the shock has become radiative. The dust is silicate in nature, though standard silicate dust models fail to reproduce the “18 \(\mu\text{m}\)” silicate feature that peaks instead at 17.3 \(\mu\text{m}\). We propose that the dense material is circumstellar material lost from the progenitor system, as with Kepler. If the CSM interpretation is correct, this remnant would become the second member, along with Kepler, of a class of Type Ia remnants characterized by interaction with a dense CSM hundreds of years post-explosion. A lack of N enhancement eliminates symbiotic AGB progenitors. The white dwarf companion must have been relatively unevolved at the time of the explosion.

**Author(s):** Brian J. Williams\(^1\), Kazimierz J. Borkowski\(^2\), Stephen P. Reynolds\(^2\), Parviz Ghavamian\(^3\), John C. Raymond\(^4\), Knox S. Long\(^5\), William P. Blair\(^6\), Ravi Sankrit\(^7\), P. F. Winkler\(^8\), Sean P. Hendrick\(^9\)


**120.10 – The Expansion Rate, Age, and Distance of the Supernova Remnant G266.2?1.2**

We reprocessed and analyzed the 2003 and 2008 Chandra ACIS data for the supernova remnant G266.2?1.2. The data for two adjacent annular wedges along a relatively bright and narrow portion of the northwestern rim indicate that it has moved by about 2.39 ± 0.57 arcsec over a period of 5.652 yr. The corresponding expansion rate (0.42 ± 0.10 arcsec/yr or 13.6 ± 5.7 %/kyr) is about half of the rate reported for an analysis of XMM data from a similar region of the remnant over a similar time interval (Katsuda, Tsunemi & Mori, 2008). A hydrodynamic analysis was performed using the models of Truelove & McKee (1999). Many scenarios were considered using broad ranges of initial kinetic energies, ejecta masses, ejecta mass density distributions, ambient densities, and evolutionary states. The results were constrained by the Chandra expansion rate (assuming it is representative of the remnant as a whole), an inferred lower limit on the forward shock speed, an upper limit on the inferred thermal X-ray emission, and energy considerations. The results of this analysis suggest that G266.2?1.2 is most likely between 2.4 and 5.1 kyr old, whether or not it was produced by a type Ia or type II event. If the remnant is expanding into the material shed by a steady stellar wind instead of a uniform ambient medium, then it could be older by a factor of up to 1.5. In no case is the remnant expected to be younger than 2.2 kyr. Therefore, it is too old to be associated with emission from the decay of Ti-44 or with features in the abundance of nitrate in South Pole ice core samples. The hydrodynamic results provide only a weak constraint on the distance of G266.2?1.2. An analysis of previously-published distance estimates and constraints suggests that the remnant is
between about 0.5 and 1.0 kpc. This limitation does not significantly affect the estimate of the age. We adopt the distance of the closer of two groups of material in the Vela Molecular Ridge (i.e. 0.7 ± 0.2 kpc, Liseau et al. 1992). This distance is consistent with the progenitor having been a member of the Vel OB1 association (Eggen 1982).

Author(s): Glenn E. Allen¹, Tracey DeLaney², Miroslav D. Filipovic³, John C. Houck⁴, Thomas Pannuti⁵, Michael D. Stage⁶


120.11 – Characterizing SASI- and Convection-Dominated Core-Collapse Supernovae

The success of the neutrino mechanism of core-collapse supernovae relies on the supporting action of two hydrodynamic instabilities: neutrino-driven convection and the Standing Accretion Shock Instability (SASI). Depending on the structure of the stellar progenitor, each of these instabilities can dominate the dynamics at the onset of explosion, with implications for the ensuing asymmetries. Here we present results of parametric time-dependent hydrodynamic simulations that examine the properties of each limiting regime under controlled conditions. The dynamics at the transition to explosion, the saturated state of the SASI with convection, sensitivity to initial perturbations, and properties of the turbulence in non-explosive cases are studied. The applicability of these results is verified in more complete radiation-hydrodynamic core-collapse supernova simulations.

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120.12 – News from Supernova Remnants and Pulsar Wind Nebulae in the TeV Band

VERITAS is an array of four atmospheric Cherenkov telescopes located in Southern Arizona and is sensitive to gamma rays above 100 GeV. Here we highlight recent VERITAS studies of supernova remnants and pulsar wind nebulae. The results provide constraints on competing particle acceleration emission models within these complex environments.

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Contribution team(s): VERITAS Collaboration

120.13 – Supernova Light Curves and Spectra from Two Different Codes: Supernu and Phoenix

The observed similarities between light curve shapes from Type Ia supernovae, and in particular the correlation of light curve shape and brightness, have been actively studied for more than two decades. In recent years, hydromonic simulations of white dwarf explosions have advanced greatly, and multiple mechanisms that could potentially produce Type Ia supernovae have been explored in detail. The question which of the proposed mechanisms is (or are) possibly realized in nature remains challenging to answer, but detailed synthetic light curves and spectra from explosion simulations are very helpful and important guidelines towards answering this question. We present results from a newly developed radiation transport code, Supernu. Supernu solves the supernova radiation transfer problem uses a novel technique based on a
hybrid between Implicit Monte Carlo and Discrete Diffusion Monte Carlo. This technique enhances the efficiency with respect to traditional implicit monte carlo codes and thus lends itself perfectly for multi-dimensional simulations. We show direct comparisons of light curves and spectra from Type Ia simulations with Supernu versus the legacy Phoenix code.

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**Institution(s):** 1. Astronomy and Astrophysics, University of Chicago, Chicago, IL. 2. University of Wisconsin, Madison, WI.

**120.14 – Pulsar Evolution within a Composite Supernova Remnant**

Supernova remnants have been observed expanding into a non-uniform density ISM. Such expansion creates asymmetry within the remnant, and we attempt to understand how this asymmetric expansion propagates through a system containing an active pulsar wind nebula. We are particularly interested in applying computational methods to such systems in order to recreate and understand the dynamics driving the formation of observed SNRs and their PWNe. We present here a two-dimensional hydrodynamics simulation of a SNR expanding into a uniform density gradient. The remnant contains an active PWN with a translational velocity of approximately 300 km/s which is expanding into freely expanding, unshocked supernova ejecta. We consider, in particular, the reverse-shock interaction state in which the wind nebula is crushed by the asymmetric reverse shock, and investigate the morphology and mixing of thermal and relativistic gas in the context of observed systems including G327.1-1.1.

**Author(s):** Christopher Kolb\(^1\), John M. Blondin\(^1\), Patrick O. Slane\(^2\), Tea Temim\(^3,4\)


**120.15 – Rotation Measure Synthesis of Cassiopeia A**

We observed Cassiopeia A with the Jansky Very Large Array between 2-4 GHz in the B, C, and D configurations to study the polarization structure in the vicinity of the shocks. We have used rotation measure synthesis to isolate the magnetic field structures. We find a dominant rotation measure structure along each line-of-sight with evidence for substructure in locations with strong X-ray, optical, and infrared thermal emission. This wide rotation measure substructure may be from the front and back shell components.

**Author(s):** Tracey DeLaney\(^1\), Matthew Stadelman\(^1\), Lawrence Rudnick\(^3\), Michael P. Rupen\(^3\), Urvashi Rau\(^3\), Sanjay Bhatnagar\(^3\), Eric Greisen\(^3\), Robert Petre\(^4\)


**120.16 – Dependence of the Observed Properties of Type Ia Supernovae on the Mass of the Progenitor White Dwarf in the Gravitationally Confined Detonation Model**

We investigate the dependence of the observed properties of Type Ia supernovae on the mass $M_{WD}$ of the white dwarf star in the single degenerate model. We find that, within the gravitationally confined detonation (GCD) model and the treatment we use for buoyancy-driven turbulent nuclear burning, the outcome of the explosion is highly sensitive to $M_{WD}$. Specifically, we find that the nuclear energy released during the deflagration phase, and therefore the amount by which the white dwarf expands prior to initiation of the detonation wave, increase
rapidly as $M_{\text{WD}}$ increases. Consequently, the amount of radioactive nickel produced, and thus the peak luminosity of the supernova, decrease rapidly as $M_{\text{WD}}$ increases. We find that, as a result, ignition at a single point (which is favored by simulations of the prior smoldering phase) and a variation in $M_{\text{WD}}$ of as little as $\sim 2\%$ can produce the observed range of peak luminosities of normal Type Ia supernovae.

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

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 the system, such as magnetic field amplification 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 allowed us to constrain the magnitude of the post-shock magnetic field in several different regions of the NW rim, where it is significantly amplified relative to the usual ambient fields expected. I will discuss our analysis in detail and comment on how MFA appears to be related to certain characteristics of the SNR shock.

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**120.18 – The Swift-BAT 104 Month Hard X-ray Survey**

The BAT hard X-ray instrument on the Swift observatory has now collected nearly ten years of data, comprising the deepest and most uniform hard X-ray all sky survey to date. We present results from the first 104 months of the survey, including the source catalog and eight-band spectra of over 1400 objects including X-ray binaries, cataclysmic variables, blazars, and AGN. The 104 month BAT survey has greater than 14 Ms of equivalent on-axis exposure over half the sky, and over 10 Ms for 90% of the sky. New results from the 104 month survey include a 4-sigma detection of the Ti-44 lines from the Tycho supernova remnant using the standard survey spectra, only the third such detection after Cas A and SN 1987A.

**Author(s):** Wayne H. Baumgartner$^{1,2}$, Craig Markwardt$^1$, Eleonora Troja$^{1,3}$, Scott D. Barthelmy$^1$, Neil Gehrels$^1$

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121 – WDs & CVs
121.02 – Studies of Accretion of Solar Material onto White Dwarfs: They are all Growing in Mass

Novae are CV systems in which a white dwarf primary is accreting material from a companion. We have accreted Solar composition material onto CO white dwarfs of 0.70, 1.00 and 1.35 Msun with accretion rates from 1.6e-10 to 1.6e-6 Msun per yr. We use both the NOVA and MESA stellar evolution codes. The resulting behavior depends on both the WD mass and accretion rate. We find that all our models undergo recurrent hydrogen flashes although some grow in mass until a helium flash occurs. Nevertheless, in no case is significant mass lost during the flash and the mass of the WD grows toward the Chandrasekhar limit. These results suggest that the single degenerate scenario is a viable channel for progenitors of Type Ia supernova explosions. We also address additional questions such as the lack of observed progenitors in the 2011fe and SN2014J Ia explosions.

Author(s): Sumner Starrfield$^1$, F. X. Timmes$^1$
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121.03 – A NuSTAR Observation of Nova V475 Sco

The first detection of copious X-ray flux from a Galactic nova with NuSTAR highlights the capabilities of this satellite for Nova research. This very fast nova was observed 10 days after the observed optical maximum and a luminous X-ray source was observed with about 1.7x10^{-11} erg/s and a thermal plasma spectrum peaking at 2.6 keV. We discuss the possible origins of the emission and physical significance for the outburst physics.

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Contributing team(s): Vikram Rana, Caltech, Jeno Sockoloski, Columbia University, Fiona Harrison, Caltech

122 – XRBs and Population Surveys
122.01 – Measuring the neutron star radius to constrain the dense-matter equation of state.

A physical understanding of the behaviour of cold ultra-dense matter - at and above nuclear density - can only be achieved by the study of neutron stars, and the thermal emission from quiescent low-mass X-ray binaries inside globular clusters have proven very useful for that purpose. The recent ~2M\_\odot mass measurements suggest that strange quark matter and hyperons/kaons condensate equations of states (EoS) are disfavoured, in favour of hadronic "normal matter" EoSs. Over much of the neutron star mass-radius parameter space, "normal matter" EoSs produce lines of quasi-constant radii (within the measurement uncertainties, of about 10%). We present a simultaneous spectral analysis of several globular cluster quiescent low-mass X-ray binaries where we require the radius to be the same among all neutron stars analyzed. The Markov-Chain Monte-Carlo method and the Bayesian approach developed in this analysis permits including uncertainties in the distance, in the hydrogen column density, and possible contributions to the spectra due to un-modelled spectrally hard components. Our results suggest a neutron star radius much smaller than previously reported, with a value R_{NS} = 9.1±1.4 km, at 90% confidence, using conservative assumptions, which suggests that neutron star matter is best described by the softest "normal matter" equations of state.
Author(s): Sebastien Guillot¹, Mathieu Servillat², Natalie Webb³, Robert E. Rutledge¹
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122.02 – Superorbital Periods in Supergiant High-Mass X-ray Binaries

Using data from the Swift Burst Alert Telescope (BAT) we discovered superorbital periods in four high-mass X-ray binaries accreting from the winds of supergiant primaries: 4U 1909+07 (= X 1908+075), IGR J16418-4532, IGR J16479-4514 and IGR J16493-4348. Together with a previously known superorbital period in 2S 0114+650, the systems show a surprising monotonic relationship between superorbital and orbital periods. We report on a continuing investigation of the superorbital modulation and searches for new superorbital periods including candidate superorbital modulation in IGR J16393-4643 (= AX J16390.4-4642) and 1E 1145.1-6141.

Author(s): Robin Corbet¹,², Hans A. Krimm³,²
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122.03 – The Harmonic Content of High-Frequency QPOs from the Relativistic Orbiting-Spot vs. Oscillating-Torus Models

Different theoretical schemes have been proposed to explain the origin of high-frequency (kiloherztz) quasi-periodic oscillations (HFQPOs) from accreting neutron stars in low-mass X-ray binaries and stellar-mass accreting black-holes. In the case of twin-peak sources, Fourier power-spectral density exhibits two dominant oscillation modes, often in the approximate ratio of small integers (3:2). Despite the rich phenomenology, base frequencies alone do not allow us to distinguish in a unique way among the most popular models. We discuss the harmonic content predicted by two competing scenarios, namely, the orbiting spot model and the oscillating torus model. By employing a ray-tracing code, we study the relativistic regime where the emerging radiation signal is influenced by effects of strong gravity (energy shifts and light bending). We consider spots moving on slightly non-circular trajectories in an accretion disk, and tori oscillating with fundamental modes. The harmonic content of the observed signal can allow us to reveal the ellipticity of the orbits and discriminate between the scheme of orbiting spots and the case of an oscillating torus. On a practical side, we estimate the required signal-to-noise ratio of the model light curve and we discuss what improvement would be needed in comparison with RXTE, depending on the source brightness.

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Institution(s): 1. Astronomical Institute, Academy of Sciences, Prague, Czech Republic. 2. Silesian University, Institute of Physics, Opava, Czech Republic.

122.04 – Looking into the Theory of Pulsar Accretion: The Case of XTE J1946+274

XTE J1946+274 is a transient accreting pulsar with a Be companion and a Cyclotron Resonance Scattering Feature (CRSF). It has been observed during several outbursts, with multiple instruments, and over a large range of luminosities. We extend previous studies to low flux using a Suzaku observation from the end of an outburst. This study focuses on the relationship between the cyclotron line energy and X-ray luminosity, which is believed to be linked to the physical processes occurring in the CRSF forming region. The physics of pulsar accretion, i.e., the process of plasma flow onto the neutron star surface, can be further constrained from its spectral properties. To this end, we discuss a new implementation of the physical continuum model developed by Becker and Wolff (2007, ApJ 654, 435). The model comprises Comptonized
black body, bremsstrahlung, and cyclotron emission. We discuss preliminary results of applying the new tool to the test case of XTE J1946+274. We are working towards making this pulsar continuum model available in Xspec.

**Author(s):** Diana M. Marcu¹, ², Katja Pottschmidt¹, ², Matthias Kühnel³, Michael T. Wolff⁴, Peter A. Becker⁵, Sebastian Müller³, Paul B. Hemphill⁶, Isabel Caballero⁷, Mark H. Finger⁸, ⁹, Peter Jenke¹⁰, Colleen Wilson-Hodge¹⁰, Felix Fuerst¹¹, Victoria Grinberg¹², Ingo Kreykenbohm³, Dmitry Klochkov¹³, Richard E. Rothschild⁵, Yukikatsu Terada¹⁴, Teruaki Enoto¹, Wataru Iwakiri¹⁴, Motoki Nakajima¹⁵, Joern Wilms³


**122.05 – GRO J1744-28: The Swift view of the reactivation of The Bursting Pulsar**

GRO J1744-28, AKA "The Bursting Pulsar", first discovered in 1995 by the Compton Gamma-Ray Observatory, has lay dormant since its 2nd outburst in 1996. On January 18th, 2014, it was detected again by Swift's Burst Alert Telescope and by the Japanese MAXI scanning X-ray telescope. Swift’s BAT triggered many times on the bright bursts seen from GRO J1744-28 during this latest outburst, and detected over 600 bursts. The reappearance of this exciting transient triggered a high cadence monitoring program by Swift/XRT to provide flux, timing and spectral coverage of the entire outburst. Here we report on these observations of this new outburst by Swift's BAT and XRT, including analysis of burst rates, periodicity and pulse profile. We also show the spectral evolution of the source as seen by Swift/XRT throughout the latest outburst.

**Author(s):** Jamie A. Kennea¹, Chryssa Kouveliotou², George A. Younes², Jon M. Miller³, David Palmer⁴, Hans A. Krimm⁵, Manuel Linares⁶


**122.06 – Determining the masses and radii of rapidly rotating, oblate neutron stars using energy-resolved waveforms of their X-ray burst oscillations**

We have developed new, more sophisticated, and much faster Bayesian analysis methods that enable us to estimate the masses and radii of rapidly rotating, oblate neutron stars using the energy-resolved waveforms of their X-ray burst oscillations and to determine the uncertainties in these mass and radius estimates. We first generate the energy-resolved burst oscillation waveforms that would be produced by a hot spot on various rapidly rotating, oblate stars, using the oblate-star Schwarzschild-spacetime (OS) approximation. In generating these synthetic data, we assume that 1 million counts have been collected from the hot spot and that the background is 9 million counts. This produces a realistic modulation amplitude and a total number of counts comparable to the number that could be obtained by a future space mission such as the proposed LOFT or AXTAR missions or the accepted NICER mission by combining data from many bursts from a given star. We then compute the joint posterior distribution of the
mass M and radius R in standard models, for each synthetic waveform, and use these posterior
distributions to determine the 1-, 2-, and 3-sigma confidence regions in the M-R plane for each
synthetic waveform and model. We report here the confidence regions obtained when
Schwarzschild+Doppler (S+D) and OS waveform models are used, including results obtained
when the properties of the star used to generate the synthetic waveform data differ from the
properties of the star used in modeling the waveform. These results are based on research
supported by NSF grant AST0709015 at the University of Illinois and NSF grant AST0708424 at
the University of Maryland.

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**122.07 – WISE Detection of Low-Mass X-ray Binaries**

I will report on the results from our search for the Wide-field Infrared Survey Explorer detection
of the Galactic low-mass X-ray binaries. Among 187 catalogued binaries, we find 13
counterparts and two candidate counterparts. For the 13 counterparts, two (4U~0614+091 and
GX~339-4) have already been confirmed by previous studies to have a jet and one
(GRS~1915+105) to have a candidate circumbinary disk, from which the detected infrared
emission arose. Having collected the broad-band optical and near-infrared data in literature
and constructed flux density spectra for the other 10 binaries, we identify that three (A0620-00,
XTE J1118+480, and GX 1+4) are candidate circumbinary disk systems, four (Cen X-4, 4U
1700+24, 3A 1954+319, and Cyg X-2) had thermal emission from their companion stars, and
three (Sco X-1, Her X-1, and Swift J1753.5-0127) are peculiar systems with the origin of their
infrared emission rather uncertain. Discussion of the results and WISE counterparts' brightness
distribution will be provided, which suggests that more than half of the LMXBs would have a jet,
a circumbinary disk, or the both.

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**122.08 – Constraining System Parameters of Eclipsing X-ray Binaries with the Swift Burst Alert
Telescope (BAT)**

Physical parameters of both the mass donor and compact object are constrained in X-ray
Binaries with well defined eclipses. The eclipse duration depends on the radius of the mass
donor, inclination angle of the system, and the orbital separation of the components. Using the
observed orbital period and Kepler's third law, the orbital separation can be written in terms of
the sum of the component masses. This stipulates that the eclipse half-angle can now be
expressed in terms of the radius, inclination angle and the sum of the masses. When pulse-
timing and radial velocity curves are available, the masses of both the donor and compact
object can be accurately determined. We present a survey of the Eclipsing X-ray Binaries IGR
J16393-4643, IGR J16418-4532, IGR J16479-4514, IGR J18027-2016 and XTE 1855-026. To
determine the eclipse half-angle in our survey, we modeled the eclipses using a symmetric step-
and-ramp function. The eclipse half-angle was found to be 15±3, 29±1, 32±1, 32±1 and 34.3±0.6
degrees for IGR J16393-4643, IGR J16418-4532, IGR J16479-4514, IGR J18027-2016 and XTE
1855-026, respectively. This is consistent with the proposed mass donors for each binary. We
place constraints on the inclination angle of the system and radius and mass of the donor star.

**Author(s):** Joel B. Coley¹, ², Robin Corbet¹, ², Hans A. Krimm³, ⁴
122.09 – Results from the first two years of the INTEGRAL Spiral Arms Monitoring Program

We describe the scientific objectives and main highlights from the first 2 years of an INTEGRAL "Key Program" consisting of high-cadence monitoring of the inner spiral arms of the Galaxy paired with ToO observations of new transients with XMM-Newton and Swift. The INTEGRAL Spiral Arms (ISA) program (25.6 ks per spacecraft revolution during visibility periods, for a total of 1.2 Ms per year since 2012) complements the successful Galactic Bulge (GB) program by extending the monitored region of the Galaxy to the Inner Perseus/Norma Arm tangents on one side of the GB, and the Scutum/Sagittarius Arms on the other. These fields feature a high density of obscured high-mass X-ray binaries (HMXBs), including Supergiant Fast X-ray Transients (SFXTs), as well as other hard X-ray emitting sources (e.g., microquasars, low-mass X-ray binaries, and magnetars) that INTEGRAL is well-suited to finding thanks to its large field of view and angular resolution at high energies even in crowded regions of the sky. Mosaic images and source light curves in 2 energy bands for ISGRI and JEM-X are being provided to the community permitting rapid dissemination of results (http://isa.gcsu.edu) which enable prompt follow-up of interesting events. The ISA project represents the cornerstone of our ongoing study of transient and variable hard X-ray populations in the Milky Way.

Author(s): Arash Bodaghee\textsuperscript{1}, Keri Spetzer\textsuperscript{1}

Institution(s): 1. Georgia College & State University, Milledgeville, GA.

Contributing team(s): The ISA Collaboration

122.10 – A Multi-Wavelength Study of the Gamma Ray Binary 1FGL J1018.6-5856

We report on a multi-wavelength study of 1FGL J1018.6-5856, the first Gamma-ray Binary discovered by the Fermi Large Area Telescope (LAT). 1FGL J1018.6-5856 consists of a O6 V((f)) star and suspected rapidly spinning pulsar, which is possibly powered by the interaction between the relativistic pulsar wind and the stellar wind of the companion. A microquasar scenario where the compact object is a black hole cannot be ruled out. We investigate long-term changes in the gamma-ray properties of the orbital modulation. Using probability weighted photometry, long-term observations with the LAT give a refined value of the orbital period at 16.549±0.007 days. Folding the gamma-ray light curves reveal a quasi-sinusoidal component as well as the presence of flare-like behavior. We also search for phase-resolved changes in the gamma ray spectral properties of 1FGL J1018.6-5856. We compare the long term variability in gamma-rays with those in the X-ray and radio bands from Swift X-ray Telescope and Australia Telescope Compact Array.

Author(s): Joel B. Coley\textsuperscript{1, 2}, Robin Corbet\textsuperscript{1, 2}, Chi C. Cheung\textsuperscript{3}, Malcolm J. Coe\textsuperscript{4}, Philip Edwards\textsuperscript{5}, Vanessa McBride\textsuperscript{6}, M. V. McSwain\textsuperscript{7}, Jamie Stevens\textsuperscript{5}

122.11 – Spectral Softening Observed in the Neutron Star LMXB SAX J1750.8-2900

We present the analysis of over 30 Swift XRT observations of the neutron star low-mass X-ray binary (LMXB) SAX J1750.8-2900 over the course of 4 years while the system was in and between the outburst and quiescent states. This has been the first Swift XRT study of the long-term behavior of SAX J1750.8-2900. We found evidence of spectral softening with decreasing luminosity from ~10^{37} to 10^{34} erg s^{-1}. While softening towards quiescence is regularly detected in black hole LMXBs and is often interpreted as as signature of an advection-dominated accretion flow, the behavior when observed in several neutron star LMXBs requires a much more complicated interpretation due to the interplay of thermal and nonthermal spectral contributions with different physical origins. We discuss the softening and flaring behavior of SAX J1750.8-2900 in the context of changing accretion regimes and the ongoing challenge in discerning the relative thermal and nonthermal components (and their sources) that shape the neutron star LMXB spectrum and its evolution.

Author(s): Jessamyn Allen1, Manuel Linares2, 3, Deepo Chakrabarty1

122.13 – Orbital modulation of the photoionized wind in Cygnus X-1

Clumpy winds of late type stars are still a major puzzle both from the observational and theoretical point of view. High mass X-ray binaries (HMXB) do not only offer us the singular chance to use the compact object as a probe for the different phases of the winds, but also help to understand the physics of the accretion flow. The black hole HMXB Cygnus X-1 is powered by the accretion of the strong, focused stellar wind from its O-type donor star HDE 226868. The wind consists of a two-component medium: cool, dense clumps of material are embedded in tenuous hot photoionized gas. The clumps cause strong absorption dips in the observed X-ray lightcurves. Using Observations with the Chandra High Energy Transmission Gratings during the hard state of the black hole, we can, therefore, separate the spectral signatures emerging from the hot gas phase of the wind, i.e., the non-dip spectra, from the features caused by the additional absorption by the clumps. Here, we present a detailed study of the orbital variations of this part of the wind and review them in the light of current focused wind models. Funded by BMWi under DLR grant 50OR1113. Work at LLNL was performed under the auspices of DOE under contract DE-AC52-07NA27344 and supported by NASA grants.

Author(s): Natalie Hell1, 2, Ivica Miškovićova1, Manfred Hanke1, Michael Nowak3, Katja Pottschmidt4, 5, Norbert S. Schulz3, Victoria Grinberg3, 1, Refiz Duro1, Oliwia K. Madej6, 7, Anne M. Lohfink8, Jerome Rodriguez9, Marion Cadolle Bel10, Arash Bodaghee11, 12, John Tomsick11, Julia C. Lee13, Gregory V. Brown7, Joern Wilms1
UMR 7158, CEA/DSM-CNRS-Université Paris Diderot, Paris, France. 10. Ludwig-Maximilians-Universität, Exzellenzcluster “Origin and Structure of the Universe”, Garching, Germany. 11. Space Sciences Laboratory, Berkeley, CA. 12. Department of Chemistry, Physics, and Astronomy, Georgia College & State University, Milledgeville, GA. 13. Harvard University Department of Astronomy/Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

122.14 – Application of a hot flow model to NGC 4151 and XTE J1118+480
We discuss properties of hot flow (ADAF) spectra at low luminosities of ~0.001 L_{Edd}, in particular, deviations from a power-law shape which affect measurements of electron temperature as well as assessments of the presence of a thermal disc component by X-ray spectral fitting. We apply our results to NGC 4151 and XTE J1118+480 and we find that their observational data require both a strong magnetic field (in approximate equipartition with the gas pressure) and a weak direct heating of electrons in the flow.

Author(s): Agnieszka Stepnik, Andrzej Niedzwiecki
Institution(s): 1. University of Lodz, Lodz, Poland.

122.15 – XSS J12270-4859: A Transformation from an X-ray Binary to a Rotation-Powered Millisecond Pulsar System
XSS J12270-4859 has been previously suggested to be a low-mass X-ray binary, and until recently the only such system to be seen at MeV-GeV energies. We present radio, optical and X-ray observations that demonstrate that XSS J12270-4859 has undergone a sudden decline in optical and X-ray brightness and no longer shows evidence for an accretion disk. Along with the recent detection of radio pulsations, these findings indicate that XSS J12270-4859 transformed to a full-fledged eclipsing "redback" system between 2012 November 14 and December 21 and presently hosts an active rotation-powered millisecond pulsar.

Author(s): Slavko Bogdanov, Cees Bassa, Anne M. Archibald, Alessandro Patruno, Jason Hessels, Gemma H. Janssen, Benjamin Stappers, Shriharsh P. Tendulkar

122.16 – Deep XMM-Newton Observations of the "Missing Link" Binary PSR J1023+0038 in an Accreting State
We present the results of two long XMM-Newton exposures of PSR J1023+0038 in its present accretion disk-dominated state, as well as contemporaneous UV, optical/IR and radio observations. These coordinated observations provide fresh insight into the behavior of this and analogous X-ray binary / radio millisecond pulsar transition systems.

Author(s): Slavko Bogdanov, Anne M. Archibald, Cees Bassa, Alessandro Patruno, Gemma H. Janssen, Victoria M. Kaspi, Benjamin Stappers, Shriharsh P. Tendulkar, Jason Hessels

122.17 – X-ray Binaries in Blue Compact Dwarf Galaxies
X-rays from binaries in small, metal-deficient galaxies may have contributed significantly to the heating and reionization of the early Universe, depending on their population and spectral shape. We investigate both properties by studying blue compact dwarfs (BCDs) as local analogs
to these early galaxies. We constrain the relation of the X-ray luminosity function (XLF) to the star-formation rate (SFR) using a Bayesian approach applied to a sample of 25 BCDs. Our results suggest a significant enhancement in the population of high-mass X-ray binaries (HMXBs) in BCDs compared to near-solar metallicity galaxies. We show that X-ray binaries in the extremely metal-poor galaxies I Zw 18 and VII Zw 403 undergo spectral state transitions. The HMXB spectral shape affects how the emitted X-rays heat the intergalactic medium, thus affecting the 21-cm signal from the epoch of reionization.

Author(s): Matthew Brorby¹, Philip Kaaret¹, Andrea H. Prestwich²
Institution(s): 1. Physics & Astronomy, University of Iowa, Iowa City, IA. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

122.18 – Initial results from NuSTAR observations of the Norma Arm
Results are presented for an initial survey of the Norma Arm gathered with the focusing hard X-ray telescope NuSTAR. The survey covers 0.2 degrees-squared of sky area in the 3--79 keV range with a minimum and maximum raw exposure time of 15 ks and 135 ks, respectively. Besides a bright black-hole X-ray binary in outburst (4U 1630-47) and a new X-ray transient (NuSTAR J163433-473841), NuSTAR locates three sources from the Chandra survey of this region whose spectra are extended above 10 keV for the first time. Imaging, timing, and spectral data from a broad X-ray range (0.3--79 keV) are analyzed and interpreted with the aim of classifying these objects. CXOU J163329.5-473332 is either a cataclysmic variable or a faint low-mass X-ray binary. CXOU J163350.9-474638 varies in intensity on year-long timescales, and with no multi-wavelength counterpart, it could be a magnetar. CXOU J163355.1-473804 features a helium-like iron line at 6.7 keV and is classified as a nearby cataclysmic variable. We close by discussing some challenges inherent in imaging crowded regions with NuSTAR, and how the lessons learned in this pilot study can help scientists who wish to use NuSTAR to observe their favorite targets.

Author(s): Arash Bodaghee¹, 2, John Tomsick¹, Roman Krivonos¹, Daniel Stern³, Franz E. Bauer⁴, ⁵, Francesca Fornasini³, Nicolas M. Barrière¹, Steven E. Boggs¹, Finn Christensen⁶, William W. Craig¹, ⁷, Eric V. Gotthelf⁸, Charles J. Hailey⁸, Fiona Harrison⁹, JaeSub Hong¹⁰, Kaya Mori⁸, William Zhang¹¹

122.19 – Giant X-ray Flares From Suspected Black Holes in Extragalactic Globular Clusters
The existence of both stellar- and intermediate-mass black holes within globular clusters has been the subject of intense debate for decades. The rich globular cluster populations of nearby elliptical galaxies provide much more fertile hunting grounds over the meager globular cluster population of the Milky Way to search for accreting black holes emitting near their Eddington limit. Extreme X-ray variability of >1e39 ergs/s sources provide the best means of identifying such black holes. We present results from our search for short-term (< few hours) X-ray flares from extragalactic globular clusters. Interesting candidates include a source that flared to 8e40
ergs/s on a ~1 minute time scale, and another source that flared by a factor of 50 to 2e39 ergs/s for several hundred seconds in four different Chandra epochs.

**Author(s):** Jimmy Irwin\(^1\), Tyler Speegle\(^1\), Ian Prado\(^1\), David Mildebrath\(^1\), Aaron J. Romanowsky\(^2\), \(^3\), Jay Strader\(^4\)


**122.20 – Recent highlights from NuSTAR Observations of extreme ULXs**

The origin of the intense luminosities displayed by ultraluminous X-ray asources (ULXs) may relate to either super-Eddington accretion or the presence of black holes more massive than the standard stellar remnants observed in our own Galaxy, e.g. intermediate mass black holes with masses of 100's or 1000's of solar masses. Although recent broadband X-ray spectroscopy of bright ULXs with the Nuclear Spectroscopic Telescope Array (NuSTAR) is suggestive of the former, a definitive answer has not yet been reached owing to continued difficulty constraining ULX masses. Here we report on highlights from our continued NuSTAR observations of extreme (L_x > 1e40 erg/s) ULXs, extending our broadband X-ray analysis into the time domain with multi-epoch observations which allow us to examine the evolution of these enigmatic sources, and thus shed further light on their accretion processes.

**Author(s):** Dom Walton\(^1\)

**Institution(s):** 1. Caltech, Pasadena, CA.

**Contributing team(s):** The NuSTAR Team

**122.21 – The Si K edge in Low-Mass X-Ray Binaries**

One of the expectations with the advent of the High Energy Transmission Grating (HETG) spectrometer onboard the Chandra X-ray Observatory was to measure precise photoelectric edges of major cosmic elements such as O, Ne, Mg, Si, S, Ar, Ca, and Fe. Early studies revealed complex absorption structures around the O K, Fe L, and Ne K edges which were identified with absorption from ionized states and which could place limits on ionization fractions in the ISM phases. The dust content in interstellar matter as well as, for example, the fraction of how much oxygen is locked into dust are issues of importance and here resolved X-ray edges can determine significant limits. We surveyed the Si K edge region in nine Galactic Low-Mass X-ray Binaries (LMXBs) and find that silicate signatures are likely ionized signatures from warm plasmas, even hot winds. We conclude that the observed edge structure does not support previous claims that most of the Si in the ISM is in form of silicates, but a significant fraction of the observed Si is local to LMXBs and ionized.

**Author(s):** Norbert S. Schulz\(^1\), Victoria Grinberg\(^2\), Claude R. Canizares\(^3\)

**Institution(s):** 1. MIT, Cambridge, MA. 2. MIT, Cambridge, MA. 3. MIT, Cambridge, MA.

**122.23 – NuSTAR Observations of the State Transition of Millisecond Pulsar Binary PSR J1023+0038**

We report 3–79 keV NuSTAR observations of the remarkable millisecond pulsar–low mass X-ray binary (LMXB) transition system PSR J1023+0038 from June and October 2013, before and after the formation of an accretion disk around the neutron star. Between June 10–12, shortly before the radio disappearance of the pulsar, the 3–79 keV X-ray spectrum was well fit by a simple power law with a photon index of $\Gamma = 1.17 \pm 0.08$ with a 3–79 keV luminosity of
7.4±0.4×10^{32} \text{ erg/s}. Significant orbital modulation was observed with a modulation fraction of 36±10\%. During the October 19–21 observation, the spectrum is described by a softer power law (\beta = 1.66±0.06) with an average luminosity of 5.8±0.2×10^{33} \text{ erg/s} and a peak luminosity of \? 1.2×10^{34} \text{ erg/s} observed during a flare. No significant orbital modulation was detected. The spectral observations are consistent with previous and current multi-wavelength observations and show the hard X-ray power law extending to 79 keV without a spectral break. Unusual, sharp edged, flat bottomed ‘dips’ are observed with widths between 30–1000 s and ingress and egress time-scales of 30–60 s. These dips are distinct from dipping activity observed in LMXBs. We compare and contrast these dips to observations of dips and state changes in the similar transition systems PSR J1824–2452I and XSS J1227.0+4859 and discuss possible interpretations based on the transitions in the inner disk.

Author(s): Shriharsh P. Tendulkar¹, Chengwei Yang²,³, Hongjun An², Victoria M. Kaspi², Anne M. Archibald⁴, Cees Bassa⁴, Eric Bellm¹, Slavko Bogdanov⁵, Fiona Harrison¹, Jason Hessels⁴,⁶, Gemma H. Janssen⁴, Andrew G. Lyne⁷, Alessandro Patruno⁸,⁹, Benjamin Stappers⁷, Daniel Stern⁹, John Tomsick¹⁰, Steven E. Boggs¹⁰, Deepto Chakrabarty¹¹, Finn Christensen¹², William W. Craig¹⁰,¹³, Charles J. Hailey⁵, William Zhang¹⁴


122.24 – The LMXB population of local early type galaxies and implications for a variable IMF

We discuss the LMXB populations of eight local early type galaxies. These galaxies have deep Chandra observations and provide strong constraints on the XLF of field and globular cluster LMXBs. Using these data, we demonstrate that the number of field LMXBs, per stellar luminosity, and their XLF’s are remarkably similar among these galaxies. We discuss the implications of this to proposed variable IMF models, showing that the IMF of stars more massive than solar appears invariant.

Author(s): Mark Peacock¹, Steve E. Zepf³, Thomas J. Maccarone², Arunav Kundu³,⁴, Anthony H. Gonzalez⁵, Bret Lehmer⁶,⁷, Claudia Maraston⁸

A Stable 3:2 Twin Peak X-ray Quasi-periodic Oscillation from an Ultraluminous X-ray Source: Evidence for a 400 solar mass black hole

X-ray high-frequency quasi-periodic oscillations (HFQPOs: 100-450 Hz) in a 3:2 frequency ratio—hypothesized to originate from close to the event horizon—have only been observed from stellar-mass black holes. Such general relativity-induced oscillations are expected to scale inversely with the black hole mass. Thus, the detection of a twin peak oscillation in an ultraluminous X-ray source in the range of a few Hz has been proposed as strong evidence for the existence of intermediate-mass black holes. We report the discovery of stable, twin-peak (3:2 frequency ratio) X-ray quasi-periodic oscillations (QPOs) from an ultraluminous X-ray source. The two QPOs at 3.32±0.06 Hz and 5.07±0.06 Hz have rms amplitudes of 3-5%. Scaling the frequencies to HFQPOs of stellar-mass black holes of known mass implies that the black hole is 428±105 solar masses. Our result not only strongly argues that some ULXs are indeed intermediate-mass black holes but also suggests that the physical phenomenon causing HFQPOs in stellar-mass black holes scales to intermediate-mass black holes.

Author(s): Dheeraj Ranga Reddy Pasham1, Tod E. Strohmayer2, Richard Mushotzky1, 2
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Discovery of a 1.69 ms radio pulsar associated with the X-ray binary XSS J12270-4859

XSS J12270-4859 is an X-ray binary associated with the Fermi LAT gamma-ray source 1FGL J1227.9-4852 (Hill et al. 2011). In 2012 December, the source underwent a transition where the X-ray and optical luminosity dropped suddenly and spectral signatures of an accretion disk disappeared (Bassa et al. 2014). We report the discovery of a 1.69 millisecond pulsar associated with this source using the Giant Metrewave Radio Telescope at 607 MHz, confirming that this system now contains an active radio millisecond pulsar. We report on radio timing observations of the source with the GMRT and the Parkes Telescope that allow determination of the orbital parameters and eclipse behavior as a function of frequency. We also describe searches for gamma-ray pulsations from the newly-visible pulsar. We thank the staff of the GMRT who have made these observations possible. GMRT is run by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research. The Fermi LAT Collaboration acknowledges support from a number of agencies and institutes for both development and the operation of the LAT as well as scientific data analysis. These include NASA and DOE in the United States, CEA/Irfu and IN2P3/CNRS in France, ASI and INFN in Italy, MEXT, KEK, and JAXA in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the National Space Board in Sweden. Additional support from INAF in Italy and CNES in France for science analysis during the operations phase is also gratefully acknowledged.

Author(s): Paul S. Ray1, Jayanta Roy2, 3, Bhaswati Bhattacharyya2, 3, Julia S. Deneva4, Fernando M. Camilo5, 6

A superburst’s impact on the accretion disk around the neutron star in 4U 1636-536
Superbursts are thought to be produced by a thermonuclear flash near the bottom of the carbon-rich ocean of accreting neutron stars. Lasting several hours, they allow for much more detailed X-ray spectra than the minute-long Type I X-ray bursts frequently observed from the same systems. Superbursts are, however, rare. We use one of only two detailed superburst observations to investigate changes in the accretion disk under the influence of the powerful burst. We find a doubling of the flux of the non-thermal spectral component that is often associated with the accretion process. Furthermore, thermal emission from the neutron star surface reflects off the accretion disk. Fits with detailed reflection models suggest a change in the ionization state of the reflecting material during the tail of the superburst. We discuss the consequences of the extra non-thermal flux and the reflection component for the interpretation of observations of both superbursts and the short X-ray bursts, which are used as probes for the unique nuclear physics deeper inside the neutron star.

Author(s): Laurens Keek¹, David R. Ballantyne¹, Erik Kuulkers², Tod E. Strohmayer³
Institution(s): 1. Center for Relativistic Astrophysics, Georgia Institute of Technology, Atlanta, GA. 2. European Space Astronomy Centre, Madrid, Spain. 3. NASA's Goddard Space Flight Center, Greenbelt, MD.

122.28 – Energy dependence of power-spectral noise in X-ray binaries

Black hole and neutron star X-ray binaries show variability on time-scales ranging from milliseconds to years. In the last two decades a detailed phenomenological picture of short-term variability in low-mass X-ray binaries has emerged mainly based on RXTE observations that cover energies above 3 keV. This picture comprises periodic or quasi-periodic variability, seen as spikes or humps in power density spectra, that are superposed on broad noise components. The overall shape of the noise components as well as the occurrence of quasi-periodic oscillations is known to vary with the state of the X-ray binary. We are accomplishing a comprehensive study of archival XMM-Newton observations in timing or burst mode of more than ten black hole and more than thirty neutron star low-mass X-ray binaries to investigate the variability properties of these sources at softer energies where the thermal disk component starts to emerge. Here we present some results of the energy dependence of the noise component in power density spectra: a discussion of the energy dependence of the power spectral state that we found in the “plateau” state of GRS 1915+105 and the intermediate state of 4U 1630-47; the dependence of the break-frequency of the band-limited noise component as well as the quasi-periodic oscillations on the studied energy band in several X-ray binaries like GX 339-4 or Swift J1753.5-0127. We will discuss the implications of these findings for the picture of the accretion geometry in black hole X-ray binaries.

Author(s): Holger Stiele¹, Wenfei Yu¹
Institution(s): 1. Shanghai Astronomical Observatory, Shanghai, China.

200 – The Nuclear Spectroscopic Telescope Array (NuStar)

Special Session – Great Lakes Grand Ballroom – 19 Aug 2014 08:30 am to 10:00 am

Chair(s):
Daniel Stern (JPL/ Caltech)

200.01 – NuSTAR Status and Plans
NuSTAR, a Small Explorer mission, the first sensitive imaging telescope operating in the high energy X-ray band, has just completed its baseline mission. This talk will describe the mission performance and present science highlights from the two-year primary mission. NASA has recently approved a two-year mission extension that will include a continuation of legacy survey programs as well as a guest investigator (GO) program. I will present plans for the GO program implementation as well as an outline of the survey programs. Significant time will be allotted for discussion and question and answer about the structure of the extended mission.

200.02 – Discovery of Diffuse Hard X-ray Emission in the Galactic Center

The inner arcminutes of the Galaxy contain one of the highest concentration of high-energy sources in the Milky Way. The supermassive black hole, pulsar wind nebulae, supernova remnants, X-ray binaries, and hot interstellar gas are copious emitters of X-rays and gamma-rays. NuSTAR provides a view of the hard X-ray (3-79 keV) band, a critical bridge between the soft X-ray and gamma-ray emission, with unprecedented sub-arcminute angular resolution. I will present analysis of NuSTAR’s view of the Galactic Center above 20 keV, which reveals entirely new contributions to the emission from this region. The hard X-ray emission from the Galactic Center is dominated by a strong point-like source, spatially consistent with the ultra-high energy gamma-ray emission detected by HESS, and a previously undetected diffuse emission extending along the Galactic plane, consistent with unresolved emission from a large population of millisecond pulsars, unusually hot intermediate polars, or black hole binaries.

Author(s): Kerstin Perez

Institution(s): 1. Columbia University, New York, NY.

Contributing team(s): The NuSTAR Team

200.03 – The Powerful Black Hole Wind in the Luminous Quasar PDS 456

Here broadband X-ray spectra of the luminous quasar PDS 456 are presented, as part of simultaneous campaign covering five NuSTAR and XMM-Newton observations during 2013-2014. The spectra show a persistent iron K-shell absorption profile in all of the observations, measured at 9 keV in the quasar rest frame, which demonstrates the presence of gas outflowing at about one third of the speed of light. Both the outflow emission and absorption components are spectrally resolved into a broad P-Cygni like profile, with the width of the profile corresponding to a FWHM velocity width of 35000 km/s. The flux of the iron K emission also responds directly to the hard X-ray continuum level, as measured in the NuSTAR data. The wind profile and response time makes it possible to measure the aperture and radial location of this wind, and thus to determine its total mass-loss rate and mechanical power. The observed wind stream starts at a radius of approximately 100 gravitational radii and spreads over a solid angle of at least 2 pi Steradian, and carries a kinetic power in excess of 10^{46} erg/s, enough to provide the feedback required by models of black hole and host galaxy co-evolution.

Author(s): James Reeves, Emanuele Nardini, Jason Gofford, Fiona Harrison, Guido Risaliti, Valentina Braitio, Michele Costa, Gabriele Matzeu, Dom Walton, Ehud Behar, P. T. O’Brien, Tracey J. Turner, Martin Ward

Institution(s): 1. Keele University, Keele, United Kingdom. 2. UMBC, Baltimore, MD. 3. California Institute of Technology, Pasadena, CA. 4. INAF – Osservatorio Astrofisico di Arcetri, Firenze, Italy. 5. INAF – Osservatorio Astronomico di Brera, Milano, Italy. 6. Department of Physics,
200.05 – Weak Hard X-ray Emission from Broad Absorption Line Quasars Observed with NuSTAR: Evidence for Intrinsic X-ray Weakness

We report NuSTAR observations of a sample of six X-ray weak broad absorption line (BAL) quasars. These targets, at z=0.148-1.223, are among the optically brightest and most luminous BAL quasars known at z<1.3. However, their rest-frame 2 keV luminosities are 14 to >330 times weaker than expected for typical quasars. Our results from a pilot NuSTAR study of two low-redshift BAL quasars, a Chandra stacking analysis of a sample of high-redshift BAL quasars, and a NuSTAR spectral analysis of the local BAL quasar Mrk 231 have already suggested the existence of intrinsically X-ray weak BAL quasars, i.e., quasars not emitting X-rays at the level expected from their optical/UV emission. The aim of the current program is to extend the search for such extraordinary objects. Three of the six new targets are weakly detected by NuSTAR with <45 counts in the 3-24 keV band, and the other three are not detected. The hard X-ray (8-24 keV) weakness observed by NuSTAR requires Compton-thick absorption if these objects have nominal underlying X-ray emission. However, a soft stacked effective photon index (?~1.8) for this sample disfavors Compton-thick absorption in general. The uniform hard X-ray weakness observed by NuSTAR for this and the pilot samples selected with <10 keV weakness also suggests that the X-ray weakness is intrinsic in at least some of the targets. We conclude that the NuSTAR observations have likely discovered a significant population (>33%) of intrinsically X-ray weak objects among the BAL quasars with significantly weak <10 keV emission. We suggest that intrinsically X-ray weak quasars might be preferentially observed as BAL quasars.

Author(s): Bin Luo¹, W. N. Brandt¹, David M. Alexander², Daniel Stern³, Stacy H. Teng⁴, Patricia Arevalo⁵, Franz E. Bauer⁵, Steven E. Boggs⁶, Finn Christensen⁷, Andrea Comastri⁸, William W. Craig⁹, Duncan Farrah¹⁰, Poshak Gandhi², Charles J. Hailey¹¹, Fiona Harrison³, Michael Koss¹², Patrick M. Ogle³, Simonetta Puccetti¹³, Cristian Saez¹⁴, Amy Scott¹, Dom Walton³, William Zhang⁴


Contributing team(s): NuSTAR Team
**201.01 – Voyager 1 Observations of Galactic Cosmic Rays in the Local Interstellar Medium**

The twin Voyager spacecraft were launched in 1977 and continue to be on a remarkable journey of exploration. Both spacecraft have crossed the termination shock of the solar wind and Voyager 1 (V1) crossed into interstellar space in ~mid-2012. At that crossing of the heliopause, the particles of heliospheric origin that had dominated the energy spectrum of most cosmic ray nuclei below approximately 50 MeV/nucleon disappeared, revealing for the first time the energy spectra of galactic cosmic rays (GCRs) down to about 3 MeV/nucleon. The intensity of GCRs has not shown any significant long-term gradient since the crossing, suggesting that V1 is observing the energy spectra of GCRs in the local interstellar medium unaffected by solar modulation. The energy spectra of H, He, C, and O have rather broad peaks in the ~20-100 MeV/nucleon energy range. The H/He ratio in this energy range is ~12 and that of C/O is ~1. We are also observing the local interstellar electron spectrum and find that a power-law energy dependence with spectral index approximately -1.5 from ~5-70 MeV is consistent with the data. We will report on the latest observations at the meeting. This work was supported by NASA under contract NNN12AA012.

**Author(s): Alan Cummings¹, Edward C. Stone¹, Bryant Heikkila², Nand Lal², William R. Webber³**  
**Institution(s): 1. Space Radiation Laboratory, Caltech, Pasadena, CA. 2. NASA/GSFC, Greenbelt, MD. 3. New Mexico State University, Las Cruces, NM.**

**201.02 – Cosmic Ray Energetics And Mass**

The balloon-borne Cosmic Ray Energetics And Mass (CREAM) experiment was flown for ~161 days in six flights over Antarctica. High energy cosmic-ray data were collected over a wide energy range from ~ 10^10 to > 10^14 eV at an average altitude of ~38.5 km with ~3.9 g/cm2 atmospheric overburden. Cosmic-ray elements from protons (Z = 1) to iron nuclei (Z = 26) are separated with excellent charge resolution. Building on success of the balloon flights, the payload is being reconfigured for exposure on the International Space Station (ISS). This ISS-CREAM instrument is configured with the CREAM calorimeter for energy measurements, and four finely segmented Silicon Charge Detector layers for precise charge measurements. In addition, the Top and Bottom Counting Detectors (TCD and BCD) and Boronated Scintillator Detector (BSD) have been newly developed. The TCD and BCD are scintillator based segmented detectors to separate electrons from nuclei using the shower profile differences, while BSD distinguishes electrons from nuclei by detecting thermal neutrons that are dominant in nuclei induced showers. An order of magnitude increase in data collecting power is possible by utilizing the ISS to reach the highest energies practical with direct measurements. The project status including results from on-going analysis of existing data and future plans will be discussed.

**Author(s): Eun-Suk Seo¹**  
**Institution(s): 1. University of Maryland, College Park, MD.**  
**Contributing team(s): the CREAM collaboration**

**201.03 – Results from the PAMELA experiment.**

PAMELA is a satellite-borne experiment, aimed at precision measurements of the charged, light component of the cosmic-ray spectrum. It consists of a magnetic spectrometer, a time-of-flight system, an electromagnetic calorimeter, an anticoincidence system and a neutron detector. The main focus of the experiment is on antimatter; other components of the spectrum that can be
investigated include electrons and light nuclei up to oxygen. Thanks to its placement out of the terrestrial atmosphere and the long exposure time, PAMELA is able to provide data with low systematic effects and high statistical significance. Its semi-polar orbit allows to detect particles of solar origin and to investigate the effects of the solar activity on the low-energy part of the galactic component of the spectrum (solar modulation). The redundancy of its detectors allows to monitor the detector performance and to measure the data selection efficiency directly from flight data. The instrument has been launched in 2006 and it is continuously taking data since then. The most important and recent results from the experiment will be presented.

Author(s): Nicola Mori

Institution(s): 1. University of Florence, Florence, Italy. 2. INFN Florence, Sesto Fiorentino, Italy.

Contributing team(s): PAMELA collaboration

201.04 – Galactic Cosmic Ray Origins with the SuperTIGER Long-Duration Balloon Instrument

The Super Trans-Iron Galactic Element Recorder (SuperTIGER) long-duration balloon instrument was developed by Washington University in St. Louis, NASA Goddard Space Flight Center, Caltech, Jet Propulsion Laboratory, and the University of Minnesota to measure the abundances of galactic cosmic ray elements from 26Fe to 40Zr with high statistics and single element resolution, and to extend exploratory measurements to about 60Nd. SuperTIGER launched from Williams Field, McMurdo Station, Antarctica, on December 8, 2012 and made over 2.5 revolutions around the continent, flying for a record 55 days and returning data on over 50 million heavy cosmic ray nuclei. The instrument, the methods of charge identification employed, and preliminary results from the SuperTIGER I balloon flight will be presented. The measurements of SuperTIGER will be discussed in context of their stringent tests of the OB association model for the origin of galactic cosmic rays. Finally, planned improvements to the SuperTIGER instrument and future flight plans will be described.

201.05 – Cosmic-ray Composition and Spectra below 1 GeV/nucleon: Highlights from the First 17 Years of Observations with NASA's Advanced Composition Explorer

The Cosmic Ray Isotope Spectrometer (CRIS) on NASA’s Advanced Composition Explorer (ACE) mission has been making high-precision measurements of the composition and energy spectra of galactic cosmic rays since launch in August 1997. Initially designed for the study of elements and their isotopes for atomic numbers, Z, from 2 through 30 in the energy range ~50 to ~500 MeV/nucleon, subsequent work has extended element coverage to Z~40 and energy coverage for some elements to ~1 GeV/nucleon. The first 17 years of operation included more than one and a half complete solar cycles, allowing the accumulation of a statistically significant sample of even rare nuclides and enabling studies of solar-cycle variations. A wide range of topics has been addressed using ACE/CRIS data. The confinement time of cosmic rays in the Galaxy has been inferred from abundances of secondary radioactive isotopes. A lower limit has been set on the time between nucleosynthesis and acceleration based on the primary radionuclide $^{59}$Ni. The enhancement of the $^{22}\text{Ne}/^{20}\text{Ne}$ ratio has been precisely measured and used as a constraint on the contribution of massive star outflows to the cosmic ray source. The elemental fractionation pattern for refractory and volatile elements has been derived and interpreted as evidence for cosmic-ray origin in superbubbles. The energy dependences of secondary-to-primary ratios have been used to obtain constraints on the spatial transport of cosmic rays in the Galaxy. Variations in cosmic-ray spectral shapes at low energies and in the abundances of
secondary isotopes that decay only by orbital electron capture have been used as probes of the effects of the expanding solar wind on the cosmic rays that penetrate to Earth. Selected highlights of cosmic-ray studies from the first 17 years of ACE will be reviewed and plans for extending this work during the next years of the mission will be briefly discussed.

Author(s): Mark E. Wiedenbeck¹
Institution(s): 1. JPL/Caltech, Pasadena, CA.
Contributing team(s): ACE/CRIS

202 – Space Missions: Why Do They Cost So Much?
Special Session – Great Lakes Grand Ballroom – 19 Aug 2014 10:30 am to 12:00 pm
Chair(s):
Joel Bregman (Univ. of Michigan)

202.01 – How to Respond to a NASA Announcement of Opportunity and Win
NASA aims to conduct the best science possible with open solicitations and a peer review process. This talk will explain what types of science NASA’s Science Mission Directorate (SMD) completes and then investigate more closely how PI-class missions are evaluated and selected. The proposal evaluation process will be described, including the evaluation criteria: scientific merit, scientific implementation, and technical, management, and cost feasibility including cost risk. How proposals are categorized will also be described. Finally, the areas that the selection official may consider are reviewed. If time allows, a recent AO will be used as a specific example of the process.

Author(s): Colleen N. Hartman¹
Institution(s): 1. NASA Headquarters, Washington, DC.

202.02 – Cost Estimating of Space Science Missions
Abstract: Estimating the cost of NASA’s science missions is a very difficult task. Anticipating how a system concept may evolve over time is challenging to say the least. Historical data, however, can help to estimate how the design may grow and how the schedules may change over time. An overall approach for costing such system relies on utilizing multiple methods based on historical technical, cost and schedule data to provide a robust range of estimates for future missions. This approach and other considerations for costing NASA science missions will be discussed.

Author(s): Robert Bitten¹
Institution(s): 1. The Aerospace Corporation, Chantilly, VA.

202.03 – Controlling Cost Growth in PI-led Missions
While the cost and schedule performance of PI-led competed missions is better than that of strategic missions, the majority of PI-led missions have experienced increases relative to their initial proposed cost. I will review the performance of competed missions, comparing them to flagship observatories. I will describe in general reasons for cost growth starting from assumptions made at the proposal stage to challenges with technology development, technical implementation and management. I will also describe strategies for effective implementation that can be used to manage cost growth.

202.04 – The Planning and Execution of NASA’s Strategic Science Missions
Strategic science missions are NASA’s largest and most challenging satellite missions, with costs well in excess of $1 billion, e.g. Mars Science Laboratory and the James Webb Space Telescope. These missions must be endorsed, with high priority, by the Decadal Survey process of the National Research Council (NRC), and are the most difficult ones for the NRC to properly estimate the final cost. Strategic missions are requirement driven missions, in which the requirements, often very challenging, are fixed and the ultimate cost is adjusted to meet the fixed requirements. This should be contrasted with smaller cost-capped missions, where the cost is fixed and the requirements adjusted. Strategic missions, by definition, have the most technical and management challenges. Ironically, the most challenging technologies of strategic missions have usually been done very well, since they get the most management attention, whereas on-orbit problems are usually associated with the less challenging technologies, which get less management attention, e.g. the Hubble mirror.

**Author(s):** Lennard A. Fisk¹  
**Institution(s):** 1. Dept. of Atmospheric, Oceanic and Space Sciences University of Michigan, Ann Arbor, MI.

204 – PeV Neutrinos  
**Plenary Session – Great Lakes Grand Ballroom – 19 Aug 2014 01:30 pm to 02:00 pm**  
204.01 – IceCube and the Discovery of High-Energy Cosmic Neutrinos  
The IceCube project has transformed one cubic kilometer of natural Antarctic ice into a neutrino detector. The instrument detects 100,000 neutrinos per year in the GeV to PeV energy range. Among those, we have recently isolated a flux of high-energy cosmic neutrinos. I will discuss the instrument, the analysis of the data, and the significance of the discovery of cosmic neutrinos.  
**Author(s):** Francis Halzen¹  
**Institution(s):** 1. WIPAC, Madison, WI.

205 – X-ray Binaries II  
**Oral Session – Great Lakes Grand Ballroom – 19 Aug 2014 04:00 pm to 05:30 pm**  
**Chair(s):**  
Q. Wang (Univ. of Massachusetts)  
205.01 – The Modern Black Hole X-Ray Binary Database: A Comprehensive All-Sky Observational Study  
Stellar mass black holes accreting in binary systems provide valuable insight into how binary systems evolve and how mass is transferred via accretion. With the advent of more sensitive all-sky X-ray instruments like the Swift Burst Alert Transient Monitor (BAT) and the Monitor of All-Sky X-ray Image (MAXI) telescope, the transient X-ray Universe is being probed in greater depth than ever before. Taking advantage of these resources, we have established a comprehensive database of black hole (and black hole candidate) X-ray binary activity over the last 18 years as revealed by all-sky X-ray instruments and scanning surveys. As a result, we have detected over 90 outbursts occurring in 43 transient BHXRBs, and estimate that current instruments can detect ~ 6-12 transient BHXRB outbursts every year, more than a factor of three larger than is commonly assumed. Most significantly, we find that the outbursts
undergone by BHXRBs that do not complete the canonical pattern make up ~ 50% of all outbursts occurring in Galactic BHXRBs. Such a high fraction of "failed" outbursts challenges the standard paradigm for accretion behaviour in transient BHXRBs. We present the detailed findings of our database and discuss how both the larger number of these so-called "failed" outbursts and the BHXRB outbursts in general have significant implications for the mass-transfer history of the Galactic BHXRB population.

Author(s): Bailey Tetarenko\textsuperscript{1}, Gregory R. Sivakoff\textsuperscript{2}, Craig O. Heinke\textsuperscript{1}, Jeanette C. Gladstone\textsuperscript{1}
Institution(s): \textsuperscript{1}. Physics, University of Alberta, Edmonton, AB, Canada.

205.02 – Modeling Reflection Signatures in the RXTE Spectra from X-ray Binaries: The GX 339-4 Case

Despite its limited spectral resolution, the RXTE mission has provided a vast amount of observational data for many X-ray sources over its entire lifespan of 16 years. We have started a camping to analyze all the available data for most X-ray binaries, focusing on the detection and modeling of reflection signatures. We present the results of this camping on the analysis of all available data for GX 339-4 in the hard state. Strong reflection features such as the Fe K emission line, the Fe K-edge, and the Compton hump are clearly observed on a wide range of luminosities. By fitting the spectra with the most advanced relativistic reflection models we are to impose constrains on the ionization state of the gas, the inner radius of the accretion disk, and the inclination of the system. A novel technique to improve the quality of PCA spectral data will also be discussed.

Author(s): Javier Garcia\textsuperscript{1}, Jeffrey E. McClintock\textsuperscript{1}, James F. Steiner\textsuperscript{1}, Ronald A. Remillard\textsuperscript{2}, Victoria Grinberg\textsuperscript{2}
Institution(s): \textsuperscript{1}. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. \textsuperscript{2}. Massachusetts Institute of Technology, Cambridge, MA.

205.03 – Inner Accretion Disk Regions of Black Hole X-ray Binaries

Understanding the spectral and geometric properties of the innermost regions of accretion disks in black hole X-ray binaries is a long-standing topic of active observational and theoretical pursuit. The non-trivial modification of the accretion disk spectrum due to conspiring physical effects such as Comptonization, free-free emission/absorption, bound-free opacities, and energy dissipation by magnetic processes is described by the phenomenological spectral hardening factor, which is often confined to a restricted parameter range. The inclination of the inner disk plane is often assumed to align with the binary orbital plane. Both the level of hardening of the disk spectrum and the orientation of the inner disk are difficult to constrain observationally. We present work on physically plausible ranges of the spectral hardening factor and inner disk–binary misalignment, suggesting that the previous assumptions of mild spectral hardening and alignment require closer inspection. Relaxing these assumptions, we demonstrate that adopting physically plausible values for the spectral hardening and inner disk–binary misalignment can alleviate discrepancies between different black hole spin measurement techniques.

Author(s): Greg Salvesen\textsuperscript{2,1}, Mitchell C. Begelman\textsuperscript{2,1}, Jon M. Miller\textsuperscript{3}
Institution(s): \textsuperscript{1}. Astrophysical and Planetary Sciences, University of Colorado at Boulder, Boulder, CO. \textsuperscript{2}. JILA, Boulder, CO. \textsuperscript{3}. University of Michigan, Ann Arbor, MI.

205.04 – Studying the inner accretion disk of GX 339-4 with NuSTAR and Swift
The latest outburst of the famous transient black-hole binary GX 339-4 at the end of 2013 was monitored by NuSTAR and Swift. Here we present the spectral analysis of four observations following the rise of the outburst and a final observation at the end of the outburst. During the outburst GX339-4 never left the low-hard state. The NuSTAR data provide excellent data quality to study the weak reflection component in this state. The iron line shows a significant broadening which is best described by relativistic effects close to the black-hole. If we assume a standard disk with an emissivity index of $q=3$ and a maximally spinning black-hole, the accretion disk seems to be truncated before reaching the ISCO, as expected in the low-hard state. However, a statistically equally good fit can be achieved with a black-hole spin of $a=0.42\pm0.01$. If we assume a lamp-post geometry of the corona and self consistently describe the emissivity, the data can be explained with a corona located several $r_g$ above the black-hole. In that scenario a maximally spinning black-hole and an accretion disk extending all the way to the ISCO are found. All scenarios show a weak dependence on flux, with the strongest relativistic effects measured at the highest flux phases. We discuss the physical implications of these models.

**Author(s):** Felix Fuerst

**Institution(s):** 1. SRL, Caltech, Pasadena, CA.

**Contributing team(s):** NuSTAR Galactic Binaries working group

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**205.05 – The Origin of Black-Hole Spin in Galactic Low-Mass X-ray Binaries**

Galactic field low-mass X-ray binaries (LMXBs), like the ones for which black hole (BH) spin measurements are available, are believed to form in situ via the evolution of isolated binaries. In the standard formation channel, these systems survived a common envelope phase, after which the remaining helium core of the primary star and the subsequently formed BH are not expected to be highly spinning. However, the measured spins of BHs in LMXBs cover the whole range of spin parameters from $a^*\sim0$ to $a^*1$. In this talk I propose that the BH spin in LMXBs is acquired through accretion onto the BH during its long stable accretion phase. In order to test this hypothesis, I calculated extensive grids of binary evolutionary sequences in which a BH accretes matter from a close companion. For each evolutionary sequence, I examined whether, at any point in time, the calculated binary properties are in agreement with their observationally inferred counterparts of observed Galactic LMXBs with BH spin measurements. Mass-transfer sequences that simultaneously satisfy all observational constraints represent possible progenitors of the considered LMXBs and thus give estimates of the amount of matter that the BH has accreted since the onset of Roche-Lobe overflow. I find that in all Galactic LMXBs with measured BH spin, the origin of the spin can be accounted by the accreted matter. Furthermore, based on this hypothesis, I derive limits on the maximum spin that a BH can have depending on the orbital period of the binary it resides in, and give predictions on the maximum possible BH spin of Galactic LMXBs where a BH spin measurement is not yet available. Finally I will discuss the implication that our findings have on the birth black hole mass distribution.

**Author(s):** Tassos Fragos$^1$, Jeffrey E. McClintock$^2$, Ramesh Narayan$^2$

**Institution(s):** 1. University of Geneva, Geneva, Switzerland. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

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**205.06 – High Precision Mass Measurement for the Black Hole in Nova Muscae 1991**
Mass is the fundamental parameter for an astrophysical black hole, since the accurate value of mass is a prerequisite for measuring a black hole's spin via the continuum-fitting method. Previous dynamical analyses have established that the X-ray binary Nova Muscae 1991 (GRS 1124-683) harbors a black hole. In this work, we utilize 72 high resolution Magellan Echelle (MagE) spectra and 72 strictly simultaneous V-band photometry (obtained with 2.5-m DuPont Telescope) to significantly improve the precision of the mass measurement for the black hole in Nova Muscae 1991. The spectra were taken on two consecutive nights and cover the full 11.4-hour orbital cycle. The radial velocities of Nova Muscae 1991 are determined by cross-correlating the object spectra with the spectrum of a (K3 V) template star obtained with the same instrument configuration. Five orders of the echelle spectra deliver consistent, high-quality radial velocity curves, from which the radial velocity amplitude is measured to be 406.45+/-2.40 km/s, which is consistent with previous works while the uncertainty is reduced by a factor of 3. We have also obtained the first accurate measurement of the rotational broadening of the stellar absorption lines (v sin i=82.9+/-1.1 km/s). From the MagE spectra we have determined the veiling of the stellar light by the disk emission (e.g., 61+/-1% of the total light at 5500 Å). This will allow us to correct the simultaneous photometric observation for the disk veiling effect, which will be used to accurately constrain the systemic inclination.

**Author(s):** Jianfeng Wu¹, Jeffrey E. McClintock¹, Danny Steeghs², Penelope Longa², Manuel Torres³, Luis C. Ho², Paul Callanan⁵, Mark Reynolds⁶, Jerome A. Orosz⁷, Peter G. Jonker³, ¹


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**300 – AGN II: Variability and Theory**

**Oral Session – Great Lakes Grand Ballroom – 20 Aug 2014 08:30 am to 10:00 am**

**Chair(s):**
Christopher Reynolds (Univ. of Maryland)

**300.01 – Absorption Variability in NGC 1365 Seen With NuSTAR and XMM-Newton**

Between July 2012 and February 2013, NuSTAR and XMM-Newton performed four long-look joint observations of the type 2 Seyfert NGC 1365 with the aim of measuring relativistic reflection from the inner region of the accretion disk. Fortuitously, two of observations caught the source in an unusually low absorption state, and one of these observation showed an uncovering of the central source. We have analyzed the variable absorption seen in these observations in order to characterize the geometry of the absorbing material in this source. In addition to a constant (likely distant) absorber with a column density of \(?1 \times 10^{22} \text{ cm}^{-2}\), we find a variable absorber with a range of \(N_{\text{H}}\) from \(5–25 \times 10^{22} \text{ cm}^{-2}\) and a range of covering fractions from \(0.5–1\) over the course of the four observations.

**Author(s):** Elizabeth Rivers¹, Fiona Harrison¹, Dom Walton¹, Guido Risaliti³, Daniel Stern²

**Institution(s):** 1. SRL, Caltech, Pasadena, CA. 2. JPL, Pasadena, CA. 3. INAF, Firenze, Italy.

**Contributing team(s):** NuSTAR Team
300.02 – Driving Extreme Variability: Measuring the Changing Characteristics of the X-ray Emitting Coronae in AGN

Through detailed analysis of the reflection of the X-ray continuum from the accretion disc, it is possible to probe the innermost structures right down to the innermost stable circular orbit and event horizon around the supermassive black holes in AGN. By measuring the emissivity profile of the accretion disc, that is its pattern of illumination by the coronal X-ray source, along with reverberation time lags between variability in the X-ray continuum and reflection, it has proven possible to measure the geometry and spatial extent of the corona that produces the X-ray continuum when the observed data are combined with insight gained from general relativistic ray tracing simulations. We conducted detailed analysis of both the X-ray continuum and its reflection from the accretion disc during periods of high and low X-ray flux drawn from long observations of the narrow line Seyfert 1 galaxy, 1H0707-495, totalling more than 1.3Ms with XMM Newton, as well as during the course of an X-ray flare in another narrow line Seyfert 1 galaxy, Markarian 335, observed in 2013 by Suzaku. These observations allow us to trace, for the first time, from observations, the evolution of the X-ray emitting corona that gives rise to the extreme variability seen in the X-ray emission from AGN. We detect expansion in the corona as well as variations in its energetics as the X-ray flux increases, which gives us insight into the physical processes by which energy is liberated from black hole accretion flows and allows observational constraints to be placed upon theoretical models of black hole accretion flows and associated coronae.

Author(s): Daniel Wilkins¹, Luigi C. Gallo¹, Erin Kara², Andrew C. Fabian²

Institution(s): 1. Saint Mary’s University, Halifax, NS, Canada. 2. University of Cambridge, Cambridge, United Kingdom.

300.03 – Probing Supermassive Black Hole Spins in MCG--6-30-15 and NGC 1365 with XMM-Newton and NuSTAR

We report on detailed spectral modeling of the Seyfert 1 AGNs NGC 1365 and MCG--6-30-15 using simultaneous, broadband X-ray spectra from XMM-Newton and NuSTAR. Both of these galaxies show evidence for relativistic reflection from the inner accretion disk in addition to complex, variable absorption. The high signal-to-noise across the 0.3-79 keV energy band enabled by these observations allows us to definitively disentangle the spectral signatures of the continuum, warm and cold absorption, and reflection from the torus and the inner disk in both sources. These deep pointings also enable the use of time-resolved spectral fitting in order to assess the role of each component in driving the spectral and temporal variability of the AGNs. This type of analysis allows us to isolate the relativistic reflection signatures in each object, facilitating the most accurate, precise constrains ever obtained on the spins of their supermassive black holes. We present our spin measurements, as well as a discussion of sources of systematic error. Finally, we place our results in the context of relativistic light-bending models in an effort to characterize the structure of the innermost regions of these AGNs.

Author(s): Laura Brenneman¹, Dom Walton², Andrea Marinucci³¹, Giorgio Matt³, Guido Risaliti⁴¹, Fiona Harrison², Daniel Stern⁵²

Contributing team(s): the NuSTAR team

300.04 – Modelling broad Fe K-alpha reverberation in AGN
The recent detection of X-ray reverberation lags, especially in the Fe K-alpha line region, around Active Galactic Nuclei (AGN) has opened up the possibility of studying the time-resolved response (reflection) of hard X-rays from the accretion disk around supermassive black holes. Here, we use general relativistic transfer functions for reflection of X-rays from a point source located at some height above the black hole to study the time lags expected as a function of frequency and energy in the Fe K-alpha line region. We explore the models and the dependence of the lags on key parameters such as the height of the X-ray source, accretion disk inclination, black hole spin and black hole mass. We then compare these models with the observed frequency and energy dependence of the Fe K-alpha line lag in NGC 4151. Assuming the optical reverberation mapping mass of 4.6E7 M(solar) we get a best fit to the lag profile across the Fe K-alpha line in the frequency range 1E-5 - 2E-5 Hz for an X-ray source located at a height h = 7 (+2.9,-2.6) R_G with a maximally spinning black hole and an inclination i < 30 degrees.

Author(s): Edward Cackett¹, Abderahmen Zoghbi², Christopher S. Reynolds², Andrew C. Fabian³, Erin Kara³, Phil Uttley⁴, Dan Wilkins⁵

Institution(s): 1. Wayne State University, Detroit, MI. 2. University of Maryland, College Park, MD. 3. Institute of Astronomy, Cambridge, United Kingdom. 4. University of Amsterdam, Amsterdam, Netherlands. 5. St Mary's University, Halifax, NS, Canada.

300.05 – Particle Acceleration and Plasma Dynamics during Magnetic Reconnection in Highly Magnetized Plasmas
We present two- and three-dimensional fully kinetic simulations of fast magnetic reconnection when the magnetization parameter sigma >> 1 up to sigma = 1600. The reconnection rate is observed to increase with sigma in the relativistic regime. The magnetic energy efficiently converts into kinetic energy of nonthermal relativistic particles in a power law spectrum. The power-law gets harder with sigma and system size, and approaches the -1 spectrum. The dominant acceleration mechanism is a first-order Fermi process accomplished through the curvature drift motion in magnetic flux tubes along the electric field induced by relativistic plasma flows. We have developed an analytical theory to describe the power law spectrum. We demonstrate that both continuous inflow and Fermi-type acceleration lead to the power law distributions. A general condition for the formation of power law distributions in magnetic reconnection is derived. The work shows that astrophysical reconnection sites can be important sources of high energy emissions and cosmic rays.

Author(s): Fan Guo¹, Yi-Hsin Liu¹, William Daughton¹, Hui Li¹

Institution(s): 1. Los Alamos National Laboratory, Los Alamos, NM.

300.06 – Powering jets with small-scale magnetic flux
The relativistic jets associated with radio galaxies and some X-ray binaries are generally believed to be driven by magnetic fields in the immediate vicinity of a central black hole. The classic Blandford-Znajek process, usually invoked to explain the energy and angular momentum transfer from the black hole to the surrounding plasma, requires a large-scale ordered magnetic
field and a significant magnetic flux through the ergosphere; in this scenario the jet power scales with the square of the magnetic flux. In many observed systems the presence of the required large-scale flux is questionable. I will describe an alternative model, in which jets are produced by the accretion of small magnetic loops, whose energy is amplified by the differential rotation of the accretion disk and by the rotating spacetime of the black hole. The build up of energy in these coronal flux systems eventually leads to runaway field line inflation and a temporary Blandford-Znajek phase, magnetic reconnection in thin current layers, and the ejection of bubbles of magnetically dominated plasma. In this scenario counter-rotating accretion flows actually produce jets more naturally: prograde disks power jets only when they create flux systems larger than a critical poloidal scale, whereas there is no minimal scale for retrograde accretion. The mechanism will be illustrated using new general-relativistic simulations of the coronae of rotating black holes, performed in the nearly force-free, or high magnetization, limit of MHD. The dissipation of magnetic energy by coronal reconnection events, as demonstrated in these simulations, is a potential source of the observed coronal high-energy emission from accreting black holes.

Author(s): Kyle Parfrey\(^1\), Dimitrios Giannios\(^2\), Andrei M. Beloborodov\(^3\)


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301 – Missions & Instruments

Oral Session – Great Lakes Grand Ballroom – 20 Aug 2014 10:30 am to 12:15 pm

Chair(s):
Randall Smith (Smithsonian Astrophysical Observatory)

301.01 – Athena: Exploring the Hot and Energetic Universe

The Advanced Telescope for High Energy Astrophysics, Athena, is a large X-ray observatory concept designed to provide a transformational leap in our understanding of two key questions in astrophysics: 1) How does ordinary matter assemble into the large scale structures that we see today? 2) How do black holes grow and shape the Universe? The key observational breakthroughs needed to answer these questions are to open up the Universe to high resolution X-ray spectroscopy at the peak of galaxy evolution at redshifts z=1-4, and use sensitive wide field X-ray imaging to break through into the early Universe in the X-rays, at redshifts z>6. Athena, under study for launch by ESA in 2028, provides the necessary performance to revolutionize our understanding of the Hot and Energetic Universe. These capabilities will also provide a powerful observatory to be used in all areas of astrophysics.

Author(s): Kirpal Nandra\(^1\)

Institution(s): 1. MPE, Garching, Germany.

301.02 – Instrumental limits to our knowledge of the X-ray sky

In the last decade, performances of X-ray detectors have improved over all parameter spaces (throughput, energy and spatial resolution, timing). However, the quality of our science is only as good as the quality our instruments' calibration. Measurements of X-ray observables in celestial sources are increasingly limited by systematic rather then by statistical errors. Unfortunately, all attempts at defining X-ray "standard candles" have proven unsuccessful so far. The energy scale can be still absolutely calibrated through emission lines produced by
atomic transitions in on-board or astrophysical calibration sources. Likewise, timing accuracy can be estimated using fast rotators such as the Crab pulsar. On the other hand, uncertainties at the level of the order of 10% (and more) affect the absolute flux calibration. These "cross-calibration" uncertainties are energy-dependent, thus implying uncertainties on spectral measurements. I present in this talk the calibration and cross-calibration status of historical and operational X-ray detectors. Efforts to monitor, document and improve the cross-calibration status are carried out primarily by the IACHEC (International Astronomical Consortium for High Energy Calibration: http://web.mit.edu/iachec/). I will also briefly discuss the impact that these uncertainties (may) have on fields as diverse as the measurements of spin in accreting black holes, and the determination of cosmological parameters through surveys of galaxy clusters.

**Author(s): Matteo Guainazzi**

**Institution(s):** 1. European Space Agency, Villanueva de la Cañada, Madrid, Spain.

**301.03 – Galactic TeV observations with HAWC**

The High Altitude Water Cherenkov (HAWC) Observatory is a gamma-ray and cosmic-ray detector currently under construction at the Sierra Negra volcano in the state of Puebla, Mexico. The full array will consist of 300 water Cherenkov detectors, which contain 1200 photomultiplier tubes and cover an area of 22,000m^2. It has an instantaneous field of view of 2sr, a duty cycle >90%, and is sensitive to energies between 100 GeV and 100 TeV. Data taking began in Summer 2013 with a partial array. I will present the results of HAWC observations of the Galactic plane, which include the complex Cygnus region, and other extended TeV objects with unidentified source associations.

**Author(s): Chiumun M. Hui**

**Institution(s):** 1. Physics, Michigan Technological University, Houghton, MI.

**Contributing team(s):** HAWC collaboration

**301.04 – The HEROES Balloon-borne Hard X-ray Telescope**

The High Energy Replicated Optics to Explore the Sun (HEROES) payload flew on a balloon from Ft. Sumner, NM, September 21-22, 2013. HEROES is sensitive from about 20-75 keV and comprises 8 optics modules (HPD~33"), each consisting of 13-14 nickel replicated optics shells and 8 matching Xenon-filled position-sensitive proportional counter detectors (dE/E=0.05 @ 60 keV). Our targets included the Sun, the Crab Nebula and pulsar and the black hole binary GRS 1915+105. HEROES was pointed using a day/night star camera system for astrophysical observations and a newly developed Solar Aspect System for solar observations (with a shutter protecting the star camera.) We have successfully imaged the Crab Nebula. Analyses for GRS 1915+105 and the Sun are ongoing. In this presentation, I will describe the HEROES mission, the data analysis pipeline and calibrations, preliminary results, and plans for follow-on missions.

**Author(s): Colleen Wilson-Hodge**, Jessica Gaskin, Steven Christe, Albert Y. Shih, Douglas A. Swartz, Allyn F. Tennant, Brian Ramsey, Kiranmayee Kilaru

**Institution(s):** 1. NASA’s MSFC, Huntsville, AL. 2. NASA’s GSFC, Greenbelt, MD. 3. USRA/MSFC, Huntsville, AL.

**301.05 – Performance of VERITAS**

VERITAS is an array of four Imaging Atmospheric Cherenkov Telescopes located at the Fred Lawrence Whipple Observatory in Southern Arizona, covering the energy range from ~100 GeV to ~30 TeV. Full four-telescope operations began in Spring 2007, and in Summer 2009 the first
telescope in the array was relocated to improve the sensitivity. A major hardware upgrade was completed in Summer 2012 to the camera and trigger in each telescope, lowering the energy threshold. Here we present the performance of VERITAS, determined with instrument response functions from simulations, which utilize long-term calibration measurements. Results are shown from Crab Nebula observations, validating the performance.

Author(s): Jeff Grube
Institution(s): 1. Adler Planetarium, Chicago, IL.
Contributing team(s): the VERITAS Collaboration

301.06 – The Cherenkov Telescope Array: A New Observatory for the Highest Energy Astrophysics
The Cherenkov Telescope Array (CTA) will study the extreme processes in the Universe that produce very-high-energy gamma rays. Building on the past decade of experience from H.E.S.S., MAGIC, and VERITAS, CTA will feature dozens of imaging atmospheric Cherenkov telescopes of three different sizes to detect gamma rays with energies between 30 GeV and more than 100 TeV. The observatory will be an order of magnitude more sensitive than the current generation of instruments. CTA will have a broad science program including elucidating the origins of Galactic and extra-galactic cosmic rays and the mechanisms of particle accelerators including active galactic nuclei, gamma-ray bursts, and supernova remnants; detecting or constraining dark matter particle interactions in situ in the cosmos; and measuring the energy spectra of cosmic-ray electrons and positrons.

Author(s): Justin Vandenbroucke
Institution(s): 1. University of Wisconsin, Madison, WI.
Contributing team(s): CTA Consortium

302 – The Neutron Star Interior Composition Explorer (NICER)
Special Session – Great Lakes Grand Ballroom – 20 Aug 2014 01:30 pm to 03:00 pm
Chair(s):
Zaven Arzoumanian (NASA/GSFC)

302.01 – The Neutron Star Interior Composition Explorer Mission of Opportunity
The Neutron Star Interior Composition ExploReR (NICER) is an X-ray astrophysics mission of opportunity (MoO) that will reveal the inner workings of neutron stars, cosmic lighthouses that embody unique gravitational, electromagnetic, and nuclear-physics environments. NICER achieves this objective by deploying a high-heritage instrument as an attached payload on a zenith-side ExPRESS Logistics Carrier (ELC) aboard the International Space Station (ISS). NICER offers order-of-magnitude improvements in time-coherent sensitivity and timing resolution beyond the capabilities of any X-ray observatory flown to date. Through a cost-sharing opportunity between the NASA Science Mission Directorate (SMD) and NASA Space Technology Mission Directorate (STMD) NICER will also demonstrate how neutron stars can serve as deep-space navigation beacons to guide humankind out of Earth orbit, to destinations throughout the Solar System and beyond. I will overview the NICER mission, discuss our experience working with the ISS, and describe the process of forging a partnership between SMD and STMD.

Author(s): Keith Gendreau
Institution(s): 1. NASA/GSFC, Greenbelt, MD.
302.02 – Neutron Star Equation of State Constraints from X-ray Observations of Recycled Millisecond Pulsars

The surface thermal radiation from neutron stars can serve as a powerful probe of the extremely dense matter in their centers. For "recycled" millisecond pulsars in particular, realistic modeling of the rotation-induced thermal X-ray pulsations offers a promising approach toward constraining the elusive neutron star equation of state. In this talk, I will summarize existing observational studies of millisecond pulsars with XMM-Newton and Chandra and the exciting prospect of high-precision constraints on the neutron star mass-radius relation using the Neutron Star Interior Composition ExploreR (NICER).

Author(s): Slavko Bogdanov$^1$

Institution(s): 1. Columbia University, New York, NY.

302.03 – Effects of Rapid Spin on the Spectra and Pulse Profiles of Neutron Stars

A large number of sources that are prime targets for determining neutron star masses and radii spin at 300-700 Hz. At these high spin frequencies, neutron stars become oblate and their spacetime acquires a significant quadrupole moment. In this talk, I will present the rotational broadening and distortion of thermal and line spectra due to these effects. I will also discuss the asymmetry and the energy dependence introduced by the stellar spin to X-ray pulse profiles. I will conclude by describing ways to mitigate and/or exploit these rapid spin effects when measuring neutron star radii.

Author(s): Feryal Ozel$^1$, Dimitrios Psaltis$^1$, Michi Baubock$^1$, Deepto Chakrabarty$^2$, Sharon Morsink$^3$


302.04 – Screening and Calibration of Silicon Drift Detectors for NICER.

The NICER X-ray Timing Instrument (XTI) will include 56 Silicon Drift Detectors (SDDs). These detectors, and at least eight flight spares, will be characterized prior to launch. Energy scale and spectral response between 0.2 keV and 10 keV as well as timing at those energies are explored using a Modulated X-ray Source (MXS). I will present a summary of the current status of those efforts.

Author(s): Beverly LaMarr$^1$, Ronald A. Remillard$^1$, Wayne H. Baumgartner$^2$, Michael Vezie$^1$, Gregory Prigozhin$^1$, John Doty$^3$, Craig Markwardt$^2$


Contributing team(s): NICER

302.05 – In-Flight Calibration and Test of NICER

The Neutron star Interior Composition ExploreR (NICER) is a NASA Explorer Mission of Opportunity dedicated to the study of the extraordinary gravitational, electromagnetic, and nuclear-physics environments embodied by neutron stars. Grazing-incidence optics coupled with silicon drift detectors will provide photon-counting spectroscopy and timing registered to GPS time and position, with high throughput and relatively low background in the 0.2-12 keV band. We present preliminary plans for in-flight calibration of the NICER observation systems.
after launch. This includes effective area, coalignement, optics vignetting, detector resolution, background, and absolute timing accuracy.

**Author(s):** Craig Markwardt¹, Beverly LaMarr², Keith Gendreau¹, Zaven Arzoumanian¹, ³, Ronald A. Remillard²

**Institution(s):** 1. NASA's GSFC, Greenbelt, MD. 2. MIT Kavli Institute, Cambridge, MA. 3. USRA, Greenbelt, MD.

**Contributing team(s):** NICER Team

### 302.06 – NICER’s proposed Guest Investigator and Guest Observer programs

As a Science Enhancement Option to the baseline NICER mission, which focuses on neutron star astrophysics, the NICER project team has proposed to NASA Headquarters the implementation of both a Guest Investigator (GI) and a Guest Observer (GO) program. The GI program would support theoretical and corollary multiwavelength observational investigations of neutron star phenomena during the first year of NICER's on-orbit operations. The GO program would competitively award NICER observing time and funding for astrophysics investigations beyond NICER’s core neutron star science; GO observations would be scheduled for NICER”s second year of operation. I describe the structure of these programs, their timing, and a sampling of science investigations and outcomes that can be anticipated, especially those addressing long-standing questions that remain inaccessible to current X-ray astrophysics capabilities.

**Author(s):** Zaven Arzoumanian¹, ²

**Institution(s):** 1. NASA/GSFC, Greenbelt, MD. 2. CRESST/USRA, Greenbelt, MD.

### 302.07 – Use of NICER for Study of Accretion in Polar-type Cataclysmic Variables

The Neutron-star Interior Composition Explorer (NICER) is a NASA Explorer Mission of Opportunity that will provide large collecting area (>1800 cm^2), low background (<0.2 counts/s), and high effective area in the energy range 0.2-12 keV. This makes it ideal for study of the Polar (or AM Herculis) class of cataclysmic variables, which are binaries consisting of an extremely high magnetic field white dwarf (WD) paired with a main sequence companion, locked in synchronous rotation by the strong magnetic field of the WD. Accretion from the companion to the WD proceeds without an accretion disk, resulting in roughly radial flow onto the polar cap. Emission from these systems has been modeled, using both steady-state techniques and time-dependent hydrodynamics codes, as shocked supersonic flow onto the polar caps. Both spectral and temporal (quasi-periodic oscillation (QPO)) signatures have been modeled. Simultaneous phase-locked optical and X-ray QPOs are among tests of these models that NICER will accomplish. This work is supported by NASA and the Office of Naval Research.

**Author(s):** Kent S. Wood¹, Michael T. Wolff¹

**Institution(s):** 1. NRL, Washington, DC.

### 302.08 – SEXTANT: A Demonstration of X-ray Pulsar-Based Navigation Using NICER

The Station Explorer for X-ray Timing and Navigation Technology (SEXTANT) is a technology-demonstration enhancement to the Neutron-star Interior Composition Explorer (NICER) mission. NICER is a NASA Explorer Mission of Opportunity that will be hosted on the International Space Station (ISS). SEXTANT will, for the first time, demonstrate real-time, on-board X-ray pulsar-based navigation (XNAV), a significant milestone in the quest to establish a GPS-like navigation capability available throughout our Solar System and beyond. The SEXTANT XNAV demonstration will exploit the large collecting area (>1800 cm^2), low background (<0.2
counts/s), and precise timing (<300 ns) of the NICER X-ray Timing Instrument (XTE). Taking advantage of NICER’s science observations of X-ray emitting millisecond pulsars, which are nature’s most stable clocks, the SEXTANT flight software will demonstrate real-time orbit determination with error less than 10 km in any direction, through measurements made over 2 weeks or less in the highly dynamic low-Earth ISS orbit. The completed technology demonstration will bring the XNAV concept and algorithms to a Technology Readiness Level of 8 and will inform the design and configuration of future practical XNAV implementations.

Author(s): Paul S. Ray¹, Jason W. Mitchell², Luke M. Winternitz², Monther A. Hasouneh², Samuel R. Price², Jennifer Valdez², Wayne H. Yu², Sean R. Semper², Kent S. Wood¹, Michael T. Wolff¹, Zaven Arzoumanian³, Ronald J. Litchford⁴, Keith Gendreau²


303 – Bridging Laboratory and High Energy Astrophysics
Special Session – Huron – 20 Aug 2014 01:30 pm to 03:00 pm
Chair(s):
Daniel Savin (Columbia Astrophysics Lab.)

303.01 – Charge Exchange in X-ray Astronomy
The observation of charge exchange emission potentially provides a new observational window on the structure of boundaries between hot and cold regions, their relative velocities, and the actual mixing that occurs. Interpreting such data, and even identifying that the process exists, requires accurate knowledge of the velocity-dependent partial cross sections for the production of X-ray lines by charge exchange. I will point out the computational and laboratory challenges to obtaining these atomic parameters, suggesting that a combination of theoretical and experimental efforts will be required. As an example of astrophysical charge exchange, I will discuss current work on determining the contribution of interplanetary charge exchange to the 1/4-keV diffuse X-ray background. This was once thought to be almost entirely due to thermal emission from nearby interstellar gas at 1x10^6 K -- the "Local Hot Bubble" -- but the realization that charge exchange between interstellar neutrals passing through the Solar system and heavy ions in the Solar wind would produce X rays inspired calculations of the importance of this effect. The best models showed that charge exchange in the Solar system could readily produce *all* of the observed 1/4-keV radiation, but were based on very crude and uncertain partial cross sections for the production of the many X-ray lines involved. I will report preliminary results from laboratory measurements of some of these cross sections, and from a sounding rocket flight intended to make a direct determination of the importance of charge exchange in producing the 1/4-keV background radiation.

Author(s): Dan McCammon¹
Institution(s): 1. Univ. of Wisconsin, Madison, WI.

303.02 – The Dirt on Cosmic Dust: An X-ray Perspective through Black Hole and Neutron Star Eyes
I will discuss how the combination of experimental programs at synchrotron beam-lines and high spectral resolution X-ray studies of compact objects (e.g. black holes and neutron stars), can be used as a powerful new tool for revealing new information about cosmic dust. I will
discuss the viability for this work in the context of extant (e.g. Chandra and XMM-Newton) and near-future missions (e.g. Astro-H), and our efforts to provide supporting laboratory data. Using a Galactic black hole as the primary example, I will also show how X-ray absorption studies can reveal the element-specific quantity and composition of dust and discuss implications for formation scenarios based on the dust found. Further, I will discuss how X-rays may be key to revealing a thus far missing population of grains. Time-permitting, I will show how accurate composition information can then be combined with X-ray (imaging) scattering halo studies to determine high precision distances, in one case, comparable to parallax measurements.

Author(s): Julia C. Lee


303.03 – Exploring the universe in the laboratory: photoionized plasma experiments at Z relevant to astrophysics

Many astrophysical environments such as x-ray binaries, active galactic nuclei, and accretion disks of compact objects have photoionized plasmas. Detailed x-ray spectral observations performed with the Chandra and XMM-Newton orbiting telescopes provide critical information on the state of photoionized plasmas. However, the complexity of the astrophysical environment makes the spectral analysis challenging, and thus laboratory experiments are important for data interpretation and testing of modeling codes. The Z facility at Sandia National Laboratories is a powerful source of x-rays to produce and study in the laboratory photoionized plasmas relevant for astrophysics. We discuss an experimental and theory/modeling effort in which the intense x-ray flux emitted at the collapse of a z-pinch implosion conducted at the Z pulsed-power machine is employed to produce a neon photoionized plasma. The broadband x-ray radiation flux from the z-pinch is used to both create the photoionized plasma and provide a source of backlighting photons to study the atomic kinetics through K-shell line absorption spectroscopy. The plasma is contained in a cm-scale gas cell that can be located at different distances from the z-pinch, thus effectively controlling the x-ray flux producing the plasma. Time-integrated transmission spectra have been observed with a spectrometer equipped with two elliptically-bent KAP crystals from photoionized plasmas covering an order of magnitude range in ionization parameter. The transmission data shows a rich line absorption spectrum that spans over several ionization stages of neon including Be-, Li-, He- and H-like ions. Modeling calculations are used to interpret the transmission spectra recorded in the Z experiments with the goal of extracting the charge-state distribution, electron temperature and the radiation flux driving the plasma, as well as to determine the ionization parameter of the plasma. This work is sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551, and the Z Facility Fundamental Science Program of Sandia National Laboratories.

Author(s): Roberto Mancini

Institution(s): 1. Univ. of Nevada, Reno, NV.

304 – SNR, GRB, and Gravitational Waves

Oral Session – Great Lakes Grand Ballroom – 20 Aug 2014 03:30 pm to 05:30 pm
304.01 – The Emerging Picture of Supernova Remnants and GRBs at High Energies
In the last two years, high-energy studies of supernova remnants (SNRs) and gamma-ray bursts (GRBs) have yielded many new insights regarding the nature of explosions and their environments. In this talk, I will highlight several recent advances in these fields catalyzed by high energy theory and observations, with emphasis on progenitor systems, nucleosynthesis, and particle acceleration. Finally, I will discuss anticipated advances with upcoming facilities, like Astro-H and Advanced LIGO.

Author(s): Laura A. Lopez
Institution(s): 1. MIT, Cambridge, MA.

304.02 – Efficient Collisionless Electron Heating at the Reverse Shocks of Young Supernova Remnants Revealed by Fe-K Emission Diagnostics
Although collisionless shocks are ubiquitous in astrophysics, their fundamental properties are still poorly understood. In particular, the process known as collisionless electron heating is one of the main open issues in shock physics. Here we present Suzaku deep observations of the supernova remnants (SNRs) Tycho and 0509-67.5, showing the first robust evidence for efficient collisionless heating of electrons at their reverse shocks. We detect Fe K-beta (3p->1s) fluorescence emission at ~7.1 keV, which is expected only from low-ionization plasma where Fe ions still have many 3p electrons, and so key to diagnosing the plasma state of the immediate postshock ejecta. For Tycho SNR, we reveal that the K-beta emission peaks at a smaller radius than Fe K-alpha (2p->1s) fluorescence dominated by a relatively highly-ionized component. This updates the reverse shock radius of this SNR previously determined using the high-resolution Chandra image. Comparison with our hydrodynamical simulations requires the electron temperature at the reverse shock front to be more than 10 keV, about 1000 times higher than expected from Coulomb collisions alone.

Author(s): Hiroya Yamaguchi\textsuperscript{1, 2}, Kristoffer A. Eriksen\textsuperscript{3}, Carles Badenes\textsuperscript{4}, John P. Hughes\textsuperscript{5}, Nancy S. Brickhouse\textsuperscript{6}, Adam Foster\textsuperscript{6}, Daniel Patnaude\textsuperscript{6}, Robert Petre\textsuperscript{1}, Patrick O. Slane\textsuperscript{6}, Randall K. Smith\textsuperscript{6}


304.03 – The Proper Motion and X-Ray Analysis of the Pulsar Wind Nebula, PSR J1741-2054 Using Chandra.
A pulsar dissipates its rotational energy by generating relativistic winds, which in turn produces a population of high energy electrons and positions that we observe as a synchrotron emitting nebula. If the pulsar has a high space velocity, the corresponding nebula will have a bow-shock morphology due to the pulsar wind being confined by ram pressure. Pulsar wind nebulae (PWNe) provide a good test bed to study the dynamics and interaction of relativistic outflows with their environment and the corresponding shocks that result from these interactions. They can also aid in understanding the evolution of the neutron star and the properties of the local medium with which they are interacting. Here we report on the X-ray analysis of PSR J1741-2054 carried out as a part of the Chandra XVP program (6 ACIS-S observations, totalling ~300 ks
over 5 months). By registering this new epoch of observations using X-ray point sources in the field of view to an archival observation taken 3.2 years earlier, we are able to measure the proper motion of the pulsar with >3σ significance. We also investigate the spatial and spectral properties of the pulsar, its compact nebula and extended tail. We find that the compact nebula can be well described with an absorbed power-law with photon index of \( \gamma = 1.6 \pm 0.2 \), while the tail shows no evidence of variation in the spectral index with the distance from the pulsar. We have also investigated the X-ray spectrum of the neutron star. We find nonthermal emission accompanied by a significant thermal component and will provide constraints on the overall nature of the emission.

**Author(s): Katie Auchettl\(^1,5\), Patrick O. Slane\(^1\), Roger W. Romani\(^2\), Oleg Kargaltsev\(^4\), George G. Pavlov\(^3\)**


304.04 – Explaining extended emission GRBs using accretion onto a magnetar

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. These bursts are difficult to explain using standard accretion models. We use a combination of magnetic propellering and spin down to explain the extended emission by an accretion disc and a magnetar formed during the merger event. We can reproduce the X-ray light curve if the magnetar is rapidly rotating (milli-second period), has a magnetic field of about \( 10^{15} \) gauss and if the accretion disk has a mass of 0.001-0.01 solar masses. We compare the derived magnetar properties with those for other GRBs.

**Author(s):** P. T. O'Brien\(^1\), Ben Gompertz\(^1\)

**Institution(s):** 1. University of Leicester, Leicester, England, UK, United Kingdom.

304.05 – Emission from Pair Instability Supernovae with Rotation

Pair Instability Supernovae have been suggested as candidates for some Super Luminous Supernovae, like SN 2007bi, and can also be one of the dominant types of explosion occurring in the early Universe from massive, zero-metallicity Population III stars. The progenitors of such events can be rapidly rotating therefore exhibiting a different evolutionary path due to the effects of rotationally-induced mixing and mass-loss. Proper identification of such events requires rigorous radiation hydrodynamics and non-local thermal equilibrium calculations that capture not only the behavior of the light curve but also the spectral evolution of these events accurately. We present radiation hydrodynamics and local and non-local thermal equilibrium radiation transport calculations for 90-140 M\( \odot \) rotating pair-instability supernovae covering both the shock break-out and late light curve phases. We find that for a variety of progenitor masses these events are too dim and too red in color to account for so far observed superluminous supernovae and do not seem to match other known events, in terms of spectral appearance. We discuss the qualitative differences between different radiation transport
treatments and compare our results with previous results from non-rotating pair-instability supernovae.

Author(s): Emmanouil Chatzopoulos¹, Daniel R. Van Rossum¹, Daniel J. Whalen²
Institution(s): 1. University of Chicago, Chicago, IL. 2. T-2, Los Alamos National Laboratory, Los Alamos, NM.

304.06 – Resonant Shattering of Neutron Star Crusts

The resonant excitation of neutron star (NS) modes by tides is investigated as a source of short gamma-ray burst (sGRB) precursors. We find that the driving of a crust-core interface mode can lead to shattering of the NS crust, liberating ~10⁴⁶-10⁴⁷ erg of energy seconds before the merger of a NS-NS or NS-black hole binary. Such properties are consistent with Swift/BAT detections of sGRB precursors, and we use the timing of the observed precursors to place weak constraints on the crust equation of state. We describe how a larger sample of precursor detections could be used alongside coincident gravitational wave detections of the inspiral by Advanced LIGO class detectors to probe the NS structure. These two types of observations nicely complement one another, since the former constrains the equation of state and structure near the crust-core boundary, while the latter is more sensitive to the core equation of state. I will also discuss shattering flares as electromagnetic counterparts to gravitational wave bursts during parabolic and elliptic encounters in dense star clusters.

Author(s): David Tsang¹, Jocelyn Read², Anthony Piro³, Tanja Hinderer⁴

304.07 – Electromagnetic Emission and r-process Nucleosynthesis from Late-Time Winds of Neutron Star Merger Remnant Accretion Disks

Neutron star mergers result in the formation of a remnant accretion disk around a black hole or a hypermassive neutron star. The secular evolution of these disks leads to outflows that can eject a varying fraction of the disk, in amounts comparable to or larger than material ejected promptly due to tidal forces. Here I'll discuss results from two-dimensional, time-dependent hydrodynamic simulations of the long-term (viscous) evolution of these disks, which include the relevant physics needed to characterize the dynamics and composition of the disk. Disk winds generally contribute to a ~week long transient peaking in the near-infrared (kilonova), although a blue precursor can manifest as a signature of delayed black hole formation. The composition of the outflows is expected to include heavy r-process elements when a black hole forms promptly, and lighter elements in the case of a long-lived hypermassive neutron star. Results have implications for the detection of electromagnetic counterparts of LIGO sources and for the galactic r-process element generation.

Author(s): Rodrigo Fernandez¹, Brian Metzger²
Chair(s):
Daryl Haggard (Northwestern University/CIERA)

400.01 – Black Hole Variability and The Star Formation-AGN Connection: Do All Star-forming Galaxies Host an AGN?
I will present a simple picture for the observed connection between AGN activity and star formation, in the context of a model in which all star-forming galaxies host an AGN. In this picture, black hole accretion and star formation rate (SFR) are fueled by a common supply of cold gas and are closely tied when averaged over galaxy evolution timescales (~100 Myr). However, instantaneous AGN luminosities vary rapidly over many orders of magnitude, as suggested by hydro simulations and AGN light echoes. I will show that this simple variability model broadly reproduces observed AGN luminosity functions, merger fractions, and the weak correlations between AGN luminosity and SFR for individual galaxies, and will present a new test of the model’s predictions using Herschel observations of mid-infrared-selected quasars. Overall, these results provide evidence for a relatively straightforward co-evolution between star-forming galaxies and their central black holes.

Author(s): Ryan C. Hickox
Institution(s): 1. Dartmouth College, Hanover, NH.

400.02 – Unveiling Obscured AGN with X-ray Spectral Analysis
The circumnuclear medium enshrouding AGN can now be thoroughly investigated in X-rays using physically motivated, self-consistent models that have recently become available. These advanced models allow reliable column densities (N_Hs) to be derived and can provide insight into the complex geometry of the X-ray reprocessor, constraining both the line-of-sight and global column densities. We fit the X-ray spectra of 19 SDSS [OIII] 5007 Angstrom selected type 2 AGN with these models. Though our sources represent an X-ray bright subset of the parent [OIII]-selected type 2 AGN samples, most are heavily obscured (N_H > 10^23 cm^-2) to Compton-Thick (N_H > 1.25 x 10^24 cm^-2). Four objects have different global and line-of-sight column densities. We correct the X-ray emission for absorption, calculating the intrinsic X-ray luminosity, and find that the mean Lx/L_[OIII] ratio for this sample is nearly equivalent to that of the average value for Seyfert 1 (i.e., unabsorbed) AGN.

Author(s): Stephanie M. LaMassa, Tahir Yaqoob, Andrew Ptak, Jianjun Jia, Timothy M. Heckman, Poshak Gandhi, C. M. Urry

400.03 – High levels of absorption in orientation-unbiased, radio-selected 3CR Active Galaxies
A critical problem in understanding active galaxies (AGN) is the separation of intrinsic physical differences from observed differences that are due to orientation. Obscuration of the active nucleus is anisotropic and strongly frequency dependent leading to complex selection effects for observations in most wavebands. These can only be quantified using a sample that is sufficiently unbiased to test orientation effects. Low-frequency radio emission is one way to select a close-to orientation-unbiased sample, albeit limited to the minority of AGN with strong radio emission. Recent Chandra, Spitzer and Herschel observations combined with multi-wavelength data for a complete sample of high-redshift (1<z<2) 3CRR radio sources show that about half the sample is significantly obscured with ratios of unobscured: Compton thin (22<log
Compton thick (CT, log N_H > 24.2) = 2.5:1.4:1 in these high-luminosity (log L(0.3-8keV) ~ 44-46) sources. These ratios are consistent with current expectations based on modeling the Cosmic X-ray Background. A strong correlation with radio orientation constrains the geometry of the obscuring disk/torus to have a ~60 degree opening angle and ~12 degree Compton-thick cross-section. The deduced ~50% obscured fraction of the population contrasts with typical estimates of ~20% obscured in optically- and X-ray-selected high-luminosity samples. Once the primary nuclear emission is obscured, AGN X-ray spectra are frequently dominated by unobscured non-nuclear or scattered nuclear emission which cannot be distinguished from direct nuclear emission with a lower obscuration level unless high quality data is available. As a result, both the level of obscuration and the estimated intrinsic luminosities of highly-obscured AGN are likely to be significantly (~10-1000) underestimated for 25-50% of the population. This may explain the lower obscured fractions reported for optical and X-ray samples which have no independent measure of the AGN luminosity. Correcting AGN samples for these underestimated luminosities would result in flatter derived luminosity functions and potentially change their evolution.

**Author(s):** Belinda J. Wilkes¹, Martin Haas², Peter Barthel³, Christian Leipski⁴, Joanna Kuraszkiewicz⁵, Diana Worrall³, Mark Birkinshaw⁵, Steven P. Willner¹

**Institution(s):** 1. Harvard-Smithsonian, CfA, Cambridge, MA. 2. Ruhr University, Bochum, Germany. 3. University of Groningen, Groningen, Netherlands. 4. Max-Planck-Institut fur Astronomie, Heidelberg, Germany. 5. University of Bristol, Bristol, United Kingdom.

**400.04 – Characterizing the Long-Term Optical and Infrared Color Variability of a Sample of Southern Hemisphere Blazars**

We undertook a 6-year, multiwavelength program to observe a sample of blazars in various Fermi gamma-ray states, using the Small and Medium Aperture Research Telescope System (SMARTS) 1.3m + ANDICAM instrument in Cerro Tololo, Chile. We present near-daily optical and infrared (OIR) color variability diagrams for a sample of 12 blazars. We then compare the OIR flux and color to the Fermi gamma-ray flux on similar cadence. We show that on long timescales (of order years), patterns emerge in the OIR color variability that are not seen on shorter timescales due to selection effects introduced by observing blazars in gamma-ray bright, jet-flaring states. By observing both active and quiescent jet flaring states, we show that previous short-term color variability behavior, e.g. 'redder when brighter' in FSRQs and 'bluer when brighter' in BL Lacs, represent 'snapshots' in a given blazars' color variability behavior over time. We present a schematic representation of the long-term OIR color variability in blazars, and propose that changes in the relative contribution of the disk and jet emission, migration of the gamma-emitting region to outside the broad line region, and injections of higher energy electrons in the jet itself contribute to the long-term OIR color variability that we observe.

**Author(s):** Jedidah Isler¹,², Charles D. Bailyn¹, C. M. Urry¹, Paolo S. Coppi¹, Michelle Buxton¹, Imran Hasan¹, Emily MacPherson¹

**Institution(s):** 1. Yale University, New Haven, CT. 2. Syracuse University, Syracuse, NY.

**Contributing team(s):** SMARTS

**400.05 – Simultaneous Broadband Observations of jet-dominated active galaxies with NuSTAR**
The exceptionally energetic particle populations at work within powerful relativistic jets associated with active galaxies make these sources natural targets for the NuSTAR hard X-ray instrument. This space-based satellite can observe their emission between 3 and 70 keV with unprecedented sensitivity. This emission is likely due to the synchrotron process, and particles responsible for the hard X-ray emission are also expected to produce gamma-rays via inverse Compton process observed by instruments such as Fermi Large Area Telescope, VERITAS, MAGIC and HESS. Since the launch of NuSTAR, the instrument has led simultaneous broadband campaigns on multiple gamma-ray emitting jetted active galaxies. NuSTAR was able to observe Mrk 421 during unprecedented low and high states, as well as variability in Mrk 501 consistent with a magnetic reconnection event. Additionally, the extreme blazar 1ES 0229+200 was observed with NuSTAR, together with ground based gamma-ray instruments, providing the first complete picture of the broadband emission. These invaluable observations of BL Lac-type objects were supplemented with NuSTAR observations of the exceptionally variable flat spectrum radio quasar 3C 279, observed during the highest gamma-ray state yet observed by the Fermi LAT instrument. We will share the results from these multiwavelength campaigns, with particular emphasis on the implications for the study of the most relativistic particle populations at work within the Universe.

**Author(s):** Amy Furniss

**Institution(s):** 1. Stanford University, Stanford, CA.

**Contributing team(s):** NuSTAR, VERITAS, MAGIC

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400.06 – The resolved and unresolved components of the Isotropic Gamma-ray Background

Relying on more than 5 years of data, the Fermi Large Area Telescope (LAT) has provided a new measurement of the isotropic gamma-ray background (IGRB) up to 800 GeV. In this talk I will review our current understanding of the generation of the IGRB focusing in particular on the blazar source class that comprises the majority of sources detected by the LAT. Using a detailed and improved modeling of the blazar spectra and of their evolution we estimate the broad band, 0.1–800 GeV, contribution of blazars to the IGRB. We find that thanks to their hard spectra and large local space density BL Lacertae objects provide a substantial contribution to the IGRB at high energy (i.e. above 10 GeV). This energy range is particularly interesting because both the extragalactic background light and the intergalactic magnetic field might play an important role. Finally we will also present a refined measurement of the contribution of radio galaxies and discuss the origin of any unexplained component of the IGRB.

**Author(s):** Marco Ajello

**Institution(s):** 1. Clemson University, Clemson, SC. 2. Stanford University, Stanford, CA. 3. ASI Space Data Center, Rome, Italy. 4. DESY Zeuthen, Berlin, Germany. 5. Kavli Institute for Cosmological Physics, Chicago, IL.

**Contributing team(s):** on behalf of the Fermi-LAT Collaboration

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401 – Science and Technology for a Successor to the Chandra X-ray Observatory

**Special Session – Great Lakes Grand Ballroom – 21 Aug 2014 10:30 am to 12:00 pm**

**Chair(s):**

Alexey Vikhlinin (Harvard-Smithsonian, CfA)
401.01 – Overview of the configuration, technology challenges, and science capabilities for a successor to the Chandra X-ray Observatory
I will present a straw-man configuration for a future high-throughput, high angular resolution X-ray observatory which will be a true successor to Chandra. I will discuss the major technological challenges and the current approaches for overcoming those challenges. I will also discuss the science capabilities for this observatory.

Author(s): Alexey Vikhlinin

Institution(s): 1. Harvard-Smithsonian, CfA, Cambridge, MA.

401.02 – AGN feedback on the cluster and galactic scales: What the next generation of X-ray observatories should deliver
Chandra observations of the X-ray atmospheres of galaxy clusters and early type galaxies show that AGN feedback is a critical ingredient in the low-redshift evolution of cosmic structure. However, Chandra observations of these systems are photon-starved, and key questions that can only be addressed by high-resolution imaging spectroscopy are left unanswered. I will discuss the prospects of the next generation of X-ray observatories for answering some of these key questions, and why high spatial resolution is critical if we want to settle the question of the hot-halo/radio mode of AGN feedback in galaxies.

Author(s): Sebastian Heinz

Institution(s): 1. Univ. Of Wisconsin, Madison, Madison, WI.

401.03 – Theoretical expectations for the properties of hot gas around galaxies and prospects for future detection
I will review the current theoretical predictions for the properties of hot gas around galaxies derived from cosmological simulations of galaxy formation. I will also discuss prospects for detection of such gas both at low and high redshifts with current and future X-ray emissions.

Author(s): Andrey Kravtsov

Institution(s): 1. Univ. of Chicago, Chicago, IL.

401.04 – Window into Black Hole Growth at High Redshift
I will present the status of our current understanding of black hole formation in the early universe and outline how data from future missions can help discriminate between various theoretical models. A more fundamental understanding of accretion physics as well as the observational signatures thereof, will provide a deeper view into how black holes grow and evolve at high redshifts.

Author(s): Priya Natarajan

Institution(s): 1. Yale University, New Haven, CT.

402 – The Gravitational Universe
Special Session – Huron – 21 Aug 2014 10:30 am to 12:00 pm
Chair(s):
Guido Mueller (University of Florida)

402.02 – Going Out with a Bang: Gravitational Waves from Massive Black Hole Mergers
Mergers of massive black hole binaries are expected to be the “ loudest” emitters in the gravitational wave sky. These singularly powerful events are the keystone sources for space-based gravitational wave detectors and serve as unique probes of massive black hole
astrophysics. The measurement capabilities of space-based gravitational wave detectors are unparalleled in comparison to traditional electromagnetic observations and will play a crucial role in fully understanding galaxy mergers and our theoretical understanding of strong-field gravity. This talk will illustrate how we extract information about black hole mergers from the data and how a catalog of gravitational wave observations will place strict constraints on scenarios for massive black hole formation and growth while individual merger events will serve as unique laboratories for testing General Relativity.

Author(s): Tyson Littenberg
Institution(s): 1. CIERA/Northwestern University, Evanston, IL.

402.03 – Laying the Foundation for Space-based Gravitational Wave Detection: LISA Pathfinder, the LISA Test Package, and ST7-DRS
Efforts to develop space-based observatories of gravitational waves, such as the long-standing Laser Interferometer Space Antenna (LISA) or the more recent eLISA concept that motivated ESA’s selection of a gravitational wave mission for the L3 Mission Opportunity, have traditionally been praised for their scientific potential and criticized for their technological readiness. The LISA Pathfinder (LPF) mission is a dedicated technology demonstrator for such missions. Led by ESA and a consortium of European national agencies and with a minority contribution from NASA, LPF will demonstrate several key technologies for the LISA concept. LPF includes two scientific payloads: the European LISA Technology Package (LTP) and the NASA-provided ST7-DRS. The mission will place two test masses in drag-free flight and measure the relative acceleration between them. This measurement will validate a number of technologies that are critical to LISA-like gravitational wave instruments including sensing and control of the test masses, drag-free control laws, micro-Newton thrusters, and picometer-level laser metrology. LPF is currently in the late stages of integration and test and is planned to launch in 2015. We will present the current status of the LISA Pathfinder mission and the LTP and ST7-DRS payloads as well as the expected impact on the larger gravitational-wave effort.

Author(s): James Thorpe
Institution(s): 1. NASA GSFC, Greenbelt, MD.

Contributing team(s): LPF Team

402.04 – Space-Based Gravitational-Wave Observatory Mission Concept
Space-based Gravitational-wave Observatories (SGOs) will enable the systematic study of the frequency band from 0.0001 - 1 Hz of gravitational waves, where a rich array of astrophysical sources is expected. ESA has selected “The Gravitational Universe” as the science theme for the L3 mission opportunity with a nominal launch date in 2034. This will be at a minimum 15 years after ground-based detectors and pulsar timing arrays announce their first detections and at least 18 years after the LISA Pathfinder Mission will have demonstrated key technologies in a dedicated space mission. It is therefore important to develop mission concepts that can take advantage of the momentum in the field and the investment in both technology development and a precision measurement community on a more near-term timescale than the L3 opportunity. This talk will discuss a mission concept based on the LISA baseline that resulted from a recent mission architecture study.

Author(s): Jeffrey C. Livas
Institution(s): 1. NASA Goddard Space Flight Center, Greenbelt, MD.
403 – Galaxies & ISM
Oral Session – Great Lakes Grand Ballroom – 21 Aug 2014 01:30 pm to 03:00 pm
Chair(s):
Joel Bregman (Univ. of Michigan)

403.01 – the Important Role of Dark Matter Halo in Retaining Hot Gas Content in Early-type Galaxies
It has been an ongoing puzzle as to why there is a large scatter in the amount of hot X-ray gas in optically-similar early-type galaxies. With Chandra observations, we investigated the hot gas content of a sample of early-type galaxies. We found their hot X-ray gas per stellar light \( L_X/L_{\text{opt}} \) is highly correlated with their total masses estimated through stellar kinematics. Furthermore, we found no difference in the scatter in \( L_X/L_{\text{opt}} \) between galaxies in the field and in groups and clusters. This suggests that a dark matter halo is the primary factor in determining the hot gas content, as smaller galaxies are more vulnerable to mechanisms that remove hot gas from galaxies such as galactic winds. Other factors such as flattening, environment, rotation, and star formation history may have played a relatively secondary role.

Author(s): Yuanyuan Su\(^1\), Jimmy Irwin\(^2\), Raymond E. White\(^2\), David A. Buote\(^1\), Liyi Gu\(^3\)

403.02 – The Entropy Profiles and Baryon Fractions of Isolated Elliptical Galaxies
I present results for the radial entropy profiles of the hot interstellar medium (ISM) for a sample of isolated elliptical galaxies observed with the Chandra X-Ray Observatory. Using narrow-band X-ray surface photometry in three Chandra energy bands, we find that hydrostatic models of the hot ISM incorporating a Navarro-Frenk-White dark matter halo along with a Sersic representation of the stellar mass describe the radial X-ray surface brightness profiles very well in the three energy bands. The entropy profiles generally exceed the \( r^{1.1} \) profile predicted by gravity-only cosmological simulations, but, just as found for galaxy clusters, they match the gravity-only profile well when appropriately rescaled by the gas fraction. Finally, the baryon fraction within the virial radius averaged over our sample is very consistent with the cosmic value suggesting that some of the "missing baryons" may reside in the outer hot halos of approximately Milky-Way-sized galaxies.

Author(s): David A. Buote\(^1\), Ewan O'Sullivan\(^2\), Trevor J. Ponman\(^3\)

403.03 – Studying the Galactic Contribution to the Soft X-ray Background
We introduce results of the first two years of an ongoing Suzaku Key Project for the study of Solar Wind Charge eXchange (SWCX) and a connected investigation focused on Galactic Halo (GH) and Circum-Galactic Medium (CGM). The main focus of the Key Project is to characterize SWCX emission with a three-year monitoring campaign. We are studying the temporal evolution of the Soft X-ray emission towards four nearby (~100 pc) high density clouds that absorb almost all the background photons. Comparing the X-ray emission with the product of the ACE and WIND satellites, we are developing a model of the SWCX X-ray contribution as a
function of line of sight, position of the Earth and Sun, and the flux of neutrals in the solar wind. In parallel we are analyzing “empty sky” targets a few degrees away from the high-density clouds. The contrast between on- and off-cloud lines of sight is a unique tool to probe GH and/or CGM by removing the SWCX and Local Bubble foreground. The observation of the region around MBM16, in particular, shows no evidence of any absorbed emission, compared to a significant emission from the not-too-far MBM20 region. This is evidence of a strongly patchy GH+CGM scenario, ruling out uniform models.

Author(s): Wenhao Liu¹, Massimiliano Galeazzi¹, Eugenio Ursino¹, Dimitra Koutroumpa⁴, K. D. Kuntz², Steven L. Snowden³


403.04 – Analyzing the Milky Way's Hot Gas Halo with OVII and OVIII Emission Lines

We present an analysis of the Milky Way's hot gas halo using archival XMM-Newton observations of OVII and OVIII line emission. These lines are excellent tracers of gas at ~10⁶ K, which is characteristic of the Milky Way's halo gas as well as estimates for the Local Bubble. Our model consists of a spherical ?-model for the halo gas and a constant density Local Bubble. We find an acceptable fit to the OVIII observations by modeling the emission lines with an optically thin ?-model with a normalization of norc³ = 1.3 +/- 0.4 x 10⁻² cm⁻³ kpc⁻³ and ? = 0.49 +/- 0.05.

We compare our OVIII fitting results to similar studies analyzing the Milky Way's hot gas halo using X-ray absorption lines and find our results are generally consistent with the absorption line results.

Author(s): Matthew J. Miller¹, Joel N. Bregman¹

Institution(s): 1. University of Michigan, Ann Arbor, MI.

403.05 – H.E.S.S. Observations of The Large Magellanic Cloud

With an angular resolution of less than 0.1 degree and a sensitivity to detect less than 1% of the Crab flux in fifty hours, the H.E.S.S. telescopes have the potential to detect and separate very-high-energy (VHE) gamma-ray sources in nearby galaxies. The Large Magellanic Cloud (LMC), at a moderate distance and hosting the largest star forming region in the Local Group, is the most promising target to search for extragalactic VHE gamma-ray emitters of stellar-mass scale systems. The LMC has an extraordinarily high supernova rate per unit mass compared with the Milky Way galaxy. Studying cosmic-ray accelerators in such a different environment is of considerable interest. The H.E.S.S. observations of nearly two hundred hours cover a large portion of the LMC. Within the eld of view lie various types of expected gamma-ray emitters, i.e. pulsar wind nebulae, supernova remnants, superbubbles and the unique object SN 1987A, a very young supernova remnant. The results will be reported.

Author(s): Chia-Chun Lu¹, Felix Aharonian¹⁻⁷, Francois Brun¹, Ryan Chaves³, Wilfried Domainko¹, Werner Hofmann¹, Nukri Komin⁶, Thomas Lohse⁸, Michael Mayer², Stefan Ohm², Matthieu Renaud⁴, Christian Stegmann², Jacco Vink⁵, Heinrich Voelk¹

Institution(s): 1. MPIK, Heidelberg, Germany. 2. DESY, Zeuthen, Germany. 3. DSM/Irfu, Saclay, France. 4. CNRS/IN2P3, Montpellier, France. 5. Anton Pannekoek Institute, Amsterdam, Netherlands. 6. North-West university, Potchefstroom, South Africa. 7. Dublin Institute for
Advanced Studies, Dublin, Ireland. 8. Institut fu¨r Physik, Humboldt-Universi¨t¨at zu Berlin, Berlin, Germany.

Contributing team(s): H.E.S.S. collaboration

403.06 – A NuSTAR Perspective on the Star-forming Galaxy M83

We present results from NuSTAR observations (cumulative 420 ks) of the late-type galaxy M83. This is the first investigation of the spatially-resolved hard X-ray emission from a galaxy with properties comparable to those of the Milky Way (MW). M83 is included in the NuSTAR starburst/normal galaxy survey sample, which is comprised of six nearby galaxies spanning the star formation rate (SFR) range of 1 to 80 Msol/yr. We have resolved several off-nuclear point sources in our M83 NuSTAR observations. To characterize the nature of these X-ray point sources, we construct color-color and luminosity-color diagrams in NuSTAR bandpasses and compare them with well studied binaries in the MW. The previously reported ULX in M83, which is known to have a low-mass counterpart, showed similar colors and luminosity to other ULXs observed by NuSTAR. The majority of the remaining NuSTAR point sources are likely to be black hole binaries in intermediate accretion states. We found that M83 has an integrated galaxy-wide X-ray spectrum that rapidly declines at hard X-ray energies (>10 keV). This is due to majority contributions from the few brightest X-ray binaries, which have steep X-ray spectra and dominate the total hard X-ray emission of the galaxy. Finally, we construct a first empirical calibration of the hard X-ray luminosity (10-30 keV)/SFR correlation including nearby galaxies in the archive in addition to other starburst samples (NGC253, Arp299, NGC3310, and M82).

Author(s): Mihoko Yukita¹,², Bret Lehmer¹,², Daniel R. Wik¹,², Ann E. Hornschemeier²,¹, Andrew Ptak²,¹, Vallia Antoniou³, Meg Argo⁴, Keith Bechtol⁵, Fiona Harrison⁶, Roman Krivonos⁷, Thomas J. Maccarone⁸, Daniel Stern⁶, Malachi Tatum², Tonia M. Venters², William Zhang²


404 – X-ray Binaries III, Compact and Stellar Objects

Oral Session – Great Lakes Grand Ballroom – 21 Aug 2014 03:30 pm to 05:00 pm

Chair(s):
Nicholas White (USRA)

404.01 – Timing the Beast: A Spectro-Timing Approach to Understanding X-ray Binaries

Neither spectral nor timing studies alone allow us to disentangle the complex interplay of accretion and ejection processes. In this talk, I will show how combining both methods allows for an (almost) model-independent description of X-ray binary behavior across different accretion and ejection regimes and gives clues as to the contributions of accretion disk, disk winds, jets and Comptonization corona to the X-ray spectrum. A better grasp of the long-term evolution is also crucial for the interpretation of individual high resolution observations, e.g., by Chandra. As an example, we use over 12 years of RXTE monitoring of the black hole Cygnus X-1 to build up a template of spectro-timing behavior which enables an easy comparison among accreting sources acting on different mass and time scales. In particular, we can avoid misidentification of power spectral components in other black hole binaries that are less well
sampled and therefore do not allow tracking of power spectral components across spectral states. Important is also the comparison with AGN, where many of the relevant variability time scales that shape the interaction of the supermassive black hole with its surroundings are not accessible during an astronomer's lifetime.

**Author(s):** Victoria Grinberg¹, Katja Pottschmidt²,³, Moritz Böck⁴, Christian Schmid⁵, Michael Nowak¹, Phil Uttley⁶, John Tomsick⁷, Jerome Rodriguez⁸, Natalie Hell⁵,⁹, Alex Markowitz⁵,¹⁰, Arash Bodaghee⁹, Marion Cadolle Bel¹¹, Richard E. Rothschild¹⁰, Joern Wilms⁵


**404.02 – Black Hole Jets at the Lowest Luminosities**

Both transient stellar mass black hole X-ray binaries (BHXBs) and supermassive black holes (SMBHs) spend the majority of their lives accreting at very low rates relative to their Eddington luminosities, in the so-called quiescent regime (Eddington ratios lx<1e-6). However, there are still several open questions regarding the nature of black hole jets and how they couple with the underlying accretion flow at such low accretion rates. We recently examined the X-ray spectra of all BHXBs observed by Chandra in quiescence. Although their X-ray spectra are clearly softer in quiescence compared to at moderate Eddington ratios (lx~1e-3; a trend also seen in SMBHs), we found that multiple accretion flow and jet geometries can explain the data comparably well. Furthermore, it is observationally unclear if a relativistic jet always persists deep into quiescence in the first place. In an effort to better constrain quiescent accretion flows and jets, we undertook a multiwavelength campaign in June 2013 to assemble a nearly simultaneous spectral energy distribution (SED) of the BHXB XTE J1118+480 deep in quiescence (lx~1e-8.5). Our new SED includes detections in the radio, IR/optical, UV and X-ray wavebands. XTE J1118+480 is now the second BHXB with a well-sampled SED at such a low Eddington ratio (after A 0620-00), allowing us to place new constraints on highly sub-Eddington accretion flows and jets, and opening the door for comparative studies. We apply a broadband multi-zone jet model to our new SED, and in this talk I will describe how our multiwavelength approach allows us to break degeneracies between different jet-dominated vs. hot accretion flow geometries. I will also discuss how jet properties (i.e., particle acceleration, total power, etc.) may evolve as a function of Eddington ratio, as inferred from our broadband modeling. Our new constraints anchor the low-luminosity end of black hole accretion (which is arguably the most common accretion regime), and thereby improve the utility of using radiative signatures to learn about highly sub-Eddington black holes across the entire black hole mass scale.
**Author(s): Richard Plotkin¹, Elena Gallo¹, Peter G. Jonker², Sera Markoff³, Jeroen Homan⁴, James Miler-Jones⁵, David M. Russell⁶, Samia Drappeau⁷**

**Institution(s):** 1. Astronomy, University of Michigan, Ann Arbor, MI. 2. Netherlands Institute for Space Research, Utrecht, Netherlands. 3. University of Amsterdam, Amsterdam, Netherlands. 4. MIT, Cambridge, MA. 5. Curtin University, Perth, WA, Australia. 6. NYU-Abu Dhabi, Abu Dhabi, United Arab Emirates. 7. IRAP, Toulouse, France.

**404.03 – The 100-month Swift Catalogue of Supergiant Fast X-ray Transients**

The 100-month Swift Catalogue of Supergiant Fast X-ray Transients, collects over a thousand Swift/BAT flares from 11 Supergiant Fast X-ray Transients (SFXTs), and is complete down to fluxes of about 6x1E-10 erg/cm²/s (daily timescale) and about 1.5x1E-9 erg/cm²/s (orbital timescale, averaging about 800 s) in the 15-150 keV energy band. These hard X-ray flares typically last a few hundred seconds, reach fluxes in excess of 100 mCrab (15-50 keV), and last much less than a day. Their clustering in orbital phase-space, however, demonstrates that the outbursts are a much longer phenomenon, lasting up to a few days, as previously observed in deeper Swift soft X-ray observations. This large dataset is used to probe the properties of the high and intermediate emission states in SFXTs, and to infer the properties of these binary systems, as well as to estimate the number of flares per year each source is likely to produce as a function of the detection threshold and limiting flux. We also present preliminary results from our analysis of spectral evolution-dependent flux light curves and broad-band spectroscopy of the outbursts.

**Author(s): Patrizia Romano¹, Hans A. Krimm², David Palmer³, Lorenzo Ducci⁴, Paolo Esposito⁵, Stefano Vercellone¹, Phil Evans⁶, Cristiano Guidorzi⁷, Vanessa Mangano⁸, Jamie A. Kennea⁸, Scott D. Barthelmy², David N. Burrows⁸, Neil Gehrels²**

**Institution(s):** 1. INAF-IASF Palermo, Palermo, Italy. 2. NASA/GSFC, Greenbelt, MD. 3. LANL, Los Alamos, NM. 4. IAAT, Uni. Tuebingen, Tuebingen, Germany. 5. INAF-IASF Milano, Milano, Italy. 6. University of Leicester, Leicester, United Kingdom. 7. University of Ferrara, Ferrara, Italy. 8. Pennsylvania State University, University Park, PA.

**404.04 – Near-infrared counterparts of ultraluminous X-ray sources - towards dynamical mass measurements**

Are ultraluminous X-ray sources powered by stellar or intermediate mass black holes? To answer this question we need reliable mass measurements of these systems. The best way to do this would be to measure the radial velocity curves of the companion stars and thus derive the mass functions for these black holes. This has proven to be very difficult for ULXs because the optical light from these systems is dominated by the accretion disc. However, some ULXs may have red supergiant donor stars, that are intrinsically bright in the near-infrared and may enable us to measure their radial velocity curves in that part of the spectrum. We have conducted a survey of nearby ULXs to search for near-infrared counterparts. Of our 62 targets, 11 have a counterpart that could potentially be a red supergiant (Heida et al. 2014). I will present results of this survey and initial results of our NIR spectroscopic follow-up of several of the sources where we detected a NIR counterpart.

**Author(s): Marianne Heida¹,², Peter G. Jonker¹,², Manuel Torres¹,², Erik Kool⁴, Mathieu Servillat⁴,³, Tim P. Roberts⁵, Paul J. Groot⁴, Dom Walton⁶, Dae-Sik Moon⁷, Fiona Harrison⁶**

404.05 – X-ray and Radio Pulse Profiles and X-ray Phase-Resolved Spectroscopy of the Young Isolated Neutron Star PSR J0726-2612

Isolated neutron stars (INSs) are slowly spinning, highly magnetized X-ray pulsars with thermal X-ray spectra and no detected radio emission. The long-period, strong-field radio pulsar PSR J0726-2612 was shown to be a possible INS progenitor after XMM-Newton observations revealed a thermal X-ray spectrum and sinusoidal X-ray pulsations at twice the radio spin frequency, suggesting an evolutionary link between slowly spinning, strong-field radio pulsars and INSs. We will present results from deep X-ray and radio observations of this pulsar with XMM-Newton EPIC and the Green Bank Telescope. The X-ray pulse profile shows significant harmonic content at the second, third, and fourth harmonics, and phase-resolved X-ray spectra indicate the presence of one or more absorption lines whose energies vary with phase. Phase alignment with the radio pulse profile, along with radio polarimetry, yields constraints on the multi-wavelength emission geometry.

Author(s): Megan E. DeCesar¹, David L. Kaplan¹, Paul Demorest²


404.06 – Very Bright, Very Hot and Very Long: Swift Observations of the DG CVn "Superflare" of April 23rd, 2014

On April 23rd this year, one of the 2 stars in the close visual binary dM4e system DG CVn flared to a level bright enough (~300 milliCrab in the 15-150 keV band) that it triggered the Swift Burst Alert Telescope. Two minutes later, after Swift had slewed to the direction of this source, the Swift X-ray Telescope (XRT) and the Ultraviolet Optical Telescope (UVOT) commenced observing this flare. These observations continued (intermittently) for about 20 days and yielded a fascinating case history of this colossal event, the decay of which took more than a week in the UV and soft X-ray regions, and included several smaller superimposed secondary flares. The peak 0.3-10 keV luminosity observed by the XRT of 1.9e32 erg/s at the 18 pc distance of this system is 1.5 times the 'normal' combined systemic bolometric luminosity of 1.3e32 erg/s, making this event a super-bolometric flare similar to the 2008 flare of EV Lac (also detected by Swift). The BAT and XRT spectra of this flare in the first 6 minutes indicate that the emission was dominated by very hot (>>10 keV) plasma and/or a non-thermal power-law emission. This flare is arguably the longest, most X-ray luminous and hottest flare ever seen for an M dwarf in the solar neighborhood, and is reminiscent of the 9 days long flare of the RS CVn binary CF Tuc detected by ROSAT. We discuss how these exceptional characteristics may be related to the known properties of this system, specifically to its youth (30 Myr) and rapid rotation (55 km/s).

Author(s): Stephen A. Drake¹, Rachel A. Osten², Kim L. Page³, Jamie A. Kennea⁴, Samantha R. Oates⁵, Hans A. Krimm¹, Neil Gehrels⁶, Mathew J. Page⁷, Adam Kowalski⁸

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