

**High Energy  
Astrophysics in the  
2020's and Beyond**

Rosemont, IL

18 March–21 March 2018

**Abstract Book**

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

<b>Sunday, 18 March</b>		
6:00 pm–7:00 pm	Reception, Ventanas 11 <sup>th</sup> Floor	
<b>Monday, 19 March</b>		
<b>8:00 am–8:30 am, Introduction</b>		
8:00 am–8:30 am	High Energy Astrophysics in the 2020's and Beyond: Meeting Goals	Rob Petre
<b>8:30 am–10:00 am, Invited: The View of the Agencies</b>		
Time	Talk	Speaker
8:30 am–9:00 am	NASA Astrophysics Strategy through the 2020 Decadal Survey	Paul Hertz
9:00 am–9:30 am	The NSF View	Richard Green
9:30 am–10:00 am	Overview of Decadal Survey Preparations and Process	David Lang
<b>10:00 am–10:30 am, Coffee Break</b>		
<b>10:30 am–12:00 pm, Invited: Science Issues for the 2020s I.</b>		
10:30 am–11:15 am	Astrophysics in the 2020's and the role of High Energy Astrophysics	John Mather
11:15 am–12:00 pm	The Latest Results from the Alpha Magnetic Spectrometer on the International Space Station	Sam Ting
<b>12:00 pm–1:00 pm, Lunch Break</b>		
<b>1:00 pm–4:00 pm, Invited: Science Issues for the 2020s II.</b>		
1:00 pm–1:45 pm	Astrophysics and Cosmology in the 2020s	Roger Blandford
1:45 pm–2:30 pm	Cosmic Particles in the Multi-Messengers Era	Angela Olinto
2:30 pm–3:15 pm	High Energy Astrophysics - 5 years after the Roadmap	Chryssa Kouveliotou
3:15 pm–4:00 pm	Discovery and Opportunity in the X-ray Time Domain	Daryl Haggard
<b>4:00pm–4:30 pm, Coffee Break</b>		
<b>4:30 pm–6:10 pm, Oral Talks - Science Contributed I</b>		
4:30 pm–4:40 pm	Study the first lights with background fluctuations	Nico Cappelluti
4:40 pm–4:50 pm	X-ray properties of extremely red quasars observed during the epoch of peak galaxy formation	Andy Goulding
4:50 pm–5:00 pm	Probing Cosmic-ray Physics in Star-forming Galaxies With Future High-Energy Missions	Tonia Venters
5:00 pm–5:10 pm	Modern Problems in High Resolution X-ray Absorption from the Cold Interstellar Medium	Lia Corrales
5:10 pm–5:20 pm	Joint GW-GRB Detections	Eric Burns
5:20 pm–5:30 pm	Dust Echoes in the 2020s and 2030s	Sebastian Heinz
5:30 pm–5:40 pm	Galactic positrons	Carolyn Kierans
5:40 pm–5:50 pm	The Great, Thus Far Overlooked, Value in Optical-IR Colors Measured Simultaneously with Prompt Gamma-Ray Burst Emission, for Future Space Missions	Bruce Grossan

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

5:50 pm–6:00 pm	Emission from Pulsars will Dominate the Next Decade of TeV Astronomy	Tim Linden
6:00 pm–6:10 pm	The formation and evolution of neutron stars and stellar-origin black holes	Ann Hornschemeier
6:10 pm–7:30 pm	Poster Viewing & Happy Hour	
<b>Tuesday, 20 March</b>		
<b>Time</b>	<b>Talk</b>	<b>Speaker</b>
<b>8:00 am–10:00 am, Invited: Mission Prospects I</b>		
8:00 am–8:30 am	Prospects for Currently Operating High Energy Astrophysics Observatories	Rob Petre
8:30 am–9:00 am	Ground-based Gravitational-wave detectors – Plans for the coming decade	David Shoemaker
9:00 am–9:30 am	Synergy between High Energy Astrophysics and JWST	Stephanie LaMassa
9:30 am–10:00 am	WFIRST: Project Overview, Status, and Future Science	Dominic Benford
<b>10:00 am–10:30 am, Coffee Break</b>		
<b>10:30 am–12:00 pm, Invited: Mission Prospects II</b>		
10:30 am–11:00 am	Lynx Mission Concept Study	Feryal Ozel
11:00 am–11:30 am	The LUVOIR Space Telescope	Marc Postman
11:30 am–12:00 pm	The Habitable Exoplanet Observatory (HabEx)	Daniel Stern
<b>12:00pm–1:00 pm, X-ray SIG (+Lunch)</b>		
<b>1:00 pm–2:30 pm, Invited: Mission Prospects III</b>		
1:00 pm–1:30 pm	Origins Space Telescope	Joaquin Vieira
1:30 pm–2:00 pm	Observing the miliHertz Gravitational Wave sky with LISA	James Ira Thorpe
2:00 pm–2:30 pm	Athena: ESA's next-generation X-ray observatory	Kirpal Nandra
<b>2:30 pm–3:50 pm, Invited: Probes &amp; MOOs I</b>		
2:30 pm–2:50 pm	The Imaging X-ray Explorer (IXPE)	Martin Weisskopf
2:50 pm–3:10 pm	All Sky Medium Energy Gamma-ray Observatory (AMEGO)	Julie McEnery
3:10 pm–3:30 pm	The High-Energy X-ray Probe (HEX-P)	Kristin Madsen
3:30 pm–3:50 pm	POEMMA: Probe Of Multi-Messenger Astrophysics	Angela Olinto
<b>3:50 pm–4:20 pm, Coffee Break</b>		
<b>4:20 pm–5:00 pm, Invited: Probes &amp; MOOs I</b>		
4:20 pm–4:40 pm	STROBE-X: X-ray Timing and Spectroscopy on Dynamical Timescales from Microseconds to Years	Paul Ray
4:40 pm–5:00 pm	TAP: The Transient Astrophysics Probe	Dieter Hartman
<b>5:00 pm–6:20 pm, Oral Talks: Science Contributed II</b>		
5:00 pm–5:10 pm	Unveiling the Physics of Accreting Black Holes in the Next Decade	Javier Garcia

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

5:10 pm–5:20 pm	Prospects for a high accuracy measurement of the local black hole occupation fraction.	Elena Gallo
5:20 pm–5:30 pm	Large-scale quasar jets: where do we stand and what do we need to go forward	Markos Georganopoulos
5:30 pm–5:40 pm	X-ray observations of Tidal Disruption Events in the era of Time Domain Astronomy	Erin Kara
5:40 pm–5:50 pm	The Vast Potential of Exoplanet Satellites for High-Energy Time Domain Astrophysics	Krista Smith
5:50 pm–6:00 pm	X-ray Reverberation in the Next Decade	Abderahmen Zoghbi
6:00 pm–6:10 pm	Constraining Planet Mass-Scale Objects in Extragalactic Galaxies and Immediate Environment around Supermassive Black Holes with Quasar Microlensing	Xinyu Dai
6:10 pm–6:20 pm	The First Black Holes in the Next Decade of High-Energy Astrophysics	Fabio Pacucci
6:20 pm–7:30 pm	Poster Viewing & Happy Hour	
7:30 pm–8:30 pm	Lynx Special Session	

## Wednesday, 21 March

Time	Talk	Speaker
<b>8:00 am–10:00 am, Invited: Probes &amp; MOOs II</b>		
8:00 am–8:20 am	AXIS- A High Angular Resolution X-ray Probe Concept Study	Richard Mushotzky
8:20 am–8:40 am	The Transiting Exoplanet Survey Satellite (TESS) Mission	George Ricker
8:40 am–9:00 am	Arcus: Exploring the Formation and Evolution of Clusters, Galaxies, and Stars	Randall Smith
9:00 am–9:20 am	ISS-TAO	Judy Racusin
9:20 am–9:40 am	The X-Ray Astronomy Recovery Mission	Rich Kelley
9:40 am–10:00 am	The Compton Spectrometer and Imager project: Covering the MeV band using Germanium Detectors	John Tomsick
<b>10:00 am–10:30 am, Coffee Break</b>		
<b>10:30 am–12:10 pm, Invited: Ground-based Facilities I</b>		
10:30 am–10:50 am	XPP: The X-ray Polarimetry Probe	Henric Krawczynski
10:50 am–11:10 am	The Southern Gamma Survey Observatory: The Case for a Next-Generation Very High Energy Survey Instrument in the Southern Hemisphere	Tom Weisgarber
11:10 am–11:30 am	The Cherenkov Telescope Array: The Future of Very-High-Energy Gamma-Ray Astrophysics	David Williams
11:30 am–11:50 am	The Square Kilometre Array: An International Radio Telescope for the 21st Century	Bryan Gaensler
11:50 am–12:10 pm	A next-generation Very Large Array	Eric Murphy
<b>12:10 pm–1:10 pm, Gamma-ray SIG (+Lunch)</b>		

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

<b>1:10 pm–2:50 pm, Invited: Ground-based Facilities II</b>		
1:10 pm–1:30 pm	ALMA in 2020 and Beyond	Crystal Brogan
1:30 pm–1:50 pm	The Large Synoptic Survey Telescope (LSST)	Steve Kahn
1:50 pm–2:10 pm	A Vision for the Future of Multimessenger Astronomy with Neutrinos: the IceCube Gen2 Observatory	Kael Hanson
2:10 pm–2:30 pm	The Zwicky Transient Facility	Julie McEnery
2:30 pm–2:50 pm	NANOgrav	Zaven Arzoumanian
<b>2:50 pm–3:10 pm, Coffee Break</b>		
3:10 pm–4:10 pm	Panel Discussion Forum	Rob Petre
4:10 pm–4:30 pm	Rapporteur/Summary	Reynolds

<b>Mission Poster Session</b>		
1	Theresa Brandt	NASA's Physics of the Cosmos Program and Analysis Group: Decadal Survey Support
3	Karl Smith	Space Science at the Intelligence and Space Research Division of Los Alamos National Laboratory
4	Pragati Pradhan	Exploring transient detection with WFI onboard Athena
5	David Burrows	US Contributions to the Athena Wide Field Imager
6	Eric Miller	Reducing the Athena WFI Background with the Science Products Module: Lessons from Chandra ACIS and Suzaku XIS
7	Esra Bulbul	Characterizing Particle Background of Athena WFI for the Science Products Module: Swift XRT Full Frame and XMM-PN Small Window Observations
8	Laura Brenneman	Using Lessons Learned from Hitomi to Inform the ATHENA In-Flight Calibration Plan
9	Lynne Valencic	Arcus: Observatory Science
10	Scott Wolk	Arcus: Exploring exoplanets in X-rays
11	Laura Brenneman	Arcus: Black Hole Feedback Science
12	Ralph Kraft	The Lynx High-Definition X-ray Imager (HDXI): Instrument Concept and Preliminary Design
13	David Goldfinger	Wide Field Observations with the Micro-X Telescope
14	Michael Loewenstein	The Advanced X-ray Imaging Satellite Probe Mission: Overview
15	Edmund Hodges-Kluck	The AXIS View of Galaxies Near and Far
16	Brian Williams	Supernova Remnant Science with AXIS
17	William Zhang	Silicon Meta-Shell X-ray Optics for Astronomical Missions: High Resolution, Light Weight, and Low Cost
18	Lisa Winter	Time-domain Astronomy with the Advanced X-ray Imaging Satellite
19	Colleen Wilson-Hodge	STROBE-X: X-ray Timing & Spectroscopy on Dynamical Timescales from Microseconds to Years
20	Lisa Winter	AMEGO: A First Look at the MeV Emission from Local Seyfert Active Galaxies
21	Jeremy Perkins	Development of the AMEGO Subsystems
22	Regina Caputo	AMEGO: Simulations of the Instrument Performance

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

23	Kristin Madsen	Optical Instrument design of the High-Energy X-ray Probe (HEX-P)
24	Sean Pike	The Focal Plane of the High-Energy X-ray Probe (HEX-P)
25	Koji Mori	Concept of a Future Japan-lead mission for a Broadband X-ray Imaging Spectroscopy with High-angular Resolution: the FORCE Mission
26	Lorenzo Amati	The Transient High-Energy Sky and Early Universe Surveyor (THESEUS)
30	Brian Grefenstette	MonSTER: The Monitoring Spectroscopic Telescope for Energetic Radiation
31	Fabian Kislak	The SuperCONducting Titanium Imager SCOTTI and High Resolution X-ray Imaging Spectroscopy in the next Decade
32	Clio Sleator	The Compton Spectrometer and Imager
33	Henrike Fleischhack	Towards a New Era in Galactic Gamma-Ray Astronomy
34	J. Grove	GAMERA: a $\gamma$ -ray telescope for the gravitational wave astrophysics era
35	Richard Miller	Ex Luna Scientia: The Lunar Occultation Explorer (LOX), A New Paradigm for Nuclear Astrophysics
36	John Mitchell	Ultra-Heavy GCR measurements beyond SuperTIGER: The Heavy Nuclei eXplorer
37	Nepomuk Otte	Trinity: An instrument to detect cosmogenic neutrinos with the Earth skimming technique
38	Joshua Wood	Impact of Next Generation Instruments on the Search for Galactic Neutrino Sources
39	Carol Scarlett	Experimental Techniques to Detect Exotic Particle Interactions
40	Herman Marshall	The Future of Soft X-ray Polarimetry
41	Melville Ulmer	Some Suggestions for 1 keV Science for a compelling Major Mission
43	John Tomsick	The High-energy Astrophysics SmallSat for Polarization and Positrons
44	Jason Hogan	Mid-band Atomic Gravitational-wave Interferometric Sensor (MAGIS): Satellite Mission Concept and Astrophysics Science Reach.
45	Chi Cheung	Gravitational Wave Astrophysics with MAGIS: progenitors and pre-merger localizations of Advanced LIGO/Virgo binary-merger events
47	Chiumun Hui	MoonBEAM: A Beyond Earth-orbit Gamma-ray Burst Detector for Gravitational-Wave Astronomy
48	Hiromasa Miyasaka	Development of the Hard X-ray Imaging Pixel Detectors with Custom ASIC for Astrophysical Applications
49	Andreas Zoglauer	Determining the Performance of Future High-energy Space Missions with MEGALib
50	Jeffrey Livas	Possible LISA Technology Applications for Other Missions
51	Daniel Castro	Panchromatic Astrophysics - the Great Observatories Approach and the Future of Astronomy
52	Kenji Hamaguchi	Study of Particle Acceleration in eta Carinae with the MeV Electron-Tracking Compton Camera

## Science Poster Session

1	Martin Elvis	Balance & Tension: Building a Broad & Deep Astrophysics Program with Astro2020
3	Bidzina Kapanadze	Swift Target of Opportunity Observations of X-ray Flares in BL Lacertae Objects
4	Tatehiro Mihara	Recent results of MAXI on ISS
5	Mark McConnell	The Role of High Energy Polarimetry in Understanding GRBs
6	Sylvain Guiriec	A Unified Model for GRB Prompt Emission from Optical to Gamma-Rays: Exploring GRBs as Standard Candles
7	Erik Kuulkers	INTEGRAL search for gravitational-wave gamma-ray counterparts

# High Energy Astrophysics in the 2020's and Beyond

Rosemont, IL 18 March–21 March 2018

8	James Rodi	Searching for Fermi/GBM Untriggered SGRB Candidates with INTEGRAL/PICsIT
9	Meicun Hou	Chandra detection of Intracluster X-ray sources in Virgo and Fornax
10	Ian Evans	The Chandra Source Catalog Release 2.0
11	Francesca Civano	The Chandra Source Catalog 2.0: Preparing for the future using the Golden Present
12	Zhenlin Zhu	A New Chandra Perspective of X-ray-Emitting, Close Binaries in the Nuclear Star Cluster
13	Joy Nichols	X-ray Evolution of the Symbiotic Binary R Aqr : 2000-2005
14	Michael Nowak	High Spectral Resolution Observations of Ultrafast Outflows in AGN and ULX
16	Nathan Lee	Sub-Eddington super-massive black holes in Fornax Cluster early types
17	Haocheng Zhang	Multi-wavelength polarimetry of blazar jets: theoretical predictions and observability
19	Vincent Lakey	Halo Model Calculation of the Angular Cross Correlation Between the the Thermal Sunyaev-Zel'dovich Effect and Diffuse X-ray Emission In Galaxy Group and Cluster Halos
20	Timothy Kallman	3D Mapping of the Neutral X-ray Absorption in the Local Interstellar Medium
21	Gregory Brown	Laboratory Astrophysics for 21st century X-ray Observatories
22	Lorenzo Natalucci	Cyclotron absorption features in Supergiant Fast X-ray transients: the case of IGR J16418-4532
23	Bradford Snios	Temporal Variability and Proper Motions in the Jet of Centaurus A
24	Miao Li	How Supernovae-driven Hot Outflows Regulate Circumgalactic Medium
25	Shuo Zhang	Diverse Origin of Galactic Center Non-thermal X-ray Filaments
23	Jeremy Hare	High-mass gamma-ray binaries in X-rays and at higher energies.
28	Noel Klingler	What we can learn from high-resolution observations of pulsar wind nebulae
29	Bradford Snios	Physical Properties Within the Cocoon Shock of Radio Sources
30	Eric Perlman	Jet Physics, Current X-ray Observations and the Next Decade
31	Eileen Meyer	Jets from Black Holes: The Chandra Revolution and Future Prospects
32	Lia Corrales	High Resolution Imaging Spectroscopy of Quiescent Sgr A*
33	Natalie Hell	Disentangling the complex geometry of the clumpy absorber in high-mass X-ray binaries with time-resolved high-resolution spectroscopy
34	Edmund Hodges-Kluck	Measuring Gas Velocities in Galactic Hot Halos
36	Steve Zepf	Testing for black holes in globular clusters with X-ray observations
37	Andrew Ptak	High-resolution X-ray Spectroscopy of Starburst Galaxies
39	Norbert Schultz	High Resolution X-Ray Spectroscopy: Distribution of Matter in and around Galaxies
40	Hao Zhou	Observing Extended TeV Gamma-Ray Structures with HAWC
41	Peter Polko	Magnetic Alignment of Accretion Discs
42	Anjali Gupta	Warm-hot Circum Galactic Medium of Galaxies of Galaxies
43	Sanskriti Das	Discovery of warm-hot CGM around a starburst L* galaxy

## The Transient High-Energy Sky and Early Universe Surveyor (THESEUS)

Lorenzo Amati (Italian National Institute for Astrophysics (INAF))

### *Abstract*

The Transient High-Energy Sky and Early Universe Surveyor (THESEUS) is a space mission concept, developed by a large international collaboration and currently under evaluation by ESA within the Cosmic Vision - M5 selection process. THESEUS aims at exploiting Gamma-Ray Bursts for investigating the early Universe and at providing a substantial advancement of multi-messenger and time-domain astrophysics, also in strong synergy with the large observing facilities of the '20s and '30s. These goals will be achieved through a unique combination of instruments allowing GRBs and X-ray transients detection over a broad FOV (more than 1sr) with 0.5-1 arcmin localization, an energy band extending from several MeVs down to 0.3 keV and high sensitivity to transient sources in the soft X-ray domain, as well as on-board prompt (few minutes) follow-up with a 0.7 m class IR telescope with both imaging and spectroscopic capabilities. THESEUS will address main open issues in cosmology such as, e.g., star formation rate and metallicity evolution of the inter-stellar and intra-galactic medium up to redshift 10-12, signatures of Pop III stars, sources and physics of re-ionization, the faint end of the galaxy luminosity function. In addition to early Universe science, THESEUS will provide a fundamental contribution to time-domain and multi-messenger astrophysics by detecting, localizing, and identifying the electromagnetic counterparts to sources of gravitational radiation, which will be routinely detected in the late '20s / early '30s by next generation facilities like aLIGO/aVirgo, eLISA, KAGRA, and Einstein Telescope and, more in general, of several classes of transient sources, thus providing an ideal synergy also with the large multi-wavelength observatories of the near future like LSST, ELT, TMT, SKA, CTA, ATHENA).



## WFIRST: Project Overview, Status, and Future Science

Dominic Benford (NASA / GSFC)

### *Abstract*

The Wide-Field InfraRed Survey Telescope (WFIRST) is being prepared as the next major Astrophysics mission to follow JWST. The observatory payload consists of a Hubble-sized telescope aperture with a wide-field instrument for near-infrared imaging and spectroscopy plus an exoplanet coronagraph operating at visible wavelengths using state-of-the-art wavefront sensing and control. The wide-field instrument is optimized for large area surveys, with performance requirements driven by programs to study cosmology and exoplanet detection via gravitational microlensing. All data will be public immediately, and a substantial general observer program will be supported. The WFIRST Project is presently in Phase A, with a transition to Phase B expected in Spring 2018. While the mission has been designed to enable the candidate observing programs studied thus far, the actual science investigations selections will be made much closer to the launch date, slated for the mid-2020s. We will present an overview of the present mission design and expected performance, science cases enabled by this design, a summary of Project status, and plans for the future selection of observing programs.

## NASA's Physics of the Cosmos Program and Analysis Group: Decadal Survey Support

Theresa Brandt (NASA Goddard Space Flight Center)

### *Abstract*

NASA's Physics of the Cosmos (PCOS) Program (<https://pcos.gsfc.nasa.gov>) supports a diverse range of community activities aimed at providing useful input to the Decadal Survey Committee. We will discuss PCOS's support of the Lynx Large Mission Study, the Probe studies, and to the Physics of the Cosmos Program Analysis Group (PhysPAG) (<https://pcos.gsfc.nasa.gov/phypag/phypag.php>). The PhysPAG provides a number of avenues for individual community members to engage with their colleagues and NASA. Examples include the currently forming Multimessenger Astrophysics Science Analysis Group (MMA SAG) and the Science Interest Groups (<https://pcos.gsfc.nasa.gov/phypag/phypag-sigs.php>), including the X-ray, Gamma-ray, Cosmic Ray, and Gravitational Wave SIGs. We will discuss the ways the community can engage, coordinate, and collaborate through these open-membership groups to provide input to both the Decadal Survey and to NASA in general.

## Arcus: Black Hole Feedback Science

Laura Brenneman (Smithsonian Astrophysical Observatory)

### *Abstract*

Arcus, a proposed NASA/MIDEX mission currently in Phase A, will revolutionize high-resolution X-ray spectroscopic investigations into outflows from both supermassive and stellar-mass black hole systems. With an effective area  $>250 \text{ cm}^2$  between  $12\text{-}50 \text{ \AA}$  ( $>400 \text{ cm}^2$  between  $16\text{-}28 \text{ \AA}$ ) and  $R \sim 2500$ , Arcus will offer an order-of-magnitude improvement on the sensitivity of present-day gratings. These advances will enable measurements of the column densities, ionization states and velocities of the outflowing gas with unprecedented precision and accuracy in both absorption and emission. Multiple ions of C, N, O, Ne, S and Fe fall within Arcus's energy range, facilitating gas density measurements through helium-like emission line groupings. These density measurements, when combined with ionization measurements and knowledge of the continuum flux (obtained through Arcus's zeroth order spectrum), will provide the first definitive constraints on the launching radii and the physical mechanisms driving the outflows, while simultaneous knowledge of the outflowing gas velocity will yield the total momentum carried away by these winds. Connecting the momenta of AGN and stellar-mass black hole outflows from their launching points to downstream in the outskirts of galaxies through synergistic observations with JWST and ALMA will provide the first comprehensive view of feedback between black holes and their surrounding ISM/IGM.

## Using Lessons Learned from Hitomi to Inform the ATHENA In-Flight Calibration Plan

Laura Brenneman (Smithsonian Astrophysical Observatory)

### *Abstract*

The Hitomi mission flew a unique set of four very different instruments, including an X-ray micro-calorimeter and soft X-ray imager, a hard X-ray imager and a soft Gamma-ray detector. As such, the in-flight calibration plan had to take into account not just the needs of each instrument on its own, but also how best to cross-calibrate them with each other and with instruments on earlier X-ray missions. The proposed targets were selected largely from existing IACHEC studies which were then vetted through a systematic, iterative analysis of simulated spectra using fiducial responses provided by the instrument teams and spectral models culled from the IACHEC and the literature. This process yielded valuable insights on the expected calibration tolerances as a function of observing time allocated for each instrument and for the mission as a whole. Though the Hitomi mission was unfortunately brief, we can adapt the techniques used and lessons learned in formulating and vetting the in-flight calibration plan to future missions. ATHENA will also fly both a micro-calorimeter and an imaging CCD detector, and we are currently in the process of developing its in-flight calibration strategy. In this presentation I will describe our methods and their Hitomi-based heritage.

## ALMA in 2020 and Beyond

Crystal Brogan (NRAO)

### *Abstract*

The Atacama Large Millimeter/submillimeter Array (ALMA) is now in full operations and has become the premiere ground-based facility in its wavelength range. I will summarize the current status of ALMA, as well as the community-driven long term development vision for the observatory as outlined in the ALMA 2030 Roadmap.

## Laboratory Astrophysics for 21st century X-ray Observatories

Gregory Brown (LLNL)

### *Abstract*

The laboratory astrophysics program at the Lawrence Livermore National Laboratory's EBIT-I electron beam ion trap facility has been in operation for over 25 years, and in that time many measurements have been made which have proven necessary to interpret high resolution spectra from celestial sources. Although our understanding has improved greatly over the past decades, future x-ray observatories, which will carry instruments with unprecedented sensitivity and spectral resolution, will again challenge our understanding of atomic processes used to diagnose astrophysical sources, and will provide the impetus to even higher accuracy, more complete laboratory measurements. Some examples of recent and planned measurements will be given, including measurements conducted at both LLNL's EBIT facility as well as using the Max Planck Institute's portable electron beam ion trap. Part of this work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and is supported by NASA Grants to LLNL and NASA/GSFC.

# Characterizing Particle Background of Athena WFI for the Science Products Module: Swift XRT Full Frame and XMM-PN Small Window Mode Observations

Esra Bulbul (Harvard-Smithsonian Center for Astrophysics)

## *Abstract*

The Wide Field Imager (WFI) is one of two focal plane detector systems of the ESA's Athena X-ray observatory. The Science Products Module (SPM) will have on-board processing algorithms that will reduce the Athena WFI particle background level by improving background rejection on board. We examine the Swift XRT Full Frame and XMM-Newton Small Window Mode observations to understand and characterize the physics of the particle background. Particularly, we determine phenomenological correlations between high energy particle events and X-ray events to improve the rejection of particle background events. We will also present how these results could be used to reduce the expected background in the Athena WFI observations by the SPM processing.

## Joint GW-GRB Detections

Eric Burns (NASA/GSFC)

### *Abstract*

The joint detection of a binary neutron star merger as GW 170817 and GRB170817A enabled seminal results in fundamental, nuclear, and astrophysics. Searches in one messenger can be made more sensitive by including information from the other messenger, enabling additional joint detections. Highlights of science possible from future population studies are measuring  $H_0$  with standard sources between Type 1A SN and the CMB, and inferring the evolution of the elemental composition of the universe through time. High Energy survey missions can see these GRBs to the earliest times in the universe, which is unlikely to be matched anytime soon at lower energies, but could be match with the proposed third generation ground-based gravitational wave interferometers. If these interferometers can measure higher frequencies, they would allow for a direct observation in gravitational waves of binary neutron stars from inspiral through ringdown, which with a jointly observed GRB could tell us how quickly a jet can launch following the formation of a black hole, and either set more stringent fundamental physics limits or find evidence of new physics. We will discuss the necessary future capabilities in the keV to MeV energy range and for third generation GW interferometers. If time permits we will discuss the capabilities needed for future X-ray survey and narrow-field instruments, as well as the additional joint GW-EM science these capabilities will enable.



## US Contributions to the Athena Wide Field Imager

David Burrows (Penn State Univ.)

### *Abstract*

The Athena Wide-Field Imager instrument will include several US hardware contributions, including a special electronics processing board called the Science Projects Module (SPM), contributions to the design and testing of the detector readout ASIC, and instrument heat pipes. I will discuss these contributions, with emphasis on the SPM, which is a collaboration between Penn State, MIT, and SAO.

## Study the first lights with background fluctuations

Nico Cappelluti (University of Miami)

### *Abstract*

Direct detection of SMBHs seeds at high redshift is one of main goals of Lynx and Athena. The properties of these objects are unknown but Chandra observations of the unresolved CXB fluctuations and its counterparts in Spitzer bands might have lifted the curtain on these objects by identifying peculiar patterns in the clustering of IR and X-ray joint fluctuations. I will present new results obtained from a collection of deep fields from Chandra. We measure a strong large scale clustering signal above the foregrounds whose origin is still unknown. I will present results and their implications about the nature of early black holes.

## AMEGO: Simulations of the Instrument Performance

Regina Caputo (UMD/NASA/GSFC)

### *Abstract*

The gamma-ray energy range from several hundred keV to a hundred MeV has remained largely unexplored since the observations by instruments on the Compton Gamma-Ray Observatory (1991- 2000) and on INTEGRAL (since 2002). This energy range is particularly challenging because it is firmly in the Compton-dominated regime where the interaction cross section is minimized. Accurate measurements are critical for answering a broad range of astrophysical questions. To address these questions, we are developing AMEGO: All-sky Medium Energy Gamma-ray Observatory, to investigate the energy range from 200 keV to  $>10$  GeV with good energy and angular resolution and with sensitivity approaching a factor of 20-50 better than previous measurements. This instrument will be capable of measuring both Compton-scattering events at lower energies and pair-production events at higher energies. To achieve these ambitious goals Monte Carlo (MC) simulations will play a crucial role guiding the design of AMEGO. I will present an overview of the AMEGO simulation campaign using the MEGAlib framework, as well as the initial results for effective area and angular resolution, as well as sensitivity projections.

# Panchromatic Astrophysics - the Great Observatories Approach and the Future of Astronomy

Daniel Castro (SAO)

## *Abstract*

The combination of observations from the comparably sensitive space based telescopes Spitzer, Hubble and Chandra that span the electromagnetic spectrum has resulted in some of the most important astrophysical results of our time. These Great Observatories were deliberately planned to be synergistic and panchromatic. The launch of the James Webb Space Telescope next year will surely lead to many exciting discoveries over a wide variety of astrophysical and planetary science fields in the near future. However, the high cost of its “flagship mission” approach used for its commissioning, design and construction, also marks the end of the panchromatic access that powers 21st century astrophysics, as no Far-IR, UV or X-ray successor can launch for a decade or more, by which time JWST will likely be gone. In this work, we highlight some of the most significant discoveries that relied on incorporating observations in different wavelengths from NASA's “Great Observatories”, and argue for a similar panchromatic approach for the future.

Gravitational Wave Astrophysics with MAGIS: progenitors and pre-merger localizations of  
Advanced LIGO/Virgo binary-merger events

Chi Cheung (NRL)

*Abstract*

Gravitational wave observations in the  $\sim 30$  mHz to 3 Hz range (mid-band) provide degree-scale localizations and binary system parameters prior to their merger detections with Advanced LIGO/ Virgo. MAGIS, the Mid-band Atomic Gravitational Wave Interferometric Sensor, is a proposed NASA probe-class space mission concept, described in a companion contribution (J. Hogan et al.). Here, the astrophysics questions that can be addressed with MAGIS mid-band gravitational wave observations will be described in further detail. The MAGIS team is a collaboration between institutes in the U.S. including Stanford, AOSense, Harvard, NASA/GSFC, NASA/JPL, NIST, NRL, and UC Berkeley, and international partners at Birmingham, Bordeaux, CNRS, Dusseldorf, Ecole Normale Supérieure, Florence, Hannover, and Ulm University.

## The Chandra Source Catalog 2.0: Preparing for the future using the Golden Present

Francesca Civano (Harvard & Smithsonian Center for Astrophysics)

### *Abstract*

The Chandra X-ray Observatory has obtained more than 15,000 targeted imaging observations since launch, all of which include an excellent reservoir of unexplored information. The Chandra Source Catalog release 2.0 (CSC 2.0) is now including all ACIS and HRC-I imaging observations publicly released prior to the end of 2014, performing detection and extracting source properties, making them available in an easy format, ready for scientific discoveries. The 315,000 X-ray sources in CSC 2.0 allow scientists to perform statistical studies by making use of the extensive set of uniformly calibrated properties (more than 100 per source) in multiple energy bands and across a broad range of source fluxes. The large area covered ( $\sim 600$  deg<sup>2</sup>) by CSC 2.0 samples widely different astrophysical environments, providing both large samples of extragalactic sources at cosmological distances and hot and cool stars in our own galaxy. The large area is also ideal for discovering rare and new X-ray sources. In this talk, I will briefly present the new catalog release on behalf of the CSC team and discuss with examples how catalog studies can provide significant information for planning future X-ray missions and keep the community busy until their advent. This work has been supported by NASA under contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the Chandra X-ray Center.

## High Resolution Imaging Spectroscopy of Quiescent Sgr A\*

Lia Corrales (Einstein Postdoctoral Fellow)

### *Abstract*

Our Galaxy's central supermassive black hole, Sgr A\*, feeds from the winds of young massive stars orbiting it. But Sgr A\* is surprisingly dim, shining about 100,000 times less than expected given its environment. This problem has motivated a host of theoretical models to explain low-level radiatively inefficient accretion flows with mechanisms such as winds, jets, and magnetic fields. I will present recent work on the high resolution X-ray quiescent spectrum of Sgr A\* obtained with 3 Ms of Chandra HETG observations from the Chandra Galactic Center X-ray Visionary Program. This is our only chance to get a high resolution spectrum of quiescent Sgr A\* emission, until a micro-calorimeter mission with Chandra-like or better imaging resolution is approved. We will evaluate how high resolution micro-calorimeter spectra can improve our understanding of low-level black hole accretion by characterizing the wind outflows and non-thermal contributions to Sgr A\*'s X-ray spectrum.

## Modern Problems in High Resolution X-ray Absorption from the Cold Interstellar Medium

Lia Corrales (Einstein Postdoctoral Fellow)

### *Abstract*

The X-ray energy band is sensitive to absorption by all abundant metals in the interstellar medium (ISM) — carbon, oxygen, neon, silicon, magnesium, and iron — whether they are in gas or dust form. Photoelectric edges seen in high resolution X-ray spectra of Galactic X-ray point sources allow us to measure absolute abundances of gas and solid phase metals in the ISM, with fewer underlying assumptions. X-ray absorption fine structure (XAFS) in the photoelectric edge also reveals dust grain mineralogies and grain sizes. We review open problems in the field of astromineralogy, including problems in reconciling X-ray absorption spectroscopy with ISM observations at other wavelengths. In the future, high resolution imaging spectroscopy enabled by micro-calorimeters can probe the constituent elements of large dust grains, which are relatively invisible in absorption. Gratings spectroscopy is also necessary to obtain high resolution spectra at soft energies, required for probing the state of neutral carbon and oxygen -- the two most abundant interstellar metals and the two most important actors in the field of astromineralogy.



# Constraining Planet Mass-Scale Objects in Extragalactic Galaxies and Immediate Environment around Supermassive Black Holes with Quasar Microlensing

Xinyu Dai (Univ. of Oklahoma)

## *Abstract*

Gravitational microlensing provides a unique probe to study the population of lens objects and the emission region of the innermost parts of quasar accretion disks. We show that the current X-ray observations of microlensing signatures of emission close to the innermost stable orbit are able to constrain the population of lens objects down to planet mass scales. In particular, we found a planet mass fraction to be larger than 0.0001 of the halo mass, which is equivalent to 2,000 unbound objects ranging from Moon to Jupiter mass, free floating between stars, per main sequence star in the lens galaxy of RXJ1131-1231. In addition, two microlensing effects can be used to constrain black hole spins and X-ray reflection regions for high redshift quasars. The first effect is the excess iron line equivalent widths of lensed quasars compared to normal AGN, and the second is the distribution of iron line peak energies of lensed quasars. A microlensing analysis of the iron line equivalent widths prefers high spin values and very steep iron line emissivity profiles for quasars at  $z \sim 2$ . We will also discuss the prospect of these sciences in the era of the next generation of X-ray telescopes.

## Discovery of warm-hot CGM around a starburst L\* galaxy

Sanskriti Das (The Ohio State University)

### *Abstract*

Most of the baryons in a spiral galaxy are believed to reside in the warm-hot circumgalactic medium (CGM), out to the virial radius of the galaxy. In addition to the Milky Way, the CGM has been detected in soft X-ray emission only around massive galaxies, with mass insufficient to close their baryonic budget. We have now discovered massive, hot, extended CGM around the star-forming late-type L\* galaxy NGC3221. I will present our Suzaku observations and models of the CGM profile which will add to the ongoing quest to understand the physics of the CGM and its relation to other galaxy properties such as the star formation rate.

## Balance & Tension: Building a Broad & Deep Astrophysics Program with Astro2020

Martin Elvis (Harvard-Smithsonian CfA)

### *Abstract*

21st Century astrophysics is inescapably a pan-wavelength endeavor. The discovery of gravitational waves from a neutron star merger is exemplary: LIGO and VIRGO made the GW detection, but follow-ups with Y-ray, X-ray, optical and IR telescopes gave us a far more complete understanding of the physics. To maintain this capability we need several comparably sensitive “flagship” telescopes, operating in tandem. Yet with JWST we will lose this familiar capability provided by the Great Observatories. If the Astro2020 Decadal Survey recommends a rank-ordered list of JWST-class missions, we will have one flagship every decade or so, and must wait decades to follow up JWST discoveries in X-rays, Y-rays, and the far-IR. How can we escape this bind? Three approaches will help: balance, tensioning, and embracing commercial space. The community can pressure the Decadal via white papers to propose as its #1 priority a balanced portfolio of missions across the spectrum. The NASA probe-class and ESA M-class white papers contain at least half-a-dozen “giant leap” missions – ones that are at least 10X or 100X the power of their predecessors. Together these span the spectrum that JWST does not cover: far-IR, UV, X-ray, hard-X-ray, Y-ray. Together, including Lynx, they would cost about the same as JWST. With a portfolio the threat of cancellation is real, as that would still leave a strong program. That looming threat is liable to concentrate minds toward staying in budget. How can this portfolio win against a giant mission? By making the playing field level. Use the “tensioning” technique: always choose between equal cost alternatives. No single probe is likely to win against a JWST-class mission, but a set of probes could well provide better science per dollar. If the Decadal makes this choice explicit, the case for the smaller missions can be heard. Does this choice mean no more giant missions? No. Commercial space has brought launch costs down by a factor 3 already. Studies suggest that cheap mass to orbit allows spacecraft costs at 1/3 of present prices, with only ~30% mass increases. These savings should be fully realized by 2030, allowing truly large, LUVOIR-scale, telescopes into the program at an affordable price.

## The Chandra Source Catalog Release 2.0

Ian Evans (Harvard-Smithsonian Center for Astrophysics)

### *Abstract*

The second major version of the Chandra Source Catalog, CSC release 2.0, roughly triples the size of the previous catalog to  $\sim 375,000$  detections, corresponding to more than 315,000 unique X-ray sources. Compared to the previous version of the catalog, the limiting sensitivity for compact sources in CSC release 2.0 is significantly enhanced. This is achieved by using a two-stage approach that involves stacking (co-adding) multiple observations of the same field prior to source detection, and then using an improved source detection approach that enables detection of point source down to  $\sim 5$  net counts on-axis for exposures shorter than  $\sim 15$  ks. Improvements to the catalog Bayesian aperture photometry code provide robust photometric probability density functions (PDFs) in crowded fields even for low-count detections. All post-aperture photometry properties (e.g., hardness ratios, temporal variability) are computed directly from the PDFs. Release 2.0 also adds a Bayesian Blocks analysis of the multi-band aperture photometry PDFs to identify multiple observations of the same source that have similar photometric properties, and that therefore can be analyzed simultaneously to improve S/N. By combining Chandra's sub-arcsecond on-axis spatial resolution and low instrumental background with consistent data processing, CSC release 2.0 delivers a wide variety of uniformly calibrated properties and science ready data products for detected sources across a broad range of fluxes. This uniformity supports statistical investigations of large samples of objects using the catalog, as well as individual source studies, making CSC release 2.0 an excellent source of reference data for developing simulations in support of future high energy astrophysics missions. This work has been supported by NASA under contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the Chandra X-ray Center.

## Towards a New Era in Galactic Gamma-Ray Astronomy

Henrike Fleischhack (Michigan Technological University)

### *Abstract*

The field of very-high-energy (VHE,  $E > 100$  GeV) gamma-ray astronomy is entering an era of precision measurements. Over the last decade, innovations in instrumentation have led to a drastically improved understanding of the most energetic objects in the Universe. New results by the High Altitude Water Cherenkov Observatory (HAWC) have shown the unique insights that large-field-of-view survey instruments like HAWC can provide to the field. The recent 2HWC catalog and other publications have revealed gamma-ray emission from several large extended sources such as TeV halos surrounding pulsar-wind nebulae. Synergies between ground- and space-based survey and pointing instruments have already led to the identification of several new sources and source candidates. In this presentation, we will explore the potential of future improvements to the field: Upgrades to current instruments as well as the planned Southern Gamma Survey Observatory (SGSO) which will further improve our view of the VHE sky. These innovations will also open the door for further synergies between different instrument types. In particular, we will discuss future opportunities for galactic astrophysics: Further study of TeV halos, the search for large extended structures such as possible counterparts of the Fermi bubbles at TeV energies, gamma-ray emission from molecular clouds, and the search for Galactic transients.

# The Square Kilometre Array: An International Radio Telescope for the 21st Century

Bryan Gaensler (University of Toronto)

## *Abstract*

The Square Kilometre Array (SKA) will be the largest and most powerful radio telescope ever constructed, and will answer fundamental questions in astronomy, cosmology, and fundamental physics. The scale of the SKA represents a huge leap forward in manufacturing, data processing and supercomputing, and is the result of a global effort involving hundreds of scientists and engineers from more than 100 organizations in 20 countries. I will present the planned capabilities and construction time line for the SKA, will review the ways in which the SKA will advance high-energy astrophysics, and will highlight recent results from the SKA precursor facilities now taking data in Australia and South Africa.

Prospects for a high accuracy measurement of the local black hole occupation fraction.

Elena Gallo (University of Michigan)

*Abstract*

I will discuss the feasibility of a few per cent level measurement of the local black hole occupation fraction through imaging observations of local volume galaxies with next gen high-resolution X-ray missions, such as AXIS and Lynx. I will provide quantitative estimates of how the occupation fraction accuracy and observational strategy vary as a function of a series of parameters, including the instrument angular resolution, exposure time, distance, and host galaxy stellar mass. This measurement can be efficiently carried out by combining dedicated, snapshot observations of low mass galaxies with a commensal survey approach and will establish a benchmark for any model which aims to reproduce the assembly of galaxies and their nuclear black holes. Concurrently, it will yield an independent constraint to black hole seed formation models, complementing orthogonal efforts which will be carried out at high red-shifts.

# Unveiling the Physics of Accreting Black Holes in the Next Decade

Javier Garcia (Caltech)

## *Abstract*

The physics of accretion onto compact objects such as black holes in binary systems (black-hole binaries; BHBs) and active galactic nuclei (AGN) has been one of the main subjects of study in high energy astrophysics for several decades. Despite the many advances on both observational and theoretical fronts, there are several important questions that remain unanswered. In particular, the physical origin of the hard X-ray continuum in accreting black holes is still unknown, as it can be explained by either a Comptonizing gas of hot electrons (the “corona”) or the base of a relativistic jet. The geometry and properties of this central source of X-rays are still a mystery. Meanwhile, the irradiation of the accretion disk by hard photons produces distinct spectral features (particularly from Fe K-shell transitions), which are used to estimate the spin of the black hole (reflection spectroscopy). In BHBs, one controversial subject concerns the truncation of the accretion disk, with predictions that differ by orders of magnitude when reflection spectroscopy and/or timing techniques are implemented. Another unexpected result is the questionably large abundance of iron required by most reflection models to explain the observable data from both BHB and AGN alike. The strong correlations among these and other important parameters pose serious limitations on the understanding of accreting sources. Here we discuss the challenges that theoretical models need to face, as well as the requirements that future X-ray missions will need to meet in order to mitigate many of the current controversies in the field. Specifically, we produce simulations implementing different flavors of relativistic reflection models to evaluate the reach of the next generation of instruments in the characterization of the observable spectra. We make recommendations regarding instrumental capabilities (i.e., energy coverage, effective area, spectral and timing resolution) that will be needed to constrain parameters of interest including black hole spin, disk inner radius, Fe abundance, the coronal temperature and geometry.



## Large-scale quasar jets: where do we stand and what do we need to go forward

Markos Georganopoulos (UMBC)

### *Abstract*

The properties of quasar large-scale jets are still not well understood. As these jets are thought to be an important energy source in heating the host galaxy cluster, it is important to pin down their physics. A set of questions has recently emerged: Are large-scale quasar jets highly relativistic with a kinetic power comparable to or exceeding the Eddington Luminosity, or are they mildly relativistic – yet still accelerating electrons in situ at least up to 100 TeV? Are they TeV-silent or do they produce more TeV photons than the TeV BL Lacertae objects themselves? We implicitly assume that practically all of the power dissipation takes place at the base of the jet, but can it be that comparable dissipation takes place in the kpc-scale jet? I will discuss these open questions, as well as what can be done with the current instrumentation, and what we hope we can do with extended capabilities across the electromagnetic spectrum.

## Wide Field Observations with the Micro-X Telescope

David Goldfinger (Massachusetts Institute of Technology)

### *Abstract*

Micro-X is a sounding rocket borne telescope that uses Transition Edge Sensor microcalorimeters to perform high resolution spectroscopy. In its first flight configuration, it will use an imaging mirror to observe extended sources, leveraging the combination of its high energy resolution and its imaging capabilities. As the next generation of X-ray microcalorimeter based satellites will be coming online in the 2020s to fill this niche, Micro-X will adapt to a new configuration to maximize its field of view by removing the imaging mirror in order to operate in searches for diffuse emission lines, such as the expected signal from a decaying dark matter candidate in the X-ray band. We describe the modifications that will take place to reach this new configuration and our projections of the results achievable with this new instrument.

X-ray properties of extremely red quasars observed during the epoch of peak galaxy formation

Andy Goulding (Princeton University)

*Abstract*

Rapidly accreting obscured black holes have long since been predicted to drive powerful winds that clear out gas in the host galaxy and shut off star formation, during so-called quasar feedback events. Identifying the obscured quasar population, particularly at early epochs where they may have made the strongest impact on galaxy formation, has always been a critical goal of X-ray surveys. However, X-ray studies of high-redshift obscured and reddened quasars have yet to reach a consensus on black hole growth and AGN feedback in these systems. I will present our recent results using Chandra and XMM on the X-ray properties of a sample of  $z \sim 3$  extremely red quasars that present powerful outflows. I will further discuss how our currently limited quasar sample can form the basis for observations with the next generation of X-ray telescopes, allowing us to robustly determine the accretion properties of the full population of heavily obscured quasars that are under-going the most powerful feedback events in the early Universe.

## The NSF View

Richard Green (National Science Foundation)

### *Abstract*

The National Science Foundation is investing in several cross-cutting research initiatives called Big Ideas. One of those is Windows on the Universe, a broad approach to multi-messenger astrophysics. The Division of Astronomical Sciences (AST) is actively participating in the development of the new program, recognizing the synergy of ground-based observing facilities with orbiting high-energy observatories. This talk examines the portfolio of facilities and grants investments in astronomy and physics, both current and planned, with particular application to the future of time-domain and multi-messenger science. The major ground-based projects likely to submit for consideration of the upcoming Decadal survey will be discussed.

# MonSTER: The Monitoring Spectroscopic Telescope for Energetic Radiation

Brian Grefenstette (Caltech)

## *Abstract*

The Monitoring Spectroscopic Telescope for Energetic Radiation (MonSTER) is a 6U CubeSat science mission concept aimed at taking advantage of the technological progress of SmallSats in the 2020s. The goal of the mission is to provide time-resolved, broadband X-ray spectroscopy (3-30 keV) of stellar mass X-ray Binary systems (XRBs) as they undergo outburst. Since the RXTE ceased operation, there has not been an instrument with sufficient spectral resolution and sensitivity to provide uninterrupted coverage of these systems. As a result, the study of XRB outbursts has been limited to short (tens of ks) snapshots with larger observatories such as NuSTAR, the Neil Gehrels Swift Observatory, and XMM-Newton occurring only once every few weeks. MonSTER will be dedicated to following individual XRBs for weeks or months at a time, with instrumentation optimized for sensitivity and spectral resolution across the crucial iron line complex. In combination with reflection spectroscopy and timing techniques, MonSTER will monitor the evolution of XRBs as they transition through their outburst, providing a complete picture of the dynamics of key parameters such as the composition, ionization state, and inner radius of the accretion disk; the temperature, optical depth, and temperature of the corona; and in the case of black holes, their spin. Here we present the baseline satellite design, its conception operations, and an overview of the expected scientific return.

# The Great, Thus Far Overlooked, Value in Optical-IR Colors Measured Simultaneously with Prompt Gamma-Ray Burst Emission, for Future Space Missions

Bruce Grossan (University of California Space Sciences Laboratory)

## *Abstract*

A number of fast telescopes such as ROTSE-III and others have made single-band optical measurements of long gamma-ray bursts (GRBs) during prompt  $\gamma$ -ray emission. The results are not so illuminating: the ratio of optical/gamma varies by several orders of magnitude, and no emission mechanism has been unambiguously identified. Rough correlation of optical and  $\gamma$  light curves in some cases suggests related emission; there is no correlation in others. However, no simultaneous measurement of multiple optical-IR (OIR) bands has ever been made; the broad-band OIR spectral shape remains unknown. We do know there is valuable information in this shape: spectral indices identify the synchrotron emission case, and the self-absorption frequency gives the radius of emission, the electron thermal Lorentz Factor, and B-field strength (Shen & Zhang 2009). Other emission processes can also be identified by shape. Extinction can be identified by red colors, giving information about dust around a single star at high- $z$ ; the evaporation of dust during the GRB in  $\sim 1$  min (e.g., Perna et al. 2003), could be dynamically measured. No planned space mission has prompt multi-channel OIR capability. This can be achieved with only  $\sim 30$  cm aperture, by covering the 1-2 Sr FOV of  $\gamma$  instruments in  $< \sim 10$  s, e.g., by steering a telescope beam with a moving mirror (Grossan et al., 2014), or having the spacecraft point like Swift, but more quickly. Separate beams can be fed to multiple cameras simultaneously via dichroics. As GRBs are usually extinguished (Perley et al. 2009), IR coverage is critical; large, slow telescopes are necessary for sensitive ground-based IR, but space low background allows small, fast telescopes, so a space platform is required. Such a space instrument would make progress on the GRB emission mechanism, add knowledge of the physical conditions in the jet, and study dust at high- $z$ . On-board processing would give rapid high-quality positions that would allow spectroscopy about a minute after trigger, when the target is several mag brighter than with current delays. This, in turn, could provide absorption line mapping of the high- $z$  universe with many bright GRBs, instead of the faint galaxies or rare quasars otherwise.

# GAMERA: a $\gamma$ -ray telescope for the gravitational wave astrophysics era

J. Grove (Naval Research Laboratory)

## *Abstract*

We describe GAMERA, a SmallSat concept for a single, large, broad-band (20 keV — 2 MeV), wide field-of-view ( $>2\pi$  sr) instrument that would serve as the prime  $\gamma$ -ray telescope for gravitational wave (GW) astrophysics in the Advanced/LIGO-Virgo era. GAMERA could be built today using components currently at TRL 6 or higher, thus can be quickly developed for an existing SmallSat-class spacecraft bus, assembled, tested, and launched by the time Advanced/LIGO-Virgo reach their design sensitivities in the  $\sim 2023+$  timeframe. The instrument consists of an array of scintillator detectors with effective area 5 times greater than Fermi GBM and more than half that of Compton BATSE. It will detect short GRBs (SGRBs) like the low-luminosity GRB170817A, coincident with the binary neutron star merger event GW170817, at 3x greater distances (120 Mpc). Moreover, with its excellent time resolution and large area, it will perform detailed spectral analyses of such bursts to characterize the prompt  $\gamma$ -ray emission component in detail. To enable joint GRB and sub-threshold GW signal searches seeded on the  $\gamma$ -ray detection, GAMERA will provide typical degree-scale localizations. This could potentially uncover GW emission signals beyond the nominal horizon distances achievable by the ground-based interferometers alone. GAMERA will provide the most detailed GRB physics measurements achievable within the low-cost SmallSat envelope ( $< \$35M$ ). This includes detections, localizations, and spectral characterizations that will be markedly improved over currently deployed  $\gamma$ -ray monitors. In addition to forefront GRB physics, GAMERA will provide continuous monitoring of other types of  $\gamma$ -ray transients, addressing the physics of accreting pulsars, magnetars, and Galactic binary systems. Acknowledgment: Work at NRL was supported by the Chief of Naval Research. We thank Dr. William Purcell of Ball Aerospace for valuable discussions and input.

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

Sylvain Guiriec (The George Washington University)

## *Abstract*

The Band function traditionally used for Gamma Ray Bursts (GRB) often fails to fit their prompt emission spectra. Our new model composed of three separate components provides an excellent description of the time-resolved prompt emission: a thermal-like and two non-thermal components. For the first time, analysis of GRBs with correlated optical and gamma-ray prompt emission show that our new model describes very accurately the whole broadband spectrum from the optical regime to higher energy gamma rays. In addition, this new model enables a new luminosity/hardness relation intrinsic to one of the non-thermal components showing that GRBs may be standard candles. If statistically confirmed, this relation will be used to (i) constrain the mechanisms powering GRB jets, (ii) estimate GRB distances, (iii) probe the early Universe, and (iv) constrain the cosmological parameters. I will present this new unified model using analysis of GRBs detected with various observatories and instruments such as Fermi, CGRO/BATSE and the combination of the three instruments on board Swift and Suzaku/WAM. I will discuss here the striking similarities of GRB spectral shapes, whose components inform on the nature of the prompt emission, as well as the possible universality of the proposed luminosity/hardness relation in the context of our new model.



## Warm-hot Circumgalactic Medium of Galaxies

Anjali Gupta (Columbus State Community College)

### *Abstract*

Mapping the hot circumgalactic medium (CGM) and the intergalactic medium (IGM) is one of the two main drivers of the Lynx and next new X-ray mission, Athena. While we need Lynx/Athena to map the hot CGM and IGM, X-ray observatories like Chandra/XMM-Newton/Suzaku are well-equipped to probe the tip of the iceberg of the CGM and IGM parameter space. Indeed, over the past fifteen years we have worked hard to detect the hot CGM and IGM with mixed results. I will present Chandra observations probing our Milky Way halo in absorption. Together with XMM and Suzaku data on 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. Similar to the Milky Way, other spiral galaxies should also have massive, extended reservoirs of ionized hot gas in the CGM. I will also present Suzaku observations characterizing the warm-hot CGM in a nearby late type galaxy NGC3221. 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.

## Discovery and Opportunity in the X-ray Time Domain

Daryl Haggard (McGill University/McGill Space Institute)

### *Abstract*

Ambitious X-ray observatories have enabled a rapid expansion in our knowledge of the X-ray time domain. With state-of-the-art facilities like Chandra, XMM Newton, and Swift performing surveys over a decade and counting, variability catalogs are increasingly rich. Meanwhile, high time resolution from the likes of NuSTAR and NICER (and RXTE before them) continue to uncover new physics in individual systems. These efforts have led to the discovery of high-energy EM counterparts to the first binary neutron star merger detected via gravitational waves, a likely pulsar-ULX connection, possible magnetar oscillations, X-ray flares from the closest supermassive black hole, Sgr A\*, and enabled reverberation mapping of AGN, to name only a few. I will review recent highlights from the X-ray time domain and briefly describe what we hope to achieve with upcoming and proposed X-ray missions.

## The X-ray chirp of supermassive black hole binaries in the LISA band

Zoltan Haiman (Columbia Univ.)

### *Abstract*

I will review our understanding of the final stages of coalescence of supermassive black hole binaries (SMBHBs) in galactic nuclei, based on recent numerical simulations and analytic arguments. The gravitational waves (GWs) from SMBHBs with masses between  $10^4 - 10^7 M_{\text{sun}}$  can be detected with the Laser Interferometer Space Antenna (LISA), once their orbital frequency exceeds  $10^{-4} - 10^{-5}$  Hz. The binary separation at this stage is of order  $100 R_g$  (gravitational radius), and the orbital speed is  $v/c = O(0.1)$ . I will argue that at this stage, the SMBHBs will be producing bright electromagnetic (EM) radiation, with inevitable periodic brightness modulations that track the GW chirp. This emission is produced by streams of gas reaching within  $O(10) R_g$  of the individual BHs, heated by strong shocks. The emission is most likely to arise in the X-ray bands, and will exhibit prominent periodicity at the binary's evolving orbital frequency. This "X-ray chirp", tracking the GW chirp signal, arises because of hydrodynamical modulations of the accretion rate, as well as from relativistic Doppler modulation and lensing effects. Advanced localization of the source by LISA weeks to months prior to merger will enable a measurement of this X-ray chirp by wide-field X-ray instruments, allowing secure identification of the GW source, and new tests of accretion physics and the nature of gravity.

# Study of Particle Acceleration in eta Carinae with the MeV Electron-Tracking Compton Camera

Kenji Hamaguchi (NASA's GSFC)

## *Abstract*

Massive stellar binary systems are suspected to drive particle acceleration via shocks of their wind-wind collision (WWC). The supermassive star, eta Carinae, with the strongest WWC activity in our neighborhood, shows emission signatures from this process in the extremely high X-ray and GeV/TeV gamma-ray energy bands. Since the WWC shock occurs steadily, persistently, and predictably, massive binary systems are potentially important systems for studying particle acceleration by the Fermi process in an astrophysical setting. However, the spectrum has a huge gap between these bands, where emission from the inverse-Compton and pion-decay processes can be clearly distinguished. This is because no sensing technology has been established to detect MeV gamma-ray photons with a required sensitivity. The Electron-Tracking Compton Camera (ETCC), SMILE, developed by Kyoto University should dramatically improve MeV gamma-ray sensitivities by tracking both the scattered gamma-ray photon and recoiled electron of each incoming MeV gamma-ray photon. A prototype of this camera has successfully detected MeV gamma-ray sources on-ground in various conditions and the latest development, SMILE-2, plans a short flight for an astronomical observation in 2018 April, which is expected to detect multiple MeV sources. Our goal is to fly a developed version of this ETCC in a spacecraft. In this poster, we discuss particle acceleration physics revealed with future ETCC satellite observations of eta Carinae and the other colliding wind binary systems.

## A Vision for the Future of Multimessenger Astronomy with Neutrinos: the IceCube Gen2 Observatory

Kael Hanson (University of Wisconsin - Madison)

### *Abstract*

Neutrinos are ideal astronomical messengers that bring information across vast cosmological distances. Neutral, they are not deflected by galactic and intergalactic magnetic fields. Weakly interacting, they are not diffused by interstellar matter nor photon fields nor even by thick shrouds of material surrounding the exotic, high energy astrophysical particle accelerators where they are produced. They arrive at the observer in pristine form. Catching these ghostly particles, however, is an enterprise: cubic kilometers of target material must be instrumented to yield a handful of events per year. The IceCube detector has turned a billion tons of ice at the South Pole into a neutrino telescope. In 2013, IceCube reported the discovery of a flux of neutrinos of astrophysical origin consistent with isotropic sources, establishing the existence of hadron accelerators and the detectability of the neutrino flux from them. In 2017, the new real-time alerting system of IceCube released an ATEL following the appearance of a high-energy neutrino event in the detector. Follow up observations confirm emission of high energy gamma rays from the blazar TXS0506+056. This latter event marks the beginning of neutrino multimessenger astronomy. The IceCube collaboration plans to deploy additional instrumentation to expand the science achievable by this unique observatory. In the near term, the addition of 7 infill strings with advanced photodetectors will extend IceCube's sensitivity to GeV atmospheric neutrinos. The sheer tonnage of this upgraded detector will allow the detection of an unprecedented number of tau neutrinos created in transit through the Earth by the phenomenon of neutrino oscillations and will enable measurements of the tau mixing parameters to greater precision than any planned astrophysical or accelerator based detector. Further in the future will be the IceCube Gen2 Observatory, a revolutionary new observatory which will combine optical and radio detection techniques to detect neutrinos spanning ten decades in energy and presenting an order of magnitude more neutrino effective area at high energies.

## High-mass gamma-ray binaries in X-rays and at higher energies.

Jeremy Hare (The George Washington University)

### *Abstract*

High-mass gamma-ray binaries (HMGBs) are rare systems (only 6 are known with a couple more candidates) composed of a compact object with a high mass stellar companion. The type of compact object is not known for most HMGBs. They can either host a neutron star (PSR B1259-63 and TeV J2032+4130) or stellar mass black hole (Cyg X-1). We review and discuss recent results from Chandra, NuSTAR, Swift, and XMM-Newton observations of several such systems, including LS 2883/PSR B1259-63, LS 5039, and HESS J0632+057. As demonstrated by the observations of the dynamic outflow from PSR B1259-63, the high-resolution X-ray observations provide a unique insight into the complex physics of pulsar winds, massive star winds, and their interaction. We will also discuss how new (and archival) data from INTEGRAL, Fermi-LAT, and the HESS Galactic Plane Survey can increase the population of known HMGBs.

## TAP: The Transient Astrophysics Probe

Dieter Hartmann (Clemson Univ.)

### *Abstract*

The Transient Astrophysics Probe (TAP) is a wide-field multi-wavelength transient mission proposed for flight starting in the late 2020s. TAP's main science goals, called out as Frontier Discovery areas in the 2010 Decadal Survey, are time-domain astrophysics and electromagnetic counterparts of gravitational wave (GW) detections. The mission instruments include unique "Lobster-eye" imaging soft X-ray optics for a  $\sim 1600$  deg<sup>2</sup> FoV; a high sensitivity, 1 deg<sup>2</sup> FoV soft X-ray telescope based on single crystal silicon optics; a passively cooled, 1 deg<sup>2</sup> FoV Infrared telescope with bandpass of 0.6-3 micron; and a set of  $\sim 8$  NaI gamma-ray detectors. TAP's most exciting capability will be the observation of X-ray and IR counterparts of GWs involving stellar mass black holes and neutron stars detected by LIGO/Virgo/KAGRA/LIGO-India, and possibly X-ray counterparts of GWs from supermassive black holes, detected by LISA and Pulsar Timing Arrays. TAP will also discover hundreds of X-ray transients related to compact objects, including tidal disruption events, supernova shock breakouts, and Gamma-Ray Bursts reaching into the epoch of reionization.

## Dust Echoes in the 2020s and 2030s

Sebastian Heinz (Univ. Of Wisconsin, Madison)

### *Abstract*

X-ray dust tomography using dust echoes from transient X-ray sources provides a powerful tool to study the distribution and structure of interstellar dust and map out the structure of the Milky Way. As a distance indicator, dust echoes can provide extremely accurate relative distances of dust clouds and, coupled with other absolute distance calibrators, can be used to measure Galactic structure, determine distances to X-ray transients, and measure cloud sizes. We can constrain grain size distributions and composition, as well as gas-to-dust ratios. After reviewing the state of the art in this field, I will discuss the requirements for the next generation of X-ray observatories to maximize the science return of X-ray Dust Tomography.



# Disentangling the complex geometry of the clumpy absorber in high-mass X-ray binaries with time-resolved high-resolution spectroscopy

Natalie Hell (LLNL)

## *Abstract*

High-mass X-ray binaries (HMXB) are ideal objects to study the interaction between a compact object and the clumpy wind of a O/B-type star. The X-ray flux of HMXBs is highly variable with orbital phase. Superimposed on this behavior, many HMXBs exhibit irregular individual absorption events, bright flares, and off states. Changes of the average column density with orbital phase have been attributed to the presence of large-scale structures such as an accretion wake, a photoionization wake, and a possible tidal stream. Short-term variability on ks timescales and below is attributed to, e.g., absorption in and accretion of clumps from the stellar wind, or unstable hydrodynamic flows. However, the detailed structure of this complex geometry has yet to be disentangled. High-resolution spectroscopy enables us to use plasma diagnostics to distinguish plasmas of different densities, temperatures, and velocities, corresponding to different components of these structures. Compared to the time-averaged spectrum, the time-resolved spectra taken at different absorption levels show more complex behavior: new spectral features appear and lines change their relative strengths, with some transiting from emission to absorption. Careful analysis of line ratios and Doppler shifts on the ks timescales of the fluctuating absorption would allow a full 2d reconstruction of the wind structure. We can thus disentangle the complex geometry of the binary and constrain accretion and wind models. Future missions with large effective area allow us to take full advantage of the diagnostic capabilities through high-resolution spectroscopy on time scales much shorter than those in Chandra's gratings without the limitations of Chandra's low signal-to-noise ratio. Using Chandra HETG observations of two of the highest-flux wind-accreting HMXBs, the eclipsing neutron star HMXB Vela X-1 and the black hole HMXB Cyg X-1, we show the possibilities and limitations of today's instruments for these kinds of studies. We then show how future missions will revolutionize our understanding of the complex accretion in HMXBs and wind clumping in their donor stars. Work by LLNL was performed under the auspices of the U.S. DOE under Contract No. DE-AC52-07NA27344.

## NASA Astrophysics Strategy through the 2020 Decadal Survey

Paul Hertz (NASA Headquarters)

### *Abstract*

NASA's strategic objective in astrophysics is to "Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars." This objective is aligned with the science priorities of the 2010 Decadal Survey, New Worlds, New Horizons in Astronomy and Astrophysics. This presentation will summarize NASA's progress and plans for implementing the 2010 Decadal Survey, as well as its preparations for the 2020 Decadal Survey.

## The AXIS View of Galaxies Near and Far

Edmund Hodges-Kluck (University of Michigan)

### *Abstract*

The growth and evolution of galaxies cannot be understood without X-rays. X-rays are needed to view the massive, hot coronae around Milky Way-sized galaxies that provide the long-term fuel for star formation, as well as the hot outflows that remove star-forming gas from the disk and carry most of the energy and metals associated with stellar feedback. These processes were more intense at  $z > 1$  and can only be understood by measuring the properties of the hot gas and its relation to cooler material. The sub-arcsecond resolution and high sensitivity of AXIS are essential to detect hot gas in the presence of bright point sources, measure accurate temperatures and abundances, and determine its spatial separation from cooler gas. High resolution is also required to characterize the ISM in early-type galaxies, detect signatures of low-level AGN feedback, and measure the properties of X-ray binaries, which were likely major feedback agents at  $z > 1$ . I will demonstrate how AXIS will make groundbreaking measurements in both nearby and distant galaxies, and compare these measurements to existing and future observations at longer wavelengths.

## Measuring Gas Velocities in Galactic Hot Halos

Edmund Hodges-Kluck (University of Michigan)

### *Abstract*

Galaxies at least as massive as the Milky Way are surrounded by massive halos of hot ( $\log T = 6.0-6.7$  K) gas, which mediate the flow of gas into and out of the galaxy. The properties of these halos (including mass, temperature, metallicity, and bulk kinematics) influence the star formation rate and constrain models of galaxy growth and AGN or stellar feedback. Measuring these quantities is essential to understanding how galaxies form and grow, and requires sensitive X-ray observatories. We recently made the first measurement of hot halo kinematics using XMM-Newton and Chandra grating data, and showed that the hot gas around the Milky Way rotates in the same direction as the disk and with a comparable speed. This measurement is near the limit of current X-ray mission capabilities, and I will discuss the prospects for more detailed measurements in our Galaxy as well as basic velocity measurements in other galaxies with absorption lines, using future grating spectrometers such as Arcus or Lynx, and emission lines, using high resolution microcalorimeters.

## Mid-band Atomic Gravitational-wave Interferometric Sensor (MAGIS): satellite mission concept and astrophysics science reach.

Jason Hogan (Stanford University)

### *Abstract*

We consider the scientific potential and technical feasibility of gravitational wave (GW) observations in the  $\sim 30$  mHz to 10 Hz frequency range with the Mid-band Atomic Gravitational-wave Interferometric Sensor (MAGIS) [1]. MAGIS is a probe-class space mission concept, using an atom-based gravitational wave detector, that will provide all-sky strain sensitivities of  $\sim 10^{-21}/\sqrt{\text{Hz}}$  and better in the GW frequency mid-band between the LISA/L3 detector (planned 2034 launch) and ground-based Advanced LIGO/Virgo interferometers. Conceptual advances in the past several years indicate that a two-satellite constellation with science payloads consisting of atomic sensors based on laser cooled atomic Sr can achieve scientifically interesting gravitational wave strain sensitivities. Primary gravitational wave astrophysics science in the mid-band include GW observations of the binary black hole population discovered by Advanced LIGO/Virgo when such binaries are at lower frequencies, prior to their merger stage. For such systems, MAGIS will observe the binaries in their inspiral phase and will provide pre-merger, degree-scale localizations that would enable electromagnetic observations of possible precursor emission 1-week to 1-month prior to their mergers. Joint GW observations with MAGIS and Advanced LIGO/Virgo covering all stages of binary coalescence will further reduce uncertainties in the GW localizations and distances. These possibilities for MAGIS extend to neutron star binaries, and mid-band prospects for such systems will also be considered. The discovery potential of the proposed instrument also includes searches for novel cosmological sources of stochastic gravitational radiation as well as searches for ultralight scalar dark matter. The MAGIS team is a collaboration between institutes in the U.S. including Stanford, UC Berkeley, Harvard, NASA/GSFC, NASA/JPL, NIST, NRL, and AOSense, and international partners at Birmingham, Bordeaux, CNRS, Dusseldorf, Ecole Normale Supérieure, Florence, Hannover, and Ulm University. References: [1] Peter W. Graham, Jason M. Hogan, Mark A. Kasevich, Surjeet Rajendran, Roger W. Romani, “Mid-band gravitational wave detection with precision atomic sensors,” arXiv:1711.02225, (2017).

## The formation and evolution of neutron stars and stellar-origin black holes

Ann Hornschemeier (NASA GSFC)

### *Abstract*

It is critically important that we better understand neutron star (NS) and black hole (BH) populations: in addition to understanding the progenitor paths for gravitational wave sources through binary evolution, the high-energy (X-ray) emission from this population likely plays a dominant role in the early heating of the primordial IGM at  $10 < z < 20$ . The compact object mass distribution also provides one of the few tracers of how supernovae work. These stellar-origin compact objects grow through two main channels: accretion and mergers. Accretion growth---the dominant mode which is detectable via X-ray emission---is greatly affected by stellar processes such as the strength of stellar winds and binary properties such as the extent of the common envelope phase. Merger growth, detectable via gravitational waves, gives us an important snapshot view of the masses of stellar origin compact objects, and is also strongly connected to stellar evolution and star formation processes in the Universe. In this talk, I will review progress with Chandra, XMM-Newton and NuSTAR on both resolved studies of NS/BH binaries in nearby galaxies and distant surveys on the evolution of X-ray emission from NS/BHs over cosmic time. I will place this into context with our understanding of compact object populations in our own Milky Way obtained with missions such as RXTE, INTEGRAL, and Swift, and will relate these studies to the recent LIGO detections, with specific discussion of constraints of progenitor evolutionary paths. I will set the stage for next-generation imaging X-ray facilities as well as upcoming X-ray survey experiments, placing these in the context of what we will learn about star formation, stellar evolution, and galaxies with future facilities across the electromagnetic and gravitational wave spectra.

## Chandra detection of Intracluster X-ray sources in Virgo and Fornax

Meicun Hou (Nanjing University)

### *Abstract*

We present a Chandra survey of X-ray point sources in the nearest and dynamically young galaxy clusters, Virgo and Fornax. Using archival Chandra observations that sample the vicinity of 80 early-type member galaxies of Virgo, we statistically identify  $\sim 120$  intracluster X-ray sources, at a  $3.5\sigma$  significance, which are not associated with the main stellar content of the individual galaxies, nor with the cosmic X-ray background. On the other hand, no significant excess sources are found at the outskirts of a control sample of field galaxies. In Fornax, we also reveal X-ray point sources in clear excess ( $4\sigma$  significance) of the main stellar content of the cD galaxy, NGC 1399. Assisted with ground-based and HST optical imaging, we discuss the origins of these intracluster X-ray sources, in terms of supernova-kicked LMXBs, globular clusters, LMXBs associated with the diffuse intracluster light, stripped nucleated dwarf galaxies and free-floating massive black holes.

# MoonBEAM: A Beyond Earth-orbit Gamma-ray Burst Detector for Gravitational-Wave Astronomy

Chiumun Hui (NASA/MSFC)

## *Abstract*

Moon Burst Energetics All-sky Monitor (MoonBEAM) is a CubeSat concept of deploying gamma-ray detectors in cislunar space to improve localization precision for gamma-ray bursts by utilizing the light travel time difference between different orbits. Currently, the Fermi Gamma-ray Burst Monitor (GBM) has localization precision no better than a few degrees radius depending on the brightness of the burst. Facilities in other wavelengths typically are required to perform tiling observations across the localization area as it is too large for their fields of view. Joint detections from multiple observatories can greatly improve the event localization. The most recent example is the gravitational wave event GW170817 and the gamma-ray burst GRB 170817A that confirmed binary neutron star merger as progenitor of short GRB and triggered electromagnetic follow-up observations by 70 observatories that resulted in a kilonova detection from radio to X-ray. The Interplanetary Gamma-Ray Burst Timing Network has demonstrated that with an additional gamma-ray detection from a distant spacecraft, the localization uncertainties can be improved on average by a factor of 180 over localizations done by the Fermi-GBM alone. The delay in data downlinks for instruments outside the Tracking and Data Relay Satellite (TDRS) network, however, prevents rapid follow-up observations. We present here a gamma-ray SmallSat concept in Earth-Moon L3 halo orbit that is capable of rapid response and provide a timing baseline for localization improvement when partnered with an Earth-orbit instrument. Such an instrument would probe the extreme processes in cosmic collision of compact objects and facilitate multi-messenger time-domain astronomy to explore the end of stellar life cycles and black hole formations.



## The Large Synoptic Survey Telescope (LSST)

Steven Kahn (Stanford University)

### *Abstract*

LSST is a large-aperture, wide-field ground-based telescope designed to provide a time-domain imaging survey of the entire southern sky in six optical colors. Over a decade of observations, LSST will obtain  $\sim 1,000$  visits to every part of the southern hemisphere, reaching  $\sim 24$ th mag in a single visit, and  $> 27$ th mag in the co-added images. The resulting database will enable a wide variety of scientific investigations ranging from studies of small moving bodies in the solar system to the structure and evolution of the universe as a whole. The design of LSST incorporates an 8.4 m combined primary/tertiary mirror with a 3.5 m secondary, that feeds a 3.2 gigapixel camera mounted up near the secondary. The fabrication of all major components is well underway, leading to "first light" in 2020 and the onset of the ten-year survey in October, 2022. I will review the technical progress of the project and highlight some of the major scientific objectives. This construction of LSST is supported in part by the National Science Foundation through Cooperative Agreement 1258333 managed by the Association of Universities for Research in Astronomy (AURA), and the Department of Energy under Contract No. DE-AC02-76SF00515 with the SLAC National Accelerator Laboratory. Additional LSST funding comes from private donations, grants to universities, and in-kind support from the LSST Corporation Institutional Members.

## 3D Mapping of the Neutral X-ray Absorption in the Local Interstellar Medium

Timothy Kallman (NASA's GSFC)

### *Abstract*

Every modern X-ray observation contains information about the intervening interstellar medium (ISM) in the form of neutral absorption. With an ensemble of such data along with distances the three dimensional distribution of ISM density can be reconstructed. We illustrate the application of this procedure using hydrogen column densities obtained from the Exploring the X-ray Transient and variable Sky project (EXTraS) which provides  $N_{\text{H}}$  values from X-ray spectral fits of observations within the XMM-Newton Data Release. Parallax and distance measurements were obtained from a cross-correlation between the EXTraS catalog and the first GAIA Data Release. The ISM density is reconstructed using a method which takes advantage of Bayes theorem, Gaussian process and linear algebra to predict the most probable distribution of the density at any arbitrary point. The resulting map shows small scale density structures and can be compared with other determinations of the ISM structure. We discuss the application of this procedure to data from future X-ray missions.

## Swift Target of Opportunity Observations of X-ray Flares in BL Lacertae Objects

Bidzina Kapanadze (Ilia State University)

### *Abstract*

BL Lacertae objects (BLLs) constitute an extreme class of active galactic nuclei showing very complex, unpredictable flux variability, and many unsolved problems related to the jet collimation and particle acceleration, internal structure, matter content, emission mechanisms still persist. Time-by-time, BLLs undergo exclusively strong and fast X-ray--TeV flares. The Target of opportunity (ToO) observations with the satellite Swift make very important contribution in solving of the aforementioned problems. The unique characteristics of X-Ray Telescope (XRT) onboard Swift is very effective to study the BLL flux and spectral variability on various time-scales from minutes to years. To date, more than 130 our ToO requests have been approved and implemented by Swift Science Operations Team, revealing extreme flaring behaviour in several high-energy-peaked BLLs. While the past, mostly randomly-sampled XRT observations of the TeV-detected BLL source 1ES 1959+650 showed only moderate X-ray flares during 2005-2014, our intensive ToO campaigns have revealed several strong and prolonged X-ray flares since 2015 August. During our campaigns, (i) highest historical X-ray states have been recorded several times; (ii) very hard X-ray spectra, expected in the case of the hadronic contribution to the synchrotron SED, were observed many times; (iii) the source exhibited the spectral signatures of less efficient stochastic acceleration of X-ray emitting particles in some epochs that is unusual for TeV-detected BLLs; (iv) very fast X-ray flux changes during a few hundred seconds and brightness halving in about 4 hours, requiring extreme values of the jet physical parameters, are revealed; (v) uncorrelated X-ray--TeV variability are detected several times, challenging one-zone synchrotron self-Compton scenarios. Similar very important results are obtained also for other BLLs (Markarian 421, 1H 1515+660, Markarian 501, 1ES 0033+595, 1ES 1727+502 etc.) by means of the Swift ToO observations triggered by us and by other proposers. Therefore, we recommend that the future space missions should devote significant fraction of their operational time to the ToO campaigns.

## X-ray observations of Tidal Disruption Events in the era of Time Domain Astronomy

Erin Kara (University of Maryland)

### *Abstract*

Tidal Disruption Events, where a star gets ripped apart by the strong tidal forces of a supermassive black hole, create an impulse of accretion, thus providing a unique opportunity to probe accretion physics at its extremes, all while revealing properties of a population of dormant supermassive black holes. X-rays broke open the field of TDE astronomy, through initial discoveries with the ROSAT All-Sky Survey, and subsequent discoveries with the XMM-Newton Slew Survey and the Swift Burst Alert Telescope. In recent years, large optical time domain surveys have expanded the field, finding TDEs soon after the initial disruption. Several of these optical discovered TDEs have been followed up in detail with pointed X-ray telescopes, like Swift, Chandra and XMM-Newton. In this talk, I will present a few of the exciting X-ray results, including the discoveries of ultrafast outflows in two super-Eddington TDEs. I will highlight some of the open questions in the field, and how future X-ray missions will revolutionize TDE studies in the 2020s.

## The X-Ray Astronomy Recovery Mission

Richard Kelley (NASA's GSFC)

### *Abstract*

The X-Ray Astronomy Recovery Mission (XARM), an international collaboration led by JAXA and involving major participation from NASA and ESA, will employ an advanced x-ray observatory with capabilities to carry out a science program to address some of the important questions of present-day astrophysics. XARM is essentially a rebuild of the the Hitomi (Astro-H) spacecraft that was lost due to an operational mishap early in the mission in 2016, but only employs two of the original four instruments on Hitomi. The Resolve Soft X-ray Spectrometer is being developed jointly by a team led by NASA/GSFC and institutions in Japan under the direction of JAXA's Institute of Space and Astronautical Science. It is a high-resolution, non-dispersive x-ray spectrometer operating between 0.3-12 keV. It is the core instrument on XARM, providing a high-resolution spectroscopic capability ( $\sim 5$  eV) for the mission and covering the energy band where all of the astrophysically abundant elements have characteristic emission lines that can be used for a wide range of spectral studies of matter under extreme conditions. The other instrument, called Xtend and provided by JAXA, extends the field of view to produce an observatory with extraordinary capabilities using a state of the art x-ray charged couple device camera. Xtend is the responsibility of JAXA, but NASA will provide an X-ray Mirror Assembly for the instrument identical in design to the Resolve mirror assembly. XARM will be launched into low-Earth orbit (nominally 575 km circular,  $31^\circ$  inclination) from the Tanegashima Space Center, Japan, using a JAXA H-IIA rocket.

## Galactic positrons

Carolyn Kierans (UC Berkeley)

### *Abstract*

The 511 keV line from positron annihilation in the Galaxy was first detected in the 1970's, but the source of positrons is still unconfirmed and remains one of the pioneering topics in gamma-ray astronomy. Spectral studies of the emission by the high-resolution spectrometer INTEGRAL/SPI conclude that Galactic positrons predominantly annihilate at low energies in warm phases of the interstellar medium. Imaging results of the annihilation line show a spatial distribution with a strong concentration in the center of the Galaxy, while emission from the Galactic disk is faint and the scale height is poorly constrained. Positrons produced in beta decay of isotopes, such as  $^{26}\text{Al}$ , can account for most of the annihilation emission, but the observed spatial distribution, in particular the excess in the Galactic bulge, is difficult to explain. Additionally, one of the largest uncertainties in these studies is the unknown distance that positrons propagate before annihilation. In this presentation, we will summarize the history of measurements of the annihilation signal, including results by INTEGRAL/SPI and recent results from the Compton Spectrometer and Imager. We will discuss the future possibilities for progress with a focus on what measurements could be done by next-generation instruments to further our understanding of Galactic positrons.

# The SuperCONducTing Titanium Imager SCOTTI and High Resolution X-ray Imaging Spectroscopy in the next Decade

Fabian Kislak (Washington University in St. Louis)

## *Abstract*

Spectroscopy of X-ray and gamma-ray lines is one of the most powerful tools of high-energy astrophysics. Gamma-ray emission originating from decays of Ti-44 in supernova remnants offer the possibility to study ejecta from supernovae in great detail. Being due to a nuclear decay, they directly trace the spatial and velocity distribution of the ejecta. Valuable information can be obtained on both spatially resolvable and unresolved objects. The cyclotron absorption line in accreting neutron stars carries significant information about the structure of the accretion column close to the neutron star's surface. In particular in the case of Ti-44 lines at 68 and 78keV, the line width is smaller than the energy resolution of current semiconductor-based detectors. The SuperCONducTing Titanium Imager (SCOTTI) will use recently developed gamma-ray transition edge detectors in order to achieve an unprecedented resolution better than 50eV at 80keV. The detectors will be flown on a high-altitude balloon in the focal plane of a newly developed NiV/C multilayer X-ray mirror with a focal length of 12m. This mirror will be optimized to achieve an effective area more than twice as large as NuSTAR in the 60-80keV band. The telescope will be pointed by the Wallops Arc-Second Pointer (WASP) with sub-arcsecond precision. I will summarize the scientific prospects of high-resolution gamma-ray spectroscopy and introduce the technology behind SCOTTI. The balloon-borne instrument will be a proving ground for these new detectors. Even more exciting science will be possible with a future small or medium explorer satellite.

## What we can learn from high-resolution observations of pulsar wind nebulae

Noel Klingler (The George Washington University)

### *Abstract*

Thanks to its high sensitivity and unprecedented angular resolution, the Chandra X-ray Observatory (CXO) has revolutionized our understanding of pulsar wind nebulae (PWNe). Deep observations of bright PWNe, most famously of the Crab and Vela, have given us valuable insight into the anisotropy of pulsar outflows, the structures they form, and their dynamics (variable jets, synchrotron wisps, etc.). Almost nineteen years after its launch, the CXO still continues to make remarkable discoveries. In particular, the sample of PWNe where the CXO has resolved the tori and/or jets has grown to about 30. I will review the recent progress that has been made through high-resolution observations and their application to our understanding of pulsar magnetospheres and acceleration mechanisms. This will include PWN dynamics, the nebulae of supersonically-moving pulsars (SPWNe), SPWN-ISM magnetic field interactions and misaligned outflows, constraints on pulsar magnetosphere models, and the spectral properties of the relativistic uncooled electrons injected at the termination shock. I will also discuss the requirements for future PWN observations that will enable significant advances in our understanding of pulsars and their relativistic winds.



## High Energy Astrophysics - 5 years after the Roadmap

Chryssa Kouveliotou (GWU)

### *Abstract*

In 2013 the NASA/HQ Astrophysics Division stood up a committee tasked with the delivery of the Division Roadmap in the next three decades. The committee produced the “Enduring Quests-Daring Visions”, a report on the current state of the profession as well as on the future major Astrophysics research areas in two subsequent eras, each lasting ~10 years (<http://adsabs.harvard.edu/abs/2014arXiv1401.3741K>). Starting with the key conclusions of the Roadmap, I will compare its conclusions with the current scientific landscape in High-Energy Astrophysics, and will discuss the major progress and discoveries in the last 5 years. I will mostly concentrate on X and Gamma rays, but I will also discuss advances in multi-messenger astrophysics, such as e.g., Gravitational Waves, and neutrinos. Finally, I will elaborate on some of the remaining open questions in the field. This talk represents my views on what needs to be advanced in multi-messenger astrophysics in the future – as such it is constrained to more general and broad areas, rather than specific details.

## The Lynx High-Definition X-ray Imager (HDXI): Instrument Concept and Preliminary Design

Ralph Kraft (Harvard-Smithsonian, CfA)

### *Abstract*

We present the preliminary design concept for the Lynx High-Definition X-ray Imager (HDXI). The HDXI is one of two imaging detector systems included in the Lynx large mission concept study, and consists of 21 1024x1024 active pixel sensors arranged into a mosaic with a diameter in excess of 22 arcmin. The pixel size (16  $\mu\text{m}$  - 0.3") significantly oversamples the telescope PSF providing  $<0.5$  arcsec angular resolution. The sensors are tiled to match the Rowland circle of the optic providing sub-arcsec imaging resolution over a  $\sim 300$  arcmin<sup>2</sup> field of view, and a total field of  $\sim 400$  arcmin<sup>2</sup>. The default mode of operation will be a full frame mode in which all of the sensors are read out at 100 frames s<sup>-1</sup> to minimize pileup from bright sources and reduce optical contamination. There will also be a windowed mode in which a small region of one sensor will be read out at  $>10,000$  frames s<sup>-1</sup> providing 100  $\mu\text{s}$  timing resolution for bright sources. Three sensor technologies are under consideration for the HDXI: digital CCDs, hybrid CMOS sensors, and monolithic CMOS sensors. The MSFC Advanced Concepts Office (ACO) recently performed a design lab study to refine our baseline concept of this instrument, and this study was independently evaluated by an Instrument Design Laboratory (IDL) study at GSFC. In this talk, we present our instrument concept, results from the two instrument studies, and describe future work to support the overall Lynx mission concept.

## The X-ray Polarimetry Probe XPP

Henric Krawczynski (Washington Univ, St. Louis)

### *Abstract*

We discuss the scientific potential of the X-ray Polarimetry Probe (XPP), a next-generation X-ray polarimetry mission enabling transformative observations of stellar mass and supermassive black holes, neutron stars, magnetars, gamma-ray bursts, and supernova remnants. The XPP will combine large effective area mirror assemblies with a combination of Bragg, photoelectric and scattering polarimeters to achieve excellent polarimetric sensitivity over the broad energy range from 0.2 to 80 keV. The broad energy bandpass will make it possible to measure, and disentangle the linear polarization of the emission from multiple components contributing to the observed overall emission. Following up on the expected exciting results of the Imaging X-ray Polarimetry Explorer (IXPE) scheduled for launch in 2021, the XPP will characterize the polarization properties of large, representative samples of the most intriguing astrophysical source classes. The results will allow us to test the emission models developed to explain the X-ray timing and spectroscopic observations. Combining the XPP results with archival and concomitantly taken timing and spectroscopic X-ray observations will allow us to more reliably measure black hole spins and inclinations, to improve our constraints on the inner workings of black hole accretion, and to study the combined effect of relativistic precession and plasma turbulence on the dynamics of misaligned accretion disks. Other science topics include studies of the competing effects of QED and plasma birefringence on the photon polarization in accreting neutron stars, observational constraints on the physical properties of magnetar atmospheres and magnetospheres, and studies of cosmic particle accelerators.

## INTEGRAL search for gravitational-wave gamma-ray counterparts

Erik Kuulkers (ESA)

### *Abstract*

The INTERNATIONAL Gamma RAY Laboratory (INTEGRAL) has carried out a search for gamma-ray signals temporally and/or spatially coincident with gravitational-wave (GW) triggers distributed by the LIGO and Virgo collaboration (LVC). Its high duty cycle ( $\sim 90\%$ ) ensures an ideal coverage; the omni-directional and high sensitivity of the SPI Anti Coincidence shield yield the most stringent constraints on any impulsive gamma-ray signal between  $\sim 75$  keV and 2 MeV, for almost the full sky. The other INTEGRAL instruments, in particular the imager IBIS and its Veto system, provide complementary coverage in the regions with reduced sensitivity for the SPI-ACS. The relative large field of view of the INTEGRAL coded-mask instruments allows us to place stringent limits from 3 keV to 2 MeV for a large part of a GW localization region of a black-hole binary merger, when it is serendipitously covered by planned observations. Moreover, we performed follow-up observations for the most favorable GW triggers, in order to investigate any after-glow-like associated emission. We will report on INTEGRAL gamma-ray observations related to the detection of the neutron-star binary merger GW170817, as well as the non-detections related to the various GW signals from the binary black-hole mergers, and discuss the implications of our findings.

## Synergy between High Energy Astrophysics and JWST

Stephanie LaMassa (Space Telescope Science Institute)

### *Abstract*

The James Webb Space Telescope (JWST) is poised to revolutionize our understanding of fundamental astrophysical processes, from the early Universe to our own solar system. JWST supports a number of observing modes in the near-infrared and mid-infrared, offering imaging, slit spectroscopy, slitless spectroscopy, integral field unit spectroscopy, multi-object spectroscopy, and high contrast imaging. In this talk, I will highlight how JWST's unique capabilities will complement scientific advancements in high energy astrophysics.

# Halo Model Calculation of the Angular Cross Correlation Between the the Thermal Sunyaev-Zel'dovich Effect and Diffuse X-ray Emission In Galaxy Group and Cluster Halos

Vincent Lakey (Florida State)

## *Abstract*

Diffuse X-ray emission and the thermal Sunyaev-Zel'dovich (tSZ) effect are produced by the same hot gas within galaxy group and cluster halos. These two effects have different dependencies on electron density, so we can gain a better understanding of the gas by combining the two together. One straightforward way to do this is to look at the angular cross power spectrum, which we study with a semi-analytic halo model. In our model, we distribute halos via the Tinker halo mass function, use fitting formula from hydrodynamical simulations for the electron density and pressure, and calculate X-ray emission using APEC emissivities. We discuss some implications for observations.

## Overview of Decadal Survey Preparations and Process

David Lang (National Academies of Sciences, Engineering, and Medicine)

### *Abstract*

The decadal survey is the process through which the broad astronomy and astrophysics community forms recommendations to the agencies supporting its research for the next decade of activities in the fields. Activities recommended in past surveys include Hubble, Spitzer, Chandra, the James Webb Space Telescope, the VLA, Gemini, and ALMA. The most recent survey and the resulting report, “New Worlds, New Horizons in Astronomy and Astrophysics,” completed in August 2010, recommended a suite of new activities that NASA, NSF, and DOE are working to implement. Involving the community in the decadal survey process from beginning to end is essential to the success of a survey, and so in this talk we will discuss (1) preparatory activities for the survey (2) the survey’s expected schedule (3) input collection (such as science white papers and project proposals) (4) an early career astronomers and astrophysicists survey engagement event under preparation (5) a brief history of the survey process (6) how survey committee and panel members are selected (7) how the scope and charge to the survey are assembled (8) the survey’s scope (9) the cost and technical evaluation process, and (10) related topics. Community input on these topics will be sought.

## Sub-Eddington super-massive black holes in Fornax Cluster early types

Nathan Lee (University of Michigan)

### *Abstract*

We characterize the incidence and intensity of super-massive black hole activity in a sample of 29 quiescent early-type galaxies within the Fornax cluster, using the Chandra ACIS-S. Nuclear, point-like, X-ray emission is detected in 11 of our 29 galaxies, all of which are highly sub-Eddington. After accounting for the low mass X-ray binary contamination to the X-ray signal, we measure an active fraction of 17%, which sets a lower limit to the black hole occupation fraction in the sample. We employ a Bayesian linear regression analysis to investigate the dependence of nuclear X-ray luminosity on host stellar mass. Albeit a large scatter (0.7 dex), the relation is inconsistent with zero slope at the 2.6 sigma level. We conduct a controlled comparison of low-level nuclear activity as a function of environment, comparing these data to Chandra observations of Virgo and Field early types down to comparable luminosity thresholds. Taking into consideration the mass distribution differences of the three samples, we find that both the incidence and intensity of nuclear activity in the Fornax galaxies show a tendency toward lower values than those of the Field and Virgo samples. This is consistent with intergalactic dynamical effects as the principal mechanisms for suppressing accretion-powered emission, as opposed to the the alternative in ram pressure stripping holding a primary role.



## How Supernovae-driven Hot Outflows Regulate Circumgalactic Medium

Miao Li (Flatiron Institute)

### *Abstract*

The hot circumgalactic medium (CGM), where cosmic inflows interact with feedback-driven outflows, provides critical clues for galaxy formation. But X-ray observations of hot CGM around spiral galaxies are limited by the sensitivity of existing instruments, and the detected sample is still small. Also, the physics of feedback remains a bottleneck to theoretical modeling. In this talk I will introduce our numerical simulations of: 1) supernovae (SNe)-driven outflows from a multiphase ISM. With parsec-scale resolution, we quantify the loading efficiencies of mass, energy, and metals of the outflows for a wide range of star formation (SF) intensities. The volume-filling hot outflows carry the majority of the energy and metals produced by SNe, and can potentially travel to  $> 100$  kpc from MW-like galaxies; 2) how SNe-driven outflows regulate the CGM. Using galactic scale simulations, we study how galaxy potentials, existing halo gas, and SF activity affects the impact of outflows. One major goal of this project is to make synthetic X-ray observations of CGM, and identify the key physical processes that determine the observables, e.g., intensities and spatially-resolved spectra, in preparation for the next generation of X-ray satellites.

## Emission from Pulsars will Dominate the Next Decade of TeV Astronomy

Tim Linden (The Ohio State University)

### *Abstract*

Recent HAWC observations have found extended TeV emission coincident with Geminga, Monogem, and a handful of other pulsars. In this talk, I will show that these detections have significant implications for our understanding of the TeV sky. First, the isotropic nature of this emission implies that the vast majority of unassociated TeV sources are produced by pulsar activity, and provides a new avenue for detecting pulsars with radio beams that are not oriented towards Earth. Second, the luminosity function of observed pulsars implies that the combined TeV emission from unresolved pulsars dominates the diffuse TeV gamma-ray flux from the Milky Way. Lastly, the spectrum and intensity of these sources indicate that pulsars are responsible for the rising positron fraction observed by PAMELA and AMS-02. The next decade will bring forward a revolution in TeV gamma-ray astronomy, greatly enhancing our understanding of the formation and evolution of pulsar sources.

## Possible LISA Technology Applications for Other Missions

Jeffrey Livas (NASA Goddard Space Flight Center)

### *Abstract*

The Laser Interferometer Space Antenna (LISA) has been selected as the third large class mission launch opportunity of the Cosmic Visions Program by the European Space Agency (ESA). LISA science will explore a rich spectrum of astrophysical gravitational-wave sources expected at frequencies between 0.0001 and 0.1 Hz and complement the work of other observatories and missions, both space and ground-based, electromagnetic and non-electromagnetic. Similarly, LISA technology may find applications for other missions. This paper will describe the capabilities of some of the key technologies and discuss possible contributions to other missions .

## The Advanced X-ray Imaging Satellite Probe Mission: Overview

Michael Loewenstein (NASA's GSFC/UMCP/CRESST)

### *Abstract*

We present an overview of the Advanced X-ray Imaging Satellite (AXIS), a probe mission concept under study to the 2020 Decadal survey. AXIS follows in the footsteps of the Chandra X-ray Observatory with similar or higher angular resolution and an order of magnitude more collecting area in the 0.2-16 keV band over a 24' field of view. These capabilities are designed to attain a wide range of science goals such as (i) measuring the event horizon scale structure in AGN accretion disks and the spin of supermassive black holes through monitoring of gravitationally microlensed quasars; (ii) understanding AGN and starburst feedback in galaxies and galaxy clusters through direct imaging of winds and interaction of jets and via spatially resolved imaging of galaxies at high- $z$ ; (iii) probing the fueling of AGN by resolving the SMBH sphere of influence in nearby galaxies; (iv) investigating hierarchical structure formation and the SMBH merger rate through measurement of the occurrence rate of dual AGN and occupation fraction of SMBHs; (v) advancing SNR physics and galaxy ecology through large detailed samples of SNR in nearby galaxies; (vi) measuring the Cosmic Web through its connection to cluster outskirts. With a nominal late 2020's launch, AXIS benefits from natural synergies with LSST, ELTs, ALMA, WFIRST and ATHENA, and will be a valuable precursor to Lynx. AXIS utilizes breakthroughs in the construction of light-weight X-ray optics from mono-crystalline silicon blocks, and developments in the fabrication of large format, small pixel, high readout detectors.

## Optical instrument design of the High-Energy X-ray Probe (HEX-P)

Kristin Madsen (Caltech)

### *Abstract*

The High-Energy X-ray Probe (HEX-P) is a probe-class next-generation high-energy X-ray observatory mission concept that will vastly extend the reach of broadband X-ray observations. Observing over the 2-200 keV energy range, HEX-P has 40 times the sensitivity of any previous mission in the 10-80 keV band, and 10,000 times the sensitivity of any previous mission in the 80-200 keV band. A successor to the Nuclear Spectroscopic Telescope Array (NuSTAR), a NASA Small Explorer launched in 2012, HEX-P addresses key NASA science objectives, and will serve as an important complement to ESA's L-class Athena mission. On this poster we present the HEX-P optical design, which based on the NuSTAR heritage will utilize multi-layers coated on thin-shell mirrors.

## The High-Energy X-ray Probe (HEX-P)

Kristin Madsen (Caltech)

### *Abstract*

The High-Energy X-ray Probe (HEX-P) is a probe-class mission concept that will extend the reach of broadband (2-200 keV) focused X-ray observations, with 40 times the sensitivity of any previous mission in the 10-80 keV band and 10,000 times the sensitivity of any previous mission in the 80-200 keV band. HEX-P is also an important complement to ESA's L-class Athena mission, which emphasizes high-resolution spectroscopy below 10 keV. Together, HEX-P and Athena would provide a powerful capability for addressing a diverse range of questions central to modern astrophysics, working independently or in coordinated observations as the science demands. HEX-P, with an angular resolution an order of magnitude better than NuSTAR, will address key NASA science goals unique to the high-energy X-ray band, such as determining the nature of the X-ray emitting corona, tracking the cosmic evolution of the dominant population of obscured supermassive black holes, and understanding how compact binary systems form, evolve and influence galactic systems. With heritage from NuSTAR, HEX-P can be executed within the next decade.

## The Future of Soft X-ray Polarimetry

Herman Marshall (MIT)

### *Abstract*

I will present projects to measure the soft X-ray polarization of astronomical sources over the next 5-10 years. The Imaging X-ray Polarization Explorer (IXPE), a NASA mission in development, will be sensitive over the 2-8 keV band and is expected to launch in late 2020. For energies less than 1 keV, there are very few options. I will describe a design for a sounding rocket based polarimeter to work in the 0.2-0.6 keV band. The method uses gratings to disperse X-rays and laterally graded multilayer coated mirrors to reflect the spectra at incident angles near the Brewster angle. Potential targets include active galaxies, isolated neutron stars, pulsars, and nearby black hole binaries in outburst. The configuration is extensible to orbital use, possibly to be combined with other instruments to provide a bandpass from 0.2 to 50 keV, as in the X-ray Polarization Probe concept.

## Astrophysics in the 2020's and the role of High Energy Astrophysics

John Mather (NASA's GSFC)

### *Abstract*

What don't we know, why don't we know it, and what could we do about it? Anticipating the pace of discovery requires a crystal ball, which I will provide, though its accuracy is unknown. We will have many new tools available and many ideas for new ones. I will outline lessons learned from the JWST experience, from reports to hardware to flight plans and observing programs. They said it couldn't be done, but steady support enabled development of all the required technologies. Faster-better-cheaper didn't work, but better is certainly true, opening up new territories for discovery. There are many other new territories to explore, requiring new tools in high energy astrophysics.



## The Role of High Energy Polarimetry in Understanding GRBs

Mark McConnell (Univ. of New Hampshire)

### *Abstract*

The process by which some stellar-mass black holes are thought to form (either from the final stages of a highly evolved, massive star or the merger of two compact objects) results in a release of energy that exceeds anything observed in the Universe since the Big Bang itself. This energy release results in the formation of two oppositely directed jets, which can observationally manifest itself as a Gamma Ray Burst (GRB) and its afterglow emission. The initial prompt emission comes from the innermost region of the jet. The longer-lasting afterglow emission, which originates in the outer part of the jet, has been well studied across the entire electromagnetic spectrum. Although much has been learned about these afterglows, a complete picture of the GRB phenomena also requires an understanding of the inner part of the jet, closest to where the black hole is formed. We have only a limited understanding of this inner jet, as it depends on the short-lived, high-energy prompt emission, which is difficult to study given the random and short-lived nature of these sources. Questions remain about the composition, structure, energy dissipation mechanisms, and radiation mechanisms of the jet emanating from the compact object at the central engine. These questions can only be probed by polarization measurements of the prompt emission. Evidence of polarized  $\gamma$ -ray emission ( $> 100$  keV) has been accumulated in recent years, but the results are far from conclusive. A sensitive and systematic study of GRB polarization, providing definitive measurements for a large sample of events, will address these important questions. Here we shall discuss the science motivation, review the observations to date, and present some of the planned and/or proposed missions that may be able to make the required measurements.

## All Sky Medium Energy Gamma-ray Observatory (AMEGO)

Julie McEnery (NASA's GSFC)

### *Abstract*

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

## Jets from Black Holes: The Chandra Revolution and Future Prospects

Eileen Meyer (University of Maryland, Baltimore County)

### *Abstract*

High-resolution instruments like the VLA, HST, and Chandra have allowed us to map the structure and SED evolution of extragalactic jets on the kpc scale where they interact with the galactic and intergalactic environment, yet the physical description of these jets remains mysterious. Among things remaining to be settled are the particle makeup of these jets, their velocity profiles and total energy content, and in many cases even the radiation mechanism. One of the great discoveries by Chandra has been the ‘anomalous’ class of X-ray bright jets, for which the X-ray mechanism is still unsettled. I will describe some recent developments in the study of resolved X-ray detected AGN jets, including evidence for widespread variability, and discuss how a successor to Chandra will be critical to finally solving the X-ray origin problem in large-scale jets.

## Recent results of MAXI on ISS

Tatehiro Mihara (RIKEN (Institute of physical and chemical research))

### *Abstract*

Monitor of All-sky X-ray Image (MAXI) is mounted on ISS. It has been monitoring the sky with X-ray since 2009 August 15. The data is open at <http://maxi.riken.jp>. When a X-ray nova appears, MAXI issues an alert to the world in 15 s at the earliest. MAXI discovered 21 new sources in 8 years : 7 black holes (BH) binaries, 11 neutron stars (NS) binaries, 1 white dwarf binary and 2 unknown. In 2017 MAXI discovered 4 X-ray novae : MAXI J1535-571 (BH), MAXI J1807+132 (NS), MAXI J1621-501 (NS), and MAXI J1630-276 (unknown). MAXI also reported outbursts from a new source Swift J0243.6+6124 (Be binary pulsar ) and MAXI J1749-200 (=SAX J1748.9-2021?) in the globular cluster NGC 6440. MAXI J1535-571 and Swift J0243.6+6124 brightened up to several Crab and became novae of the century. Following MAXI alerts many observations in many wavelength were carried out. In 2017 MAXI team issued 28 reports on transients to ATel on these outbursts, giant flares from active stars, long X-ray bursts, X-ray upper limits for IceCube neutrino etc. We also issued GCN including 6 gamma-ray bursts and upper limits on three gravitational wave events. At the time of the NS-NS merger GW 170817, MAXI was not operated due to a high background region. MAXI scanned over GW 170817 after 1-3 minutes, but was still off. MAXI resumed observation 4 minutes after the event. So there was no observation of the extended X-ray emission which usually lasts ~100s. It was so close. As results of long-term observations, MAXI team issued the 3rd MAXI catalog and 1st galactic catalog containing 682 and 214 sources, respectively. We also studied the spin up of the NS by the mass accretion in 12 Be X-ray binaries with Ghosh and Lamb (1979) equation. In 2018, we plan to cooperate with the new instrument NICER on ISS. So far we conduct information of a nova on the Earth surface (MANGA : MAXI And NICER Ground Alert) in time scale of a day. We prepare for the automatic process in ISS. OHMAN (On-orbit Hookup of MAXI And NICER) aims a rapid follow-up by NICER in 2 minutes after MAXI discovers a new source. "Watch an X-ray nova in X-ray while it is still bright in X-ray". X-ray follow-up earlier than 3 hours remains as a discovery space in time-domain astronomy.

# Reducing the Athena WFI Background with the Science Products Module: Lessons from Chandra ACIS and Suzaku XIS

Eric Miller (MIT)

## *Abstract*

The Wide Field Imager (WFI) on ESA's Athena X-ray observatory will include the Science Products Module, a secondary CPU that can perform special processing on the science data stream. Our goal is to identify on-board processing algorithms that can reduce WFI charged particle background and improve knowledge of the background to reduce systematics. Telemetry limitations require discarding most pixels on-board, keeping just candidate X-ray events, but information in the discarded data may be helpful in identifying background events masquerading as X-ray events. We present full frame data from CCDs on-board Chandra and Suzaku, in high- and low-Earth orbit, and results of our search for phenomenological correlations between particle tracks and background events that would otherwise be categorized as X-rays. In addition to possibly reducing the Athena WFI instrumental background, these results are applicable to understanding the particle component in any silicon-based X-ray detector in space.

# Ex Luna Scientia: The Lunar Occultation Explorer (LOX), A New Paradigm for Nuclear Astrophysics

Richard Miller (University of Alabama in Huntsville)

## *Abstract*

The Lunar Occultation Explorer (LOX) will leverage the power of a new observational paradigm to transform our understanding of the nuclear cosmos (0.1–10 MeV) and establish the Moon as a platform for astrophysics. LOX will operate from lunar orbit, using the Moon as a natural occulting disk to temporally modulate cosmic sources of nuclear gamma-rays as they repeatedly rise and set over the lunar limb. The modulation signatures imprinted on acquired gamma-ray time-series data contains all the information necessary for source characterization and localization. The Lunar Occultation Technique (LOT) on which LOX is based is an efficient and validated observational approach that circumvents the complexity, technology development, and cost hurdles of the astronomical techniques traditionally employed in the MeV regime. Combined with the LOT's inherent wide-field-of-view and continuous all-sky monitoring, the LOX approach provides an innovative way of addressing fundamental questions in the nuclear gamma-ray regime. It achieves high sensitivity with a simple and scalable instrument design, while also taking advantage of the relatively benign, easily characterized, and slowly changing background environment of the Moon to provide a transformational capacity for discovery. LOX is a low-resource implementation with modest operational demands, and adopts a large-area gamma-ray spectrometer as its single instrument. This instrument is an array of individual gamma-ray spectrometer modules that operate as a single instrument (BAGEL, Big Array for Gamma-ray Energy Logging). LOX's highly scalable implementation is limited only by available mission mass and power resources, and intrinsically fault tolerant due to its inherent segmentation. All elements of LOX are high-heritage, and most have operated in-situ from lunar orbit for extended periods of time. Mission operations and operating conditions are proven and well-established, and recent proof-of-principle efforts led to the first high-energy astrophysical source detection from the Moon. These features establish LOX as a low-risk, cost-effective, and competitive venture that will provide new insights into the lifecycle of matter and energy throughout the cosmos.

## Ultra-Heavy GCR measurements beyond SuperTIGER: The Heavy Nuclei eXplorer

John Mitchell (NASA/GSFC)

### *Abstract*

The Heavy Nuclei eXplorer (HNX) is a new instrument proposed as a NASA Small Explorer by NASA Goddard Space Flight Center, University of California, Berkeley, Washington University in St. Louis, the Jet Propulsion Laboratory, the University of Minnesota, Pennsylvania State University, and Northern Kentucky University. HNX will investigate the nature of the reservoirs of nuclei at the cosmic-ray sources, the mechanisms by which nuclei are removed from the reservoirs and injected into the cosmic accelerators, and the acceleration mechanism. HNX will measure, for the first time, the abundance of every individual element in the periodic table from carbon through the actinides, providing the first measurement of many of these elements. These measurements are especially timely and important to the astrophysics community in light of the recent detection of a binary neutron star merger in gravitational radiation, gamma-rays and radio. HNX will record several thousand ultra-heavy galactic cosmic ray (UHGCR) nuclei with atomic number  $Z \geq 30$ , including about 50 actinides. This will enable sensitive tests of the relative importance of R and S neutron capture processes and binary neutron star mergers and Supernovae to the nucleosynthesis of UHGCR. To measure UHGCR with unprecedented statistics and individual element resolution over its full measurement range, HNX will use two large instruments, the Extremely-heavy Cosmic-ray Composition Observer (ECCO) using sophisticated glass detectors and the Cosmic-ray Trans-Iron Galactic Element Recorder (CosmicTIGER) using electronic detectors evolved from the SuperTIGER (SuperTrans-Iron Galactic Element Recorder) long-duration balloon instrument. HNX will be accommodated in the SpaceX DragonLab orbiting laboratory that will also return it to Earth for post-flight processing of the ECCO detectors. The scientific motivations of HNX and details of the planned mission and instruments will be discussed.

## Development of the hard X-ray imaging pixel detectors with custom ASIC for astrophysical applications

Hiromasa Miyasaka (Caltech)

### *Abstract*

We are developing imaging pixel detectors that have potential application for astrophysical missions utilizing focusing and wide field instruments, such as the Probe-Class concept The High-Energy X-ray Probe (HEX-P) and Cube-sat concept the Monitoring Spectroscopic Telescope for Energetic Radiation (MonSTER). Our hybrid-sensor consist of a Cadmium Telluride (CdTe) or Cadmium Zinc Telluride (CZT) detector with segmented anode contacts directly bonded to an application specific integrated circuit (ASIC). We have utilized a custom low noise, low power ASIC circuit developed for the Nuclear Spectroscopic Telescope Array (NuSTAR) mission which was successfully launched on June 13, 2012 as the first hard X-ray focusing telescope in space. While, NuSTAR employed 2mm thick CZT detectors, we are experimenting with thicker CZT detectors as well as CZT from different vendors. Our ASIC is also flexible enough to be used with CdTe detectors, which have better uniformity, yield, and energy resolution. For future space mission, we are also developing a new ASIC with heritage from the NuSTAR ASIC but utilizing new technology to achieve smaller pixel size and faster readout time. We will report on our detectors development status and the performance of the new detector materials mated to the NuSTAR ASIC.



## Concept of a future Japan-lead mission for a broadband X-ray imaging spectroscopy with high-angular resolution: the FORCE mission

Koji Mori (Univ. of Miyazaki)

### *Abstract*

The JAXA/NASA collaborative mission, XARM (X-ray Astronomy Recovery Mission), is the successor of Hitomi, focusing on the highest-energy-resolution X-ray spectroscopy with a planned launch in 2021. No X-ray mission is approved by JAXA after XARM. Here, we present the concept of a future Japan-lead X-ray medium-class mission, FORCE (Focusing On Relativistic universe and Cosmic Evolution). FORCE is another successor of Hitomi focusing on the broadband X-ray imaging spectroscopy in 1-80 keV with a significantly higher angular resolution of  $< 15''$  in half-power diameter. The sensitivity above 10 keV will be 10 times higher than that of any previous hard X-ray missions with simultaneous soft X-ray coverage. The primary scientific objective of the FORCE mission is to trace the cosmic formation history by searching for "missing black holes" in the entire range of the mass spectrum of BHs: "buried" supermassive black holes (SMBHs) ( $> 10^4 M$ ), which reside in centers of galaxies in a cosmological distance, intermediate-mass black holes ( $10^2$ - $10^4 M$ ), which are possible seeds from which SMBHs grow, and "orphan" stellar-mass black holes ( $< 10^2 M$ ), which have no companion, in our Galaxy. Especially, recent gravitational wave detections suggest that the number of such stellar-mass black holes is much more than we currently know. The satellite is planned to be launched by the Epsilon vehicle by ISAS/JAXA. In the current design concept, FORCE is equipped with three identical pairs of supermirrors and wide-band X-ray detectors. The focal length of the mirrors is 10 m. The silicon mirror with multi-layer coating is our primary choice of optics to achieve a good angular resolution for the wide energy band while maintaining a light weight. The detector is a hybrid of a SOI-CMOS silicon-pixel detector and a CdTe detector responsible for the softer and harder energy bands, respectively. It is basically a descendant of the hard X-ray imager onboard Hitomi with its soft-band detector replaced with the SOI-CMOS. FORCE will play a significant role in multimessenger astronomy in late 2020s with its broadband X-ray sensitivity.

## A next-generation Very Large Array

Eric Murphy (NRAO)

### *Abstract*

Inspired by dramatic discoveries from the Jansky VLA and ALMA, a plan to pursue a large collecting area radio interferometer that will open new discovery space from proto-planetary disks to distant galaxies is being developed by NRAO and the science community. Building on the superb cm observing conditions and existing infrastructure of the VLA site in the U.S. Southwest, the current vision of the ngVLA will be an interferometric array with more than 10 times the sensitivity and spatial resolution of the current VLA and ALMA, operating at frequencies spanning  $\sim 1.2 - 116$  GHz. The ngVLA will be optimized for observations at wavelengths between the exquisite performance of ALMA at submm wavelengths, and the future SKA-1 at decimeter to meter wavelengths, thus lending itself to be highly complementary with these facilities. As such, the ngVLA will open a new window on the universe through ultra-sensitive imaging of thermal line and continuum emission down to milliarcsecond resolution, as well as deliver unprecedented broad band continuum polarimetric imaging of non-thermal processes. The ngVLA will be the only facility in the world that can tackle a broad range of outstanding scientific questions in modern astronomy by simultaneously delivering the capability to: unveil the formation of Solar System analogues; probe the initial conditions for planetary systems and life with astrochemistry; characterize the assembly, structure, and evolution of galaxies from the first billion years to the present; use pulsars in the Galactic center as fundamental tests of gravity; and understand the formation and evolution of stellar and supermassive blackholes in the era of multi-messenger astronomy.

## AXIS- A High Angular Resolution X-ray Probe Concept Study

Richard Mushotzky (University of Maryland)

### *Abstract*

AXIS is a probe-class concept under study to the 2020 Decadal survey. AXIS will extend and enhance the science of high angular resolution x-ray imaging and spectroscopy in the next decade with  $\sim 0.3''$  angular resolution over a  $7'$  radius field of view and an order of magnitude more collecting area than Chandra in the 0.3-12 keV band with a cost consistent with a probe. These capabilities enable major advances in a wide range of science such as: (i) measuring the event horizon scale structure in AGN accretion disks and the spins of supermassive black holes through observations of gravitationally-microlensed quasars; (ii) determining AGN and starburst feedback in galaxies and galaxy clusters through direct imaging of winds and interaction of jets and via spatially resolved imaging of galaxies at high- $z$ ; (iii) fueling of AGN by probing the Bondi radius of over 20 nearby galaxies; (iv) hierarchical structure formation and the SMBH merger rate through measurement of the occurrence rate of dual AGN and occupation fraction of SMBHs; (v) advancing SNR physics and galaxy ecology through large detailed samples of SNR in nearby galaxies; (vi) measuring the Cosmic Web through its connection to cluster outskirts. With a nominal 2028 launch, AXIS benefits from natural synergies with the ELTs, LSST, ALMA, WFIRST and ATHENA. AXIS utilizes breakthroughs in the construction of lightweight X-ray optics from mono-crystalline silicon blocks, and developments in the fabrication of large format, small pixel, high readout rate detectors allowing a robust and cost effective design. The AXIS team welcomes input and feedback from the community in preparation for the 2020 Decadal review.

## Athena: ESA's next-generation X-ray observatory

Kirpal Nandra (Max Planck Institute for Extraterrestrial Physics)

### *Abstract*

Athena (The Advanced Telescope for High Energy Astrophysics) is a next-generation X-ray observatory to address the Hot and Energetic Universe science theme, selected by ESA as the second large mission of the Cosmic Vision program. The driving science of the mission is to understand the formation and evolution of hot gas structures in the Universe, and growth and evolution of supermassive black holes. Athena consists of a single, large-aperture X-ray telescope based on Silicon Pore Optics (SPO) technology, which can be focussed onto one of two instruments. The X-ray Integral Field Unit (X-IFU), based on TES calorimeter, technology a cryogenic instrument offering spatially resolved high resolution spectroscopy. The Wide Field Imager (WFI) features a large field of view with moderate resolution spectroscopy and high count rate capability, using Silicon DEPFET sensors. Athena is currently in Phase A, with conceptual design work ongoing along with a vigorous technology development program. In this talk the science drivers of the mission will be briefly reviewed, along with the project status.

# Cyclotron absorption features in Supergiant Fast X-ray transients: the case of IGR J16418-4532

Lorenzo Natalucci (INAF)

## *Abstract*

The detection of cyclotron resonance absorption lines in accreting HMXB with extreme transient behaviour (the Supergiant Fast X-ray Transients, SFXTs) is a powerful tool to unveil the physical processes driving their accretion modes. This technique is currently being exploited by NuSTAR, with its unique combination of wide bandpass, good energy resolution and few micro-Crab sensitivity in the hard X-ray band. We report on a 40ks observation of the candidate SFXT IGR J16418-4532 obtained by NuSTAR. The source showed flaring behaviour typical of these transients, showing two distinct accretion modes characterized by low intensity and flaring emission. The analysis reveals a clear detection of a cyclotron line at  $\sim 50$  keV. We present results of a full spectral and timing analysis of this source and discuss the prospects for similar investigations in other SFXT sources.

## X-ray Evolution of the Symbiotic Binary R Aqr : 2000-2005

Joy Nichols (Harvard-Smithsonian, CfA)

### *Abstract*

The Chandra observation of the nearby symbiotic system R Aqr taken in 2005.7 is analyzed and compared to the 2 earlier observations of this system in 2000.7 and 2004.0. Spectral fitting reveals significant variability on this time frame, with changes seen in the hardness ratio and the fluxes of emission lines. The most marked changes occur in the Fe K alpha line and nearby complexes, indicative of changes in the accretion activity. The extended jets have moved outward with a projected speed of over 500 km/s during this period. We find evidence for new jet formation on a time scale of months or years. This series of observations gives a unique view of white dwarf wind accretion in a binary system as well as jet formation and evolution. We acknowledge NASA contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the Chandra X-ray Center.

## High Spectral Resolution Observations of Ultrafast Outflows in AGN and ULX

Michael Nowak (MIT Kavli Institute)

### *Abstract*

Photoionized outflows in compact object systems --- e.g., Galactic black or Active Galactic Nuclei (AGN) --- may carry a substantial fraction of both the mass flow and accretion energy in these systems. Thus they may provide an important mechanism for feedback to the environment hosting these systems. The advent of high resolution X-ray spectroscopy with both the Chandra-High Energy Transmission Gratings (HETG) and the XMM-Newton Reflection Gratings Spectrometer (RGS) has enabled us to characterize multiple ionization states in these outflowing winds (spread over as much as three orders of magnitude in ionization parameter) as well as their velocities, typically of the order of a few hundred kilometers per second. However, there exists another class of warm absorber outflows, the so-called "ultra fast outflows" (UFOs), identified in a few AGN and more recently in Ultra Luminous X-ray (ULX) sources, with outflow velocities of the order of 10% (or more) of the speed of light. Based upon claimed XMM-RGS detections of UFOs in the AGN PG 1211+143, we have performed deep, simultaneous Chandra-HETG and HST-COS observations to confirm the presence of a highly ionized 0.056c outflow (in the system's Cosmological rest frame) in both the X-ray and UV spectra of this system. This is likely the same outflow in each of these energy bands. Similarly, we have recently completed Chandra-HETG observations of the ULX NGC 1313 X-1 in order to test the XMM-RGS detection of a similar UFO in that system. Confirming such UFO detections has been very difficult, however, as XMM-RGS has a very limited bandpass ( $<2$  keV) and modest resolution for a gratings spectrometer, while HETG has a broader bandpass and superior spectral resolution, but lacks the effective area of RGS. Spectral resolution is extremely important as UFO line widths are less than 300 km/s, and effective area is important given the faintness of the source spectra. We consider how the improved spectral resolution and higher effective area of the upcoming XARM mission and the proposed Arcus mission will improve future studies of UFOs in these and other similar systems.

## POEMMA: Probe Of Multi-Messenger Astrophysics

Angela Olinto (Univ. of Chicago)

### *Abstract*

The Probe Of Multi-Messenger Astrophysics (POEMMA) mission is being designed to identify the sources of the most extreme particles ever observed, the ultra-high energy cosmic rays (UHECRs), and to discover cosmic neutrinos above  $\sim 10$  PeV. POEMMA will consist of two satellites, flying in loose formation, each with a wide field-of-view UV photodetector, using an innovative Schmidt camera, optimized to observe both air fluorescence and air Cherenkov signals from UHECRs and neutrinos. POEMMA will measure the spectrum, composition, and sky distribution of the UHECRs above 10 EeV and the Cherenkov signals from upward-moving air showers induced from tau neutrino interactions in the Earth. POEMMA's goal is to obtain orders of magnitude higher sensitivity to the highest energy cosmic messengers compared to what is achieved by ground-based experiments in order to identify the most energetic cosmic accelerators in the universe, study the acceleration mechanism(s), and probe particle interactions at energies well-above those achieved by man-made accelerators.



## Cosmic Particles in the Multi-Messengers Era

Angela Olinto (Univ. of Chicago)

### *Abstract*

The 2010's witnessed great progress in understanding the most energetic accelerators in the Universe. The Pierre Auger Observatory and the Telescope Array (TA) measured the spectrum, composition, and sky distribution of cosmic rays from 0.1 to about 100 EeV. TA observes a possible hot-spot in the northern hemisphere while Auger discovered a large-scale dipole above 8 EeV establishing the extragalactic nature of ultra-high energy cosmic rays (UHECRs). IceCube discovered astrophysical neutrinos. A number of models have been proposed for both types of observations. In the 2020s we can finally identify the sources of these extreme particles by increasing the sensitivity to both UHECRs and astrophysical neutrinos over the full sky and by discovering the elusive EeV neutrinos associated with UHECR (BZ or cosmogenic). Innovative ground- and space-based detectors of cosmic particles are being designed that, together with photon observatories, will decipher the messages reaching Earth from these most extreme messengers.

## Trinity: An instrument to detect cosmogenic neutrinos with the Earth skimming technique

Nepomuk Otte (Georgia Tech)

### *Abstract*

The predictions of the cosmogenic-neutrino flux at  $1e9$  GeV are pretty solid and depend mostly on the composition of the primary flux of cosmic-rays above  $1e10$  GeV. It is, therefore, no surprise that the hunt to detect the first cosmogenic neutrino is a hot topic in astroparticle physics. But pushing the experimental sensitivity into the predicted flux region is a challenge. A major obstacle for experiments is to obtain a large enough acceptance while keeping costs at reasonable levels. I have performed a conceptual design study of a dedicated array of Cherenkov telescopes that uses the Earth skimming technique to detect tau neutrinos. My studies show that a fairly small Cherenkov telescope system is sufficient to reach sensitivities that are competitive with other proposed neutrino experiments in the same energy range, like ARA and ARIANNA, and outperforms them in terms of costs. In this talk I present details of the design study and discuss the proposed array of Cherenkov telescopes, which I named Trinity.

## Lynx Mission Concept Study

Feryal Ozel (University of Arizona)

### *Abstract*

Lynx is an observatory-class mission, featuring high throughput, exquisite angular resolution over a large field of view, and high spectral resolution for point and extended X-ray sources. Lynx will have the capability to observe the dawn of supermassive black holes through detection of very faint X-ray sources in the early universe. It will reveal the "invisible drivers" of galaxy and structure formation through observations of hot, diffuse baryons in and around the galaxies. Lynx will also unveil the energetic side of stellar evolution and stellar ecosystems by providing a unique perspective on stellar birth and death, internal stellar structure, star-planet interactions, the origin of elements, and violent cosmic events. The design requirements that enable these science goals provide a tremendous leap in capabilities relative to missions such as Chandra and Athena and will lead to breakthroughs across all of astrophysics.

# The First Black Holes in the Next Decade of High-Energy Astrophysics

Fabio Pacucci (Yale University)

## *Abstract*

The first black hole seeds formed when the Universe was younger than 500 Myr old and they played an important role in the growth of early ( $z=7$ ) supermassive black holes. While much progress has been made in understanding their formation and growth, their observational signatures remain largely unexplored. As a result, we are yet to detect these sources, leaving them as a major target for high energy astrophysics of the 2020's and beyond. We present a novel photometric method to identify black hole seed candidates in deep multi-wavelength surveys. The method relies on infrared and X-ray observations and selects the only two objects with a robust X-ray detection found in the CANDELS/GOODS-S survey with a photometric redshift  $z>6$ . Moreover, the case of the  $z=6.6$  Lyman alpha emitter CR7 is discussed. We show how its observational features are compatible with our black hole seed model and we present the results of our variability and spectroscopic studies with the HST and Keck. To date, these objects represent the most promising black hole seed candidates, possibly formed via the direct collapse black hole scenario. While these results are based on the best photometric observations of high- $z$  sources available to date, additional insights are expected from deeper spectroscopic and X-ray data. We review the next steps to be taken to unravel the first black holes in the high-energy domain.

## Development of the AMEGO Subsystems

Jeremy Perkins (NASA/GSFC)

### *Abstract*

The All-sky Medium Energy Gamma-ray Observatory (AMEGO) is a probe-class mission in consideration for the 2020 decadal review designed to operate at energies from  $\sim 200$  keV to  $> 10$  GeV. Both Compton scattering and pair-production events must be considered in the AMEGO design since the interaction cross section has a crossover at  $\sim$  a few MeV. AMEGO is made of four major subsystems: a plastic anticoincidence detector for rejecting cosmic-ray events, a silicon tracker for measuring the energies of Compton scattered electrons and pair-production products, a CZT calorimeter for measuring the energy and location of Compton scattered photons, and a CsI calorimeter for measuring the energy of the pair-production products at high energies. The prototype subsystems are under development at the NASA Goddard Space Flight Center and the Naval Research Lab; in this contribution we provide details on the development of the different subsystems in preparation for beam tests and a balloon flight.

## Jet Physics, Current X-ray Observations and the Next Decade

Eric Perlman (Florida Institute of Technology)

### *Abstract*

The X-ray jets of active galactic nuclei are one of X-ray astronomy's key discoveries. Nearly unknown before the launch of Chandra, there are now hundreds known. As opposed to other wavebands, in the X-rays the emission mechanism is not well constrained: both synchrotron and inverse-Compton mechanisms remain viable, contrary to what we expected to find a decade ago. The reasons for this are complex, and moving forward will require new observational tools. I will discuss recent findings and how I believe they should motivate the choice of future missions and instruments. The compact structures we see, combined with short variability timescales seen on kpc scales in three objects, require high angular resolution to investigate further. We also need an increase in effective area, particularly at high energies, to observe high-redshift objects and faint structures. X-ray polarization capability is also important, as one of the most important discriminators between inverse-Compton and synchrotron processes is the degree of polarization. Less critical for jets is improved energy resolution, as both processes are continuum in nature, but arcsecond or better imaging capability at 10 keV would increase our capability to see turnovers in the spectral energy distributions of components. We will discuss currently planned missions and how they do or do not meet these needs, and also discuss prospects for future missions into the 2020s-2030s and beyond.

## Prospects for Currently Operating High Energy Astrophysics Observatories

Robert Petre (NASA / GSFC)

### *Abstract*

As the 2010's come to a close, astronomers have access to a wealth of electromagnetic, particle and gravitational observatories, in space and on the ground. The age and condition of these facilities vary widely, with some newly commissioned, others in their prime, and yet others approaching the end of their operational life. As the decadal survey formulates its recommendations regarding what new facilities should be developed in the 2020's, it is important that the capabilities of and expectations for existing facilities be taken into consideration. This talk provides a brief survey of facilities relevant to high-energy astrophysics that are currently operating, and their prospects for operating into the next decade.

## High Energy Astrophysics in the 2020's and Beyond: Meeting Goals

Robert Petre (NASA / GSFC)

### *Abstract*

The purpose of this meeting is to provide a forum to identify the key areas of discovery for high-energy astrophysics in the next decade, and to explore ways of advocating high-energy astrophysics to the decadal survey panel. This talk offers a brief introduction to the rationale behind the meeting and its structure, and thoughts about possible themes and outcomes.



## The Focal Plane of the High-Energy X-ray Probe (HEX-P)

Sean Pike (Caltech)

### *Abstract*

The High-Energy X-ray Probe (HEX-P) is a high-energy X-ray observatory mission concept intended to succeed the Nuclear Spectroscopic Telescope Array (NuSTAR). Thanks to improved optics and focal plane design it will surpass NuSTAR's capacities, achieving sub-keV (FWHM) energy resolution, angular resolution of nearly 10 arcseconds, and microsecond temporal resolution over an energy range of 2-200 keV. We present a preliminary HEX-P focal plane design in this poster. Based on the architecture currently in use onboard NuSTAR, the focal plane of HEX-P consists of multiple detectors, each of which is a custom application-specific integrated circuits (ASIC) attached by a conducting epoxy to a semiconducting crystal such as Cadmium Telluride or Cadmium Zinc Telluride. The thickness and material properties of the semiconductor as well as the circuit design of the ASIC are important to determining the operational parameters of the focal plane and are being optimized to achieve the scientific goals of HEX-P.

## Magnetic Alignment of Accretion Discs

Peter Polko (Los Alamos National Laboratory)

### *Abstract*

There is no a priori reason why the angular momentum of material feeding a black hole accretion disc should be aligned with the spin vector of the black hole. If the disc remains misaligned, this will have significant consequences for the evolution of the spin magnitude and orientation, and the interpretation of observations of these systems. Traditionally the Bardeen-Petterson effect, based on the frame-dragging of spacetime around a spinning black hole, has been invoked as the process to torque the disc into the spin vector plane. In this talk I will show that a torque exerted by a jet can be of equal, or even bigger importance.

## The LUVOIR Space Telescope

Marc Postman (Space Telescope Science Institute)

### *Abstract*

The Large Ultraviolet-Optical-nearIR (LUVOIR) surveyor is a concept for a serviceable observatory with an aperture in the 9-m to 15-m range. The observatory is designed to enable breakthroughs in UV-visible-infrared astrophysics in the post Hubble and Webb era. LUVOIR will provide unprecedented resolution (7 - 11 mas at 500 nm) and high sensitivity to discover and characterize new objects in our solar system, to uncover new faint stellar populations in the Milky Way galaxy, to place new constraints on the nature of dark matter, to map the properties of intergalactic gas flows in and out of galaxies, and to resolve the basic building blocks of galaxies out to cosmic distances. LUVOIR will be able to deploy multi-object spectroscopy in the ultraviolet, with up to 50-fold sensitivity gains compared to Hubble and the multiplexing ability to observe more than a hundred objects at once. LUVOIR's primary camera will provide Nyquist-sampled images across a 3-arcminute field of view in two separate channels spanning the range 200 nm - 1800 nm. This LUVOIR imager will be capable of resolving 60 parsec scales at all redshifts while reaching a 5-sigma point source limiting AB magnitude of 33 (0.23 nJy) in just 10 hours and ~35 mag (0.04 nJy) in ~10 days. Finally, the high-performance coronagraph instrument on LUVOIR will survey hundreds of stars over a two-year timeframe to search for rocky planets in their habitable zones—and then study as many as 50 - 60 of those planets to search for signs of habitability and life, enabling important and stringent constraints on the frequency of remotely detectable biosignature gases in exoplanet atmospheres. In this way, LUVOIR will provide a statistically meaningful scientific answer to the question "Are We Alone?"

## Exploring transient detection with WFI onboard Athena

Pragati Pradhan (Penn State University)

### *Abstract*

X-ray transients are among the most enigmatic objects in the cosmic sky. The unpredictability of their transient behaviour has been a study of much interest in the recent years. While significant progress has been made in this direction, a more complete understanding of such events is often hampered by the delay in the rapid follow-up of any transient event. An efficient way to mitigate this constraint would be to devise a way for onboard detection of such transient phenomenon. The Wide Field Imager (WFI), which is a part of the upcoming X-ray mission Athena, with its 40' X 40' field of view can add some valuable contribution to this. In this work, we aim to discuss an algorithm for the on-board detection of X-ray transients with WFI. We will also present a few test cases for the feasibility test of that algorithm on Swift-XRT data. Finally, we discuss what type of X-ray transients are best suited for onboard detection from WFI, their probability of detections and the useful science that can follow.

## High-resolution X-ray Spectroscopy of Starburst Galaxies

Andrew Ptak (NASA/GSFC)

### *Abstract*

Starburst galaxies have strong winds that are one of the major modes of feedback that shape galaxies and disperse baryons. High-resolution X-ray spectroscopy promises to directly probe the energetics of this feedback by detecting outflow velocities in the hot outflowing gas. In addition detecting spatially-resolved highly ionized gas (He- and H-like Fe lines) correlated with regions of high star formation would be direct evidence of very hot superwind fluid. We will discuss the prospects for detecting superwind emission by simulating Athena, Lynx and XARM calorimeter observations using Chandra diffuse emission maps as input and comparing them to starburst wind models. We will also discuss the potential of observing hot starburst ISM in absorption with grating detectors on Arcus and Lynx using background AGN and ULXs as light sources. Gratings observations of ULXs also promises to directly detect energetic outflows and thus to characterize feedback from massive X-ray binaries. Finally, the need to advanced statistical techniques to properly disentangle the multiple components of emission will be discussed, particularly in cases when galaxies are only marginally resolved (XARM observations of nearby galaxies and Athena and Lynx observations of distant galaxies).

## ISS-TAO

Judith Racusin (NASA/GSFC)

### *Abstract*

The Transient Astrophysics Observer on the International Space Station (ISS-TAO) will provide X-ray and gamma-ray monitoring of the transient sky on a cost-effective platform utilizing the rapid communications capability of the ISS. The ISS-TAO instruments, the Wide Field Imager (WFI) and the Gamma-ray Transient Monitor (GTM), work together to detect new transients and automatically follow them up in the soft X-rays with a 360 square degree field of view and rapidly downlink triggers and localizations to enable follow-up observations. The WFI will also regularly respond to uplinked transient alerts within seconds-minutes after their detection to search for the counterparts to gravitational wave sources and other X-ray transients. When not chasing transients, the WFI will conduct a sky survey, observing >50% of the sky every 12 hours, observing the entire sky each year. ISS-TAO is currently undergoing a NASA Mission of Opportunity Phase A study with a launch in 2022.

# STROBE-X: X-ray Timing and Spectroscopy on Dynamical Timescales from Microseconds to Years

Paul Ray (NRL)

## *Abstract*

We describe a probe-class mission concept that provides an unprecedented view of the X-ray sky, performing timing and 0.2-30 keV spectroscopy over timescales from microseconds to years. The Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X) comprises three primary instruments. The first uses an array of lightweight optics (3-m focal length) that concentrate incident photons onto solid state detectors with CCD-level (85-130 eV) energy resolution, 100 ns time resolution, and low background rates to cover the 0.2-12 keV band. This technology is scaled up from NICER, with enhanced optics to take advantage of the longer focal length of STROBE-X. The second uses large-area collimated silicon drift detectors, developed for ESA's LOFT, to cover the 2-30 keV band. These two instruments each provide an order of magnitude improvement in effective area compared with its predecessor (NICER and RXTE, respectively). Finally, a sensitive sky monitor triggers pointed observations, provides high duty cycle, high time resolution, high spectral resolution monitoring of the X-ray sky with  $\sim 20$  times the sensitivity of the RXTE ASM, and enables multi-wavelength and multi-messenger studies on a continuous, rather than scanning basis. We describe the mission concept including updated instrument designs resulting from the GSFC IDL run in November 2017. Funding for STROBE-X is provided by NASA.

## The Transiting Exoplanet Survey Satellite (TESS) Mission

George Ricker (MIT)

### *Abstract*

The Transiting Exoplanet Survey Satellite (TESS) will discover thousands of exoplanets in orbit around the brightest stars in the sky. In a two-year survey, TESS will monitor ~200,000 pre-selected bright stars for planetary transits in the solar neighborhood at a 2-minute cadence. This survey will identify planets ranging from Earth-sized to gas giants, orbiting stars spanning a wide range of spectral types. The TESS cameras will also provide full frame images (FFI) at a cadence of 30 minutes or less. The resulting etendue will be ~5 times greater than for any optical space telescope previously flown. The FFI will provide precise photometric information for every object within the 2300 square degree instantaneous field of view of the TESS cameras. In total, more than 30 million stars and galaxies brighter than magnitude  $I=16$  will be precisely photometered during the two-year prime mission, supporting a broad range of multi-messenger investigations. In principle, the lunar-resonant TESS orbit will provide opportunities for an extended mission lasting more than a decade, with data rates of ~100 Mbits/s. An extended survey by TESS of regions surrounding the North and South Ecliptic Poles will provide prime targets for follow up observations with the James Webb Space Telescope, as well as other large ground-based and space-based telescopes of the future. The TESS legacy will be a catalog of the nearest and brightest main-sequence stars hosting transiting exoplanets, which should endure as the most favorable targets for detailed future investigations. The TESS launch as a NASA Astrophysics Explorer is to take place in Spring 2018 from Cape Canaveral on a SpaceX Falcon 9 rocket.



# Searching for Fermi/GBM Untriggered SGRB Candidates with INTEGRAL/PICsIT

James Rodi (INAF-IAPS)

## *Abstract*

The first detection of a prompt electromagnetic counterpart coincident with a gravitational wave trigger in August 2017 produced a number of surprising results. One notable example was the extremely low isotropic luminosity of the event relative to other short gamma-ray bursts (SGRBs) with known redshifts, revealing a population of low luminosity SGRBs. The most popular interpretation has been that GRB 170817A was viewed off-axis, rather than that the event had an intrinsically low luminosity. In either case, this result has spurred off-line searches for SGRBs below instrument trigger thresholds in hopes of finding similar events. Here we analyze data from the INTEGRAL soft gamma-ray detector IBIS/PICsIT ( $\sim 200$  keV - 10 MeV) to corroborate the list of publicly available untriggered SGRB candidates reported by Fermi/GBM.

## Experimental Techniques to Detect Exotic Particle Interactions

Carol Scarlett (Florida A&M University)

### *Abstract*

The use of Astrophysical data to place limits on certain types of exotic particle interactions, e.g. axion searches and weak physics, has evolved as an important technique in high energy physics. This talk will look at the possibility to measure a type of beta decay in a laboratory environment where copious positrons will be used. The aim is to better understand the role of these interactions in stellar evolution.

# High Resolution X-Ray Spectroscopy: Distribution of Matter in and around Galaxies

Norbert Schulz (MIT)

## *Abstract*

The chemical evolution of the Universe embraces aspects that reach deep into modern astrophysics and cosmology. We want to know how present and past matter is affected by various levels and types of nucleo-synthesis and stellar evolution. Three major categories have been identified so far: 1. The study of pre-mordial star formation including periods of super-massive black hole formation, 2. The embedded evolution of the intergalactic medium (IGM). 3. The status and evolution of stars and the interstellar medium (ISM) in galaxies. Today a fourth category relates to our understanding of dark matter in relation with these three categories. The X-ray band is particularly sensitive to K- and L-shell absorption and scattering from high abundant elements like C, N, O, Ne, Mg, Si, S, Ar, Ca, Fe, and Ni. Like the Lyman alpha forest in the optical band, absorbers in the IGM produce an X-ray line forest along the line of sight in the X-ray spectrum of a background quasar. Similary bright X-ray sources within galaxies and the Milky Way produce a continuum, which is being absorbed by elements in various phases of the ISM. High resolution X-ray absorption surveys are possible with technologies ready for flight within decade.  $\implies$  high efficiency X-ray optics with optical performance  $\ll 3'' \implies$  high resolution X-ray gratings with  $R > 3000$  for  $E < 1.5$  keV  $\implies$  X-ray micro-calorimeters with  $R > 2000$  for  $E > 1.5$  keV The vision for the next decade needs to lead to means and strategies which allows us to perform such absorption surveys as effectively as surveys are now or in very near future quite common in astronomy pursued in other wavelength bands such as optical, IR, and sub-mm.

## Ground-based Gravitational-wave detectors – Plans for the coming decade

David Shoemaker (Massachusetts Institute of Technology)

### *Abstract*

Gravitational waves have now shown their potential for complementing – and triggering – neutrino and electromagnetic detectors, with the GW170817 binary neutron-star observation and followup as the concrete example. Other gravitational-wave sources accessible to the current detectors are also likely to contribute to our bigger picture of the universe in the near future. In the coming decade, in addition to the two US LIGO sites and the European Virgo detector, we expect KAGRA in Japan and LIGO-India to come on line. We plan for a series of incremental improvements in sensitivity of the LIGO and Virgo detectors – by about a factor of two in sensitivity by 2020 when the current instruments are fully commissioned. KAGRA and LIGO-India should join in the following years, yielding a refined network pointing precision with 5 detectors, and funding permitting, a sensitivity improvement of another factor of 1.5 or more by 2025. Fully exploiting the 3- or 4-km infrastructure could lead to an additional factor of 3 sensitivity; gravitational events would likely be several per day, along with an SNR of some 10x better for a given event than today. That could be in place toward the end of the decade. To allow precision measurement of e.g., the Hubble constant, neutron-star binary parameters, and to reach all black-hole binaries in the universe in the mass range of 100 solar masses, would require third generation (‘3G’) gravitational-wave observatories, considerably longer than the current instruments. The very significant investments required would be rewarded with a rich range of astrophysics – both stand-alone and in synergy with electromagnetic and neutrino observations. These instruments could be observing by the mid-2030’s if the groundwork of technical development, engineering studies, and community engagement is undertaken in the 2020’s. They would be a great complement to the supermassive black-hole observations by LISA in the same time frame. We hope there will be a broad range of complementary electromagnetic and neutrino instruments to get the most out of the rich contributions from gravitational waves.

## The Compton Spectrometer and Imager

Clio Sleator (University of California, Berkeley)

### *Abstract*

The Compton Spectrometer and Imager (COSI) is a balloon-borne, soft gamma-ray (0.2-5 MeV) telescope designed to study astrophysical sources. COSI's main science goals are to measure polarization from gamma-ray bursts and compact objects, map the 511 keV positron annihilation line from the Galactic plane and bulge, and image diffuse emission from Galactic nuclear lines. COSI employs a compact Compton telescope design utilizing 12 cross-strip germanium detectors and is inherently sensitive to polarization. In 2016, COSI was launched from Wanaka, New Zealand, and completed a successful 46-day flight on NASA's new Superpressure balloon. COSI is the first science instrument designed to fly on the Superpressure balloon, which provides a potentially powerful new capability for gamma-ray instruments going forward by allowing for ultra-long duration balloon flights. The sources COSI detected during the 2016 flight include GRB 160530A, the 511 keV positron annihilation line from the Galactic plane, and some compact objects including the Crab. Our analysis efforts have so far led to two published papers (Lowell et al., 2017ab), and we are currently refining our analysis of the positron annihilation line and the compact objects. We will present an overview of the instrument, the Superpressure balloon flight, and our analysis of the 2016 flight data. We will also discuss the future flight plans of the COSI instrument.

Space Science at the Intelligence and Space Research Division of Los Alamos National  
Laboratory

Karl Smith (Los Alamos National Laboratory)

*Abstract*

The Intelligence and Space Research (ISR) division at the Los Alamos National Laboratory has been involved in numerous space-based science missions. These missions, which support both civilian and defense-related programs, require ISR to design, build, and operate sensors capable of detecting nuclear emissions and measuring radiations in space including  $\gamma$ -ray, X-ray, charged-particle, and neutron detection. The division has end-to-end capabilities for space-based missions including science definition, mission concept and design, simulation and modeling, construction and qualification, calibration, and data analysis. ISR's expertise in this area comes from a long history, over 50 years, of involvement in monitoring the atmosphere and near-Earth space environment for nuclear detonations, exploring space-weather dynamics, and studying high-energy astrophysics. This long involvement found its beginnings in the construction of Project Vela, which first discovered Gamma-ray Bursts, and continues through involvement with the Gamma-ray Burst Monitor on the Fermi Gamma-ray Space Telescope as well as fast-pointing algorithms and software designed for the Neil Gehrels Swift Observatory. The division's interests cut across a large range of topics including extreme engineering, non-proliferation, space situational awareness, hyperspectral imaging, nuclear physics, material science, space physics, radio science, time-domain astrophysics, and planetary physics.

# The Vast Potential of Exoplanet Satellites for High-Energy Time Domain Astrophysics

Krista Smith (Stanford University - KIPAC)

## *Abstract*

The unmatched photometric precision, monitoring baselines and rapid, even sampling rates required by modern satellites designed for detecting the signal of transiting exoplanets are ideally suited to a large number of applications in high energy astrophysics. These precision instruments are currently underutilized for high energy applications perhaps due simply to lack of intersectional marketing, yet their potential is great. From the groundwork laid by Kepler and its successor, K2, we have learned a great deal about the precautions and considerations required to utilize instruments and data idealized for exoplanet transit searches. I will exemplify this by discussing the results for AGN from Kepler, as well as summarizing additional high-energy results from other areas from Kepler and K2 with an emphasis on accretion. I will then discuss upcoming exoplanet missions and how well they are suited to high energy astrophysical applications based on small differences in their intention and design, with the intention of making their use more accessible to our community.

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

Randall Smith (Smithsonian Astrophysical Observatory)

### *Abstract*

Arcus provides high-resolution soft X-ray spectroscopy in the 12-50Å bandpass with unprecedented sensitivity both in effective area and spectral resolution. The Arcus science goals include (1) measuring the effects of structure formation imprinted upon the hot baryons that are predicted to lie in extended halos around galaxies, groups, and clusters, (2) tracing the propagation of outflowing mass, energy, and momentum from the vicinity of the black hole to extragalactic scales as a measure of their feedback and (3) exploring how stars, circumstellar disks and exoplanet atmospheres form and evolve. Arcus uses 12m focal length grazing-incidence silicon pore X-ray optics (SPO) that ESA has developed for the Athena mission. The focused X-rays from these optics are diffracted by high-efficiency Critical-Angle Transmission gratings and detected with flight-proven CCDs. Both the optics and grating technologies have achieved mission readiness thanks to support from NASA and work by the Arcus and Athena teams. The science requirements have been confirmed using a complete system raytrace, which has also been used to develop the alignment tolerances for the optical system and also to create the complete baseline observing program, ensuring self-consistency throughout. Modest spacecraft power and telemetry combined with straightforward mission planning enables low-cost and robust operations, as most observations will be long (~100 ksec), uninterrupted, and pre-planned.



## Physical Properties Within the Cocoon Shock of Radio Sources

Bradford Snios (SAO)

### *Abstract*

We present a spatial and spectral analysis of the cocoon shock of the archetype FRII radio galaxy Cygnus A using 2 Msec of Chandra exposure. In studying the cocoon shock, we seek to learn interesting physical properties of the shocked medium and radio source. The deep exposure is used to determine an AGN outburst age of 20 Myr and mean outburst power of  $10^{46}$  erg/sec. Weak shocks are measured over most of the cocoon, and the pressure is found to be approximately uniform throughout the bulk of the radio lobes. Using the pressure determinations with observed X-ray jet properties, we find the data to be consistent with light jet models, suggesting that negligible fractions of the kinetic power and momentum flux are carried in the jet by rest mass. We will demonstrate with simulations how proposed X-ray missions will allow us to apply the discussed methods to multiple FRII sources as well as expand on these results through use of high resolution spectroscopy.

## Temporal Variability and Proper Motions in the Jet of Centaurus A

Bradford Snios (SAO)

### *Abstract*

Centaurus A is the nearest, massive, early-type galaxy and has the nearest AGN with an active radio jet. Knotted structures have been observed in Centaurus A's jet in both radio and X-ray bands, and radio observations have shown proper motions for several knots. Investigation of proper motion is also possible in X-rays by exploiting Chandra's excellent spatial resolution. We present evidence of temporal variability and proper motion from Chandra observations of Centaurus A. After careful alignment of the images, difference maps over a 15-year timespan show brightness variations of 35-75% for several larger knots in the jet. These variations are used to estimate magnetic field strengths within the knots. Other knots show an average projected proper motion of  $0.6c$ , or  $0.17''$ , over the baseline, which is consistent with radio observations.

## The Habitable Exoplanet Observatory (HabEx)

Daniel Stern (JPL/ Caltech)

### *Abstract*

HabEx is one of four candidate flagship missions being studied in detail by NASA, to be submitted for consideration to the 2020 Decadal Survey in Astronomy and Astrophysics for possible launch in the 2030s. It will be optimized for direct imaging and spectroscopy of potentially habitable exoplanets, and will also enable a wide range of general astrophysics science. HabEx aims to fully characterize planetary systems around nearby solar-type stars for the first time, including rocky planets, possible water worlds, gas giants, ice giants, and faint circumstellar debris disks. In particular, it will explore our nearest neighbors and search for signs of habitability and biosignatures in the atmospheres of rocky planets in the habitable zones of their parent stars. Such high spatial resolution, high contrast observations require a large (roughly greater than 3.5m), stable, and diffraction-limited optical space telescope. Such a telescope also opens up unique capabilities for studying the formation and evolution of stars and galaxies. We present some preliminary science objectives identified for HabEx by our Science and Technology Definition Team (STDT), together with a first look at the key challenges and design trades ahead.

## Observing the miliHertz Gravitational Wave sky with LISA

James Thorpe (NASA GSFC)

### *Abstract*

The early results from LIGO and VIRGO have excited the scientific community and the general public alike. While these facilities will continue to improve, and even more capable facilities will be developed in the coming decades, ground-based observatories can open only a portion of the gravitational wave spectrum. The Laser Interferometer Space Antenna (LISA) is a space-based observatory targeting the source-rich milliHertz Gravitational Wave band. The mission will consist of a triangular constellation of three identical spacecraft, separated from one another by 2.5 million kilometers and trailing the Earth in a heliocentric orbit at a distance of 60 million kilometers. By employing the drag-free technology demonstrated on LISA Pathfinder along with long-baseline laser interferometry, LISA will be sensitive to gravitational wave strains at the  $10^{-22}$  level for frequencies from 0.1mHz to 1 Hz. The expected sources in these band include millions of compact binaries in the Milky Way, capture of stellar remnant black holes by nuclear black holes in nearby galaxies, and mergers of massive black holes in the distant universe. Selected in 2017 by the European Space Agency (ESA) as a large-class mission in, LISA is currently in formulation with a planned launch in the early 2030s. ESA is joined by NASA and a consortium of European Member States in developing the mission and these same three entities will collaborate to implement the mission. In this talk, I will provide a brief overview of the LISA mission concept, the technologies, and the science case. I will place particular emphasis on potential multi-messenger applications involving LISA and other instruments under consideration for the 2030 timeframe.

# The Latest Results from the Alpha Magnetic Spectrometer on the International Space Station

Samuel Ting (MIT)

## *Abstract*

AMS has collected more than 115 billion charged cosmic rays during its first seven years in space.

## The High-energy Astrophysics SmallSat for Polarization and Positrons

John Tomsick (UC Berkeley/SSL)

### *Abstract*

The High-energy Astrophysics SmallSat for Polarization and Positrons (HASSPP) is a hard X-ray/soft gamma-ray (0.02-5 MeV) mission concept to measure the polarization of pulsars and accreting black holes (stellar mass and Active Galactic Nuclei) and to map the 0.511 MeV electron-positron annihilation emission from the Galactic Center. HASSPP uses Cadmium Zinc Telluride (CZT) detectors that are stacked to increase efficiency for Compton interactions, providing the polarization sensitivity. A  $1 \times 1 \text{ deg}^2$  field of view is obtained using a Tungsten collimator, which, along with shielding surrounding the detector, provides a low background. A 2-year SmallSat mission could obtain polarization measurements for at least a dozen sources and could also regularly monitor bright sources like the Crab and Cyg X-1 to look for changes in polarization strength or angle. In addition, such a mission would provide a 0.511 MeV map covering  $>25 \text{ deg}^2$  around Sgr A\* to determine if it is a positron source. The main technology development that would be required to fly HASSPP in the 2020s is to configure the CZT detectors in a stacked configuration. Here, we describe the mission concept, the science it could enable, and a potential plan to develop the stacked CZT.

## The Compton Spectrometer and Imager project: Covering the MeV band using Germanium Detectors

John Tomsick (UC Berkeley/SSL)

### *Abstract*

The Compton Spectrometer and Imager is a 0.2-5 MeV Compton telescope capable of imaging, spectroscopy, and polarimetry of astrophysical sources. Such capabilities are made possible by COSI's 12 germanium cross-strip detectors, which provide for high efficiency, high resolution spectroscopy, and precise 3D positioning of photon interactions. In 2016, COSI had a successful flight from New Zealand on a NASA super pressure balloon. The instrument functioned well during the 46 day flight, and the payload was recovered in Peru. Science results from the flight include imaging and spectroscopy of the positron annihilation emission in the Galactic Center, polarization constraints for a gamma-ray burst, and studies of the Crab nebula and accreting black holes. In this presentation, we will discuss the technical advances that were made for COSI as well as further advances that are planned for an major upgrade to our balloon payload, COSI-X. Although long flights with the super pressure balloon enable significant scientific advances, we have also studied satellite mission concepts, and we will discuss future possibilities.

## Some Suggestions for 1 keV Science for a compelling Major Mission

Melville Ulmer (Northwestern Univ.)

### *Abstract*

The Lynx STDT has suggested reducing the maximum energy to about 1keV from about 7 keV (for Chandra). This top energy range, plus if we reduce the requirement of the collecting area to 10x Chandra, reduces the requirement for increased surface area over Chandra from 10x Chandra to about 1/7 times 10x Chandra or only about 30 m<sup>2</sup> total. Furthermore, we suggest that advances in electronics, cryo-coolers and the like make it plausible to fill the FOV of the telescope with a mega-pixel TES camera. We discuss some of the exciting science than can be done with such a mission. This includes addressing Dark Matter, Dark Energy, and X-ray flare frequency related to M stars' habitable zones.



## Arcus: Observatory Science

Lynne Valencic (Johns Hopkins Univ.)

### *Abstract*

Arcus is a free-flying MIDEX satellite selected for Phase A and set to launch in 2023. Its bandpass ( $\sim 10\text{-}50 \text{ \AA}$ ), high resolution ( $R > 2500$  between  $22\text{-}25 \text{ \AA}$ ), and effective area ( $\sim 350 \text{ cm}^2$  between  $22\text{-}25 \text{ \AA}$ ) make it ideal for studying numerous systems after its baseline mission concludes. Hot star winds show strong but poorly understood variable spectra, as do cataclysmic variables and super-soft sources that may be the progenitors of Type Ia supernovae, while the nature of the ISM still not well known. Arcus will also allow observations of small extended sources like supernova remnants.

## Probing Cosmic-ray Physics in Star-forming Galaxies With Future High-Energy Missions

Tonia Venters (NASA Goddard Space Flight Center)

### *Abstract*

Cosmic ray feedback on a galaxy's interstellar medium (ISM) can substantially influence the galaxy's formation and evolution. Cosmic rays ionize and heat the ISM, regulating star formation. Cosmic-ray transport can also result in galactic winds that will drive material out of galaxy disks and enrich the intergalactic medium. In order to assess the influence of cosmic ray feedback (relative to other types of feedback) in driving the conditions for galaxy formation and evolution, we need to better understand the complex interplay among cosmic rays, galaxy magnetic fields, and the ISM (the CR-B-ISM relationship) in a variety of interstellar environments. The sole means for probing cosmic-ray physics in other galaxies is through the byproducts of their interactions with gas and radiation in their environments, including the broadband non-thermal diffuse spectrum observable from hard X-rays to TeV gamma rays. Observations of nearby galaxies by Fermi in the GeV band and Imaging Atmospheric Cherenkov Telescopes in the TeV band have resulted in the first detections of non-AGN galaxies outside of the Milky Way. Recent NuSTAR observations of starburst galaxies such as NGC 253 and M82 enable the most sensitive search to date for their diffuse inverse Compton emission in the hard X-ray band (10-30 keV). Such extremely deep observations are made with very long exposures and are currently only available for very nearby galaxies; however, they provide a glimpse of what we may expect from next-generation facilities. In this talk, I will discuss the latest results from high-energy observations of nearby star-forming galaxies, including the connection between the gamma-ray, radio, and far-infrared emission. I will discuss the implications of these results for these galaxies' cosmic ray populations. Finally, I will set the stage for next generation high-energy facilities, including (but not limited to) HEX-P, FORCE, AMEGO, CTA, and IceCube-Gen2.

## Origins Space Telescope

Joaquin Vieira (University of Illinois at Urbana-Champaign)

### *Abstract*

The Origins Space Telescope (OST) is the mission concept for the Far-Infrared Surveyor, a study in development by NASA in preparation for the 2020 Astronomy and Astrophysics Decadal Survey. Origins is planned to be a large aperture, actively-cooled telescope covering a wide span of the mid- to far-infrared spectrum. Its spectrographs will enable 3D surveys of the sky that will discover and characterize the most distant galaxies, Milky-Way, exoplanets, and the outer reaches of our Solar system. Origins will enable flagship-quality general observing programs led by the astronomical community in the 2030s. The Science and Technology Definition Team (STDT) would like to hear your science needs and ideas for this mission. The team can be contacted at [firsurveyor\\_info@lists.ipac.caltech.edu](mailto:firsurveyor_info@lists.ipac.caltech.edu). This presentation will provide a summary of the OST STDT, our completed first mission concept and an introduction to the second concept that will be studied at the study center in 2018. This presentation will also summarize key science drivers and the key study milestones between 2018 and 2020.

# The Southern Gamma Survey Observatory: The Case for a Next-Generation Very High Energy Survey Instrument in the Southern Hemisphere

Thomas Weisgarber (University of Wisconsin - Madison)

## *Abstract*

Ground-based very high energy (VHE) survey instruments, such as HAWC and its predecessors Milagro and ARGO-YBJ, have been highly successful in using northern hemisphere observations to broaden our understanding of both Galactic and extragalactic sources of particles in the TeV energy band. With their wide fields of view and continuous monitoring capabilities, these observatories have also proven to be valuable complements to the imaging atmospheric Cherenkov telescopes (IACTs), which are more sensitive but have limited fields of view and cannot observe during daylight. The success and complementarity of these ground-based observatories motivate the development of the next-generation Southern Gamma Survey Observatory (SGSO), a proposed instrument to be constructed at an altitude of  $>4.5$  km in the southern hemisphere. SGSO will expand existing VHE survey capabilities to the southern hemisphere, improve substantially upon the sensitivity of previous instruments, and complement the upcoming CTA project in a manner similar to the current interplay between HAWC and the IACTs. In this talk, I will present the science case for SGSO, including five primary science drivers: (1) A survey of the Galactic plane, including a search for highly extended objects and a survey in the 100-TeV energy range and beyond. (2) An extragalactic monitoring program aimed at understanding the nature of high-energy particle acceleration in blazars. (3) Observations of gamma ray bursts, particularly those coincident with gravitational wave events, to further constrain theoretical models for their emission mechanisms. (4) A search for dark matter annihilation or decay from the numerous, nearby dwarf galaxies and the extended halo around the Galactic center. (5) Exploring the origin of the cosmic-ray anisotropy discovered by the northern hemisphere observatories and completing the cosmic-ray sky map at TeV energies. I will also highlight the role that SGSO will play in identifying electromagnetic counterparts to neutrino and gravitational wave sources in the era of multimessenger astronomy newly opened by IceCube, ANTARES/KM3NeT, LIGO/Virgo, and similar instruments.

## The Imaging X-ray Explorer (IXPE)

Martin Weisskopf (NASA/MSFC)

### *Abstract*

The Imaging X-ray Explorer (IXPE) will be the next in the line of NASA's Small Explorer Missions. Selected in 2017 January, IXPE is planned to be launched into an equatorial orbit in 2021 April. IXPE will study the x-ray polarization properties of dozens of sources per year, representing several source categories: Active Galactic Nuclei (AGN); Microquasars; Radio Pulsars and Pulsar Wind Nebulae (PWNe); Supernova Remnants (SNR); Magnetars; and Accreting X-ray Pulsars. Besides obtaining spectro-polarimetry at moderate (proportional-counter) energy resolution, IXPE will conduct phase-resolved polarimetry of bright (isolated and accreting) pulsars, as well as imaging x-ray polarimetry of the brightest extended sources (e.g., PWNe and SNR). In partnership with the Agenzia Spaziale Italiana (ASI), NASA and prime contractor Ball Aerospace will design, develop, integrate, test, commission, and operate the IXPE Observatory. NASA Marshall Space Flight Center (MSFC) provides project leadership, x-ray mirror assemblies, x-ray performance testing and calibration, and the Science Operations Center (SOC). ASI provides the Malindi ground station, software support to the SOC, and funding for the polarization-sensitive x-ray detectors from Istituto di Astrofisica e Planetologia Spaziali/Istituto Nazionale di Astrofisica and Istituto Nazionale di Fisica Nucleare at Pisa and Torino. Ball Aerospace provides the spacecraft, payload alignment and assembly, integration and testing, and the Mission Operations Center (MOC) through the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP).

## Supernova Remnant Science with AXIS

Brian Williams (Space Telescope Science Institute)

### *Abstract*

We present an overview of the supernova remnant (SNR) science that will be achieved with the Advanced X-ray Imaging Satellite (AXIS). AXIS follows in the footsteps of the spectacularly successful Chandra X-ray Observatory with similar or higher angular resolution and an order of magnitude more collecting area in the 0.3-10 keV band. These capabilities enable major advances in several areas of SNR science. These include, but are not limited to: 1) a more thorough spatial mapping of the ejecta products of both intermediate-mass and iron-group elements in core-collapse and Type Ia SNRs, particularly in remnants with a small diameter. The iron-group elements, specifically Cr, Mn, and Ni, are extremely important for constraining the explosion mechanism for SNe, but are generally weak and difficult to detect with Chandra, XMM-Newton, and Suzaku. 2) Studying the interface of a shock wave with the ambient ISM/CSM to constrain the degree of particle heating and acceleration at shock fronts. Chandra has only provided upper limits on shock precursor emission, and a detailed study of the thermal and nonthermal emission at the shock with greatly increased photon count rates will constrain the properties of the immediate post-shock plasma. 3) A high spatial resolution X-ray observatory will continue to build on the legacy begun by Chandra of studying the proper motion of young remnants. Directly measuring the dynamics of an SNR's evolution is crucial for understanding the explosion mechanism, and with the order of magnitude increase collecting area, we can measure the expansion of individual elemental species in the ejecta. 4) We will greatly increase the statistics of SNRs in nearby galaxies, going much faster and deeper than Chandra's observations. The increased depth of coverage would allow us to do spectroscopy in places where it was previously possible only to do rudimentary statistics. We can compare the local SNR population with the local star-formation rates for galaxies, important for supernova progenitor models. Finally, there is significant ancillary science that can be achieved by surveying nearby galaxies.

# The Cherenkov Telescope Array: The Future of Very-High-Energy Gamma-Ray Astrophysics

David Williams (UC, Santa Cruz)

## *Abstract*

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

# STROBE-X: X-ray Timing & Spectroscopy on Dynamical Timescales from Microseconds to Years

Colleen Wilson-Hodge (NASA/MSFC)

## *Abstract*

We describe a probe-class mission concept that provides an unprecedented view of the X-ray sky, performing timing and 0.2-30 keV spectroscopy over timescales from microseconds to years. The Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X) comprises three primary instruments. The first uses an array of lightweight optics (3-m focal length) that concentrate incident photons onto solid state detectors with CCD-level (85-130 eV) energy resolution, 100 ns time resolution, and low background rates to cover the 0.2-12 keV band. This technology is scaled up from NICER, with enhanced optics to take advantage of the longer focal length of STROBE-X. The second uses large-area collimated silicon drift detectors, developed for ESA's LOFT, to cover the 2-30 keV band. These two instruments each provide an order of magnitude improvement in effective area compared with NICER and RXTE, respectively. Finally, a sensitive sky monitor triggers pointed observations, provides high duty cycle, high time resolution, high spectral resolution monitoring of the X-ray sky with  $\sim 20$  times the sensitivity of the RXTE ASM, and enables multi-wavelength and multi-messenger studies on a continuous, rather than scanning basis. We include updated instrument designs resulting from the GSFC IDL run in November 2017. For the first time, the broad coverage provides simultaneous study of thermal components, non-thermal components, iron lines, and reflection features from a single platform for accreting black holes at all scales. The enormous collecting area allows detailed studies of the dense matter equation of state using both thermal emission from rotation-powered pulsars and harder emission from X-ray burst oscillations. The combination of the wide-field monitor and the sensitive pointed instruments enables observations of potential electromagnetic counterparts to LIGO/Virgo and neutrino events. Extragalactic science, such as constraining bulk metallicity of medium to high redshift clusters and nearby compact groups and unprecedented timing investigations of active galactic nuclei, is also obtained.



## AMEGO: A First Look at the MeV Emission from Local Seyfert Active Galaxies

Lisa Winter (Los Alamos National Laboratory)

### *Abstract*

The NASA concept probe mission, the All-Sky Medium Energy Gamma-ray Observatory (AMEGO), will observe a previously poorly studied energy band from 200 keV to greater than 10 GeV. AMEGO will reveal new details about Seyfert Galaxies and potentially detect hundreds of new MeV AGN. Previous efforts to view the MeV range with the Imaging Compton Telescope (COMPTEL) did not have high enough sensitivity to study the non-thermal tail of electron distribution for black hole systems. The non-thermal tail is important to understand the processes relating to temperature regulation of the hot corona surrounding the black hole accretion disk. AMEGO can reveal the non-thermal tail, which may be caused by gamma-gamma pair production or reconnection. With AMEGO's increased sensitivity and broad MeV energy range, the MeV emission spectra of a large sample of Seyfert Galaxies can be observed for the first time.

## Time-domain Astronomy with the Advanced X-ray Imaging Satellite

Lisa Winter (Los Alamos National Laboratory)

### *Abstract*

The Advanced X-ray Imaging Satellite (AXIS) is a concept NASA Probe class mission that will enable time-domain X-ray observations after the conclusion of the successful Swift Gamma-ray burst mission. AXIS will achieve rapid response, like Swift, with an improved X-ray monitoring capability through high angular resolution (similar to the 0.5 arc sec resolution of the Chandra X-ray Observatory) and high sensitivity (ten times the Chandra count rate) observations in the 0.3-10 keV band. In the up-coming decades, AXIS's fast slew rate will provide the only rapid X-ray capability to study explosive transient events. Increased ground-based monitoring with next-generation survey telescopes like the Large Synoptic Survey Telescope will provide a revolution in transient science through the discovery of many new known and unknown phenomena – requiring AXIS follow-ups to establish the highest energy emission from these events. This synergy between AXIS and ground-based detections will constrain the rapid rise through decline in energetic emission from numerous transients including: supernova shock breakout winds, gamma-ray burst X-ray afterglows, ionized gas resulting from the activation of a hidden massive black hole in tidal disruption events, and intense flares from magnetic reconnection processes in stellar coronae. Additionally, the combination of high sensitivity and angular resolution will allow deeper and more precise monitoring for prompt X-ray signatures associated with gravitational wave detections. We present a summary of time-domain science with AXIS, highlighting its capabilities and expected scientific gains from rapid high quality X-ray imaging of transient phenomena.

## Arcus: Exploring exoplanets in X-rays

Scott Wolk (SAO)

### *Abstract*

Arcus is a NASA/MIDEX mission under development in phase A. It is a freeflying, soft X-ray grating spectrometer with the highest-ever spectral resolution in the 8-51 Å (0.24 - 1.55 keV) energy range. The Arcus bandpass includes the most sensitive tracers of diffuse million-degree gas: spectral lines from O VII and O VIII, H- and He-like lines of C, N, Ne and Mg, and unique density- and temperature-sensitive lines from Si and Fe ions. The high effective area and low noise in the lines make it well suited to the investigation of exoplanet atmospheres. Hot Jupiters can form extended evaporating atmospheres (to 1.7 optical radii). The density and extent of high-altitude atmospheric layers can be studied with Arcus through energy-resolved transit observations sensitive to different elements. Soft X-ray photons are absorbed by low column densities in the atmosphere, causing deep transit light curves, while harder X-rays probe yet deeper layers. While relatively few X-ray bright exoplanet hosts are now known today, the list will be greatly increased by TESS, which conduct an all-sky survey for transiting exoplanets.

## Impact of Next Generation Instruments on the Search for Galactic Neutrino Sources

Joshua Wood (University of Wisconsin-Madison)

### *Abstract*

Searches for Galactic neutrino sources have often relied upon extrapolating gamma-ray measurements at lower energies to higher energies where the IceCube and ANTARES neutrino observatories are most sensitive. However, new results from the High Altitude Water Cherenkov Observatory (HAWC) have provided for the first time gamma-ray measurements of the Galactic plane above 50 TeV which should directly correspond to observable neutrinos in current experiments assuming these photons have a hadronic origin. In this presentation we will discuss the current sensitivity of IceCube to the HAWC measurement above 50 TeV and explore the impact of upgrades to HAWC and IceCube-Gen2 as well as the planned Southern Gamma Survey Observatory (SGSO) on the search for Galactic neutrino sources.

## Testing for black holes in globular clusters with X-ray observations

Steve Zepf (Michigan State Univ.)

### *Abstract*

The question whether globular clusters host black holes has been of longstanding interest. This interest has grown dramatically with the LIGO detection of merging black holes, as black hole mergers in globular clusters are one of the leading explanations for these LIGO sources. However, determining whether black holes are common in globular clusters and if so what are their typical masses has been an observational challenge. One of the most successful ways to identify candidate black holes in globular clusters is to identify globular cluster X-ray sources with very high luminosities that are much greater than the Eddington limit for neutron stars. However, observations of luminous X-ray sources in star forming regions have shown that at least in these young systems neutron star accretors can be extraordinarily bright. In this contribution we discuss ways to compare these to two classes of objects, both with current data and future missions, with the ultimate goal of determining whether black holes are common in globular clusters and plausible sources for black hole mergers observed in gravitational waves.

## Multi-wavelength polarimetry of blazar jets: theoretical predictions and observability

Haocheng Zhang (Purdue University)

### *Abstract*

Multi-wavelength polarimetry will be a great opportunity for the high-energy astrophysics in the 2020s. For astrophysical jets, radio and optical polarimetry have already been very successful, as demonstrated by the recent suggested connection between optical polarization angle swings and blazar gamma-ray flares. This indicates that the magnetic field can actively participate in the particle acceleration process. With the selection of IXPE and several other X-ray and MeV polarimeters in the proposal phase, it is a good time to explore in detail the potential of high-energy polarization signatures and their observability by current instruments. Here we will present theoretical predictions of the blazar multi-wavelength polarization signatures and the observing strategy based on the capability of the high-energy polarimeters. From the theoretical aspect, in a realistic partially ordered magnetic field, we find that the hadronic blazar model predicts a similar polarization degree for the high-energy radiation as the optical counterparts, while the leptonic model generally predicts less than half of that. Therefore, simultaneous optical polarization degree and detection/upper limits set by the high-energy polarimeters can distinguish the leptonic and hadronic models. We will further illustrate that, although blazar flares due to shocks, magnetic reconnection events, or magnetic turbulence, exhibit similar spectra and light curves, they can be distinguished through their drastically different multi-wavelength polarization signatures. These signatures are likely to be observable with current-generation high-energy polarimeters. Observationally, our study suggests that multi-wavelength polarimetry expects better scientific returns if triggered by flaring events instead of long-term monitoring. This is because the high-energy polarization is likely to be strong and very stable during blazar flares, and simultaneous radio and optical polarization signatures can best constrain the blazar jet physics.

## Diverse Origin of Galactic Center Non-thermal X-ray Filaments

Shuo Zhang (MIT)

### *Abstract*

A unique phenomenon of the Galactic center region is the existence of numerous non-thermal filamentary structures, whose source nature has been under debate. The NuSTAR Galactic center and Galactic plane observation campaign has allowed us to detect four non-thermal X-ray filaments above 10 keV: G359.89-0.08 or Sgr A-E, G359.97-0.038, G0.13-0.11 and G359.95-0.04. These hard X-ray filaments are among the brightest in the soft X-ray band of 2-8 keV, with luminosities above  $8 \times 10^{32}$  erg/s at a distance of 8 kpc. The broadband 3-79 keV NuSTAR data points to a diverse origin for these filamentary structures: Sgr A-E is best explained by a magnetic flux tube trapping 100 TeV cosmic-ray electrons; G359.97-0.038 can be best interpreted as Sgr A East interacting with the 50 km/s cloud; G0.13-0.11 and G359.95-0.04 are pulsar wind nebula candidates. High throughput and high angular resolution allowed by the next generation X-ray telescopes like Lynx will be able to probe more fainter X-ray filaments, reveal their sub-structures and answer whether there is dominant source origin for this unique type of sources.

# Silicon Meta-Shell X-ray Optics for Astronomical Missions: High Resolution, Light Weight, and Low Cost

William Zhang (NASA's GSFC)

## *Abstract*

Future X-ray observatories in the 2020s and 2030s, from small Explorers to flagships, require telescopes of unprecedented angular resolution and effective area. Yet they must still fit under stringent launch and budgetary envelopes, which mean that these telescopes must be lightweight and of very low production cost per unit effective area. In this paper we describe an approach that can meet those manifold requirements. The approach is based on precision polishing of single-crystal silicon, which has the potential of achieving the highest possible angular resolution and lowest possible weight. In combination with a mass-production process, it also has the potential of achieving the lowest possible cost per unit effective area. Adopting the traditional philosophy of minimizing constraints, we align and bond each mirror segment at four locations, which are optimized for minimal distortion under gravity and after gravity release, to form meta-shells. The salient features of the meta-shells are that they are optically precise and structurally stiff and that they preserve the axial symmetry of X-ray optics, affording easy and accurate integration into final mirror assemblies. We will describe the motivation for this approach, its development status, and its prospects for enabling both near-term and long-term X-ray astronomical missions, including OGRE, STAR-X, FORCE, HEX-P, TAP, AXIS, and Lynx.



## Observing Extended TeV Gamma-Ray Structures with HAWC

Hao Zhou (Los Alamos National Laboratory)

### *Abstract*

The High Altitude Water Cherenkov (HAWC) Observatory, located in central Mexico at 4100 m above sea level, is sensitive to gamma rays between a few hundreds GeV and  $>100$  TeV. Thanks to its large field of view of 2 steradians, HAWC has a unique capability to observe large extended TeV gamma-ray structures such as nearby pulsar wind nebulae and Galactic diffuse emission. The HAWC collaboration recently reported the discovery of TeV gamma-ray emission extending several degrees around two nearby middle-aged pulsars Geminga and B0656+14. The morphological and spectral studies on these two sources provide a direct measurement on the diffusion coefficient of particles and thus constrain the origin of local positron excess. We will present the HAWC observations on these nearby pulsar wind nebulae and the diffuse emission in the Galactic plane, as well as a perspective on future wide-field-of-view TeV gamma-ray experiments such as Large High Altitude Air Shower Observatory (LHAASO) and planned Southern Gamma Survey Observatory (SGSO).

## A New Chandra Perspective of X-ray-Emitting, Close Binaries in the Nuclear Star Cluster

Zhenlin Zhu (Nanjing University)

### *Abstract*

Based on decade-long, ultra-deep Chandra observations toward the Nuclear Star Cluster (NSC), we study the statistical (temporal, spectral, spatial) properties of  $\sim 3600$  X-ray sources, presumably close binary systems that form and evolve in one of the most dynamic environments in our Galaxy. The vast majority of the X-ray sources, detected down to a luminosity of  $10^{31}$  erg/s, exhibit little long-term variability; a dozen sources, on the other hand, have been identified as transients. The equivalent width and relative strength of the iron lines, measured from the cumulative source spectrum, suggest that these sources primarily comprise of magnetic and non-magnetic cataclysmic variables, in comparable numbers. These sources have a radial distribution closely following the near-infrared starlight, which places a strong constraint on the number of dynamically-formed close binaries within the NSC.

## X-ray Reverberation in the Next Decade

Abderahmen Zoghbi (University of Michigan)

### *Abstract*

X-ray reverberation focuses on using time delays in X-ray to probe the immediate environments of accreting black holes. Work in the last a few years allowed the first detections and characterization of such delays in AGN and Galactic black holes. Here, I will summarize the latest results from several campaigns with XMM-Newton and NuSTAR, and discuss the outlook for the next decade.

## Determining the Performance of Future High-energy Space Missions with MEGAlib

Andreas Zoglauer (Space Sciences Lab / UC Berkeley)

### *Abstract*

The Medium-Energy Gamma-ray Astronomy library (MEGAlib, <http://megalibtoolkit.com>) is a set of software tools for the simulation and data analysis of hard X-ray and gamma-ray instruments used for astrophysical as well as terrestrial applications. The library includes all necessary data analysis tools for calibrations (Fretalon framework), for simulating data in space and terrestrial radiation environments (Cosima), visualizing detectors and events (Geomega, Eview), creating various response files (Responsecreator), reconstructing events using conventional and machine learning tools (Revan), performing high-level analysis such as image reconstruction (Mimrec), and many more. MEGAlib is open source (<https://github.com/zoglauer/megalib>), has a completely object-oriented design, is written in C++, and is based on ROOT and Geant4. MEGAlib was from the ground up designed to be able to simulate a wide variety of instruments and technologies in the space radiation environment. This makes MEGAlib the perfect tool to determine the performance (e.g. sensitivity, effective area) of such instruments and perform trade-off studies between various designs and technologies. MEGAlib has been applied to a wide range of past (e.g. COMPTEL, MEGA, NCT, Hitomi), existing (e.g. COSI, GRIPS, NuSTAR), under construction (e.g. COSI-X, ComPair, BurstCube), and envisioned (e.g. AMEGO, eASTROGAM) instruments. In the presentation, we will give an overview of the general and newly developed capabilities (such as machine learning based analysis, improved image deconvolution) of MEGAlib with emphasis on the capabilities applicable to perform trade-off studies and performance estimates for future high-energy space missions.