The High Energy Astrophysics Division Newsletter

In this Issue:

From the Chair

ROB PETRE (NASA/GSFC)

I'd like to thank everyone who made our March HEAD meeting in Monterey a great success. The meeting provided an opportunity to celebrate our 50th anniversary in style, with uniformly excellent talks during both the regular and special sessions, a remarkable number of outstanding posters, and well-attended social events. The HEAD Executive Committee deserve congratulations for constructing an exciting program, and the support staff at AAS headquarters for handling the logistics. Special thanks go to HEAD Secretary Mike Corcoran and AAS meetings coordinator Elizabeth Scuderi who did the heavy lifting.

At the meeting, we welcomed the newly elected Executive Committee members. Mike Corcoran was reelected to a second term as Secretary. Frits Paerels takes over as Treasurer. Joining the Executive Committee as at-large members are Erin Kara and Alexander van der Horst. I'd like to express the gratitude of the Division to all who stood for office; we had a strong slate of candidates. Also, on behalf of the rest of the executive committee and the entire HEAD membership, I'd like to thank outgoing Treasurer Keith Arnaud and Executive Committee members Laura Lopez and Niel Brandt for their outstanding service.

We also introduced a revision of the HEAD bylaws. In addition to cosmetic changes, such as removal of unnecessary sections and properly referring to the AAS governing body, the revised bylaws contain an update of the process for filling a vacant Vice Chair position consistent with the current six-year Chair cycle (Vice Chair – Chair – Past Chair) and an update of membership classes consistent with those defined by the AAS. A subsequent vote by the membership led to overwhelming passage of the bylaws. I'm extremely grateful to the Executive Committee for developing the revisions.

Some of the items dropped from the by-laws will be incorporated into a new "policies and procedures" document. This document will capture the HEAD workings that are not detailed to the bylaws, including the division prize nomination and selection process, organization of HEAD meetings, and the Executive Committee nomination process. This document is in the early stages of formulation; it is hoped that a draft will be made available for membership comment by the end of the year.

The Division is also planning to introduce one or more new awards to supplement our current set: the dissertation award, the mid-career award, and the Bruno Rossi Prize. The Executive Committee will be soliciting suggestions through a questionnaire that we plan to make available in the next few weeks. We encourage you to send us your ideas. We hope to develop a substantive proposal for new awards by the next HEAD business meeting at the January 2020 AAS meeting.

This year, in addition to celebrating our 50th anniversary, we passed a second major milestone: HEAD membership has now surpassed the 1,000 mark. The HEAD is the second largest of the six AAS divisions, and is under-

going healthy membership growth.

Finally, I'd like to encourage all of you to participate in the 2020 Decadal Survey of Astronomy and Astrophysics. Even though there were no presentations about it at the Monterey meeting, the Decadal Survey was a topic of frequent discussion, for good reason. It is the most important strategic planning activity for our field. Not only is it essential that we all pay close attention to it, but we all need to take advantage of the opportunities to provide input. *Fermi*, the youngest high energy mission named in a decadal survey, just celebrated its 10th year in orbit. The April 2018 meeting demonstrated that there exist a large number of excellent concepts for large and medium class high energy astrophysics missions. Our future as a field depends critically on successful advocacy for our science and for the missions that enable our science. Please take the opportunity to participate in the process.

HEADlines

MEGAN WATZKE (CXC)

On April 10th, press conferences were held simultaneously around the world to announce the results from the Event Horizon Telescope. The image of the shadow of the supermassive black hole at the center of M87 became arguably the largest news story ever from a singular astrophysical release, being draped across the front pages of the world's largest newspapers, on televisions screens around the globe, and in social media feeds everywhere. HEAD missions, including *Chandra* and *NuSTAR*, played a supporting role in coordinated observations during the April 2017 EHT run, and this was included in some of the media coverage of story. As the EHT prepares future announcements, there should be more opportunities to connect it with other high-energy astrophysics results and missions.

On December 9, 2018, high-energy astrophysics and astronomy as a whole lost one of its giants with the passing of Riccardo Giacconi. Befittingly, there were obituaries in media outlets around the globe commemorating his life and career, including the Boston Globe, New York Times, The Washington Post, and many more. A Memorial Symposium to celebrate the Riccardo's life and work, organized by The Space Telescope Science Institute, Center for Astrophysics | Harvard & Smithsonian, the Johns Hopkins University, European Southern Observatory, and Associated Universities, Inc. will take place at the National Academy of Science, Washington, DC, this June.

In other media matters, Schramm winner Josh Sokol gave an excellent talk to the HEAD meeting in Monterey about how he and other journalists cover high-energy astrophysics and science in general.

As always, HEAD missions produced a slew of news throughout the past six months. Some of the press releases covering our division were:

November 19, 2018 "From Gamma rays to X-rays: New Method Pinpoints Previously Unnoticed Pulsar Emission"

December 13, 2018 "A Hero for a Heroic Age"

December 17, 2019 "The Faintest Edge of the Violent Universe Revealed Through its Tiny Fluctuations"

January 9, 2019 "Shredded Star Leads to Important Black Hole Discovery"

January 10, 2019 "Holy Cow! Mysterious Blast Studied with NASA Telescopes"

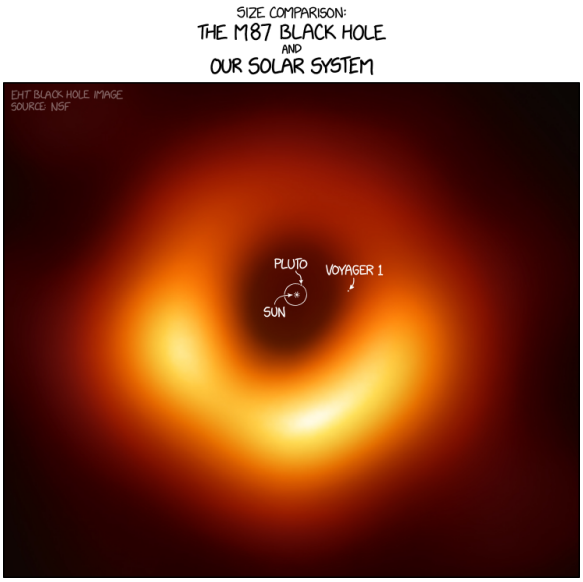
February 14, 2019 "Where is the Universe Hiding its Missing Mass?"

February 20, 2019 "In Colliding Galaxies, a Pipsqueak Shines Bright"

March 19, 2019 "NASA's *Fermi* Clocks 'Cannonball Pulsar' Speeding through Space"

March 20, 2019 "Giant 'Chimneys' Vent X-rays from Milky Way's Core"

April 10, 2019 "Black Hole Images Makes History: NASA Telescopes Coordinated Observations"



The XKCD perspective on the Event Horizon Telescope image of the supermassive black hole in M87. Credit: Randall Munroe/XKCD.

LIGO-VIRGO Scientific Collaborations

PATRICK BRADY (UNIVERSITY OF WISCONSIN. MILWAUKEE), DAVID SHOEMAKER (MIT), AND GUIDO MUELLER (UNIVERSITY OF FLORIDA)

LIGO and *VIRGO* resumed their hunt for gravitational waves on April 1, after receiving a series of upgrades

to its lasers, mirrors, and other components. The combined *LIGO* detectors increased their sensitivity by about 40 percent over their last run while *VIRGO* almost doubled its sensitivity. These improvements led to four significant alerts in the first month of observing – a detection rate of one per week. This is at the upper range of the anticipated detection rate. The O3 observing run is planned to last about 1 year, and the Japanese KAGRA detector intends to join the run for the final months growing the network to 4 detectors.

The strain data from the preceding science run (O2) have been released and are now available through the Gravitational Wave Open Science Center. The O2 observing run began on November 30, 2016 and ended on August 25, 2017. Observations in O2 include seven binary black hole mergers, as well as the first binary neutron star merger observed in gravitational waves, all recently published with the GWTC-1 catalog. Along with the strain data, the release contains detailed documentation and links to open source software tools.

On February 15, 2019, the NSF, along with UK and Australian funding agencies, announced the funding of an additional upgrade of the twin *LIGO* detectors. Advanced *LIGO* Plus (or A+) will use frequency-dependent squeezed light and new mirror coatings to further increase the sensitivity and the probed volume for coalescing binaries by a factor of 5 to 8 (depending on the astrophysical source characteristics). This will not only lead to an increase in the expected detection rate to potentially once per day but also allow greater precision in tests of general relativity and improve our understanding of neutron star physics. It is expected that this upgrade will be ready for observing in 2024. *VIRGO* is planning a similar upgrade, and *LIGO* India – a 3rd Advanced *LIGO* detector – will come online in 2025.

The Gravitational Wave International Committee (GWIC) has spawned a subcommittee to assess the astrophysics, instrument science, and governance of next generation observatories and their detectors. This work has led to a number of Decadal White Papers which will be issued as a report in summer 2019.

Patrick Brady of the University of Wisconsin Milwaukee has been elected spokesperson of the *LIGO* Scientific Collaboration. He succeeds outgoing spokesperson David Shoemaker.

The Laser Interferometer Space Antenna Ira Thorpe (NASA/GSFC), Guido Mueller (University of Florida), Michele Vallisneri (JPL)

Steady progress continues in the development of the Laser Interferometer Space Antenna (*LISA*) mission. The European Space Agency-led *LISA* project is currently undergoing a mid-Phase A review to assess progress on the detailed design of the mission. One part of this review will examine design concepts for the *LISA* spacecraft that have been developed in parallel studies with two European industrial partners. A second part of this review will cover the detailed design of the *LISA* instrument, the development of which is being led by the *LISA* Consortium, supported by and in collaboration with a group of European National agencies, industrial partners, ESA, and NASA. Both portions of the review are expected to be completed in 2019.

NASA is contributing to the *LISA* design effort through the development of a number of subsystems for potential contribution to the ESA-led mission. These include a telescope system for mitigating diffraction losses across the long *LISA* baselines, a stabilized laser system, a non-contact charge management system based on the UV photoelectric effect for controlling electric charge on the freely-flying *LISA* test masses, an electric micropropulsion system leveraging heritage from the ST7 mission, and a high-fidelity heterodyne receiver (aka "phasemeter") for measuring and processing the interformetric signals generated on the *LISA* optical bench. NASA and ESA are also investigating options for additional spacecraft elements which could form part of the eventual NASA contribution. A final agreement on roles and responsibilities will be secured near ESA's Mission Adoption milestone, currently expected in the early 2020s. In the meantime, the ESA, NASA, and Consortium instrument teams are working closely together to ensure that the tightly-integrated *LISA* measurement system is being developed in a coordinated fashion,.

The *LISA* Consortium has established itself as the focal point of the international *LISA* science community. The Consortium now includes over 1000 members in more than 20 different countries. In addition to contributions on payload design, the *LISA* Consortium will contribute to the development of data analysis tools and the scientific exploitation of the *LISA* data. The Consortium gathered at the University of Florida in late April for their 4th collaboration meeting where they worked to coordinate activities and discuss progress in each of these areas. Researchers interested in joining the Consortium should visit the *LISA* consortium website.

The attention of the *LISA* community in the US is particularly focused on the 2020 Decadal Survey of Astronomy and Astrophysics. While the Astro2020 Statement of Task established *LISA* as part of NASA's program of record and emphasized that *LISA* need not be ranked, it also invited Astro2020 to comment on the current scope of NASA's activities and potentially make recommendations for changes. The US *LISA* community believes that an increased NASA role in *LISA* science and instrumentation would benefit both the US astrophysics community as well as the *LISA* mission as a whole. The NASA *LISA* Study Team (NLST), a US community team that provides input to NASA on *LISA* science, developed a dozen white papers on elements of the *LISA* science case, many of them in collaboration with colleagues in other areas of astrophysics including electromagnetic observers, computational modelers, and theorists. These whitepapers are

available on the NASA *LISA* website. The NLST is continuing to coordinate Astro2020 activities including submissions to the Activities, Projects, and state of the profession Consideration (APC) call as well as participation in town halls and other activities. Researchers interested in NLST activities should contact the NLST chair, Kelly Holley Bockelmann (k.holley@vanderbilt.edu).

IceCube

KAEL HANSON, WIPAC DIRECTOR AND PI OF THE ICECUBE UPGRADE PROJECT (UNIVERSITY OF WISCONSIN, MADISON)

The IceCube Neutrino Observatory will remain the preeminent facility for high-energy neutrino astronomy and multi-messenger astrophysics through the next decades by getting a series of extensions. In late 2018, the US National Science Foundation committed $23 million, and collaborating institutions allotted $15 million more, toward the construction and deployment of seven additional strings of densely spaced, advanced photodetector modules during the 2022/2023 austral summer season. In the long term, the planned IceCube-Gen2, ten times larger than the current IceCube main array, will provide a decisive boost to neutrino astronomy.

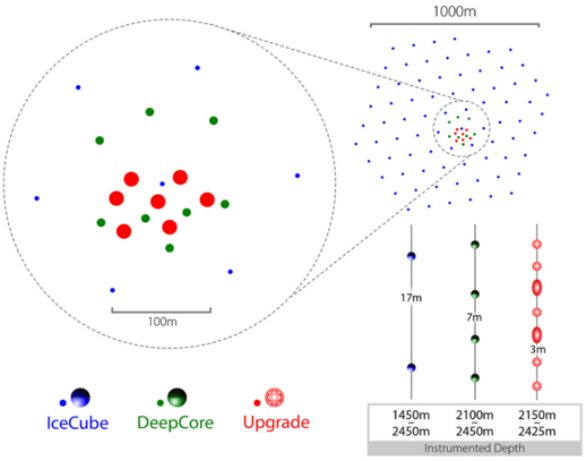


Figure A: plan view of the IceCube Upgrade. The seven strings (red dots) will be deployed at the center of the existing IceCube array (top right). In addition to the reduced string spacing (25 meters vs 125 meters in IceCube) the intra-string spacing of optical modules on a string is 5× more dense, forming a 5-megaton instrumented volume with sensitivity to neutrino interactions below 10 GeV.

The IceCube Upgrade modules will form an infill array within the DeepCore of IceCube, bringing the energy threshold of the IceCube facility down below 10 GeV. In this energy region, IceCube, already a capable instrument for the study of neutrino particle properties using atmospheric neutrinos as a natural beam (see e.g. Atmospheric tau neutrino appearance in IceCube or Improved measurements of neutrino oscillations with IceCube), will dramatically extend its sensitivity to $\nu_\mu \to \nu_\tau$ oscillations, allowing IceCube to measure the unitarity of the Pontecorvo-Maki-Nakagawa-Sakata (PMNS) matrix, constrain the "atmospheric" neutrino mixing parameters, and determine, with the JUNO detector currently under construction, the neutrino mass eigenstate hierarchy. These measurements will require the deployment of advanced sensors and calibration instrumentation that will also help the existing IceCube detector understand the characteristics of the natural material – the glacial ice – that it uses to explore high-energy phenomena.

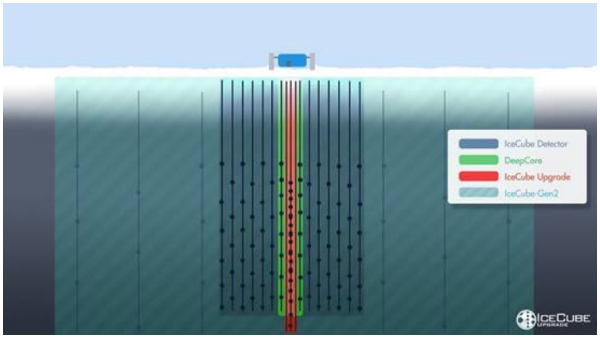


Figure B: Schematic of the IceCube Neutrino Observatory and future extensions. The IceCube Upgrade, to be deployed in 2022/23, is shown in red and will consist of seven new strings at the bottom-center of the current array. The future IceCube-Gen2 will instrument a ten-times-larger volume, with strings of sensors deployed at distances of 200 meters or more.

The IceCube Upgrade comprises seven deep-ice strings that densely instrument the clear ice at the South Pole between about 2100 m and 2450 m beneath the surface of the Polar Plateau. The close spacing of the strings, the dense packing of optical sensor modules on each string, the large area, and the segmented photocathodes employed in the modules will allow the reconstruction of particle interactions in the ice induced by atmospheric neutrinos that are produced when cosmic rays collide with atmospheric nuclei. These neutrinos propagating through the Earth exhibit a quantum mechanical phenomenon called neutrino oscillations: neutrinos produced as one particular flavor (electron, muon, or tau) can change their identities and be detected as another flavor. By measuring the neutrino events' flavors, energies, and zenith angles in the IceCube Upgrade, collaborating scientists will be able to constrain the least well understood matrix element of the PMNS matrix. Because the matrix must be unitary, a deviation of this matrix element from a value required to satisfy unitarity would point to new physics: nonstandard interactions or hidden neutrino flavors.

In order to achieve the precision necessary for determining the oscillation parameters the IceCube Upgrade must deploy, calibration devices are necessary, in addition to novel optical sensor instrumentation, to characterize the optical properties of the ice in which IceCube is embedded. Despite it being an exceptionally transparent optical medium with attenuation lengths approaching

200 meters, the ice has been imprinted with a complex, layered structure according to prehistoric weather and volcanic activity. Also, at the few percent level, glacial flow induces optical anisotropies. Imperfect knowledge of these optical properties currently limits the precision of IceCube's high-energy neutrino angular resolution and particle (flavor) identification. The same improvements in ice models required for the IceCube Upgrade will be used to improve IceCube data. There are several aspects of the impact of these improvements on high-energy astrophysics and multimessenger astronomy: (a) IceCube's real-time alert system will benefit from the reduced angular errors, giving follow-up observations better localized targets for coincident detection; (b) improved flavor identification of neutrinos from high-energy sources will better constrain the physics behind particle acceleration in the exotic objects or perhaps even point to physics beyond the Standard Model affecting neutrino propagation over cosmological distances; (c) perhaps the most compelling argument is the possibility of applying improved ice models to IceCube historical data retroactively, where point sources previously obscured by limited angular resolution but nevertheless present in the IceCube 14-year data archive could immediately leap out of IceCube's reprocessed sky maps.

The Chandra X-ray Observatory

ROGER BRISSENDEN (SAO) AND MARTIN C. WEISSKOPF (NASA/MSFC)

Chandra has carried out more than 19 years of highly successful and productive science operations. The *Chandra* X-ray Observatory is unique in its capability for producing the sub-arcsecond X-ray images that are essential to accomplish the science goals of many key X-ray and multi-wavelength investigations in current astrophysical research. The Project is looking forward to many more years of scientific productivity. In recognition of this, NASA has chosen to continue the mission and has extended the contract to operate *Chandra*, potentially through September 2027.

With the approach of *Chandra*'s 20th anniversary of operations, which will occur on July 23, 2019, those of us involved with the observatory look forward to celebrating this significant milestone, but at the same time note with sadness the recent death of Riccardo Giacconi, to whom we owe much for his insights and leadership toward the development of *Chandra*.

Chandra's 20th anniversary is being celebrated with a wide variety of colloquia, meetings and presentations, including a scientific symposium in Boston, December 3–6, 2019, an event at the National Air and Space Museum in August 2019, and a special session at the American Astronomical Society meeting in Seattle held in January 2019. Please check the schedule of events to keep up with the 20th anniversary celebration.

The *Chandra* Project is currently participating in NASA's periodic Senior Review (SR) of operating missions. We submitted the required SR proposal on March 15, 2019 and will host the SR panel's site visit in May.

The Observatory continues to operate extremely well overall but with a number of incremental changes in performance, due primarily to the gradual accumulation of molecular contamination on the UV filter that protects the ACIS detector, and to progressive degradation of the spacecraft's multi-layer insulation. Condensation on the filter reduces ACIS's sensitivity to low-energy X-rays (but does not affect the HRC). The decline in insulation effectiveness requires extra effort in scheduling observations, but has not significantly affected *Chandra*'s observing efficiency.

Although *Chandra*'s overall efficiency has not been significantly affected, the increasingly stringent thermal constraints on *Chandra* pointing have made scheduling of observations more difficult. It is sometimes necessary for *Chandra* to point in a direction that will pre-cool a particular subsystem before pointing at a target that will cause it to heat. To enable *Chandra* to stay within its temperature limits without losing efficiency by pointing at blank sky to cool off, the CXC Director, in consultation with the MSFC Project Science group and the *Chandra* Users Committee, authorized a call for White Paper proposals for *Chandra* Cool Targets (CCTs). CCTs constitute a large pool of targets distributed across the sky, so that a cooling target is always available for mission planning. CCTs will be scheduled if no appropriate General Observer (GO) or Guaranteed Time Observer (GTO) targets are available. Since there is no guarantee that a particular CCT will be observed, GO and GTO observers can apply for CCT targets to address their own science in response to the annual Call for Proposals. If a GO or GTO proposal for a specific CCT is approved, that target will be removed from the CCT database. In response to this call, 41 White Papers were submitted. Four reviews, based on science topic, were conducted, with reviewers from the CXC, MSFC and outside institutions. The reviews approved 22 programs, with approximately 22,000 CCTs. The first CCTs were observed in January, 2019.

In December 2019, one (of five) solar panel subarrays for one of *Chandra*'s three batteries failed. The flight team took appropriate engineering and software measures to reconfigure ballast resistors. Ample solar power remains available, and there is no impact to science or spacecraft operations.

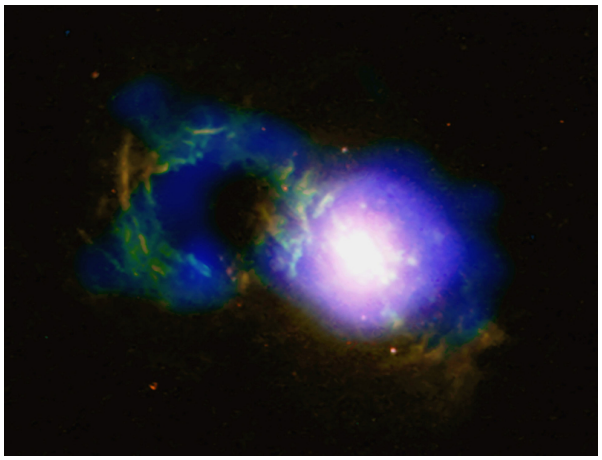
The combined effects of expected accumulated radiation damage and increasing temperature on *Chandra*'s aspect camera CCD have begun to affect the camera's ability to detect faint stars. Left unchecked, this trend would present difficulty in acquiring and tracking guide stars, which could decrease mission efficiency or preclude observation of some targets. We have successfully implemented strategies to mitigate the effects, and continue work in this area.

The *Chandra* Operations Control Center (OCC), from

which mission operations are conducted, is moving from its current site in Cambridge, Massachusetts to a new location in Burlington, MA. Construction of the new OCC is complete and system testing is in its final phase. We have successfully communicated with *Chandra* from the Burlington OCC, and are conducting an intensive program of large-scale operational simulations and demonstrations with the spacecraft to verify the OCC's capabilities. Following the completion of testing and readiness reviews, full mission operations from the new facility are expected to begin in May 2019.

Release 2.0 of the *Chandra* Source Catalog (CSC), which contains 374,349 detections from 315,875 sources, is nearing completion. Pipeline processing of all source properties is complete, with reprocessing of a small set of sources in work. All properties and data products for all master sources can be accessed through the CSCview application.

In December 2018 the *Chandra* X-ray Center (CXC) issued a call for proposals for Cycle 21 observations. Scientists worldwide submitted 515 proposals, including 425 proposals for observing and 90 for archive and theory research. The observing proposals requested a total of 83.7 Msec of telescope time, an oversubscription factor of approximately 5.4. The Cycle 21 peer review will be held in June 2019. A restriction on CXC funding during the partial government shutdown in December and January required us to suspend issuing *Chandra* grants. We have since initiated funding of *Chandra* grants for all Cycle 20 observations made through April.



Multi-wavelength view of the "teacup galaxy" from Chandra with help from XMM. From "Tempest in a Teacup", High Energy Astrophysics Picture of the Week. Credit: X-ray: NASA/CXC/University of Cambridge/G. Lansbury et al; optical: NASA/STScI/W. Keel et al; radio: NRAO/VLA

NASA announced the selection of 24 Fellows for the 2019 NASA Hubble Fellowship Program (NHFP), which supports postdoctoral researchers performing research across all of NASA astrophysics. NHFP postdocs are named as Hubble, Einstein, and Sagan fellows, depending on their research topics. Seven of those selected for 2019 were Einstein Fellows.

The *Chandra* Press Office has been active in issuing image releases, science press releases and other communications of *Chandra* research results. The annual *Chandra* Newsletter (#24) was released and distributed in April. Information about the *Chandra* Observatory and the *Chandra* X-ray Center may be found at the *Chandra* web site.

XMM–Newton

LYNNE VALENCIC (JHU & NASA/GSFC)

Successful submissions from the Eighteenth Call for Proposals for *XMM–Newton* were announced in December 2018, and observations will begin in May. The Nineteenth Call for Proposals will open August 20, and the final date to submit proposals will be October 11. The final approved program will be announced in mid-December.

The SOC is hosting a workshop, "Astrophysics of Hot Plasma in Extended X-ray Sources" June 12–14 in Villafranca del Castillo, Madrid, Spain. The workshop will summarize the current understanding of plasmas in galactic halos and winds and the interstellar medium. Attention will also focus on upcoming missions and the importance of plasma codes in data interpretation.

Proceedings and presentations from the 2018 symposium, "Time-Domain Astronomy: A High Energy View" are now available online.

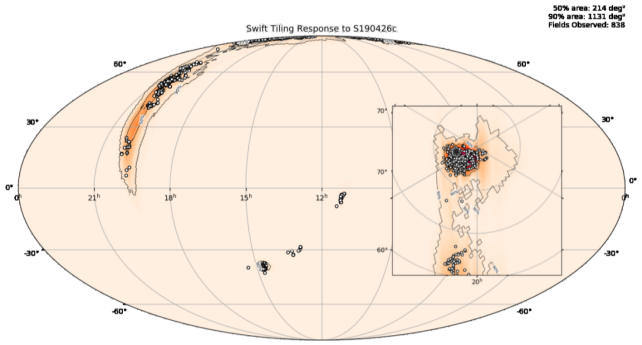
The Neil Gehrels Swift Observatory

ELEONORA TROJA, BRAD CENKO (NASA/GSFC)

The Neil Gehrels Swift Observatory continues to operate flawlessly and to support 4 Target of Opportunity (ToO) requests per day in addition to observing gamma-ray bursts (GRBs) and Guest Investigator (GI) targets. *Swift* is by far the most active mission in terms of the number of ToOs accepted and variety of sources observed.

The Burst Alert Telescope aboard *Swift* continuously scans the sky producing one of the most sensitive all-sky surveys in the hard X-rays. The survey is especially useful for finding nearby active galaxies, especially those obscured at other wavelengths by gas and dust. Using high resolution IR observations of active galaxies detected with BAT, a team of astronomers found a surprising number of galaxies in the final stages of merging together into single, larger galaxies. Peering through thick walls of gas and dust surrounding the merging galaxies' cores, the research team captured pairs of supermassive black holes drawing closer together before they coalescence into one giant black hole. Most prior observations of merging galaxies have caught the coalescing black holes at earlier stages, when they were about 10 times farther away. When the black holes finally do collide, they will unleash enormous energy in the form of gravitational waves.

On April 1st, 2019, *LIGO* and its Italian partner, *VIRGO* began their search for gravitational waves, called O3 for third observing run. During the first month of operations the *LIGO-VIRGO* network spotted five stellar collisions, including the first possible neutron star – black hole merger on April 26th. *Swift* responded to the alert and observed thousands of galaxies within the *LIGO-VIRGO* localization in order to find the luminous electromagnetic counterpart of the gravitational wave signal.



On April 26th, 2019, the LIGO-VIRGO network issued an alert for a possible neutron star - black hole event, dubbed S190426c. The Neil Gehrels Swift Observatory began pointed UV and X-ray tiling of the localization region of S190426c 142 minutes after the GW alert. The campaign continued for 2 days and observed over 32% of the galaxy-convolved localization in >800 fields covering thousands of massive galaxies.

The *Swift* Guest Investigator (GI) program will continue to solicit proposals in GRB and non-GRB research during Cycle 16. NASA's Research Opportunities in Space and Earth Sciences (ROSES) 2019 and the *Swift* Appendix were released on March 14, 2019. Updates on the Cycle 16 GI Program and the deadline for proposal submission will be posted on the *Swift* Proposals web site.

NuSTAR

DANIEL STERN (JPL), FIONA HARRISON (CALTECH)

NuSTAR continues to operate without any significant performance or calibration issues. *NuSTAR* AO-5 proposals were due March 25, and we are pleased to announce that the response to both the standard observing proposals (time requests < 500 ksec) and large proposal opportunities were strong. We received 186 regular proposals for 26.1 Msec of time, an oversubscription factor of 4. We also received 12 large proposals for >500 ksec each, with an oversubscription of 3.5. Target of Opportunity proposals continue to be popular, with an oversubscription factor of 10.

The *NuSTAR* User's Committee, chaired by John Tomsick of UC Berkeley, is interested to hear suggestions from the community about how *NuSTAR* can continue to be responsive to community priorities. If you have suggestions, please email nucchair@lists.srl.caltech.edu.

NuSTAR high-energy X-ray light (green) overlaid on false-color optical SDSS image of M51, the Whirlpool Galaxy, and its companion, M51b. X-ray emission from the centers of the galaxies is associated with accretion onto supermassive black holes. Several ultraluminous X-ray sources (ULXs) are evident, including the neutron star ULX to the east (left) of the nucleus of the primary galaxy. Credit: NASA/JPL-Caltech; IPAC

On the science front, Brightman et al. (2018, ApJ, 867, 110) present a comprehensive study of M51, the Whirlpool galaxy, combining data from *NuSTAR* and *Chandra*. Both galaxies in this merging system are active, with the nucleus of the primary, M51a, found to have Compton-thick levels of obscuration. Whereas the process of merging is generally expected to enhance nuclear activity, this study shows that both galaxies have very low accretion rates, with Eddington ratios $< 0.01\%$. This study also reports on the broad-band X-ray spectra of several ultraluminous X-ray sources (ULXs) in the system, including one ULX known to be associated with an accreting neutron star.

The Neutron Star Interior Composition Explorer

KEITH GENDREAU (NASA/GSFC), ZAVEN ARZOUMANIAN (NASA/GSFC)

In early March, 2019, NASA's *NICER* mission commenced observations for Cycle 1 of its Guest Observer (GO) program. Thanks to the tremendous dedication of members of the *NICER* Guest Observer Facility (GOF) team, peer review of the 84 proposals received by the December 2018 submission deadline proceeded on schedule despite the prolonged U.S. Government shutdown. The review resulted in the selection of 49 proposals, for observations of 108 unique targets. The *NICER* project supplemented its initial allocation of 5 Msec of total GO science exposure by up to an additional 1 Msec to accommodate

the possibility that many of the proposed targets of opportunity (ToOs) could be triggered. Approximately 30% of the approved proposals were for ToOs, and a similar fraction anticipated observations coordinated with other space- and ground-based telescopes, including *NuSTAR* – an agreement between the two projects enabled *NuSTAR* time awards through the *NICER* proposal review, while *NICER* time will be awarded in the *NuSTAR* Cycle 5 review. *NICER*'s soft X-ray (0.2–12 keV) passband complements *NuSTAR*'s coverage at higher energies, with a unique combination of timing, energy resolution, sensitivity, and throughput (several Crabs of flux without pileup) capabilities. As a payload hosted on the International Space Station, *NICER* also offers scientifically valuable scheduling flexibility, as well as real-time commanding and prompt data availability. ToO requests from the community are encouraged – a Web-based ToO request form is available at the *NICER* website, as is the mission's short-term observing schedule.

NICER's first Nature paper resolved a long-standing ambiguity in the evolution of accretion onto a BH in outburst, with uniquely rich data on the bright transient MAXI J1820+070. Credit: NASA/NICER; E. Kara et al., UMD

NICER's presence at the 233rd AAS meeting in January 2019 and the 17th Divisional HEAD meeting included a number of scientific highlights:

- Insights into the geometric evolution of a black hole's accretion environment in outburst, the subject of a media briefing by Erin Kara (U. Maryland and NASA GSFC) and the cover article for the January 9 issue of Nature.
- An invited progress report by Anna Watts (U. Amsterdam) on *NICER*'s key neutron star mass and radius inference investigation through modeling of the thermal X-ray light curves of rotation-powered millisecond pulsars (MSPs).
- A report of multiple "anti-glitches" during the rapid accretion-driven spin-up of the ultraluminous X-ray pulsar NGC 300 ULX-1 (Ray et al. 2019).
- Multiple first detections with *NICER* of X-ray pulsations from a handful of known radio and gamma-ray MSPs (Guillot et al. 2019).
- The discovery of spectral features – emission near 1 keV and absorption at 1.7 and 3 keV, all consistent with the instrument's spectral resolution – in photospheric radius expansion bursts from the ultracompact neutron star binary 4U 1820−30 (Strohmayer et al. 2019).

The *NICER* public data archive comprises, as of this writing, more than 13,000 observations, where a unique "ObsID" represents data collected for a single target on a single day. Data analysis tools are distributed through the HEAsoft package, and calibration products are available through the HEASARC Calibration Database. The mission's continued operations beyond September 2019, including the second half of the GO program's Cycle 1, are contingent upon a successful outcome in NASA's 2019 Astrophysics Senior Review.

AstroSat

K. P. Singh (IISER, Mohali), Dipankar Bhattacharya (IUCAA, Pune), S. Seetha (URSC, Bengaluru)

The Science Working Group (SWG) of *AstroSat* has fixed 2 Msec of observing time per year, the "Legacy" proposals that were announced in the last newsletter. A few observations under this program selected for AO6 are currently being carried out. The data observed under the Legacy program will not have any lock-in period and will be opened nationally and internationally immediately through ISSDC after usual quality checks and some pre-processing. The time allotted for *AstroSat* calibration has been enhanced from 3% to 5% of the overall observatory time from Oct 1, 2019 onwards. New observation proposals for the next regular cycle of observations, AO7, to be scheduled for Oct 1, 2019 – Sept 30, 2020, were received between March 11 – April 23 this year and are under review. Observations for Targets of Opportunity are being processed as requests are received and approved.

On the performance of the instruments, all attempts to revive the Near Ultraviolet (NUV) channel of the Ultraviolet Imaging Telescope (UVIT) have failed, and it continues to be out of commission. The Far Ultraviolet (FUV) and the Visible (VIS) channels of UVIT continue to function normally. Two units of the Large Area X-ray Proportional Counter (LAXPC) – LX10 and LX20 – are being operated. However, LAXPC 10 is operated under lower gain. Tne Cadmium Zinc Telluride Imager (CZTI), and the Soft X-ay Telescope (SXT) continue to function normally and are available for observations.

A COSPAR Capacity building workshop to train pre- and post-PhD students/scientists was held at the Indian Institute of Science Education and Research, Mohali, India from March 9–20, 2019. Thirty six students (selected from 136 applicants) from all over India, Turkey, China, Sweden and Nigeria participated and carried out science projects based on *XMM–Newton*, *Chandra*, and *AstroSat* data. The workshop was sponsored by COSPAR, IISER-Mohali, ISRO, ESA, NASA, and CXC. Lecturers and tutors were drawn from India, USA, Holland, UK, Spain and Italy. More details will follow in the COSPAR newsletter.

Attendees at the COSPAR capacity building workshop, Indian Institute of Science Education and Research, Mohali, India, March 9–20, 2019. If you look closely you may see the former HEAD Treasurer. Credit: T. Belloni

There were a number of interesting new results from *AstroSat*, in particular:

- The detection of high time-variable polarization, with higher emission at energies above the peak energy from GRB 171010A.
- The detection of a cyclotron resonance scattering feature (CRSF) at ∼5 keV in the X-ray spectrum of a Be/X-ray binary pulsar SXP 15.3 in the Small Magellanic Cloud during its outburst in late 2017. The source had reached a luminosity level of close to the Eddington limit during the observations. This measurement indicates a magnetic field strength of 600 billion gauss for the neutron star.
- The detection of a pulse-phase dependent cyclotron scattering feature (CRSF) at ∼22 keV in a high mass X-ray binary pulsar 4U 1538–152.

Be sure to see the *AstroSat* picture of the month for new, interesting images which highlight *AstroSat* science results.

X-Calibur

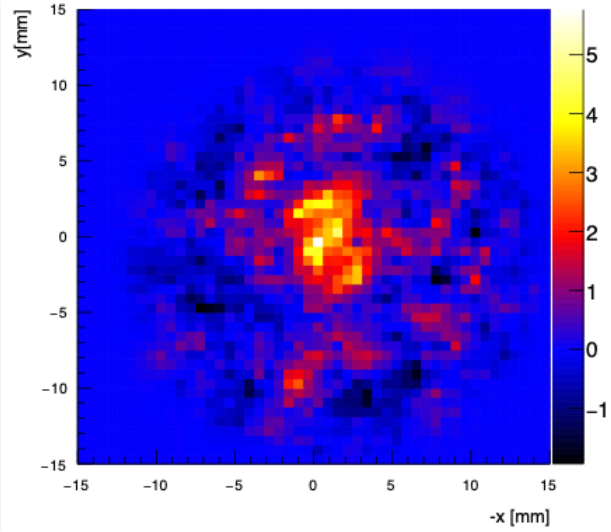
H. Krawczynski (Wash. Univ. in St. Louis) and F. Kislat (Univ. New Hampshire) for the X-Calibur team

The *X-Calibur* hard X-ray polarimetry mission was launched on a Long Duration Balloon flight on 12/29/2018 from McMurdo (Antarctic). The experiment uses the Wallops Arc Second Pointer (WASP) to point an 8m long carbon fiber optical bench, equipped with the InFOCμS X-ay mirror and a scattering polarimeter, at X-ray bright neutron stars and black holes.

Launch of X-Calibur on 12/29/2018

During the 2.5 days of the flight, the experiment acquired a rich data set on the X-ray pulsar GX 301-2 with *X-Calibur* flux, spectral and polarization information, and simultaneous and near simultaneous NICER and Swift X-Ray Telescope (XRT) and Burst Alert Telescope (BAT) data. GX 301-2 is in a ~ 40.5-day orbit with the B1 Ia hypergiant Wrey 977, a $\sim$ 50 solar mass star $\sim 470,000$ times brighter than our sun. *X-Calibur* detected strong pulses from the neutron star, clearly showing the ~ 684s periodicity caused by the neutron's star spin. The observations enabled the very first constraints on the 15 keV–35 keV polarization of the hard X-ray emission from a mass accreting neutron star. GX 301-2 is a particularly interesting object as it exhibits Cyclotron Resonant Scattering Features (CRSFs) at 35 keV and 50 keV showing that the neutron star supports a very strong magnetic field of several times 10^{12}G, more than a trillion times stronger than the ~ 0.5G magnetic fields on Earth. In the presence of such strong fields, Quantum Electrodynamics (QED) predicts very high linear polarization fractions of the X-rays owing to their interactions with virtual electron and positron pairs. This strong-field prediction of QED cannot be tested in terrestrial laboratories because it only becomes measurable at extremely strong magnetic field strengths. The publication of the *X-Calibur* results is in preparation.

The flight duration was determined by a helium leak in the balloon. After the flight, the polarimeter and shield were successfully recovered from the landing site. Tests at Washington University show that the polarimeter is fully functional. The *X-Calibur* team recently joined forces with Japanese and Swedish groups previously working on the balloon-borne hard X-ray polarimeter *PoGO+* (Polarized Gamma-ray Observer) which observed the Crab and Cygnus X-1 in 2016.



The X-ray pulsar GX 301-2 as seen in X-Calibur's "tail end detector" used to confirm the proper pointing of the telescope. The color graph shows the excess counts from GX 301-2 after background subtraction in arbitrary units. The spatial extent of the excess reflects the mirror's point spread function.

The team is now working on preparing three follow-up flights of an improved payload called *XL-Calibur*. *XL-Calibur* will use the 12m spare mirror of the *Hitomi* Hard X-ray Telescope (HXT) and a modified polarimeter-shield assembly with thinner detectors and additional neutron shielding to achieve a more than one order of magnitude better signal-to-noise ratio than *X-Calibur*. The team proposed three flights of *XL-Calibur*: two from Kiruna, Sweden (Summer 2021 and Summer 2022), and one from McMurdo, Antarctic (December 2024). The flights will enable *XL-Calibur* to observe a sample of archetypical X-ray sources with simultaneous observational coverage with the Imaging X-ray Polarimeter Explorer (*IXPE*) scheduled for launch in 2021. While IXPE measures the polarization of 2 keV–8 keV X-rays, *XL-Calibur* covers the 15 keV–80 keV energy range. For more information, see the *X-Calibur* website.

The Fermi Gamma-Ray Space Telescope

ELIZABETH HAYS (NASA/GSFC), CHRIS SHRADER (NASA/GSFC AND THE CATHOLIC UNIVERSITY OF AMERICA), DAVE THOMPSON, JULIE MCENERY (NASA/GSFC), LYNN COMINSKY (SONOMA STATE UNIVERSITY)

The *Fermi* spacecraft and both instruments continue routine operations, scanning the gamma-ray sky continuously. The solar panel issue that occurred in March of last year has been circumvented by modifications to the observing strategy.

Recent science highlights include:

- The fourth catalog of high-energy gamma-ray sources (4FGL) seen by the *Fermi* Large Area Telescope is now available. With more than 5000 sources, it is the deepest survey yet of the sky at photon energies from 50 MeV – 1 TeV.

- The extended data set available from *Fermi* allowed an indirect measurement of the star-formation history of the universe. Clemson University scientists led this effort, which used the absorption of energetic gamma rays by the Extragalactic Background Light (EBL) to determine the evolution of the EBL with time.

- *Fermi* scientists teamed up with radio astronomers to track a fast-moving pulsar that originated in the supernova that also produced the CTB 1 supernova remnant. The 10-year gamma-ray data set allowed a measurement of the pulsar's proper motion, showing that it is one of the fastest-moving neutron stars in the Galaxy.

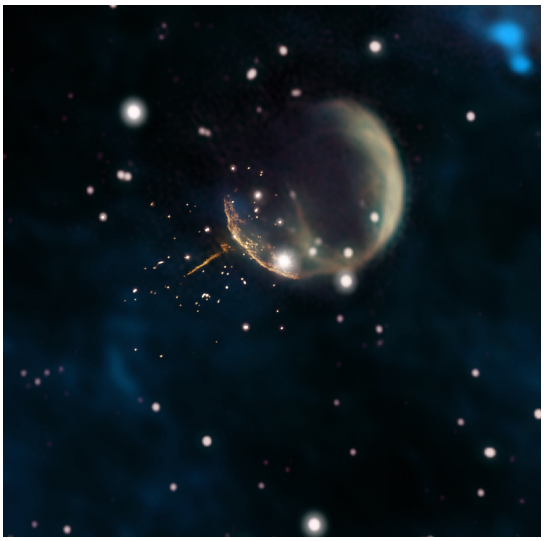
Current *Fermi* software and documentation are available through the *Fermi* Science Support Center. On October 15, the FSSC released a major software update, Fermitools 1.0.0, which uses the Conda package manager for installation. The source code is now hosted on GitHub. For instructions on how to install the tools, release notes, troubleshooting, error reporting, and other related documentation, see the Fermitools Wiki.

Cycle 12 proposals were received in March and reviews are underway. Additional information is available at the *Fermi* Science Support Center website.

The Ninth International *Fermi* Symposium will be held in South Africa in the spring of 2020.

Fermi's latest discoveries and the 10-year gamma-ray skymap are highlighted in a new poster by SSU's Aurore Simonnet. Simonnet has also designed a beautiful series of three *Fermi*-inspired "art posters" including a pair of merging neutron stars, the gamma-ray skymap and *Fermi*

itself. If you would like hard copies of any or all of these, please email lynnc@universe.sonoma.edu. Quantities are limited.



The CTB 1 supernova remnant resembles a ghostly bubble in this image, which combines new 1.5 gigahertz observations from the Very Large Array (VLA) radio telescope (orange, near center) with older observations from the Dominion Radio Astrophysical Observatory's Canadian Galactic Plane Survey (1.42 gigahertz, magenta and yellow; 408 megahertz, green) and infrared data (blue). The VLA data clearly reveal the straight, glowing trail from pulsar J0002+6216 and the curved rim of the remnant's shell. CTB 1 is about half a degree across, the apparent size of a full Moon. The pulsar's proper motion was measured by the Fermi Large Area Telescope. Credits: Composite by Jayanne English, University of Manitoba, using data from NRAO/F. Schinzel et al., DRAO/Canadian Galactic Plane Survey and NASA/IRAS

INTEGRAL

ERIK KUULKERS (ESA/ESTEC) AND STEVE STURNER (CRESST/UMBC & NASA/GSFC)

In November 2018, ESA's Science Programme Committee (SPC) confirmed the continued operation of *INTEGRAL* for the 2019-2020 cycle, and indicative extension for an additional two years. *INTEGRAL* has proven to be of great value to pursue investigations that were not foreseen at the time of its launch. This is exemplified by the role of *INTEGRAL* in the prompt observation and follow-up of Gravitational Wave detections, an important contribution to the future of multi-messenger astronomy. This is excellent news for *INTEGRAL* and the science community.

The spacecraft, payload and ground segment have been generally performing nominally. The most noticeable anomaly occurred on October 29, 2018 with the SPI data processing electronics (SDPE), related to memory location corruption and affecting the recording of on-board spectra. To mitigate the impact, between early November and early February SPI was running in science/photon-mode, but with the spectra accumulation switched off. This suppression had no impact on the science data or science data analysis. Subsequently, the on-board Instrument Application Software (IASW) was patched and the spectral accumulation function has been re-activated.

SPI annealing (#32) took place from January 20 until February 6. If one considers the high level of degradation before the annealing ($E/E \sim 0.21\%$ at 1764 keV), the recovery, while not perfect, is satisfactory ($E/E \sim 0.18\%$ at 1764 keV). Nevertheless, the global energy resolution continues slowly to drift. A Crab calibration observation was performed on March 11, 2019, in coordination with *XMM–Newton*, *NuSTAR*, *NICER* and *Swift*.

Sandro Mereghetti (Italy) and Sergey Sazonov (Russian Federation) will be new members of the *INTEGRAL* Users Group (IUG) for a period of 3 years starting July 2019. The IUG meeting #21 took place on November 7–8, 2018, at ESA/ESTEC, The Netherlands. The IUG discussed the recent release of OSA11 as well as the cross-calibration between instruments onboard *INTEGRAL* as well as instruments other high-energy satellites. The *INTEGRAL* legacy archive was also discussed. The next IUG meeting (#22) is going to take place at ESA/ESOC, Germany, June 11–12, 2019.

The 12th *INTEGRAL* Conference, "*INTEGRAL* Looks AHEAD to Multi-Messenger Astrophysics", took place in Geneva, February 11–15, 2019 with 146 participants. The Conference Proceedings will be published in the Journal of the Italian Astronomical Society. The 2019 Mikhail G. Revnivtsev Prize, established by ESA/INTEGRAL, IKI and INAF, was awarded to Thomas Siegert (MPE, Germany), for his substantial contribution to the *INTEGRAL* scientific legacy with his work on the nucleosynthesis in our Galaxy.

The AO-17 call for observing proposals opened on February 25, 2019, with a deadline on April 5, 2019. The total number of proposals received was 63 and the total requested observing time requested was ∼73 Msec, where 10% of the requested total ToO time has been taken into account. This corresponds to a time over-subscription by a factor of 3.5. Twenty two proposals requested joint time with *NuSTAR*, *Swift* and/or *XMM–Newton*. The TAC meeting is scheduled for May 13–15, at ESAC.

Science observations during this reporting period were performed mostly as planned. The *INTEGRAL* Burst-Alert System (IBAS) system triggered due to flaring activity of the newly discovered black-hole candidate MAXI J1348-630 (see GCN Circular #23799) with ToO observations initiated from January 29, 2019 (see ATel #12471). Another *INTEGRAL* ToO observation of this source took place on February 25–27, 2019. A public Target-of-Opportunity (ToO) observation of the transient black-hole binary MAXI J1820+070 took place on March 26–28. *INTEGRAL* also participated in an extensive radio to gamma-ray campaign of AT2018cow, new kind of supernova, a fast-rising blue optical transient (FBOT). The source rose to a peak luminosity 4×10^{44} erg s^{-1}, ex-

ceeding those of superluminous supernovae. The multi-wavelength analysis indicates that AT2018cow harbored a "central engine", either a compact object or an embedded internal shock produced by interaction with a compact, dense circumstellar medium. ESA participated in the PR release with a news item on January 10, 2019.

In November 2018, the *LIGO/VIRGO* collaboration announced the catalog of GW events during the first two observing runs O1 and O2 (GWTC-1) with 11 high-confidence and 14 marginal events. *INTEGRAL* observations are available for 20 out of the 25 events consistent with the *INTEGRAL* duty cycle. For each of the observed events, *INTEGRAL* was sensitive to the entire *LIGO/VIRGO* localization region and a preliminary search did not reveal any new significant impulsive gamma-ray counterparts (Savchenko *et al.* 2018, GCN Circular #23517).

The *LIGO/VIRGO* facilities recently started observing run O3 on April 1, and three candidate GW events have been reported so far: S190408an, S190412m, S190425z. The latter is probably a pair of neutron stars merging, and *INTEGRAL* started to perform dedicated ToO follow-up observations, about 6 hours after the GW event (see GCN Circular #24178). *INTEGRAL* was also used to perform a search for a prompt gamma-ray counterpart of the cosmic neutrino candidate IceCube-190221A (see GCN Circular #23927).

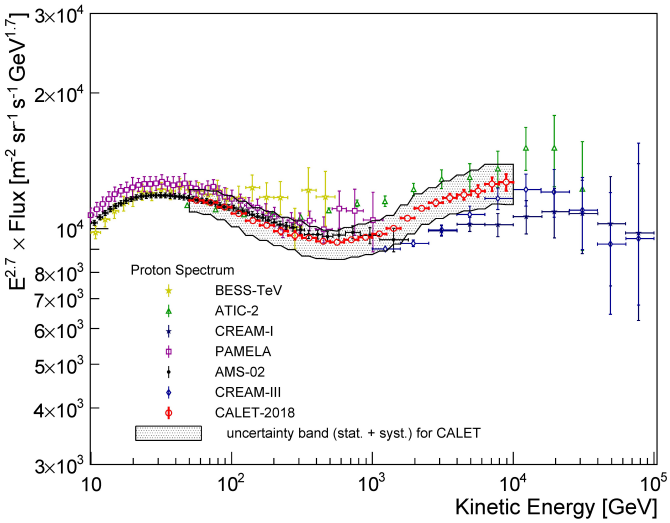
A team from the University of Southampton is utilizing a back-projection approach to analyze *INTEGRAL* slew data which cannot be analyzed using the standard cross-correlation technique. It is estimated that sources brighter than 50 to 70 mCrab can be observed in a single slew. The analysis of slew data will significantly contribute to the study of hard X-ray transient sources and the long-term monitoring of transient activity of persistent sources.

As of April 2, 2019, the total number of *INTEGRAL* refereed publications since launch is 1606, including 7 thus far in 2019.

CALET

JOHN WEFEL (LSU)

The CALorimetric Electron Telescope (*CALET*) instrument on the International Space Station continues to function well, returning good data on cosmic ray electrons, nuclei, gamma rays and transient events. *CALET* underwent a technical/scientific review by JAXA, plus a team of scientists, and was approved to continue taking data for a full five-year mission, nominally through first quarter of 2021. The analysis of *CALET* data continues to move forward with the recent publication of the high energy proton spectrum. *CALET* confirms a hardening in the proton spectrum starting in the 100's of GeV energy range and extending to, at least, 10 TeV. Extension of the result to higher energy will be possible with the additional data and further analysis. At the other end of the energy range, the raw detector counting rates from the top scintillator layers are finding use as baseline monitors for solar induced magnetospheric effects. These counting rates have now been made available in a public archive. Progress reports on other *CALET* analysis projects will be presented at this summer's International Cosmic Ray Conference.



The proton spectrum measured by CALET from 10 GeV to 10 TeV compared to previous results. Credit: CALET

Physics of the Cosmos News

T. J. BRANDT (PCOS CHIEF SCIENTIST, NASA/GSFC) & P. TZANAVARIS (ASSOCIATE RESEARCH SCIENTIST, NASA/GSFC-CRESST)

NASA's Physics of the Cosmos (PCOS) program explores some of the most fundamental questions regarding the physical forces and laws of the universe: from testing General Relativity to better understanding the behavior of matter and energy in extreme environments, the cosmological parameters governing inflation and the evolution of the universe, and the nature of dark matter and dark energy. To enable current and future missions to address these questions, the PCOS Program Office engages the community through a number of activities, including through the PCOS Program Analysis Group (PhysPAG) and facilitating 2020 Decadal Survey preparations, and reviews strategic technology capability gaps, prioritization, and development.

We have had several changes in the Program Office since the last newsletter. We are pleased to announce that Dr. Dan Evans joined as NASA Headquarters Program Scientist, while Dr. Rita Sambruna continues to work with us as Deputy. Dr. Terri Brandt has been confirmed as PCOS Chief Scientist. Our new Program Manager, Preston Burch, joins us after working, among other things, as Program Manager for the Hubble Space Telescope Program.

PhysPAG includes everyone interested in the PCOS program via six Science Interest Groups (SIGs); this probably means you! The PhysPAG enables regular communication between the PCOS community and NASA. The

Chair and Executive Committee (EC) are appointed PhysPAG members whose responsibilities include organizing meetings and collecting and summarizing community input with subsequent reporting to the Astrophysics Division Director. EC members' terms last ∼2 years, with 5 EC members rolling off this December. We welcome applications from a diverse range of community members; this diversity enables the PhysPAG EC to better reflect the community to NASA. Look for a call for applications later this year. More details on PhysPAG and the EC are on our website.

PCOS sessions at the AAS January, HEAD March, and APS April meetings included exciting science results and forward-looking themes. Our PCOS & PhysPAG meeting at the AAS January meeting featured a suite of multi-messenger talks. At our APS April meeting we featured the Decadal Survey with talks from the Decadal Co-Chair Fiona Harrison and NASA's activities from Paul Hertz and Rita Sambruna. As always, all presentations can be found on our website. We are looking forward to hosting more PCOS & PhysPAG and SIG & SAG sessions in 2020 at the January 2020 AAS, April 2020 APS, and the HEAD Fall 2020 meeting. We encourage you to join us in person or via remote connection!

The PhysPAG Science Interest Groups have also been active, including X-ray, Gamma-ray, Cosmic Ray, and Gravitational Wave SIGs organizing sessions at AAS, HEAD, and APS meetings. We give a particular thanks to all the EC and community members and PCOS staff who stepped up at AAS when the government shutdown prevented government workers from attending. The SIGs have also been facilitating and supporting community Decadal science white papers. Their websites and articles (X-ray, Gamma-ray, Cosmic Ray) in this newsletter detail their activities. The Multimessenger Astrophysics Science Analysis Group (MMA SAG) facilitated community members' submitting ten Decadal science white papers. As described in the MMA SAG article and website, we welcome you to join the next task of summarizing the goals and plans for the APAC report.

In addition to engaging the community through the PhysPAG structure, the PCOS Program Office continues to host and facilitate work on the *LISA* and *Athena* studies. This includes supporting the NASA *LISA* Study Team members who submitted 11 white papers in support of the science goals that will be addressed by *LISA* and other space-based gravitational wave observatories. We would like to take the opportunity to thank all of you who made all these volunteer efforts a success!

With the detection of gravitational waves, this astrophysics field has now come of age. In response, NASA HQ Astrophysics Division has created a task force to assess NASA's role in strategic optimization of Gravitational Wave Electromagnetic Counterpart astrophysics. The task force study will last between 6–8 months beginning in April 2019, and deliver a final report to HQ. Please see theTerms of Reference for more details.

NASA HQ updated the Astrophysics Implementation Plan (AIP) at the end of 2018 to include progress made by the Astrophysics Division in implementing the 2010 Astrophysics Decadal Survey recommendations since the 2016 update. For changes, please see the December 2018 Update, as well as Section 2 of the updated AIP.

We welcome your input on PCOS science topics, particularly through the relevant PhysPAG Science Interest Groups. In particular, you can submit technology gaps (deadline June 2019), or apply to be a PhysPAG EC member. We also look forward to seeing you either in person or virtually at our upcoming meetings and encourage you to join our email list and check our website for news.

The X-ray Science Interest Group

RYAN HICKOX (DARTMOUTH), JOHN TOMSICK (UNIVERSITY OF CALIFORNIA BERKELEY)

This year is an exciting one for X-ray astronomy as it marks the 20th anniversary of both Chandra and XMM-Newton, and there has also been great progress in looking forward to the future of the field.

X-ray astronomy has played a prominent role so far in contributions to the Astro2020 Decadal Survey. Over 50 Science White Papers relevant to X-ray astronomy were submitted to the survey, covering a very wide range of science including supermassive black holes and AGN, galaxies, groups, clusters, and the circumgalactic medium, star formation, the interstellar medium, exoplanets, supernovae and supernova remnants, stellar-mass black holes, and neutron stars. The X-ray Science Interest Group (XRSIG) helped coordinate these efforts by hosting a dedicated webpage to list relevant White Papers. We also focused the XRSIG meeting at the 2019 AAS meeting in Seattle in January on Decadal submissions, with presentations from the leaders of a number of white papers across a broad range of science – thanks in particular to those who stepped at the last minute to fill the gap left by our colleagues affected by the government shutdown! At the 17th Division HEAD meeting in March in Monterey, CA, the XRSIG meeting included an overview of the science in White Papers relevant to X-ray astronomy. We also heard reports about possibilities for U.S. involvement in ESA's *Athena* observatory, and programmatic status and technology development for the *Lynx* mission concept study.

A great deal of progress on future X-ray observatories was presented at the USRA symposium on "The Space Astrophysics Landscape for the 2020s and Beyond", in April 2019. The eROSITA and ART-XC instruments are scheduled to launch in June 2019 aboard the *Spectrum-Röntgen-Gamma spacecraft*, with some collaborations from the US community on follow-up observations and analysis of the large anticipated yield of X-ray sources. The development of the *XRISM* mission to replace the calorimetric capabilities of *Hitomi* is progressing with launch scheduled by 2021. In terms of mission

concept studies relevant to X-ray astronomy, the study of the *Lynx* flagship X-ray mission continues apace with the final report scheduled for submission to the Decadal Survey later this year, while the funded NASA probe studies (*AXIS*, *STROBE-X*, *TAP*, and *POEMMA*) as well as additional X-ray mission concepts (e.g., *HEX-P*, *XPP*) including some small satellites (e.g., *HaloSat*, *HSP*, *VXTO*, *XQCSat*) continue to make progress. (There is of course a great deal of exciting work in this area; please feel free to let us know about any additional missions or concepts that aren't listed here.) The USRA symposium also highlighted exciting developments in both mirror and detector technology, including new milestones in angular resolution for lightweight optics and array sizes for microcalorimeters, that will be critical for the next generation of X-ray observatories.

Going forward, the next key deadline for Astro2020 is July 10, for submission of White Papers on activity, project, and state of the profession considerations (APC). Our next XRSIG meeting is scheduled for the Winter AAS meeting in Honolulu in January 2020, and we welcome recommendations or suggestions for presentation topics. We would also like to remind members of the community that positions on the PhysPAG Executive Committee will be open in 2020 and encourage any interested colleagues to apply. Looking forward to seeing you at an upcoming meeting!

The Gamma-ray Science Interest Group

Sylvain Guiriec (The George Washington University & NASA/GSFC), John Tomsick (University of California Berkeley)

The gamma-ray community produced more than 25 white papers for the 2020 Decadal Review showcasing its exciting science. About 600 white papers were submitted overall and 74 of them mentioned "gamma-rays" in the title or abstract. A strong showing! The Gamma-ray Science Interest Group (GammaSIG) helped in coordinating and centralizing this effort via workshops and telecon meetings. A particularly strong and organized effort was provided by the All-sky Medium Energy Gamma-ray Observatory (*AMEGO*) team.

GammaSIG has been organizing special sessions at US science conferences. The special session at the January AAS meeting focused on finalizing the Decadal Review White Papers. GammaSIG resumed its nominal activities at the Monterey HEAD meeting with a very well attended session mixing theory and instrumentation presentations. The theme of the GammaSIG session at the April APS meeting was how GammaSIG can be organized to better serve the community.

GammaSIG will continue regular telecon meetings to discuss science, to share news and results about current missions, and to keep the community informed about future missions as well as technology development.

The International Space Station Transient Astrophysics Observatory (*ISS-TAO*) and the ComptonSpectrometer and Imager (*COSI-X*), which completed their Phase A Concept Study Reports and had their NASA site visits for the Explorer Mission of Opportunity call, were, unfortunately, not invited to continue to Phase B. *Glowbug* and *BurstCube* are still on track. If you have upcoming-missions news that you want to share, please use the GammaSIG mailing list or inform the GammaSIG co-chairs Sylvain Guiriec (sylvain.guiriec@nasa.gov) and John Tomsick (jtomsick@ssl.berkeley.edu).

The GammaSIG community is very eager to hear about all exciting news concerning future gamma-ray missions, which will always push further the limit of our knowledge of our universe at its extremes.

The Cosmic Ray Science Interest Group

James Beatty (The Ohio State University), Abigail Vieregg (University of Chicago), Marcos Santander (University of Alabama)

Abigail Vieregg and Marcos Santander have joined as co-chairs of the SIG, while Igor Moskalenko has completed his service. We thank Igor for his work in the SIG during his term. James Beatty's appointment as co-chair will end in 2019.

The SIG hosted a mini-symposium at the 2019 APS April Meeting in Denver, CO. The program included an invited overview talk on direct cosmic ray measurements by Prof. Stephane Coutu (Penn State) and contributed talks on recent results from *CALET* by Prof. Greg Guzik (LSU), cosmic ray anisotropy measurements with *HAWC* and *IceCube* by Dr. Juan Carlos Díaz Vélez (UW-Madison), and results on the fourth *ANITA* flight by Andrew Ludwig (UChicago). The presentations are available from the PhysPAG website.

The session concluded with open discussion time, including a presentation on the structure and mission of the CRSIG and an overview of relevant white papers submitted to the Astro2020 decadal call. Out of about 600 papers submitted to the decadal, 16 deal with cosmic rays, either addressing questions of origin, composition, spectrum, or their multi-messenger connections.

The CRSIG chairs encourage the community to contact them with questions and suggestions on activities or topics they would like to see the SIG address. For more information, please contact James Beatty (beatty.85@osu.edu), Abigail Vieregg (avieregg@kicp.uchicago.edu), or Marcos Santander (jmsantander@ua.edu). People interested in the activities of the group are also invited to join our mailing list.

NASA Multimessenger Astrophysics Science Analysis Group

J. W. Conklin (Chair of the PhysPAG Executive Committee, U. Florida) & T. J. Brandt (PCOS Chief Scientist, NASA/GSFC)

The first observations of gravitational waves and associated signatures across the electromagnetic spectrum due to compact object mergers have ushered in a new era in synergistic multimessenger astrophysics. The NASA Multimessenger Astrophysics Science Analysis Group (MMA SAG) is an approximately one year activity that started in June 2018, aiming to analyze the potential scientific benefits of multimessenger observations made possible by NASA observatories in the 2020s and beyond, working in conjunction with each other and with other ground- and space-based instruments. The SAG's charter describes the purpose and organization of the SAG in more detail.

During the early phase of the MMA SAG, members of the astrophysics community were organized into teams centered on astrophysical sources and bringing together expertise in a variety of astrophysical messengers. These "source teams" collaborated on topics that included supermassive black hole binaries, stellar-mass black hole binaries, neutron star and white dwarf binaries, GRBs, and supernovae. The community teams produced ten science white papers on these topics that were submitted to the Astro2020 Decadal Survey, including one MMA overview paper.

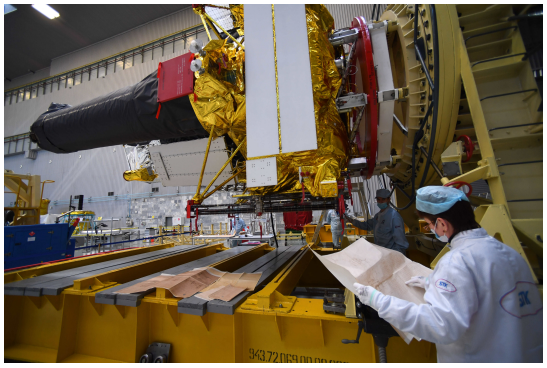
The next steps of the SAG are to review the set of science goals described in these white papers, determine if any important topics are missing or need further expansion, and document its analysis in a report that will be submitted to the NASA Astrophysics Advisory Committee (APAC), and made publicly available in the summer of 2019. The APAC advises NASA's Astrophysics Division Director on this and other activities. We invite anyone who is interested to join this exciting activity! Please check the MMA SAG website to learn how you can get involved.

Spectrum Röntgen Gamma/eROSITA

A. Merloni (MPE), M. Pavlinsky (IKI), P. Predehl (MPE), S. Sazonov (IKI)

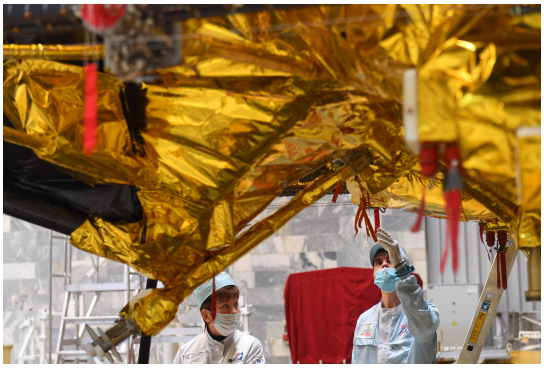
On April 23rd a "State Commission Review" took place in Moscow to assess the launch readiness of the Spektr-RG satellite. The commission approved the shipment of the fully integrated spacecraft to Baikonur, which took place on Thursday, April 25th. This is the first of a series of actions that will initiate the launch campaign proper. The launch itself, with a ProtonM/Block-DM03 rocket/upper stage system, is scheduled for June 21st, with a short-time backup on June 22nd and an alternaltive slot on July 12th/13th.

SRG is ready to be placed in the container for the final shipment to Baikonur. eROSITA, with its hexagonal cover is on the bottom, ART-XC, of longer focal length, is placed above it. Credit: Sergey Mamontov, RIA Novosti.



Final preparations before the shipment. Credit: Sergey Mamontov, RIA Novosti.

After two first orbit-correction maneuvers the spacecraft will be placed onto an orbit in the direction of the L2 Lagrangian point, about 1.5 Million kilometers from earth. Two further orbit corrections, after about 10 and 20 days, will insert SRG into a large halo orbit around the L2 point. Due to the long degassing and camera commissioning time for eROSITA, the calibration program and "early science" observations will begin with ART-XC as the primary instrument, starting from day 22 (July 12th) to day 63 (August 24th). On August 25th, about 64 days after launch, the eROSITA Calibration and Performance Verification observations will begin (with ART-XC is in operational mode), and should last for an anticipated period of 8-10 weeks. The detailed plan for the ART-XC and eROSITA Calibration and Performance Verification observations should be finalised in May, and circulated to the wider astronomical community.



The removal of the "red tags", the last action before the launch, is scheduled for the end of May. Credit: Sergey Mamontov, RIA Novosti.

Athena: Revealing the Hot and Energetic Universe

KIRPAL NANDRA (MPE), DIDIER BARRET (IRAP), RANDALL SMITH (CfA), AND FRANCISCO J. CARRERA (IFCA, CSIC-UC) FOR THE *Athena* SCIENCE STUDY TEAM AND THE *Athena* COMMUNITY OFFICE

Athena is approaching a major milestone, the Mission Formulation Review (MFR), which is currently scheduled for Q4 2019 and marks the end of Phase A. The last 6 months have also seen the successful completion of the first major review of both instruments, the Instrument Preliminary Requirements Reviews (IPRRs). These reviews were by necessity staggered, as they involve both ESA's *Athena* team and the instrument teams presenting to reviewers selected from ESA and Member State space agencies. The WFI I-PRR was completed in Q4/2018, while the X-IFU I-PRR was completed in Q1/2019. Another milestone was recently achieved when ESA formally recognized the two *Athena* instrument consortia at the end of 2018. The implementation phase starts with mission adoption in Q4 2021, with the subsequent schedule leading to launch in in 2030/31.

The two prime contractors under consideration to build the *Athena* spacecraft have continued to work on their designs for the Science Instrument Module (SIM) that will connect the instruments to the spacecraft. This work will be complete by August 2019, in preparation for the MFR.

The development of the WFI is progressing steadily. At the end of October 2018, the WFI passed a critical milestone with the successful completion of the IPRR. The review was held jointly by ESA and the German Space Agency (DLR) over a period of six weeks and addressed important issues related to the instrument and the consortium. The successful IPRR concluded Phase A (Feasibility Study) of the instrument and officially started Phase B (Preliminary Definition). The next milestones are the Instrument System Requirements Review ($\sim$ 2020) and Instrument Preliminary Design Review ($\sim$ 2022). Mentioned above the Instrument Consortia Consolidation (ICC) Process was completed in December 2018 with the official endorsement of the WFI Consortium by ESA.

The instrument and technology development activities progress steadily. Flight-like, full-size DEPFET sensors are currently in production at the Semiconductor Laboratory of the Max Planck Society and should be available for test in the summer. Following a trade-off study based on an extensive test campaign using the output of the previous production run, the decision about the DEPFET readout mode was taken. The mode of choice (so called Drain Readout) will enable the required fast readout while ensuring an excellent spectroscopic performance.

Since the last HEAD newsletter there have been two meetings of the WFI consortium. The 8th Meeting was held at the Faculty of Science of Lisbon University, Portugal from November 20–22, 2018, and the 9th at MPE, March 26–28, 2019. Both featured around 100 scientists and engineers who celebrated the successful IPRR and consortium consolidation, and discussed the next steps in the development of the instrument throughout Phase B.

In December 2019, the *Athena* Community Office (ACO) released the fifth issue of the *Athena* Community Newsletter. On top of the usual welcome, updates on the project, news from the instruments and short bios from some members of the *Athena* community, this issue included a science nugget entitled "Shaken and stirred galaxy clusters through Athena's eyes".

Combining the ACO's usual participation in the International Day of Women and Girls in Science on February 11 with the International Year of the periodic table of chemical elements, we have prepared several short videos with female members of the *Athena* community on the periodic table of the elements, which can be seen in our YouTube channel.

The *Athena* gallery is being populated with up-to-date figures and images related to the mission, including figures of merit, simulated images and spectra, artistic impressions and illustrations from the nuggets.

The yearly call for new members of the *Athena* community was issued in December 2018: we have now reached 800 members supporting the scientific and technological activities of the mission. Look for yourself in the *Athena* community map.

Athena was featured in presentations at a number of recent conferences, including several US meetings e.g. the 223rd AAS in Seattle, WA, the 17th HEAD meeting in Monterey and the meeting on the Space Astrophysics landscape for the 2020s and beyond in Potomac, MD. Slides from some of the above talks are available at the *Athena* website.

You can keep up-to-date with *Athena* via the community website, or on Twitter (@AthenaXobs) and Facebook. Important notifications are sent to the *Athena* Community through bimonthly Brief News emails.

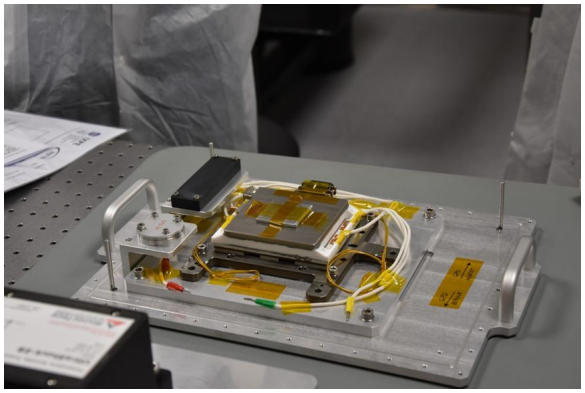
Following on from the successful ESO and SKA exercises, the *Athena* community has continued to explore the exploitation of synergies with major future facilities. An exercise looking into synergies with *LISA* was organized by ESA and was recently concluded, with publication of

the results pending. A more general multi-messenger synergy activity organized by the *Athena* Science Study Team and co-ordinated by Luigi Piro of IAPS, Rome, is also ongoing, with a kickoff meeting held in Alicante in November 2018. Activities looking into synergies with LSST are also ramping up, with a core team established (including several US scientists), chaired by Mike Watson of the University of Leicester.

The Imaging X-ray Polarimetry Explorer

M. C. Weisskopf, Brian Ramsey, & Steve O'Dell (NASA/MSFC)

Following a successful Ground System Preliminary Design Review (GS-PDR) held in February, the *IXPE* Project moves toward its Mission Critical Design Review (M-CDR), scheduled for late June. Due to the maturity and stability of the Observatory design, long-lead items continue to be procured or manufactured. Everything from some flight cable harnesses to at least two flight-quality polarization-sensitive detectors are now complete. The US Government furlough impacted neither the prime contractor nor the *IXPE* Italian Partners; however, it did interrupt activities at MSFC, most notably production of mirror modules. Nevertheless, a restructured X-ray calibration plan accommodates the consequences of the 5-week furlough without delaying the launch, still scheduled for 2021 Spring.



An IXPE flight detector. Credit: NASA/M. Weisskopf.

The X-ray Imaging and Spectroscopy Mission

Richard Kelley (NASA/GSFC) & Brian Williams (NASA/GSFC)

Steady progress is being made on finishing the NASA hardware contributions to *XRISM*. The flight detector assembly and magnetic refrigeration system are complete and in the process of being integrated before going through extensive performance and environmental tests this spring, followed by calibration measurements with a variety of laboratory X-ray sources this summer. The integrated system, referred to as the Calorimeter Spectrometer Insert, is scheduled to be delivered to Japan in October 2019. The first set of aperture thermal blocking filters is complete, and all of the reflectors ($\sim 4,000$) for the two x-ray mirrors have been fabricated. The first two quadrants of the first X-ray Mirror Assembly have been assembled and are in testing at a 100 m X-ray beam line at Goddard.

In Japan, the *XRISM* mission has successfully completed the preliminary design review process. The mission critical design review is planned for fall 2019. The project is working toward a launch in early 2022.

The *XRISM* Science Team is currently busy discussing potential targets for the mission to observe during the 6 month "Performance Verification" (PV) phase. This is a phase of the mission, occurring after the initial checkout and calibration phases (which will last a few months), during which the performance of the instruments will be verified through the observations of a wide variety of celestial targets. These targets will be selected via a consensus of the Science Team, and will span the range of the types of targets that *XRISM* will observe during its Guest Observer phase, which will commence immediately after the conclusion of the PV phase. All PV phase data will enter in the public archive one year after the observation is complete.

At the time of this writing, the *XRISM* Science Team is preparing for a team meeting to be held at the Institute of Space and Astronautical Sciences in the Tokyo area from May 14–17. This meeting will consist of project status updates, plans for mission operations, general science policy discussions, initial reports from various sub-groups on potential PV targets, and talks from various other ground and space-based missions on the synergies with *XRISM* in the 2020s.

May will also mark the first meeting of the Joint Executive Steering Group (JESG), taking place at JAXA HQ in Tokyo and coinciding with the *XRISM* Team meeting. The JESG represents a high-level agency to agency interface, with representatives from NASA and JAXA HQ present to discuss any mission-level issues that may arise.

Finally, JAXA has convened a standing board known as the "External Science Advisory Panel" (ESAP). The ESAP consists of members from the US, Japan, and Europe, and is organized as a body of senior astronomers, not involved with the *XRISM* project, to occasionally consult for advice on matters of science policy, mission operations, or anything else that might benefit from an outside opinion. ESAP members do not receive data access during the PV phase, and do not become Science Team members. We are pleased to announce that the two US members that have agreed to join this panel are Nancy Brickhouse (CfA) and Gerry Kriss (STScI).

The Cherenkov Telescope Array

DAVID WILLIAMS (UCSC)

On January 17, 2019, the prototype Schwarzschild-Couder Telescope (pSCT) for the Cherenkov Telescope Array (CTA) was unveiled at a special inauguration event at the Center for Astrophysics Harvard & Smithsonian, Fred Lawrence Whipple Observatory (FLWO) in Amado, Arizona. A dual-mirrored Medium-Sized Telescope, the SCT is proposed to cover the middle of CTA's energy range (80 GeV – 50 TeV).

The SCT's complex dual-mirror optical system improves on the single-mirror designs traditionally used in gamma-ray telescopes by dramatically enhancing the optical quality of their focused light over a large region of the sky and by enabling the use of compact, highly-efficient photo-sensors in the telescope camera.

The inauguration of the Schwarzschild-Couder Telescope. Credit: Deivid Ribeiro, Columbia University.

The week following the inauguration, the camera was operated for the first time with the mirrors uncovered in a commissioning test run. During the first few minutes of this "first light" run on the evening of January 23, cosmic-ray-induced Cherenkov air shower events were identified in the raw, uncalibrated camera data. Videos show 50 nanoseconds of a single event in which the Cherenkov air shower development is recorded by the camera with one nanosecond resolution (time between video frames). The pSCT camera triggers when several neighboring pixels detect light within a few nanoseconds of one another. The camera has a modular design, with 25 modules each containing 64 pixels. The central module is not yet installed, in order to shine a laser beam along the central axis for telescope alignment, and a neighboring module was disabled during the test run. The pixel amplitudes are raw and uncalibrated, but the early results are a major milestone for the SCT team. The pSCT commissioning will continue in 2019, including alignment of the mirror panels of both the primary and secondary mirror, positioning of the camera with respect to the focal plane and calibration of the camera data.

Lynx

DOUG SWARTZ (USRA & NASA/MSFC), JESSICA GASKIN (NASA/MSFC)

Lynx is one of four large-mission concept studies NASA is sponsoring in preparation for the 2020 Astrophysics Decadal Survey. The *Lynx* concept study is led by a community-driven Science and Technology Definition Team (STDT) charged with defining an exciting mission that addresses compelling science objectives advancing the boundaries of our knowledge about the high energy universe. The *Lynx* team established a baseline Design Reference Mission (DRM) early last Fall. The four enabling technologies of the DRM are the grazing incidence Silicon Meta-shell Optics (SMO) built of mono-crystalline silicon substrates in a highly modular design, the large field-of-view high spatial resolution High-Definition X-ray Imager (HDXI) optimized for deep survey science, the spectrophotometric imaging *Lynx* X-ray Microcalorimeter (LXM) optimized for spectral mapping of extended structures, and the Critical Angle Transmission (CAT) X-ray Grating Spectrometer (XGS) providing extremely high spectral resolution in the soft X-ray band. Given this suite of telescope components, the study team at NASA's Marshall Space Flight Center and the Smithsonian Astrophysical Observatory have greatly refined all aspects of the *Lynx* mission concept in preparation for the final report due in August 2019.

In November 2018, the STDT met to develop a less costly reduced architecture by carefully considering the trade between cost and capability with a goal to provide a range of possibilities to inform the Decadal Survey. Many variants were discussed, from reductions in instrument and optics capabilities to elimination of instruments. The reduced architecture and several options will be included in the *Lynx* final report. In early March, the *Lynx* STDT and several *Lynx* Science Working Group members led the preparation of science white papers submitted in response to a Decadal Survey invitation to the community. These white papers focused on how our understanding of the scientific frontiers in astronomy may be advanced in the next decade and beyond. Topics covered the full range of thematic science areas including (to name just a few): X-ray studies of exoplanets and their irradiating stars, X-ray lensing studies of quasars and galaxies, stellar X-ray spectroscopy, and the origin of the early massive black holes.

The special section of the Journal of Astronomical Telescopes, Instruments, and Systems focusing on *Lynx*-

specific technology developments is expected to be published in June 2019. This issue will contain over 20 peer-reviewed papers detailing the key *Lynx* technologies, their designs, and their current capabilities. A *Lynx* calibration workshop was held in Huntsville, March 12–14, 2019. The purpose of the workshop was to define the technical approach for calibration, assess existing and planned support equipment and facilities especially at MSFC's X-Ray and Cryogenic Facility (XRCF), and correlate ground and flight calibration plans. In addition, the workshop addressed the proposed post-Phase A development scope and programmatics for all *Lynx*-enabling technologies and developed the overall observatory assembly, integration and test sequence, content, and schedule. There were also reviews and validations of technical development plans for the payload science instruments and optics. In advance of the *Lynx* final report submission, NASA has assembled a Large Mission Concept Independent Assessment Team (LCIT). The LCIT will conduct a cost and technical credibility analysis that is an independent assessment and validation of the technical, cost, and schedule requirements described in the concept draft final report of each of the four large mission concept studies. The *Lynx* team delivered material to the LCIT to support their work on April 26, 2019. The delivery included detailed plans for maturing the *Lynx* enabling technolgies, estimates of mission costs, development schedules, and appraisals of project-level risks and risk mitigation.

AstroPoetry Corner

M. F. Corcoran (NASA/GSFC/The Catholic University of America)

"Installed in the fall of 2018 on the south side of the Physical Sciences Complex [at the University of Maryland], this garden honors the work of Professor Joseph Weber (1919-2000). This garden features an installation of solid aluminum cylinders that were the cores of gravitational-wave "bar" detectors, which were invented, built, and operated by Professor Weber. Each bar was hung horizontally by cables at its middle, leaving the ends free to vibrate. Electromechanical sensors were attached to the bars to pick up the tiny oscillations that would be induced by passing gravitational waves emitted from astrophysical objects in the universe, as predicted by Einstein's general theory of relativity. [Weber's] visionary efforts led to the birth of a new field of research, which eventually came to fruition with the direct detection of gravitational waves in 2015. The garden is planted with dianthus, lambs ear, and oakleaf hydrangea, with a crushed stone edging." Credit: University of Maryland Arboretum and Botanical Garden

A Hecatomb for Urania
(for VT)

A hard lesson learned
through the indivisible passage of time:
there is a profound danger in speaking
openly of those you love.
Safer indeed to catalog trifles, ponder our excesses,
with mathematical precision illustrate
the eternal, external, and
internal constitution of a world
we believe we've mastered.
Around us, we know now,
a virgin universe shakes and trembles.

Somehow we're removed
from the center of things: miracles
clothed in the commonplace.
so we rise in these dark times to center ourselves
collect the tiring light, struggle
to make the darkness visible,
temporize to halt our peculiar
motion through the cosmic void,
temporarily.

The essence of a primordial egg
like love so suddenly spilled out,
a libation of sorts:
Muse, pluck your quivering strings, inspire us;
Old artificer, bespangled in galaxies, dark attraction
hold us in thy stead;
Horizon of darkness, feeding back to blackness
reveal yourself to us;
Blackness twirling eternally
move us,
between life and death and back to life again.