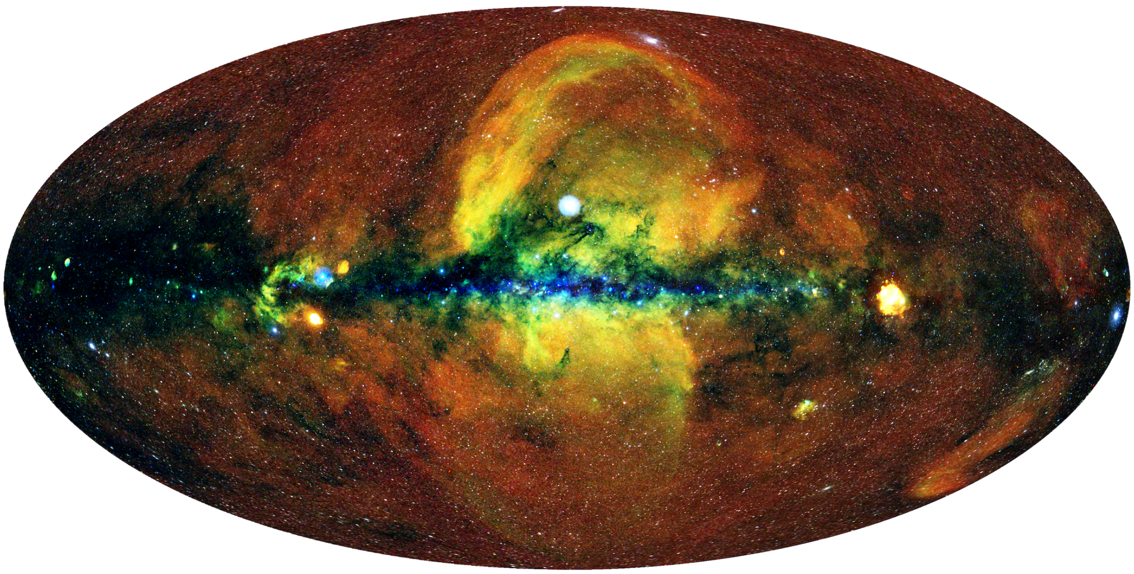
The High Energy Astrophysics Division Newsletter

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



The energetic universe as seen with the eROSITA X-ray telescope on SRG. As eROSITA scans the sky, the energy of the collected photons is measured with an accuracy ranging from 2% - 6%. Photons are color-coded by energy (red for energies 0.3–0.6 keV, green for 0.6–1 keV, blue for 1–2.3 keV). The eROSITA all-sky X-ray image has a resolution of about $10''$ and a corresponding dynamic range of more than one billion; for display purposes, the image above has been smoothed with a $10'$ FWHM Gaussian.

In this Issue:

View From the Chair

FIONA HARRISON (CALTECH)

Last Spring, when I wrote the introduction for the first installation of the HEAD newsletter under my term as Chair, after cancellation of the 18th Divisional meeting in Tucson, I looked forward to meeting again at the January AAS meeting. Of course, we now know that it is unlikely that we will see each other in person before summer. That said, the division remains active in planning ways to stay connected and to communicate the many exciting scientific results from our members, missions and observatories.

In June, we instituted the HEAD virtual seminars, monthly Zoom talks open to the community and intended to highlight new results, particularly from our student and early-career members. The seminars have been very high quality, and also well attended. If you have an interesting result, or want to communicate your research, please sign up to give a talk. Videos of the talks are available on the HEAD Youtube channel.

We are also pleased to announce our HEAD Dissertation Prize finalists: Adi Foord, Renee Ludlam, and Guang Yang. Selected from an outstanding and broad set of candidates, Guang, Adi, and Renee will give talks at the virtual 237th AAS meeting this January during the HEAD special session on Monday, January 11 starting at noon ET. The Dissertation Prize winner will be selected after these talks.

There are lots of other HEAD activities planned for the January AAS meeting. The second HEAD session on Tuesday January 12 celebrates fifteen years of astounding time-domain astrophysics from the Neil Gehrels Swift Observatory. The Rossi Prize talk, also on Tuesday, will be given by Shep Doeleman for the spectacular Event Horizon Telescope images of M87. Although we will have to forgo the food and drink, we will hold the HEAD Business Meeting 7 – 8 pm Tuesday, when we will announce the winner of the 2021 Rossi Prize. A slimmed-down version of the 18th Divisional meeting will take place as a "meeting-within-a-meeting" during the 238th AAS Meeting in Anchorage in June. We hope that this will be in person, but of course that depends on factors outside of our control; however with vaccines on the horizon we remain hopeful.

Finally, a reminder to vote in the HEAD elections. You should have received an email with the candidate roster, and link to where you can vote for two new members of the executive committee. We will announce the results of the election at the January Business Meeting (assuming, of course, that all recounts and legal challenges are resolved by then).

Best wishes for the holidays, New Year, and most of all I hope you stay safe.

HEADlines

MEGAN WATZKE (CXC)

While the coronavirus still dominates the media landscape, many reporters have also found the bandwidth to process other science news that has nothing to do with pandemic. And, of course, while we may be distracted here on Earth, the rest of the Universe carries on.

The June AAS meeting was an excellent example of how science marched on. Held virtually for the first time, the meeting allowed media to participate in press conferences (largely) the same way they have prior to the pandemic. Throughout the last half year, NASA, ESA, universities, and other institutions have continued to release results from its high-energy missions and experiments.

A sample of the recent news from HEAD missions since last May includes:

- November 4, 2020 "NASA Missions Help Pinpoint the Source of a Unique X-ray, Radio Burst"
- October 30, 2020 "Assessing the Habitability of Planets Around Old Red Dwarfs"
- September 22, 2020 "Data Sonification: Sounds from Around the Milky Way"
- August 25, 2020 "NASA Missions Explore a 'TIE Fighter' Active Galaxy"
- July 28, 2020 "Dead Star Emits Never-Before Seen Mix of Radiation"
- July 16, 2020 "Runaway Star Might Explain Black Hole's Disappearing Act"
- June 18, 2020 "X-rays from a Newborn Star Hint at Our Sun's Earliest Days"
- June 17, 2020 "A Cosmic Baby Is Discovered, and It's Brilliant"
- June 1, 2020 "Scientists Detect Crab Nebula Using Innovative Gamma-ray Telescope, Proving Technology Viability"

In May, a committee selected Steven Nadis, a freelancer based in Cambridge, MA, as the recipient of the 2020 David N. Schramm Award, HEAD's award for excellence in science journalism covering high-energy astrophysics. His winning article, Ripple Effect, appeared in the May 2019 issue of Discover Magazine.

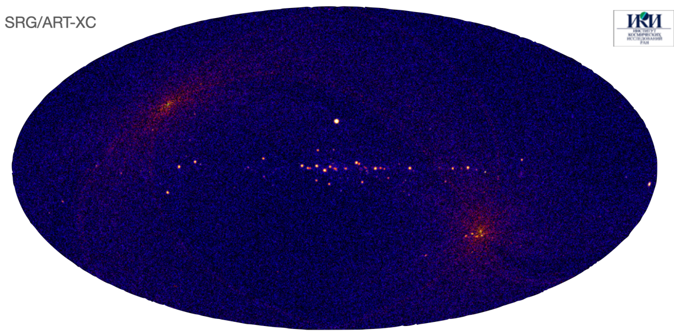
As always we encourage shameless self-promotion. If you've got a recent science result that may be of interest to the public at large, please contact the HEAD press officer, Megan Watzke. And if you've got an interesting image based on (or involving) high-energy observations, contact Mike Corcoran for consideration as a High Energy Astrophysics Picture of the Week.

Spektr-RG, ART-XC & eROSITA

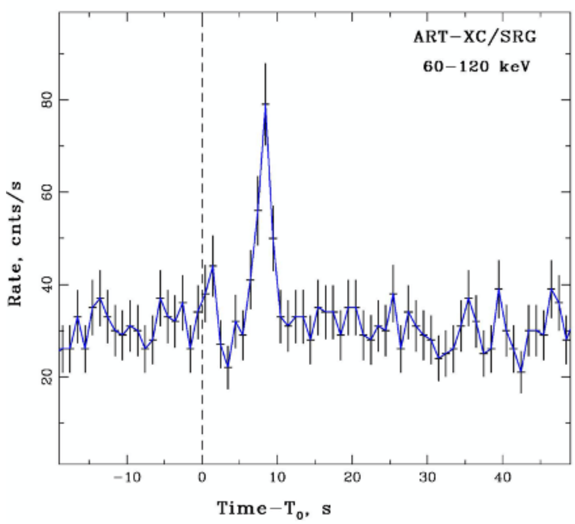
A. MERLONI (MPE), A. LUTIVONOV (IKI), P. PREDEHL (MPE), S. SAZONOV (IKI)

We are very sad to report the tragic loss of Dr. Mikhail Pavlinsky, the PI of the ART-XC telescope, on July 1. The ART-XC telescope has been renamed in his honor. The Mikhail Pavlinsky ART-XC telescope has been operating on board the SRG satellite for almost one and a half years, and its performance fully meets expectations so far. All in-flight characteristics have proved to be close to pre-launch performance. In particular, the point spread function is better than $1'$ (half-power diameter) in survey mode. All telescope systems are healthy and operating nominally. The all-sky survey is continuing smoothly, with scientific data received at the ART-XC Science Data Center at IKI in Moscow on a daily basis.

ART-XC completed its first scan of the sky (Dec. 2019-June 2020) and has detected more than 600 sources, of which $\sim$40% are extragalactic (mostly AGN and also a few tens of rich clusters of galaxies) and $\sim$60% are Galactic (X-ray binaries, cataclysmic variables, supernovae remnants, etc.). ART-XC has also discovered a few tens of new X-ray sources, including a dozen heavily obscured active galactic nuclei (identified with the help of optical follow-up observations) and a number of interesting transient sources. These early mission results confirm the anticipation that ART-XC will create the best all-sky map in the 4 – 12 keV energy band in the history of X-ray astronomy upon completion of the 4-year all-sky survey.

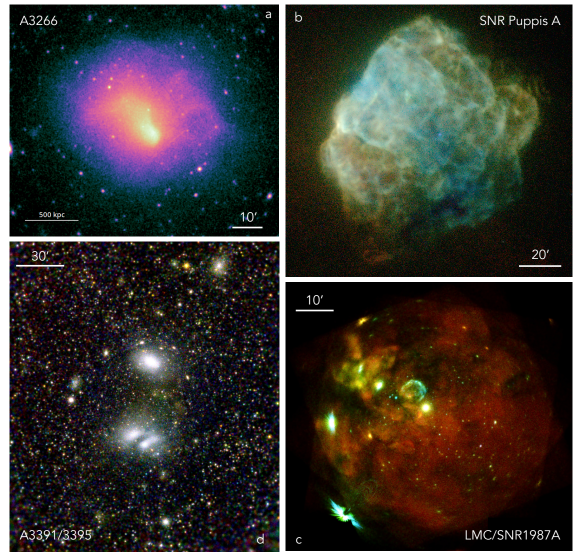


Map of the sky in hard X-rays (4 – 12 keV, Galactic coordinates) obtained by the Mikhail Pavlinsky ART-XC telescope during the first 6 months of the all-sky survey (Dec. 2019 – June 2020). Only the brightest of the more than 600 detected sources are visible on such a large scale. Credit: IKI



Profile of a gamma-ray burst detected by the Mikhail Pavlinsky ART-XC telescope through the side walls of the detectors in the energy range of 60 – 120 keV. The dashed line corresponds to the start of the GRB.

In survey mode, the ART-XC telescope observes about 1% of the sky per day with a sensitivity of $\sim 10^{-11}$ erg cm^2 s^{-1} in the 4 – 12 keV energy band. This sensitivity is much better than the typical values for other wide-field or all-sky instruments. Thus, ART-XC can provide the community with early triggers of new, exciting X-ray events with a localization accuracy of $\sim 15''$. The near-real time analysis software (NRTA ART-XC) provides a typical response time of 1 – 2 hours from the beginning of the downlink for the detection of such events. ART-XC has already detected several dozen X-ray transients of different kinds, including X-ray outbursts from known and new sources, as well as gamma-ray bursts. It is important to note that ART-XC is capable of detecting bright gamma-ray bursts up to energies of $\sim$120 keV from almost the entire sky through the side walls of the detectors.



Four images taken by SRG/eROSITA during its early operations phases. From the top left, clockwise: (a) The Abell 3266 cluster of Galaxies (image taken in the 0.5 – 2.1 keV energy range, exposure ∼74ks), showing the disturbed and turbulent hot atmosphere; (b) the Supernova Remnant Puppis A (a "false color" X-ray image in the energy bands 0.2 – 0.5, 0.5 – 1 and 1 – 2 keV, exposure ∼60ks); (c) part of the Large Magellanic Cloud, centered on the bright SNR 1987A, showing the hot multi-phase gas permeating the closest neighbor of the Milky Way (a "false color" X-ray image in the 0.5 – 1, 1 – 2 and 2 – 4.5 keV energy bands, exposure ∼80ks); (d) a wide field centered on the interacting triple clusters system Abell 3391/3395 (a "false color" X-ray image in the 0.4 – 0.8, 0.8 – 1.5 and 1.5 – 3 keV energy bands, average exposure ∼20ks). Courtesy of J. Sanders, P. Predehl, F. Haberl (MPE), T. Reiprich (AIfA, Bonn). MPE/IKI.

The unique properties of the SRG/eROSITA telescope are its ability to take deep images, which are highly sensitive to both point-like and diffuse emission, over very large areas of the sky. This is realized by virtue of the large field of view of the telescope, and by the "raster-scan" observing mode, which delivers uniform exposures over rectangular fields of size up to $\sim$150 deg^2 at a time. The science analysis of eROSITA Calibration and Performance verification data continues, and an "Early Data Release", with a suite of accompanying papers, is expected to be published next Spring.

The first SRG All-Sky Survey was conducted between December 13, 2019 and June 11, 2020, delivering an average exposure with eROSITA of about 200s/cos(λ), where λ is the ecliptic latitude, while the 1 square degree area around the ecliptic poles is revisited every four hours, accumulating an exposure of about 30ks per survey. A preliminary analysis of the eROSITA all sky survey detected more than one million X-ray point sources and about 20,000 extended sources. This is comparable to, and indeed may exceed, the total number of X-ray sources known before eROSITA. Multi-wavelength identifications using the WISE and Gaia catalogs indicate that about 80% of the point sources are distant Active Galactic Nuclei (comprising, among others, $\sim$80% of all known Blazars), and 20% coronally active stars in the Milky Way, including about 150 planet-hosting stars (this is about $\sim$10% of all known planet-hosting stars outside of the Kepler Field).

LIGO/Virgo: Results from the Third Observing Run

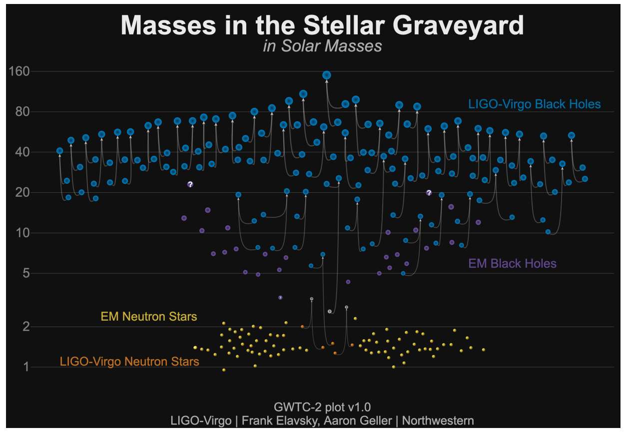
Patrick R. Brady
(University of Wisconsin. Milwaukee, on behalf of the *LIGO* Scientific Collaboration)

LIGO and *Virgo*'s third observation run (O3) ran from April 2019 until its early suspension in March 2020, about a month prior to the planned date due to COVID-19. The run had a month-long break during October 2019 for detector upgrade work and so was divided into O3a and O3b for before and after the break.

A total of four exceptional events have been announced from O3 so far – together with an updated event catalog, GWTC-2, which includes O3a and brings the total number of high-confidence gravitational-wave detections to 50 in less than five years.

The first O3 exceptional event announced, in January 2020, was GW190425. This chirplike signal was detected on April 25th 2019 and was consistent with a binary neutron star merger at a distance of about 520 million light years. However, the combined mass of the two merging objects was unusually high, around 3.4 times the mass of our Sun, and a clear outlier from the Galactic population of binary neutron star systems observed by radio astronomers. This suggests that GW190425 may have formed differently from these known Galactic binaries. To date no electromagnetic counterpart or neutrino signal associated with GW190425 has been identified. This is not surprising, however, in view of its distance and the fact that it was localized to only about 16% of the entire sky.

Next to be announced, in April 2020, was GW190412, a binary black hole merger detected on April 12, 2019 and the first in which the two black holes are definitely unequal in mass: about 30 times and 8 times the mass of the Sun. The main gravitational-wave emission from a binary system, at twice the orbital frequency, is analogous to the fundamental frequency heard when plucking a guitar string. However, it is also possible to have emission at harmonics of this fundamental frequency – just like "overtones" in music – and asymmetric systems are predicted to emit gravitational waves with stronger, higher harmonics. Indeed, the signal from GW190412 supports the hypothesis that there are higher harmonics, by a factor of greater than 1000:1.



Plot showing the masses of all compact binaries detected by LIGO/Virgo as reported in GWTC-2, with black holes in blue and neutron stars in orange. Also shown are stellar mass black holes (purple) and neutron stars (yellow) discovered with electromagnetic observations. Credit: LIGO/Virgo/Northwestern Univ./Frank Elavsky

June 2020 saw the announcement of GW190814, a compact binary merger event that was observed by the *LIGO* Hanford, *LIGO* Livingston and *Virgo* detectors on August 14th 2019. This is an especially intriguing source as the heavier compact object is a black hole approximately 23 times the mass of the Sun while the lighter companion has a mass between 2.5 and 3 Solar masses. This makes GW190814 the most asymmetric system observed with gravitational waves to date, even more asymmetric than GW190412. Moreover, the mass measured for the lighter compact object makes it either the lightest black hole or the heaviest neutron star ever discovered in a system of two compact objects – but we can't be sure which. GW190814 poses many interesting questions about the masses of compact objects, their formation and the properties of neutron star matter. Future observations of more asymmetric systems like this one should help to answer those questions.

In September 2020 a fourth O3 exceptional event was announced. Detected on May 21, 2019, GW190521 is the most massive black hole merger ever observed by *LIGO* and *Virgo* and the merger remnant, at nearly 150 solar masses, is the first clear detection of an "intermediate-mass" black hole. Moreover, the mass of the larger progenitor black hole sits squarely in the "Pair Instability" mass gap, indicating that it was not the direct product of stellar collapse, and posing a number of challenging questions about the likely formation channels for this system – such as whether it might be the result of a series of hierarchical mergers. The astrophysical implications of this event, including its usefulness as a test of strong-field general relativity, are explored in a companion article to the main GW190521 discovery paper.

Finally, in late October 2020, a series of papers were submitted to the Arxiv presenting an updated catalog, GWTC-2, of 50 confident gravitational-wave detections since September 2015, including 39 detections from O3a. Thus, remarkably, O3a produced about three times more confidently-detected gravitational-wave events than the two previous observing periods combined. In GWTC-2 we have introduced a revised naming convention for our reported gravitational-wave events. The old convention of just using the date of the observation continues for previously published events, including the four exceptional events discussed above. For new GWTC-2 events, however, the UTC time of their detection is added to their name; for example GW190701_203306 was detected at 20:33:06 UTC on July 1st 2019. This way, we can have unique names even for two events detected on the same day, as happened three times in O3a.

Full details of the O3 exceptional events announced to date, the GWTC-2 catalog papers and the scientific results contained therein can be found on our website. You can also find recordings of a recent series of webinars about these discoveries on our *LIGO Virgo* YouTube channel.

With all of these discoveries announced in 2020, the future of gravitational-wave astronomy is increasingly promising. Analysis the O3b observing run is currently in progress and will further expand our growing gravitational-wave transient catalog. Following O3, detectors will undergo additional engineering improvements to further increase their astrophysical reach in time for the fourth observing run, which is scheduled to begin in 2022. While we await instrumental improvements and the construction of new detectors, the gravitational-wave community will continue to explore the nature of black holes and neutron stars throughout the universe.

(Adapted from articles first published in the March 2020 and September 2020 editions of the LIGO Magazine.)

IceCube Neutrino Observatory

MADELEINE O'KEEFE (UNIVERSITY OF WISCONSIN–MADISON)

Construction work on the IceCube Upgrade was supposed to start this November, but those plans were changed because of the COVID-19 pandemic. Antarctica remains the only coronavirus-free continent, so activities at the South Pole – including maintaining and operating the IceCube observatory – have been able to continue as usual. But now that the Pole is opening back up, the U.S. Antarctic Program is taking special precautions to keep COVID-19 out of Antarctica, including limiting the number of people who will deploy this season.

We had planned to send a few dozen people to start work on the Upgrade this austral summer. Instead we will only be sending down two new winterovers (who must first undergo extensive quarantines) and bringing our two current winterovers home safely.

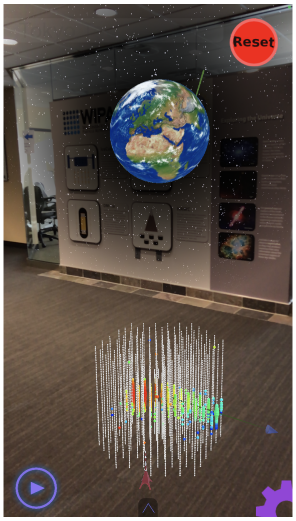
Up north, IceCube collaborators have been involved in some exciting new science results.

A number of collaborators, led by Robert Stein of DESY, co-authored *A high-energy neutrino coincident with a tidal disruption event*. On October 1, 2019, IceCube reported the detection of a neutrino (IC191001A) with an energy of approximately 0.2 PeV and a 59% probability of being of astrophysical origin. Seven hours later, the Zwicky Transient Facility observed the direction of that neutrino. They found the candidate neutrino source to be a radio-emitting tidal disruption event (TDE) called AT2019dsg. TDEs are rare transients that occur when stars pass close to supermassive black holes. The authors' analysis found that AT2019dsg provides an ideal site for PeV neutrino production, and the association suggests that TDEs contribute to the still-unexplained cosmic neutrino flux.

Meanwhile, IceCube's PI, Professor Francis Halzen, co-authored a paper with other IceCube collaborators, *Neutrino emission during the γ-suppressed state of blazars*, which describes a study of the mechanisms that lead to astrophysical particle acceleration and neutrino production. They compared data from three blazars with high-energy neutrino counterparts—including TXS 0506+056, the blazar that IceCube identified as a source of high-energy neutrinos in 2017—and found that they all experienced a short-term γ suppression at the time that the neutrino was detected. This suggests that we should not expect a γ-flare during the high-energy neutrino emission and, in fact, we should focus on studying γ minimums. If this model is correct, then it is substantially easier to discover neutrino-blazar connections, and it is possible that previously recorded IceCube and *Fermi*-LAT observations are already sufficient to identify the origin of the bulk of the high-energy neutrinos detected from the universe.

In late September, an augmented reality app for IceCube was released to the public. Called IceCubeAR, or IceBear, the app shows visual representations of neutrino events from real IceCube data in augmented reality. IceCubeAR users can view a number of IceCube's previous detections, and they will also receive real-time alerts about neutrino candidate events mere minutes after IceCube makes an interesting detection. (However, not all of these candidate events turn out to be astrophysical neutrinos.) IceCubeAR is available for download on the iOS App Store and the Google Play Store. You can also find it by searching "IceCubeAR" in the respective stores. The project was headed by IceCube collaborator Lu Lu, a postdoc at Chiba University in Japan who will soon join the faculty of the Wisconsin IceCube Particle Astrophysics Center at UW–Madison. It was co-developed by Colin Baus, Vsevolod Yugov, and Thomas Hauth.

We must note that this app is intended to be a fun tool for outreach; users cannot make scientific discoveries with IceCubeAR. If you have scientific questions on IceCube alerts, you may contact IceCube's real-time oversight committee at roc@icecube.wisc.edu.



Screenshot from the new IceCube augmented reality app, IceCubeAR. Credit: IceCube Collaboration

The Chandra X-ray Observatory

Roger Brissenden (SAO),
Martin C. Weisskopf (NASA/MSFC)

The *Chandra* X-ray Observatory has carried out more than 21 years of highly successful and productive science operations. *Chandra* is unique for its capability to produce 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 *Chandra*'s important role in high-energy astrophysics, NASA has chosen to continue the mission and extend the contract to operate the *Chandra* X-ray Observatory, with science observing potentially through September 2027.

Dr. Patrick Slane, a senior astrophysicist at the Center for Astrophysics | Harvard & Smithsonian (CfA), has been appointed Director of the *Chandra* X-ray Center (CXC), succeeding Dr. Belinda Wilkes upon her retirement. Dr. Slane has been involved with *Chandra* since before its 1999 launch, serving in roles including leader of the science mission planning team and as the CXC's Assistant Director for Science. Dr. Slane received his Ph.D. in physics from the University of Wisconsin at Madison, and he became a research astrophysicist at the SAO in 1988. Having taught high school physics and astronomy prior to his Ph.D. studies, Dr. Slane is particularly interested in science education, and is committed to promoting diverse participation in the study of astronomy, and science generally, at all levels. Dr. Slane's research interests include the study of supernova remnants, young neutron stars, and pulsar wind nebulae. Dr. Slane began as CXC Director on September 28.

Dr. Wilkes served as CXC Director since 2014, succeeding Dr. Harvey Tananbaum. Dr. Wilkes joined the CfA in 1984 and has been a part of the CXC for many years, including as deputy leader of the User Support Group and Assistant Director of the CXC. Prior to her work on *Chandra*, Dr. Wilkes served as a data verification scientist for the *EINSTEIN* mission and as lead data scientist for the *ROSAT* program. As CXC Director, Dr. Wilkes oversaw many major accomplishments for the mission, including two highly successful Senior Reviews conducted by NASA, the move of the *Chandra* Operation Control Center (OCC) to a new state-of-the-art facility, the multi-faceted celebration of the mission's 20th anniversary for both the scientific community and the public, and the extension of the CXC contract with NASA. Dr. Wilkes has recently been selected as a Fellow of the American Physical Society. She will be missed and we thank her for her commitment to *Chandra*.

Dr. Patrick Slane. Credit: CXC

Since March 2020, *Chandra* science and mission operations have been challenged by the coronavirus pandemic. CXC staff have successfully adapted to a new environment in which working remotely is the norm, with a minimum number of staff physically at the OCC and the science center to carry out spacecraft communications and computer system operations. Our primary goals are ensuring the health of our staff and maintaining the continued normal operation of *Chandra*. Protocols and schedules are in place to keep operators physically and temporally separated and to properly clean the OCC. In the next phase of response to the pandemic, procedures have been instituted to increase the number of staff in phases, maintaining reduced occupancy and physical separation.

Normal operation of the spacecraft, as well as processing and distribution of data and support of the scientific community, have continued unabated. In addition, operations staff and instrument scientists responded effectively to two spacecraft anomalies during the pandemic. Both were resolved successfully with staff working from remote locations. In May 2020 the spacecraft transitioned to safe mode due to a timing error in the command sequence. No hardware was involved and *Chandra* returned to science operations within a few days. In August a hardware anomaly in the High Resolution Camera required staff to turn off the HRC. After careful analysis, planning and review, the HRC's control electronics were swapped to its redundant circuits (*Chandra* is equipped with duplicate sets of electronics and hardware for many functions). Procedures have been carried out to return the HRC to full observing, which will be completed after checkout of the HRC-S configuration. The HRC has resumed its role of providing radiation monitoring for protection for the instruments, and the ACIS instrument is carrying out normal science observing.

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 ($\lesssim$ 1.5 keV). The decline in thermal insulation effectiveness requires extra effort in scheduling observations, but has not significantly affected *Chandra*'s observing efficiency.

The *Chandra* Source Catalog version 2.0 (CSC 2.0) was released to the community in October 2019. CSC 2.0 is the second major release of the catalog, and represents a significant improvement over its previous version in terms of sky coverage, sensitivity and capabilities. The catalog includes measured and derived properties for 317,167 unique compact and extended X-ray sources, allowing statistical analysis of large samples as well as studies of individual sources.

The call for proposals for Cycle 22 observations, which was issued in December 2019, resulted in 519 proposals, including 426 proposals for observing and 93 for archive and theory research. The observing proposals requested a total of 9.5 Msec of telescope time, for an oversubscription factor of $\sim$ 4.3. The Cycle 22 peer review, held remotely in June 2020, approved 142 observing proposals and 22 proposals for archive and theory research.

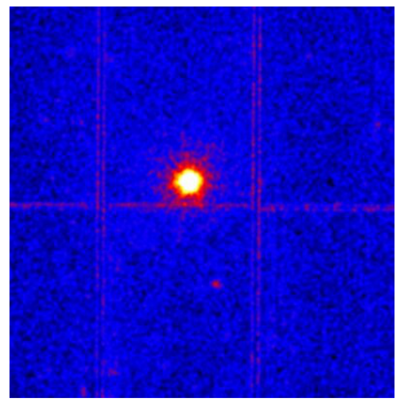
The CXC held a workshop, *Chandra* Frontiers in Time-Domain Science, in October 2020. The workshop, which was conducted via remote access, featured 36 invited speakers.

The *Chandra* Press Office has been active in issuing image releases, science press releases and other communications of *Chandra* research results. A complete listing is available at the Press Office webpage. As always, more Information about the *Chandra* Observatory and the *Chandra* X-ray Center can be found at the CXC's website.

XMM–Newton

Lynne Valencic (JHU/NASA) and Kim Weaver (NASA)

The 20th Announcement of Opportunity closed on October 9. In all, 447 proposals were received, from 373 different PIs in 29 countries. Including Co-I's, about 1600 scientists were involved in this AO. A substantial number of proposals (23%) were requests for joint time with *XMM–Newton* and another mission (*NuSTAR*, *HST*, *Swift*, VLT, *Chandra*, NRAO, or H.E.S.S.) The over-subscription factor was 6.9. The final program will be announced in mid December, and observations will begin in May 2021.



XMM–Newton observation of an outburst of Swift J1818.0–1607, the youngest pulsar yet identified. Credit: P. Esposito/ESA

The SOC plans at present to host a workshop May 25–28 2021, "A High Energy View of Exoplanets and their Environments" in Villafranca del Castillo, Madrid, Spain. The workshop will focus on such topics as exoplanetary atmospheres, stellar high-energy irradiation, exoplanet formation, and interactions between stars and exoplanets. This workshop is particularly timely considering the proliferation of exoplanet discovery missions (like *TESS*, *CHEOPS*, and *PLATO*), and the next generation of X-ray missions soon to be available (such as *SRG*-eROSITA and *Athena*).

The Neil Gehrels *Swift* Observatory

Eleonora Troja (UMD/GSFC) & Brad Cenko (GSFC)

The Neil Gehrels *Swift* Observatory continues to operate flawlessly. It supports five 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 number of ToOs accepted and different sources observed.

In April and June 2020, the candidate binary supermassive black hole OJ 287 underwent a dramatic outburst at UV, optical, and X-ray wavelengths, the second brightest since the beginning of *Swift* multi-year monitoring in late 2015. Observations with *Swift*, *NuSTAR*, and

XMM–Newton are consistent with an after-flare predicted by the binary black hole model of OJ 287, where the disc impact of the secondary black hole triggers time-delayed accretion and jet activity of the primary black hole.

Late on April 27, *Swift* spotted a new round of activity from the magnetar called SGR 1935+2154. It was the object's most prolific flare-up yet, a storm of rapid-fire X-ray bursts, each lasting less than a second. The storm, which raged for hours, was picked up at various times by *Swift*, *Fermi*, and *NICER*. About 13 hours after the storm subsided, one special X-ray burst erupted. It was accompanied by an extremely bright, very short (ms) radio outburst, detected by CHIME and STARE2. The flare-up represents the first fast radio burst (FRB) ever seen from within our Milky Way galaxy and shows that magnetars can produce these mysterious and powerful radio blasts previously only seen in other galaxies.

While the Burst Alert Telescope (BAT) on-board *Swift* is primarily known for the discovery of GRBs, it also is conducting the most sensitive all-sky survey at hard X-ray wavelengths. Analysis of the hard X-ray light curve of the nearby galaxy Mrk 915 revealed evidence for periodic modulation, with a period of 3 years. Indicative of two mini-disks around a binary supermassive black hole , this would mark the first time such a system was discovered at hard X-ray wavelengths.

The *Swift* Guest Investigator (GI) program received 127 proposals in Cycle 17, the first dual-anonymous peer review process for *Swift*. Proposal review is underway, and results are expected to be announced in early 2021. *Swift* will continue to solicit proposals in GRB and non-GRB research during Cycle 18, with an estimated deadline of September 2021. Updates on the Cycle 18 GI Program and the deadline for proposal submission will be posted on the *Swift* Proposals web site.

The Neutron Star Interior Composition Explorer

Keith Gendreau &
Zaven Arzoumanian (NASA/GSFC)

NICER mission operations continue unimpeded during shelter-in-place and telework measures instituted in response to the COVID-19 pandemic, thanks to accommodations made at NASA's Goddard and Marshall Space Flight Centers. These changes enable operations team members to generate observing schedules, command the *NICER* payload on the International Space Station (ISS), and manage pipeline processing of data from their homes.

Data collection for Cycle 2 of *NICER*'s Guest Observer (GO) program will be complete in early 2021. We received 112 proposals for Cycle 3 observations by the November 17 proposal deadline. Dual-anonymous peer review of these proposals will take place in January 2021, and observations for approved investigations will begin on March 1. Through this Cycle, more than 7 Ms of science observing time will be devoted to successful GO proposals, including targets of opportunity (ToOs) and investigations that are coordinated with other telescopes. *NICER* also commits substantial time to its Legacy Science program of neutron star studies and fulfills unanticipated ToO observation requests from a growing community of users worldwide. Details of successful GO proposals and ToO requests, a ToO request submission form, and the mission's short-term observing schedule are available at *NICER*'s HEASARC website.

The *NICER* team is making steady progress toward implementing enhanced ToO capabilities. Currently, prompt (within hours) response to urgent ToO requests is available during regular business hours, when operations staff members are on duty; off-hours requests are handled on a reasonable-effort basis. The ability to schedule a ToO is always contingent on target visibility afforded by *NICER*'s ISS environment. The planned enhancements will substantially automate and speed up ToO response, especially during off-hours. In addition, *NICER* observations will be triggered directly, without ground intervention, by the Japan Aerospace Exploration Agency's Monitor of All-sky X-ray Image (*MAXI*) payload onboard ISS. The effort, dubbed "OHMAN" (the On-orbit Hookup of *MAXI* And *NICER*), promises trigger responses on several-minute timescales or less, delivering prompt observations of fleeting phenomena with approximately 15 times the effective area of *Swift*'s X-ray Telescope.

Recent notable *NICER* science results:

- Ricci et al. (2020; ApJ 898, L1) describe the extraordinary evolution of the "changing-look" active galactic nucleus (AGN) 1ES 1927+654 during a densely sampled 450-day monitoring campaign. Initially dominated by a power-law component, the AGN's X-ray spectrum becomes thermal following an optical/UV outburst, while its luminosity drops by nearly four orders of magnitude. Over approximately 300 days, the nonthermal component reemerges, with strong variability, and the original luminosity is recovered. A candidate explanation for this behavior is the interaction between the accretion flow and debris from a tidally disrupted star.
- Neilsen et al. (2020; ApJ 902, 152) report on time-resolved spectroscopy of a bright, highly absorbed flare during the historically anomalous faint state of the Galactic black hole binary GRS 1915+105. The flare spectrum shows evidence of high column-density partial covering absorption and extremely deep absorption lines. The time-dependent ionization of the obscuring gas suggests a radially stratified absorber; among other scenarios, a vertically extended outer disk could be responsible for the current obscured state.
- Ng et al. (2020; ATel #14124) discover rapid (376 Hz) pulsations from the faint X-ray transient IGR

J17494−3030, and establish a 75-minute orbital period, placing this object in the small category of known accreting millisecond pulsars in an ultra-compact binary.

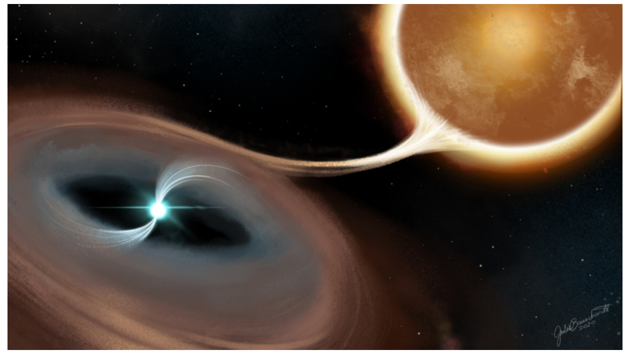
NICER's archive of public data currently comprises more than 25,000 observations—where a unique "ObsID" represents data collected for a single target on a single day—offering high-time-resolution spectroscopic information in the soft (0.2 – 12 keV) X-ray band for hundreds of targets. The NICERDAS data analysis tools are distributed through the HEAsoft package, and calibration products are available through the HEASARC Calibration Database. Continuing upgrades include improved response files and tools for modeling *NICER*'s background; feedback on their performance is welcome through the HEASARC helpdesk system. To foster more in-depth communications with users, *NICER* intends to establish a *NICER* Users Group (or NUG), consisting of 6 – 8 scientists (or NUGettes) with substantial experience relevant to *NICER* science and instrumentation, who will serve two-year terms. Letters expressing interest and applicant CVs will be solicited through an announcement posted on the *NICER* homepage on HEASARC and via HEAD and other mailing lists.

NuSTAR

DANIEL STERN (JPL), FIONA HARRIS (CALTECH)

The *NuSTAR* mission continues to operate nominally on orbit. With over 800 refereed publications, *NuSTAR* continues to be a highly productive satellite exploring the hard X-ray (>10 keV) universe with unrivaled sensitivity and resolution. *NuSTAR* Cycle 6 observations began on July 1, 2020, and *NuSTAR* coordinated observing programs with the *Chandra*, *INTEGRAL*, *NICER*, *Swift*, and *XMM–Newton* observatories continue to be available through AOs for each of those facilities, with most of those facilities also providing time in the *NuSTAR* AO.

We are pleased to announce a rotation of the *NuSTAR* User's Committee (NUC) membership. Daniel Wik of the University of Utah will be replacing John Tomsick of UC-Berkeley/SSL as Chair of the committee, and Joel Coley, Andrea Marinucci, and Aarran Shaw will be rotating on, with Fred Baganoff, Slavko Bogdanov, John Tomsick, and Andreas Zezas rotating off. We are very appreciative of the advice the NUC provides to the project, representing input from the broad community of scientists that use *NuSTAR* for their scientific research and ensuring that the interests of the guest investigator community are well-served by the project. We are thankful for the efforts of the people rotating off the NUC, and look forward to advice from the new committee. Users are encouraged to contact Dr. Wik with issues, concerns, or input for *NuSTAR*, and our intention is rotate 3-4 new people onto the NUC annually.



Artist's impression of a magnetic CV: material from the companion star flows towards the hot white dwarf and forms an accretion disk. The magnetic field of the white dwarf is strong enough to disrupt the innermost regions of the disk, forcing the material to flow along the magnetic field lines onto the poles of the white dwarf. Credit: Julie Bauschardt

On the science front, results from a *NuSTAR* Legacy survey of Galactic white dwarf binary stars was recently published in Shaw et al. (2020; MNRAS, 498, 3). The survey observed 19 magnetic cataclysmic variable stars (CVs), in which matter from a main sequence companion is accreted along magnetic field lines onto the poles of a magnetic white dwarf. The white dwarf magnetic fields are a million times stronger than the Earth's, and in such systems, the accreting material from the companion star flows along the magnetic field lines, forming an X-ray emitting shock as it reaches the white dwarf surface. The shock temperature provides a measure of the white dwarf mass, and the survey founds that magnetic CVs typically have a mass 3/4 that of the Sun. This is similar to the mass of non-magnetic CVs, but is 50% larger than non-accreting white dwarfs. Though it is tempting to suggest that the extra mass has been gained through the accretion of matter from their companions, many theories say that the extra accreted mass should be lost in thermonuclear explosions, or novae. Despite this, the growing evidence for accreting white dwarfs being more massive than non-accreting white dwarfs suggests some gaps in our understanding of the accretion-nova cycle. One theory is that lower mass accreting white dwarfs could be hidden from view because their accretion phase is unstable, and they don't appear as X-ray sources.

AstroSat

DIPANKAR BHATTACHARYA (IUCAA)

The *AstroSat* mission has completed its design life of five years in September 2020 and it has now been decided to continue the mission support for a longer period in the future.

An important recent result reported from *AstroSat* has been the detection of Lyman continuum emission from a galaxy at a redshift $z = 1.42$. Lyman emission in this redshift range had not been detected before. This detection suggests a high ($> 20\%$) escape fraction of ionizing radiation from such galaxies near the peak of cosmic star formation, and sheds new light on the reionization of the universe.

AstroSat also continues to report detailed spectro-temporal studies of compact objects. *AstroSat* observations of neutron star binaries revealed the broadband characteristics of X-Ray bursts in Cyg X-2 (New Astronomy 83, 101479) and 4U 1323-62 (RAA 20, 98), and detailed the spectral evolution along the Z-track of GX17+2 (ApSS 365, 41; MNRAS 499, 2214) and LMC X-2 (MNRAS 497, 3726). *AstroSat* timing studies of pulsations in SAX J1748.9-2021 (MNRAS 492, 4361), GRO J2058+42 (ApJ 897, 73), 4U 1909+07 (MNRAS 498, 4830), 3A 0726-260 (RAA 20, 155) and the Galactic ULX pulsar Swift J0243.6+6124 (which showed detectable pulsations up to 150 keV, MNRAS 500, 565), have all revealed interesting new features of the X-ray emission process and have underscored the role of a hot coronal component.

AstroSat observations of black hole systems, such as 4U 1630-472 (MNRAS 497, 1197), Swift J1658.2-4242 (A&A 641A, 101), MAXI J1820+070 (MNRAS 498, 5873) and GRS 1915+105 reach similar conclusions. Analysis of *AstroSat* observations of GRS1915+105 (MNRAS 499, 5891) and LMC X-1 (MNRAS 498, 4404) provided estimates of the mass and the spin of the black holes in these systems.

AstroSat has also made important observations of other accreting systems. *AstroSat* revealed a transition from a normal to a Super Soft Source state (arXiv:2010.11455) in the symbiotic white dwarf binary V3890 Sgr, during its 2019 outburst. *AstroSat* UV spectroscopy confirmed the symbiotic nature of the source SU Lyn (MNRAS 500, L12). UV observations of the neutron star X-Ray binary Her X-1 showed the presence of emission from both the accretion disk and the heated surface of the donor star, and yielded constraints on the geometry of the disk (ApJ 889, 131). Analysis of the cyclotron line present in this system indicated that the magnetic field strength at the X-Ray emission region declined by $\sim$ 8% from 1996 to 2006, and has remained steady since (MNRAS 497, 1029). Analysis of *AstroSat* Wide band X-Ray spectra of a number of Blazars and their temporal variability (MNRAS 492, 796; ApJ 897, 25) led to the discovery of a relationship between the short term variability amplitude and long term mean flux level.

The Fermi Gamma-Ray Space Telescope

Elizabeth Hays, Chris Shrader, Dave Thompson, Judy Racusin, Julie McEnery (GSFC), Lynn Cominsky (Sonoma State U.)

The *Fermi* Gamma-ray Burst Monitor and Large Area Telescope remain oblivious to the corona virus and continue to scan the gamma-ray sky continuously. The Flight Operations Team and the Instrument Operations Teams continue to manage the observatory and instruments, working remotely due to the COVID-19 pandemic.

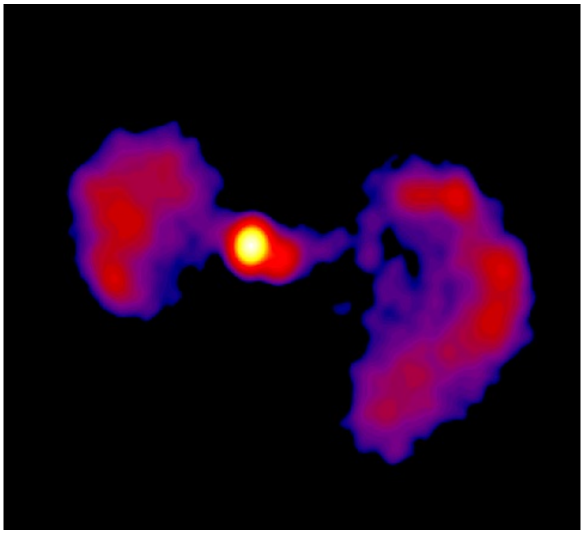
The LAT team has released an incremental version (4FGL-DR2, for Data Release 2) of the fourth full catalog of LAT sources, based on 10 years of survey data in the 50 MeV – 1 TeV energy range. Other science highlights:

- LAT data have been used in a search for axion-like particles from supernovae as a possible source of dark matter.
- A puzzling indication of gamma-ray periodicity in a gas cloud, powered by the SS433 system, has been found using LAT data.
- Possible periodic gamma radiation from a number of active galactic nuclei was reported by an international team using LAT data.
- A multiwavelength study involving *Fermi*, *Chandra*, and ground-based radio telescopes has revealed activity within the past century from active galaxy TXS 0128+554. One of the radio images bears a suspicious resemblance to Darth Vader's Tie-fighter.
- The computing power of about 10,000 graphics cards in the distributed computing project Einstein@Home has uncovered a gamma-ray millisecond pulsar in a fast, 75-minute orbit with a low-mass companion.

Current *Fermi* software and documentation are available through the *Fermi* Science Support Center. The latest source code is now hosted on GitHub. Installation instructions, release notes, troubleshooting, error reporting, and other related documentation can be found on the Fermitools Wiki on GitHub. The *Fermi* Gamma-ray Burst Monitor Team announced the first public release of the GBM Data Tools, a Python API for GBM Data. The GBM Data Tools are a high-level interface to public GBM data that enables GBM data reduction and analysis, and allows the general user to incorporate GBM analysis within their own scripts and workflows.

Cycle 13 Guest Investigator proposals resulted in 41 new programs being selected for Stage 1. The submission deadline for Stage 1 *Fermi* Cycle-14 Guest Investigator proposals is February 19, 2021, 16:30 EST. A *Fermi-TESS* joint program opportunity is available starting in Cycle 14. All NASA GI/GO programs will transition to a Dual Anonymous Peer-Review process, and this policy is in effect for Cycle 14 and beyond.

The *Fermi* project has organized a splinter session at the January 2021 AAS Meeting (January 13, 2021, 12:00 EST). The goal of this session is to make the broader astronomical community aware of opportunities to participate in *Fermi* science through the Guest Investigator Program, which will be described in detail in an interactive forum. In particular, recent changes to the program, notably the requirement now applicable to all NASA GI/GO programs for a dual-anonymous proposal preparation and evaluation process, will be discussed.



This image shows active galaxy TXS 0128+554 at 15.4 gigahertz as observed by the Very Long Baseline Array (VLBA), a globe-spanning network of radio antennas. The colors correspond to the radio signal's intensity, from low (purple) to high (yellow). Any resemblance of this galaxy far, far away to a Tie-fighter is purely coincidental. Credit: NRAO

The Ninth International *Fermi* Symposium, originally planned to be held in South Africa March 29 – April 3, 2020, has been postponed until April 12 – 16, 2021.

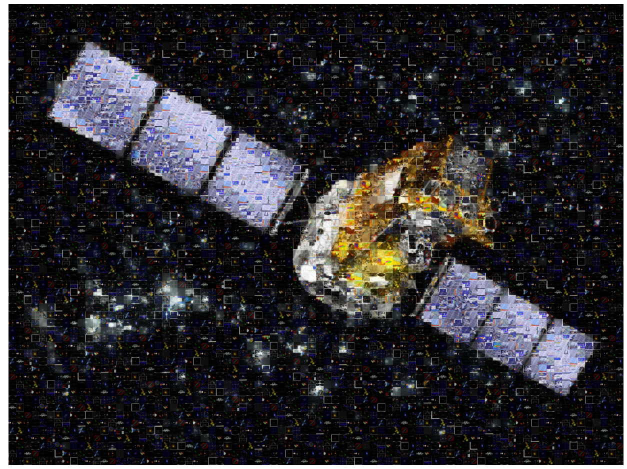
Epo's Chronicles, the story of Alkina and her spaceship Epo, as they travel around our galaxy trying to discover their origins, has been revived. This original webcomic was created as part of the *Fermi*, *Swift*, *NuSTAR* and *XMM-Newton* education and public outreach programs at Sonoma State University from 2008 to 2013. The entire series of more than 200 "eposodes" is available in four languages: English, Spanish, French and Italian. Updates have been made to content, as well as for accessibility, with transcripts (in each language) for the beautifully illustrated drawings created by Aurore Simonnet. A great resource for remote learning, *Epo's Chronicles* is aimed at learners in middle or high school, as well as members of the public who are interested in astronomy and space science.

INTEGRAL

Erik Kuulkers (ESA/ESTEC), Steve Sturner (CRESST/UMBC & NASA/GSFC)

On October 17, *INTEGRAL* celebrated 18 years of operations! For this occasion an *INTEGRAL* image based on a mosaic of all the images from the *INTEGRAL* Picture of the Month was prepared by ISOC.

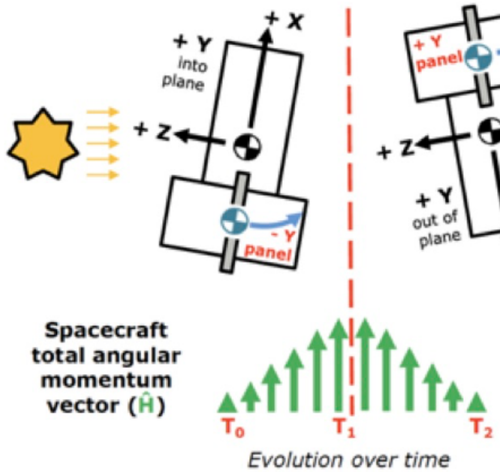
During the ESA SPC meeting held on October 1, *INTEGRAL* operations were extended through 2022. *INTEGRAL* will need to prepare for an end of operations by December 2022. However, at the same time, ESA would like to engage in a creative process for *INTEGRAL* and develop innovative concepts that could be presented, e.g., at the June 2021 SPC meeting and would make it attractive for the SPC to re-evaluate their decision to not extend further operations into the 2023–2025 period. An *INTEGRAL* User's Group (IUG) meeting on November 24–25 has been scheduled to discuss the outcome of the SPC meeting and a possible new strategy to bring *INTEGRAL* back into the game for 2023 and beyond.



An image of INTEGRAL composed of a mosaic of INTEGRAL images. Credit: INTEGRAL Science Operations Centre; ESA

Science operations proceeded nominally until May 16, when *INTEGRAL* entered Emergency Safe Attitude Mode (ESAM) #8 during a Reaction Wheel Bias (RWB) maneuver, triggered by an imbalance in Reaction Control Thruster commanding. While still in safe mode on May 17, an unexpected, large de-pointing of the satellite (of the order of 70 degrees) took place, coincident with a sudden drop of fuel system pressure from 5.4 to 5 bar. Afterwards, recovery from ESAM was successfully performed. Test RWB maneuvers were performed under close monitoring. During an RWB on July 17, another massive drop in pressure was observed, down to a level at which the subsystem is effectively unusable.

In response to the continued problems with the Reaction Control System, a scheduling strategy that minimizes the accumulation of angular momentum with the goal of making operations entirely free from the need for RWBs has been implemented since mid-July. This new strategy is controlling the speeds of the wheels based on a complete slew about the spacecraft Sun-line Z-axis (a.k.a. the "Z-flip"), performing science observations with well-chosen dwell times and positions in the sky in order to cancel out as much as possible the accumulation of angular momentum caused by the radiation pressure on the Solar panels. The strategy is enhanced during the time that the spacecraft is within the Earth's radiation belts by selecting a perigee passage attitude which makes use of the gravity gradient torque close to Earth. Regular telemeetings of the ISOC and MOC/FCT/FD teams are taking place in order to discuss current and future mission planning strategies and prepare scheduling procedures as well as developing tools to aid in planning observations given this new observing strategy. The root cause of the anomaly is still under investigation.



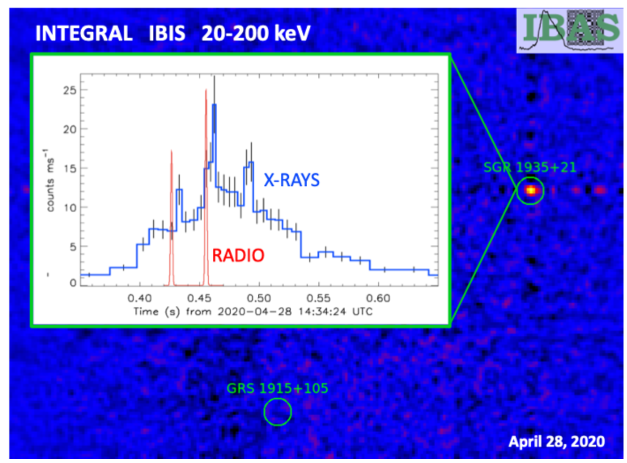
The "Z-flip". Credit: INTEGRAL; ESA

It must be emphasized that the Reaction Control System anomaly had no impact on the scientific instruments. Acceptance of Targets of Opportunities was officially resumed on August 5 and scientific observations during the reporting period were performed following, as closely as possible, the long-term plan.

The 35th SPI annealing took place in September. The camera switch-on has been performed smoothly, with one germanium detector (#8) showing a somewhat higher noise (about 27% worse energy resolution @ 198 keV), probably due to aging of the detector that will require attention by the instrument team. Another detector (#12) that showed bad performance in previous annealing recovered a nominal energy resolution, presumably thanks to the performed outgassing. If one considers the high level of degradation before the annealing ($\Delta E/E \sim 0.21\%$ @ 1764 keV), the recovery, while not perfect, is satisfactory ($\Delta E/E \sim 0.19\%$ @ 1764 keV). The global energy resolution continues with its slow deterioration.

The 18th Announcement of Opportunity (AO-18) for observing proposals closed on May 4. The total observing time requested was about 70 Msec, corresponding to an observing time oversubscription by a factor of 3.35. The proposals request data rights for 336 sources with 14 proposals requesting joint time with *NuSTAR*, *Swift*, and/or *XMM–Newton*. The Time Assignment Committee (TAC) completed the review of the proposals in June with 49 being selected. The TAC also granted the joint time to 12 proposals.

INTEGRAL took part in the annual cross-calibration observation campaign of the quasar 3C273 with *Chandra*, *NICER NuSTAR*, *Swift*, and *XMM–Newton* in July. A coordinated Guest Observer program, between *INTEGRAL*, *XMM–Newton*, and *NuSTAR*, took place mid-August to observe the X-ray binary Her X-1. On October 4–6, an out-of-TAC coordinated observation between *INTEGRAL* and Spektr-RG/ART-XC of SRGA J043520.9+552226 (a new hard X-ray transient detected by the ART-XC earlier this year as an X-ray counterpart to the optical transient AT2019wey), found it to be X-ray bright again (see ATel #14100). An out-of-TAC, Target-of-Opportunity (ToO), observation was done on October 15 – 17 on the famous nearby blazar BL Lac that has been in very high state since this summer.



Half-a-second exposure obtained with INTEGRAL/IBIS during the April 28 burst of SGR 1935+2154, clearly showing that it originated from SGR 1935+2154, and not from the nearby black hole binary GRS 1915+105. The INTEGRAL/IBIS light curve (20 – 200 keV, inset) shows that the burst had three narrow peaks, two of which lagged by about 6 milliseconds the two radio pulses shown in red. Credit: INTEGRAL; ESA

A radio outburst from SGR 1935+2154 on April 28 was of exceptional interest, because, for the first time, a radio burst – independently discovered by the CHIME and STARE2 radio telescopes – was seen to accompany a magnetar high-energy burst. *INTEGRAL* was the first satellite to announce this remarkable high-energy burst to the astronomical community (only 5 seconds after its occurrence), thanks to the automatic analysis carried out in real time by the *INTEGRAL* Burst Alert System (Mereghetti et al. 2020, ApJ 898, L29). The burst seen by the high-energy imager onboard *INTEGRAL*, IBIS, shows three narrow peaks, two of which lagged the two pulses seen at radio wavelengths by about 6 milliseconds. The radio properties of the April 28 burst were very similar to those of Fast Radio Bursts (FRBs), a class of extra-galactic radio sources of unknown origin and never observed to date at other wavelengths.This discovery established the first direct observational link between a magnetar and an FRB-like radio source.

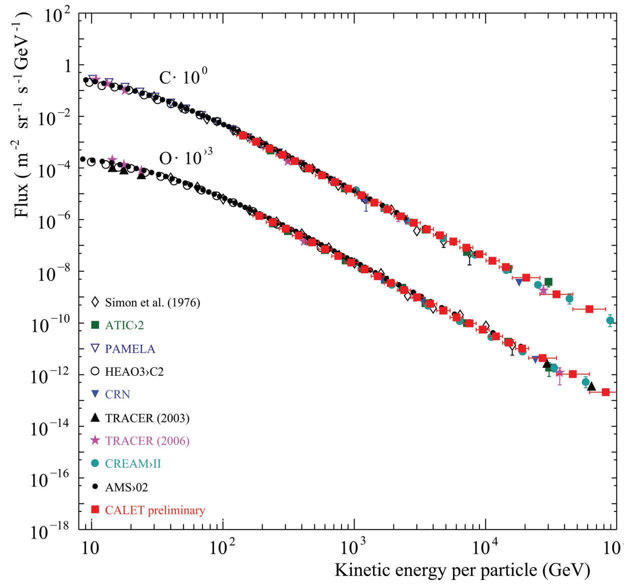
INTEGRAL has observed Cygnus X-1 many times in the 2002 – 2017 interval, providing the largest hard X-ray (20 – 100 keV) data set for this source. A recent analysis uncovered one more puzzle related to the accreting system geometry. The emission from the source in this energy band is believed to be dominated by inverse Comptonization of soft (infrared to soft X-ray) photons from the accretion disk by the hot electrons from the plasma near the black hole (or above the disk). Comptonization models predict that, if these electrons are mostly thermal, the slope of the hard X-ray spectra is predominantly regulated by the geometry of the disk-plasma system, with changing sizes of the disk and plasma regions. Analysis of the *INTEGRAL* data identified six distinct regions. This result is surprising, because a continuous transition between the two extreme spectral states (pure soft, disk-dominated and pure hard, plasma-dominated) was expected, as observed in the soft X-ray band. The uncovering of these distinct accretion modes was possible only because *INTEGRAL* provided the first extensive high-quality data set in this energy band. No clear theoretical explanation of the distinct modes exists, however. Future *INTEGRAL* observations of Cygnus X-1, together with a more advanced spectral and timing analysis, should help solve the puzzle.

Due to the COVID-19 pandemic, the *INTEGRAL* Conference 2020 “Towards the third decade of X and Gamma ray observations" has been postponed to May 2021 24–29. The venue, scope and objectives of the conference remain unchanged. As of November 3, there are 1747 refereed publications since launch; of these, 68 have been published in 2020.

CALET

JOHN WEFEL (LSU)

The CALorimetric Electron Telescope (*CALET*) mission on the International Space Station (ISS) continues to return excellent data. *CALET* just completed five years of on-orbit data collection and is in negotiations for an extended mission phase. Electron and gamma-ray data keeps accumulating while detailed analysis has focused, recently, on the nuclei. After publishing the detailed analysis of the cosmic ray proton spectrum and demonstrating a spectral hardening above 500 GeV, similar analysis is being applied to the cosmic ray Carbon and Oxygen spectra. The C and O flux over four decades in total energy shows good agreement with previous data. However, it is not possible to determine if a hardening exists in the spectra of these elements without a more detailed analysis. This new analysis has now been completed, and a manuscript is being reviewed by Phys. Rev. Letters. Detailed results will be available soon.



The Carbon and Oxygen spectra measured by CALET from 10 to 10^5 GeV per particle (total energy). The results are compared to previously reported balloon and satellite measurements. Credit: CALET

The *CALET* team has continued to analyze Gamma-ray bursts with the CGBM instrument. A summary of the past five years of data yields 234 gamma-ray burst events, over the energy range 40 – 1000 keV, whose log duration distribution clearly shows two peaks. The short duration distribution may reflect events from binary neutron star mergers or neutron star – black hole mergers. *CALET* analyzes its data in concert with gravitational wave events (54 events to date) but has found no detections, yet. Further, *CALET* data is being used in analyses of Relativistic Electron Precipitation (REP) events observed at the ISS and connected with ion cyclotron or whistler mode waves (JGR Space Physics,10.1029/2020JA027875).

The High Energy Astrophysics Science Archive Research Center

LORELLA ANGELINI & ALAN SMALE (NASA/GFC)

Happy Birthday HEASARC! November 2020 marks 30 years of operation of the HEASARC that since its inception promoted an innovative way for data archiving, software and data accessibility. From an historical prospective prior to 1990, missions produced data in unique formats which required specialized analysis software, written with no concept of reusability or export to different computer platforms and often with little or no documentation. As a result it was very difficult for astrophysicists outside the mission teams to analyze data even from pioneering missions as the Ariel 5, COS B, or HEAO 1 satellites. Data from some missions were effectively not usable soon after the mission operation phase ended. With few exceptions, very limited capabilities for on-line or even public data access existed. The HEASARC "golden rules" (data in FITS with standard format, a multi-mission approach for data calibration and analysis and open data access) have changed this culture and made it easier for missions to create an archive in a cost effective way, and for users to access data quickly and to analyze data from different missions. While HEASARC will face further challenges to keep up with innovation and community requests, for this birthday it is time to thank all personnel who have contributed throughout the years to all aspects of the HEASARC, and the community for its support. It was timely that the ADASS prize for an "Outstanding Contribution to Astronomical Software" has just been awarded to HEASARC Emeritus, Bill Pence, for his work on CFITSIO, a key software package widely used throughout astronomy and beyond to access data in FITS format, which he developed at the HEASARC.

The HEASARC has continued its operations without interruption during this year marked by the COVID-19 pandemic, and statistics of the past year show that the community has not reduced their use of HEASARC data or services. During the summer several new data sets were added to the HEASARC archive. These are:

- The Wisconsin All-Sky Survey maps obtained from the sounding rocket program to map the diffuse X-ray background at multiple bands between 0.1 and 6 keV. The program consisted of a series of rocket flights launched between late 1972 and early 1980.
- The X-ray Quantum Calorimeter sounding rocket experiment (XQC) was a calorimeter flown on a series of rocket flights to provide high resolution spectra of the soft X-ray diffuse background and to test the instrumentation to be flown on future X-ray missions. The instrument was flown six times between December 1995 and March 2013. The archive includes the final spectra and responses for each of the flights.
- The MAXI all-sky maps obtained with the data collected by the MAXI SSC instrument in the time period between August 17, 2009 and August 27, 2011. The maps are background subtracted, exposure corrected, and provided in different bands within the 0.7 – 7.0 keV energy range. These maps are available from the HEASARC as well as from DARTS.

The HEASARC is seeking other community contributed results obtained either from balloon or rocket flights that have not been archived, or special published legacy results obtained using several datasets that may be useful to the community. A portal to submit these results will soon be available and promoted via the HEAD and PCOS news.

The HEASARC also released Version 6.28 of the HEASoft package on August 14, 2020. This release was largely driven by updates to NuSTARDAS (v.2.0.0), including an extractor fix and a number of performance improvements, along with upgrades to CFITSIO/CCFITS, *Swift* XRT tools, heasptools, and XSPEC. On October 5, 2020, HEASARC released a beta version of heasoftpy, a Python 3 package that allows users to more easily integrate HEASoft tools into Python workflows by providing Python wrappers to the HEASoft tools. The heasoftpy web page provides examples and further details. The HEASARC welcomes any user feedback on these new capabilities via the HEASoft/ftools Feedback form.

Physics of the Cosmos News

Brian Williams (NASA/GSFC, Acting PCOS Chief Scientist)

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.

A few personnel changes have recently occurred in the PCOS Program Office. Barbara Grofic (NASA/GSFC) has taken over as the Program Manager from the retiring Preston Burch. Terri Brandt (NASA/GSFC) has temporarily stepped aside as PCOS Chief Scientist to attend to other duties; her role is being filled in an acting capacity for approximately six months by Brian Williams, Zaven Arzoumanian, and Kim Weaver (all from NASA/GSFC).

The PCOS Program Analysis Group (PhysPAG) includes everyone interested in the PCOS program via six Science Interest Groups (SIGs); this probably means you! Other articles in this newsletter give updates on the activities of our SIGs, including the Cosmic Ray SIG, the Gamma-ray SIG, the Gravitational Wave SIG, and the X-ray SIG. The PhysPAG provides for the PCOS community to regularly engage with the Program Office. PhysPAG Executive Committee (EC) members organize meetings, collect and summarize community input, and report to the Astrophysics Advisory Committee (APAC) and the Astrophysics Division Director. EC members' terms last ~ 2 years, and several members will be rolling off in December 2020, when a group of new members will be appointed.

In November of 2020, PCOS teamed up with the Cosmic Origins Program Office (COR) and the Astrophysics Science Division at NASA/GSFC to sponsor the annual meeting of the National Society of Black Physicists. We staffed a virtual booth for the meeting, where we engaged with meeting attendees to tell them all about NASA Astrophysics and the various opportunities offered.

The PCOS Program Office is currently soliciting community input on gaps between the current state of the art and technology needed for the strategic missions of the coming decades to achieve science goals. The next prioritization will take place in 2021. You can submit an entry for these technology gaps at the Astrophysics Technology Development website. Submissions are due by June 1st, 2021.

We encourage anyone interested in PCOS science to join our email list, where we regularly highlight news items of interest to the PCOS community.

The X-ray Science Interest Group

Ryan Hickox (Dartmouth), John Tomsick (University of California Berkeley)

There continue to be many exciting developments in new and upcoming X-ray astronomy missions. In November the Imaging X-ray Polarimetry Explorer (*IXPE*) passed its Key Decision Point-D review and has entered Phase D, which includes assembly, integration and testing, and launch. The launch is scheduled for October 2021. The X-ray Imaging and Spectroscopy Mission (*XRISM*), a collaboration between the Japan Aerospace Exploration Agency (JAXA) and NASA, along with ESA, continues development and assembly and is scheduled for launch in Fall 2022. This summer the eROSITA telescope onboard the Spectrum-Roentgen-Gamma mission completed its first full sweep of the sky, detecting more than a million sources and providing the most sensitive X-ray view of the full sky to date.

As we head into the new year, the NASA PCOS X-ray Science Interest Group is planning our usual session at the (virtual) AAS Annual Meeting in January. The session will be held on Wednesday, Jan 13 from 6:50 to 8:20pm EST and will focus on the science and accomplishments of current and future Explorer-class X-ray missions.

As always, we encourage nominations for the PhysPAG Executive Committee, and we look forward to continuing to engage with the X-ray astronomy community!

The Gamma-ray Science Interest Group

Sylvain Guiriec (GWU), Marcos Santander (UA), Bindu Rani (AU)

GammaSIG welcomes Marcos Santander, University of Alabama, as the new co-chair.

GammaSIG will organize a splinter session at the APS 2021 meeting. The session will cover the current and near-future gamma-ray missions. 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 and technology development.

Together with CRSIG and GWSIG, GammaSIG will organize a joint multi-messenger astronomy (MMA) session in the upcoming AAS 2021 meeting. The session will focus on key strategies to maximize the outcome of the multi-messenger astronomy.

GammaSIG will continue organizing workshops, hackathons, and similar activities on instrument design, data analysis and analysis tools, and statistical methods, among others. We will circulate a survey to collect your ideas and suggestions.

The Cosmic Ray Science Interest Group

Abigail Vieregg (University of Chicago), Marcos Santander (University of Alabama)

The Cosmic Ray Science Interest Group (CR-SIG) chairs welcome input, questions and suggestions from members of the cosmic ray and astrophysical neutrino community regarding future missions or studies that are relevant to the astrophysics portfolio of NASA.

Members are encouraged to contact the chairs directly (Abigail Vieregg and Marcos Santander). People interested in the activities of the group are also invited to join our mailing list.

A splinter session will be organized by the CR-SIG at the APS April 2021 meeting, which will cover current and future cosmic-ray and astroparticle missions. The CR-SIG will also participate in the joint organization (together with the GR-SIG and GW-SIG) of a multi-messenger astronomy (MMA) session at the 237th AAS Meeting in January 2021. The session will focus on major science questions for MMA in the coming decade and the strategies to address them.

The Gravitational Wave Science Interest Group

Nicolas Yunes (University of Illinois at Urbana-Champaign), John W. Conklin (University of Florida), Jillian Bellovary (QCC/AMNH) and Sean McWilliams(WVU)

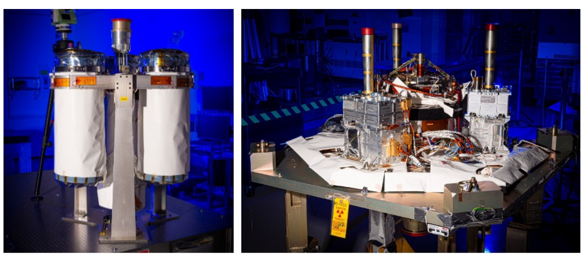
The GW SIG is planning to organize a session at the January 2021 AAS meeting, which will be held virtually due to the COVID-19 pandemic. The speakers for this session are yet to be selected, but likely topics will include the recent *LIGO* results of the O3 run, the future of NANOGrav in light of the NSF decision to decommission Arecibo, a status update on *LISA*, and recent results in numerical relativity. The GW SIG is also planning to organize a Focus Session on *LISA* science at the April 2021 APS Meeting that was going to be held in Sacramento, California (April 17–20, 2021), but will now probably be held virtually. Further information about upcoming GW SIG meetings can be found at the PhysPAG website.

The Imaging X-ray Polarimetry Explorer

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

The *IXPE* Team is hard at work preparing the mission for launch in late 2021. Here we provide updates on the status of the mission since the previous Newsletter. Recent significant events include a successful System Integration Review (SIR) held by the (external) Standing Review Board in September, and the successful passage of Key Decision Point D (KDP-D) held by the SMD Associate Administrator in early November. All 3 flight Detector Units (DUs) and all 3 flight Mirror Module Assemblies (MMAs) were assembled, environmentally tested, and X-ray calibrated, in Italy and at MSFC, respectively.

The prime contractor, Ball Aerospace, has received and inspected the 3 flight DUs, installed calibration sources, and conducted bench acceptance testing, all with remote supervision by the Italian Instrument Team (due to COVID-19 constraints). Likewise, Ball has received and inspected the 3 flight MMAs and installed thermal shields, all with remote MSFC supervision (again, due to COVID-19 constraints). Recently, Ball installed the 3 DUs and 3 MMAs onto the Observatory's "Payload" and accurately aligned them, such that the 3 telescopes (MMA + DU) will be co-aligned upon orbital deployment of the boom, which establishes the 4-m focal length of the X-ray telescopes.



IXPE Mirror Module Assemblies (MMAs) mounted on mirror module support structure (left); Detector Units (DUs) mounted on spacecraft top deck (right). Credit: Ball Aerospace

In addition, Ball has completed assembly of the Observatory's "Spacecraft", which provides the non-mission-specific functions of a 3-axis-stabilized satellite. With KDP-D completed, Ball will now integrate the Payload and the Spacecraft forming the Observatory, and then perform Observatory-level environmental testing. Meanwhile, MSFC will use its 100-m beamline to X-ray calibrate the spare MMA alone and then with the spare DU at the focal plane, comprising a polarization-sensitive imaging telescope.

The X-ray Imaging and Spectroscopy Mission

RICH KELLEY (NASA GSFC); BRIAN WILLIAMS (NASA GSFC)

Development continues on the *X-ray Imaging and Spectroscopy Mission*. While the COVID-19 pandemic forced NASA personnel to return home from Japan in the spring of 2020, several teams have been allowed to return beginning in the summer of 2020. A team of 5 NASA personnel traveled to Japan in July, with 3 more traveling in August and 2 more in October. We anticipate that future trips will continue as necessary to support the integration and testing of the Resolve instrument. These trips happened as a result of extraordinary planning efforts on the side of both the NASA and JAXA project management, and were more strenuous than normal on the travelers, who generally had to quarantine for two weeks in Japan upon arrival, before beginning any work! The launch date for the mission has shifted to Japanese fiscal year 2022, which runs from April 2022 to March 2023. We are now targeting a Fall 2022 launch date.

At GSFC, in-person work has resumed on the production of the X-ray Mirror Assemblies. Both mirrors (one for each of the two *XRISM* instruments) have been assembled and are currently undergoing testing and calibration. The mirrors are expected to be delivered to Japan in 2021.

On the science side, the Science Management Office for the mission is currently selecting the targets for the 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. This process was not immune to the effects of the COVID-19 pandemic, and the need for a remote review has slowed the process somewhat. We are now targeting January 2021 to have the selections for the PV phase targets finalized and publicized. It is anticipated that a call will come out in ROSES 2021 for the *XRISM* Guest Scientist Program, under which astronomers who are not part of the *XRISM* Science Team can become involved in analysis of the PV phase data for specific targets.

As we move closer to launch, plans are underway to offer *XRISM* data analysis workshops for interested participants to learn how to plan and propose for *XRISM* observations, as well as how to analyze the data once they get it. We will also develop online guides and tutorials to assist in preparing the community, both before and after launch. Members of the *XRISM* Project Science Office are available to visit your institution from now through launch (once NASA travel is permitted again, that is) to give a colloquium or seminar on *XRISM* and the breakthrough science the mission will enable. We are also able to give virtual talks.

Athena: Revealing the Hot and Energetic Universe

RANDALL SMITH & LAURA BRENNEMAN (CFA), KRISTIN MADSEN (NASA/GSFC & UMBC), AND JON MILLER (U. MICHIGAN)

The *Athena* Community Office (ACO) has just published the 8^{th} *Athena* Newsletter, with complete details about the mission status including the upcoming efforts to write the "Red Book," the formal document ESA requires to go for mission adoption, as well as the upcoming

Athena A&A special issue. This update therefore focuses only on US-specific activities, and we encourage all HEAD members to download and read the ACO newsletter.

The *Athena* Science Study Team (ASST) has established a number of Working Groups (WG), each with a number of Topical Panels (TP) that are populated via open calls to the community. These calls occur once per year, and a new call has just been opened. As noted by the ACO, "Applications are open to all researchers with appropriate background and a strong interest in scientific and technical matters related to the *Athena* mission, especially – but not only – to early career researchers. Admission of researchers working for industrial partners is possible if appropriate justification is provided." General information about these panels is available at the *Athena* website, and you can apply to join.

One particular item of interest is that two new *Athena* topical panels have been created, #3.6, *Multi-Messenger* and #3.7, *Physics Beyond the Standard Model*. A description of these panels by the co-chairs can be found in the *Athena* Newsletter.

ESA has chosen the X-ray & Cryogenic Facility (XCRF) at MSFC as the baseline calibration and performance test facility of the Mirror Assembly Module (MAM). In anticipation of this activity, NASA has worked with ESA and the *Athena* Calibration Working Group on defining the test and calibration requirements of the MAM Demonstrator, Qualification, and Flight model, and MSFC are starting work in early 2021 to upgrade the XRCF facility with new stages, new beam monitors, and detector system.

The Demonstrator is full scale MAM, but only one out of the six sectors will be populated with silicon pore optic (SPO) mirror modules (MM). There will be 10 MMs (out of 100 per sector) at different radii, and the primary goal of the Demonstrator is to validate the mechanical and thermal stability of the mechanisms that hold the MMs. The XRCF will be receiving and testing the Demonstrator model, pre- and post-environmental, as early as 2023. The measurements from the Demonstrator are used to down-select the spacecraft vendor. The Qualification model will be the flight enginering unit and will have more than one sector populated by 20 – 30 MMs to test the alignment of individual sectors. The Qualification model is expected in 2024/25, and the Flight model in 2028/29.

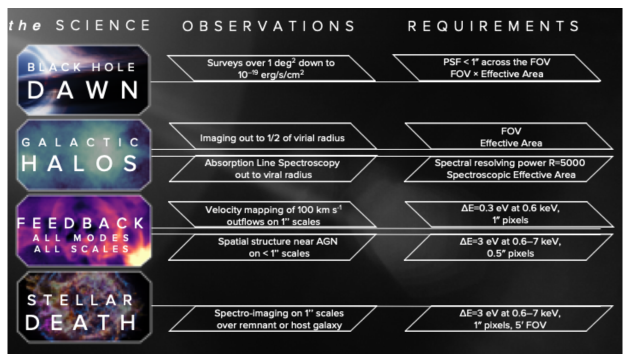
The NASA *Athena* Study Team (NAST) is planning its first meeting of 2021 for February (exact date TBD). Topics will include an update on the mission and instrument status, update on the U.S. mission contributions and the ground calibration plan, preparations for contributions to ESA's mission red book, and the science papers being prepared for an A&A special issue. The topic of serendipitous sources in the *Athena* FOV has also been raised as a point of interest. Other suggestions or concerns regarding *Athena* can be sent to NAST co-chairs Laura Brenneman and Jon Miller.

The Lynx X-ray Observatory

Jessica Gaskin (NASA/MSFC), Doug Swartz (USRA/MSFC)

The *Lynx* X-ray Observatory is one of four large-mission concept studies sponsored by NASA under consideration by the 2020 Astrophysics Decadal Survey. The *Lynx* Concept Study Report was submitted by the community-led Science and Technology Definition Team (STDT) to the Decadal Committee in August of 2019. Extensive technology maturation plans for the *Lynx* enabling technologies are also publicly available.

Lynx is designed to be a Great Observatory which will open a new era in our understanding of nature by advancing many scientific frontiers. *Lynx* will provide the depth and breadth to answer some of the most significant and fundamental questions on the scientific landscape of tomorrow. Specifically, the *Lynx* concept addresses three fundamental science pillars: 1) seeing the dawn of black holes in the early universe, 2) revealing drivers of galaxy formation and evolution, and 3) unveiling the energetic side of stellar evolution and stellar ecosystems.



The Lynx science traceability matrix adapted from the Lynx concept study report by Alexey Vikhlinin, Lynx STDT Community Co-Chair.

These science goals trace to specific requirements of subarcsecond imaging across a modest field of view, a large effective area, a high spectral resolving power at soft X-ray energies, and imaging spectroscopy over a range of spatial and spectral resolution scales. The technical capabilities can be achieved with an extremely powerful combination of a large effective area high resolution mirror assembly, a large field-of-view X-ray imager, an imaging spectrometer optimized for spectral mapping of extended structures, and an X-ray grating spectrometer for extremely high spectral resolution in the soft X-ray band. All these technologies continue to be advanced by teams across the US and Europe although work has been, as with all things, hindered by the ongoing pandemic.

While the *Lynx* community eagerly awaits the report of the Decadal Survey on Astronomy and Astrophysics, expected in the spring of 2021, the *Lynx* Study Office continues numerous outreach activities. These included a series of digital exhibits at the virtual 236th AAS meeting in June and online presentations at the 3rd Bologna

Technological Advances in X-ray Astronomy meeting in July. Please follow us on Twitter @lynxobservatory and Facebook and visit our mission and program office web sites for more information on *Lynx*.

LISA

I. Thorpe (NASA/GSFC); G. Mueller (U. Florida); M. Vallisneri (JPL/Caltech); S. Barke (U. Florida)

The Laser Interferometer Space Antenna (*LISA*) continues its development both in Europe and the US. ESA kicked off an extension of Phase A activities in October, with two industrial contractors developing detailed designs of both the spacecraft and payload. These designs will accommodate critical subsystems such as the optical bench, gravitational reference sensor, and telescope that are being developed by ESA Member States and NASA. Phase A is expected to be completed in Fall 2021 with the Mission Formulation Review. The next major milestone after MFR is Mission Adoption, which is anticipated in 2024.

NASA is focused on completing technology development activities for likely contributions to the *LISA* payload. One key subsystem are the telescopes: *LISA* requires a total of six 30-cm telescopes, with wavefront errors below 35 nm over the lifetime of the mission to minimize the coupling of telescope motion into measured armlength changes (which are monitored to detect gravitational waves). In addition, each telescope needs to meet a stringent pm/$\sqrt{\text{Hz}}$ pathlength stability requirement, which dictates the use of low expansion glass such as ULE or Zerodur. As reported in the last newsletter, L3Harris has been selected to develop a suitable design, build a structural thermal model, and then two engineering development units. These units will be assessed by NASA and will then be available for system-level tests in Europe. The L3Harris design and manufacturing approach is currently being peer reviewed, and production of the models is expected to start later this year.

The *LISA* laser is another likely contribution from NASA, although parallel development efforts continue in Europe. A total of twelve lasers are required for *LISA*, each of which must deliver 2 W (at end of life) to the optical bench. Both the NASA and ESA teams are developing a laser head based on a Master Oscillator Power Amplifier architecture using a non-planar ring oscillator as the master oscillator, and a fiber-based power amplifier. The NASA team is currently assembling two demonstration units at Technology Readiness Level (TRL) 5, for delivery to ESA in early 2021, a milestone that was delayed due to lack of lab access as a result of COVID-19 precautions. An independent review of the laser design and reliability is being conducted with the NASA Engineering and Safety Council.

A final focus for NASA technology development is the charge management system, which uses UV photoemission to control the bulk potential of the test mass relative to its housing. Doing so is vital to reduce force noises acting on the test mass below the required level. Test-mass charging is caused by highly energetic particles that penetrate the spacecraft and reach the test mass directly or via secondary electron emission, leading to charging rates of about 50 e^-/s, depending on spacecraft size, shielding provided by the test-mass housing, and orbit. NASA is partnering with the University of Florida to develop a UV light unit for charge control, which would be integrated into the Gravitational Reference Sensor being developed under Italian leadership. The UF team, together with their industrial partner, are approaching the TRL 5 milestone.

The 13th International *LISA* Symposium was held online on September 1 – 3, 2020. Despite all potential downsides, this change made the conference more open and accessible, not only for members of the *LISA* Consortium but also for the interested public as a whole. The 3-day, 4-hours-per-day agenda featured a diverse, early-career group of presenters. Plenary talks, with topics ranging from multi-messenger astronomy and data analysis to fundamental physics and instrumentation, were presented by Nick Stone, Ewan Fitzsimons, Sachiko Kuroyanagi, Mansi Kasliwal, Stas Babak, Sweta Shah, Helvi Witek, Jenny Greene, and Valeriya Korol. The agenda featured parallel science sessions, town halls, topical discussion sessions, and a Diversity, Equity, and Inclusion training session. In addition, a large number of prerecorded talks were submitted and published on the Symposium website.

The nine organizers and a support crew of seven volunteers worked hard to coordinate four discussions, 30 live presentations, and over 200 pre-recorded talks. The technical team, led by Simon Barke, developed a custom web platform based on open source software and publicly available streaming services. This allowed no conference fees to be charged, and created an online experience that allowed participants to interact and network much as they would during a face-to-face meeting. Each talk had its dedicated webpage with live chat and "question and answer" areas to drive interaction. The platform offered an easy-to-search participant database with message board, a job market, and private virtual meeting spaces.

The Symposium attracted 1100 participants from all over the world – more than three times the attendance of the largest *LISA* face-to-face meeting so far. Feedback was overwhelmingly positive. In a survey among attendees, almost 90% of respondents supported the addition of online live video feeds and pre-recorded talks to upcoming in-person meetings. Such a change will give a voice to researchers who might otherwise be unable to travel to face-to-face meetings. On top of that, the meetings will generate rich libraries of publicly available online talks.

AstroPoetry Corner

Relativity
(for Stephen Hawking)

When we wake up brushed by panic in the dark
our pupils grope for the shape of things we know.

Photons loosed from slits like greyhounds at the track
reveal light's doubleness in their cast shadows

that stripe a dimmed lab's wall – particles no more –
and with a wave bid all certainties goodbye.

For what's sure in a universe that dopplers
away like a siren's midnight cry? They say

a flash seen from on and off a hurtling train
will explain why time dilates like a perfect

afternoon; predicts black holes where parallel lines
will meet, whose stark horizon even starlight,

bent in its tracks, can't resist. If we can think this far,
might not our eyes adjust to the dark?

— Sarah Howe