The High Energy Astrophysics Division Newsletter

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

In this Issue:

VERITAS is celebrating its 15th year of complete four-telescope array operations. The photo shows VERITAS Telescope 1 conducting observations at the Fred Lawrence Whipple Observatory in southern Arizona. Credit: J. Quinn (VERITAS Spokesperson)

View From the Chair

Fiona Harrison (Caltech)

It has been an eventful Fall, with the release of the Decadal Survey, and much planning for upcoming meetings. We are taking the first steps to once again meet face to face as a community. We hope to see a good fraction of you at the 239th AAS meeting in Salt Lake this January, where we'll have a number of HEAD-centric events, including the Rossi Prize Lecture by Francis Halzen on detections of cosmic high-energy neutrinos, a special HEAD session from the recent Shaw Astrophysics Prize winners, another HEAD special session on neutron star results from *NICER* and *LIGO*, and the HEAD business meeting (where we'll introduce the new prize winners, the new HEAD Executive committee members, and have a toast or two). We are also planning for our first in-person HEAD meeting since the 17th meeting in Monterey. The 19th HEAD meeting will be in Pittsburgh in March at the Omni William Penn Hotel, a beautiful, historic downtown hotel; abstract submission and registration are now open.

The 2020 Decadal report, Pathways to Discovery in Astronomy and Astrophysics for the 2020's was released on November 4, 2021. The report lays out a scientific roadmap for the coming decade and beyond and presents an ambitious program of activities. There are many opportunities for the high energy community, from time domain missions to probe-class and preparation for a large strategic mission. The upcoming HEAD meeting will provide an opportunity for the community to share ideas and begin to plan for advancing high energy astrophysics in the coming decades.

This fall has been a busy time for the HEAD Executive Committee. In addition to preparing for the upcoming AAS and HEAD meetings, we are also reviewing nomination for five HEAD awards: the Rossi Prize, the Mid-Career Prize, the Dissertation Prize, the Innovation Prize and a new award, the Early-Career Prize. We had a healthy number of excellent nominations and the selection process is proving to be challenging, a good sign for the community. Also, this fall, we are electing new members of the Executive Committee: the Vice Chair (replacing Randall Smith, who will be ascending to the Chair position), the Secretary, the Treasurer and two council members. I'll be moving to replace Rob Petre as Past Chair, and Rob will be rotating off the Committee. Thanks for all the guidance Rob!

HEADlines

Megan Watzke (CXC)

During the past six months, high-energy astrophysics was featured in stories ranging from CNN to the New York Times, and hundreds of others. While name recognition of individual telescopes or missions may be elusive for a majority of the non-expert public, it is clear that the science conducted by HEAD researchers is of extreme interest. HEAD researchers, missions, and topics are even being explored in a new BBC/NOVA series "Universe Revealed", airing online and on PBS.

The following list of press releases is just a small sample of the many stories that were released to the public on HEAD missions and topics. They reflect the breadth of research being done by our community and the public's appetite to learn more about the high-energy Universe.

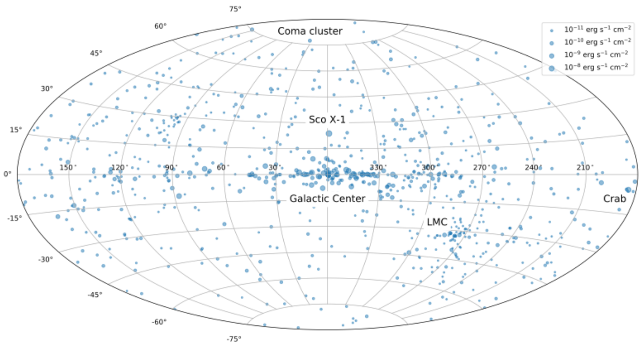
- June 3, 2021 "Front-row View Reveals Exceptional Cosmic Explosion"
- June 7, 2021 "New X-ray Map Reveals Growing Supermassive Black Holes in Next-Gen Survey Fields"
- June 16, 2021 "The Give and Take of Mega-Flares from Stars"
- June 28, 2021 "Matter Highway in Space Makes Galaxy Clusters Grow"
- July 9, 2021 "The Mystery of What Causes Jupiter's X-ray Auroras Is Solved"
- July 26, 2021 "NASA's Fermi Spots a Supernova's 'Fizzled' Gamma-ray Burst"
- July 28, 2021 "Stanford Astrophysicists Report First Detection of Light from Behind a Black Hole"
- October 25, 2021 "Chandra Sees Evidence for Possible Planet in Another Galaxy"

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, objects or processes, contact Mike Corcoran for consideration as a High Energy Astrophysics Picture of the Week.

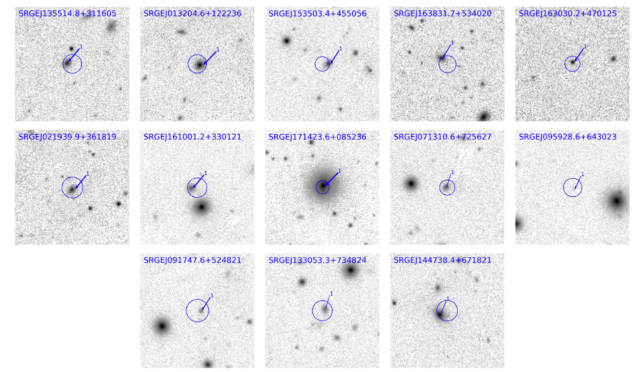
Spektr-RG, ART-XC & eROSITA

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

The Mikhail Pavlinsky ART-XC telescope is continuing its all-sky survey. Using the data collected during the first two scans (December 2019 - December 2020), scientists have produced a map of the whole sky in the 4-12 keV energy band and a catalog of 867 detected sources (Pavlinsky et al. 2021). The point source sensitivity limit varies between 0.3 mCrab near the ecliptic plane and 0.05 mCrab near the ecliptic poles, while the typical localization accuracy is $\sim$15 arcseconds. Most of the sources are known extragalactic objects (active galactic nuclei and clusters of galaxies) or Galactic sources (X-ray binaries, cataclysmic variables, coronally active stars and supernova remnants), but there are several dozens of newsources as well. A program of optical follow-up observations has been started, which has already led to the identification of several previously unknown active galactic nuclei and cataclysmic variables. By the end of the 4-year survey, the ART-XC survey is expected to significantly surpass previous surveys conducted in similar energy bands in terms of the combination of angular resolution, sensitivity, and sky coverage.



Positions (in Galactic coordinates) of the X-ray sources detected by ART-XC in the 4-12 keV energy band during the first year of the all-sky survey. The symbol size reflects X-ray brightness. Credit: Pavlinski et al. (2021)



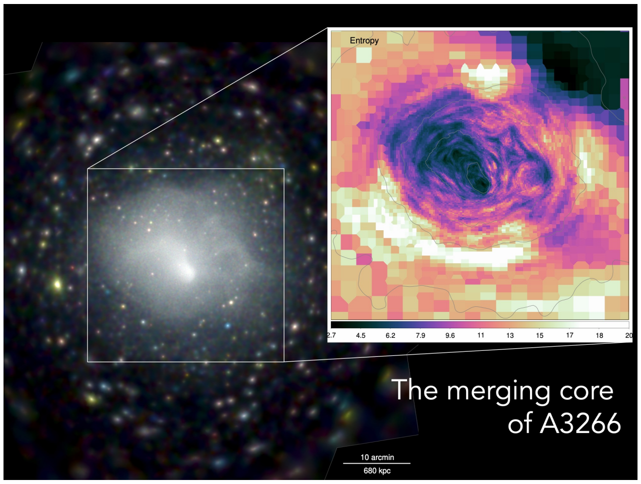
Locations on the sky of the first TDEs discovered by SRG/eROSITA. In each panel (Pan-STARSS optical image), the circle denotes the localization region of the X-ray flare and the arrow shows the TDE host galaxy. Credit: Sazonov et al. (2021)

In the 1970-80s, it was predicted that when a star passed close to a supermassive black hole in the nucleus of a galaxy, it could be torn apart by tidal forces. The subsequent accretion of the stellar debris onto the black hole could lead to a spectacular X-ray outburst. Several events of this kind were first discovered in the early 1990s by the *ROSAT* orbital observatory. Since then, tidal disruption events (TDEs) have been discovered by optical and ultraviolet telescopes. However, such events remained rare. The high sensitivity and wide field of view of the eROSITA telescope aboard *Spektr-RG* has allowed scientists to start a massive search for TDEs in the Universe. The first results of this endeavor have been presented by Sazonov et al. (2021). The 13 reported TDEs were selected among X-ray transients detected by eROSITA during its second sky survey (June 10 to December 14, 2020) and confirmed by optical follow-up observations. The nearest event occurred in a galaxy at a distance of 160 Mpc, while the most distant TDE occurred in a galaxy at a redshift $z = 0.58$, i.e. about 6 billion years ago. Using this unique sample, the researchers constructed the X-ray luminosity function of TDEs. It turned out that the TDE volumetric rate decreases with increasing X-ray luminosity, and TDEs occur on average approximately every 100,000 years in a typical galaxy. Most of the TDEs discovered by eROSITA only manifest themselves in X-rays and are thus different from TDEs found in optical surveys. However, some TDEs detected by eROSITA do show clear optical signatures. One such event, SRGe J131014.2+444315, was recently reported on by Gilfanov et al. (2021). The different properties of the X-ray-selected and optically-selected TDE samples may be related to the viewing angle at which we look at a thick accretion disk formed from the stellar debris, although alternative explanations are also possible. The search for TDEs with eROSITA is gaining momentum and some 700 TDEs are expected to be found over the whole sky by the end of the *Spektr-RG* 4-year survey.

On June 29, 2021, the German eROSITA Consortium has released the first set of eROSITA data, almost 100 individual observations of 29 distinct fields taken before the start of the all-sky scans during the so-called Calibration and Performance Verification phase of the mission. This Early Data Release (EDR) covers a wide range of different astronomical objects, from galactic neutron stars to clusters of galaxies and showcases the potential and versatility of the eROSITA telescope for imaging, spectroscopy and time domain analysis. For practical purposes, the eROSITA-DE team has divided the Cal-PV observations into four categories:

- Survey fields: scan observations of large, contiguous areas of the sky. These include the 'eROSITA Final Equatorial Depth Survey' (eFEDS), a patch of about 140 square degrees of the sky, providing a glimpse of what the whole extra-galactic sky will look like in X-rays after eROSITA completes its all-sky survey program in 2023.
- Magellanic Clouds: observations around the Small and Large Magellanic Clouds.
- Galactic fields: observations of low Galactic latitude targets ($|b| < 17$ deg).
- Extragalactic fields: observations of high Galactic latitude targets ($|b| > 17$ deg).

The eROSITA EDR consists of calibrated event files that contain the information generated by the eROSITA cameras used during the observations. These event files are created by the eROSITA Science Analysis Software System (eSASS) pipeline after the received telemetry data from eROSITA of each observation has been reformatted, packaged, and archived by a pre-processor. More specifically, the calibrated event lists of each Cal-PV observation released contain photons (i) with energies between 0.2-10 keV; (ii) flagged as "good" events from the nominal field of view, excluding bad pixels; (iii) with patterns pattern=15, i.e. including single, double, triple and quadruple events. More information on the structure of the calibrated event files and on the eSASS software it-self can be found on the EDR webpage. An associated suite of papers have been submitted to A&A, and will be published in a dedicated Special Issue.



The bright cluster of galaxies Abell 3266 observed by eROSITA during the Calibration phase. The eROSITA image is color-coded by photon energy and shows the disturbed cluster gas (white diffuse emission) as well as many background AGN and foreground stars. The inset shows the entropy distribution of the intra-cluster gas, based on the pressure and temperature of the gas and measured entirely from eROSITA data. The data have been released as part of the EDR, and are available at `https://erosita.mpe.mpg.de/edr/`. Credit: Sanders et al. (2021)

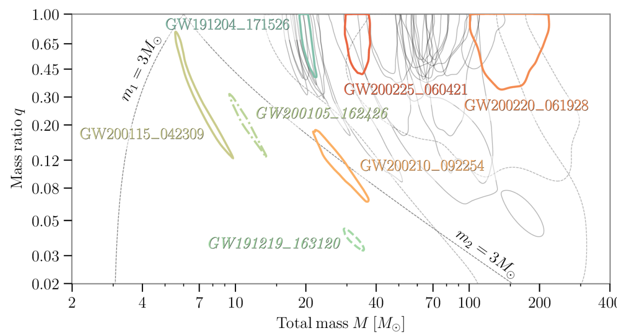
LIGO-Virgo-KAGRA Collaborations

P. R. Brady (U. Wisconsin-Milwaukee)

Work has continued at *LIGO* Hanford, *LIGO* Livingston, *Virgo* and *KAGRA* to improve the detectors for the next observing run O4. Taking into account the most recent impacts of local and global conditions, *LIGO-Virgo-KAGRA* plan to start the fourth observing run (O4) in mid-December 2022. *LIGO* is targeting a binary neutron star range (angle averaged) of 160 – 90 Mpc. *Virgo* is targeting 80 – 115 Mpc. *KAGRA* should run with greater than 1 Mpc range at the beginning of O4, and will work to improve the sensitivity toward the end of O4.

On November 7, 2021, the *LIGO* and *Virgo* collaborations released bulk strain data taken during the second six months of O3. This is the O3b data release. It includes data taken between November 1, 2019 and March 27, 2020. The data is available from the Gravitational Wave Open Science Center, which also hosts tutorials and links to various tools for analyzing the data.

On the same day, the *LIGO-Virgo-KAGRA* Collaboration (LVK) also released the third Gravitational-Wave Transient Catalog (GWTC-3). Since the last catalog release, we reported an additional 35 gravitational wave events observed between November 2019 and March 2020, bringing to 90 the total number of observed events since *LIGO/Virgo* operations began. The implications of these results for our understanding of the population of merging compact binaries, cosmic expansion history, and associations of mergers with gamma-ray bursts were all discussed in related papers. It is worth highlighting the observation of gravitational waves from two neutron star-black hole (NSBH) mergers. The source of GW200105_162426 has component masses $8.9^{+1.2}_{-1.5}$ and $1.9^{+0.3}_{-0.2}\,M_\odot$, whereas the source of GW200115_042309 has component masses $5.7^{+1.8}_{-2.1}$ and $1.5^{+0.7}_{-0.3}\,M_\odot$. Taking these two sources to be representative of the NSBH population, we infer a merger rate of $45^{+75}_{-33}\,\mathrm{Gpc}^{-3}\,\mathrm{yr}^{-1}$.



Estimates of the total mass (M) and mass ratio (q) between the least massive and most massive component, for all O3b events. Each contour represents a different event and encloses the most the 90% credible region. Events highlighted in color are described in the GWTC-3.0 paper. Credit: LVK

The Collaboration has released 11 other papers since May 2021 including reports on upper limits placed on the stochastic gravitational-wave background, potential sources of continuous waves, and transients not associated with compact binary mergers. Among these papers is the Collaboration's search for dark photon dark matter using O3 data. No evidence for this form of dark matter was found; limits on the squared coupling of dark photons to baryons are a factor of 100 better than other direct dark matter detection experiments for the mass range $m_A \sim [2 - 4] \times 10^{-13}$ eV/c^2. It is exciting to see new ways to use gravitational-wave detectors to address open questions in physics. We anticipate completing our analysis of O3 data over the next 6 months thus allowing time to prepare for O4.

Following the O4 run, a further series of detector upgrades are planned, followed by a longer duration O5 observing period expected to continue into 2028. Plans are also being developed for post-O5 instrumental upgrades and observing runs that will stretch into the next decade.

IceCube Neutrino Observatory

Madeleine O'Keefe (University of Wisconsin–Madison)

The *IceCube* Collaboration celebrated the first decade of discovery with the *IceCube* Neutrino Observatory in 2021. The mostly virtual festivities concluded in September during *IceCube*'s fall collaboration meeting. A summary of the celebratory content can be found on a dedicated anniversary webpage, including recordings of events held by the University of Oxford Department of Physics and the University of Wisconsin–Madison as well as a timeline of *IceCube*'s history.

IceCube's 10th Anniversary logo. Credit: IceCube collaboration

In addition, for our IceCards project, we asked our collaborators to send us postcards from wherever they are in the world. We received dozens of heartfelt messages that include favorite memories, fun stories, lessons learned, and more recollections from our long history as a collaboration.

The content also includes "*IceCube*: 10 Years of Neutrino Research from the South Pole," a 5-minute video featuring a number of *IceCube* collaborators reflecting on *IceCube*'s first decade, and a mosaic photo of the entire collaboration.

And finally, since you can't have a proper celebration without a cake, we made one! UW–Madison graduate student and *IceCube* collaborator Maria Prado designed, baked, and decorated an intricately detailed 10th anniversary cake for our South Pole neutrino observatory. The top tier is chocolate with nutella fudge and is decorated with a star- and aurora-filled night sky and the *IceCube* Laboratory. The bottom tier, which is funfetti with cream cheese frosting, is topped with an "icy" isomalt surface and fondant flags representing the countries that are represented in the *IceCube* Collaboration. Embedded in the bottom layer are gummy "DOMs" that glow under black light. For more photos and videos of the cake, visit IceCube's website. The cake was also featured as the HEASARC picture of the week in September.

In the last 6 months, the *IceCube* Collaboration has published and submitted papers about a search for low-energy neutrinos from gravitational wave events, a new machine learning method that dramatically improves *IceCube* data processing, an analysis that puts the most general constraints on nonstandard neutrino interactions, a search for multiple flaring episodes from neutrino sources with 10 years of data, a search for relativistic magnetic monopoles, and a search for quantum gravity with *IceCube*. 10 years of *IceCube* data were also added to NASA's HEASARC archive, making them available for public use.

IceCube's 10th anniversary cake. Credit: Maria Prado

The Chandra X-ray Observatory

Edward Mattison (SAO),
Martin C. Weisskopf (NASA/MSFC)

The *Chandra* X-ray Observatory has carried out more than 22 years of highly successful and productive science operations. *Chandra* 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 *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.

Since March 2020, *Chandra* science and mission operations staff have successfully adapted to the challenges of the corona virus pandemic. Our primary goals are ensuring the health of our staff and maintaining *Chandra*'s continued normal operation. Protocols and schedules are in place to minimize the number of staff at the Operations Control Center and to keep operators physically separated. 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. On August 31, the Low Energy Transmission Grating (LETG) failed to insert properly into the telescope's optical axis. Operations staff halted science observing and quickly established that no hardware or software had failed. The LETG was retracted and science observing, without gratings, was resumed on September 2 with a loss of 122.5 ks of observing time. A thorough engineering analysis, including Fourier analysis of data from the LETG's stepper motor, showed that the anomaly was due to the temperature dependence of a capacitor in the motor drive circuit which had caused the LETG to travel 0.3% faster than normal. On 15 October revised parameters were loaded into the spacecraft's database to take account of changing temperatures, and the scheduling of both gratings during science observations was resumed.

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 (below 1.5 keV) X-rays. The decline in thermal insulation effectiveness requires considerable extra effort in scheduling observations but has not significantly affected *Chandra*'s observing efficiency.

The peer review of proposals for Cycle 23 observations, held in June, approved 134 proposals (of 517 submitted), for a total of 19.3 Ms of observing time (of 81.2 Ms requested), an oversubscription factor of 4.2.

The *Chandra* Press Office has been active in issuing image releases, science press releases and other communications of *Chandra* research results. Of note recently was widely reported detection by *Chandra* of the possible transit signature of an exoplanet in a distant galaxy, M51, about 28 million light-years from the Milky Way. A complete listing of press releases is available. Information about the *Chandra* Observatory and the *Chandra* X-ray Center can be found at the *Chandra* X-ray Center website.

XMM–Newton

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

The 21st Announcement of Opportunity closed on October 8. In all, 428 proposals were received, from 348 different PIs in 30 countries; the number of different countries involved rises to 39 if Co-I's are included. Including Co-I's, about 1500 scientists were involved in this AO. A substantial number of proposals (21%) were requests for joint time with *XMM–Newton* and another mission (*NuSTAR*, *HST*, *Swift*, VLT, *Chandra*, NRAO, *H.E.S.S*, or *INTEGRAL*). The over-subscription factor was 6.8. The final program will be announced in mid December, and observations will begin in May 2022.

The SOC hosted a virtual workshop May 25 – 28 2021 on the topic of "A High Energy View of Exoplanets and their Environments". The workshop focused on such topics as exoplanetary atmospheres, stellar high-energy irradiation, exoplanet formation, and interactions between stars and exoplanets. Posters can be found online.

The Neil Gehrels Swift Observatory

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

The Neil Gehrels *Swift* observatory continues to operate flawlessly and to support 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 ToO accepted and different sources observed.

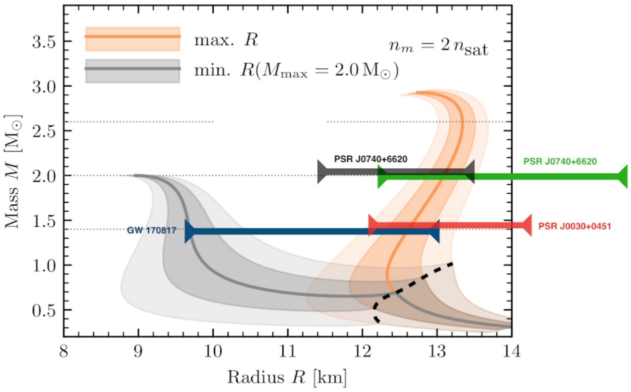
A team of scientists used *Swift* to detect gamma-rays from "mellow" supermassive black holes (SMBHs) and connect them to high-energy neutrinos (Kimura et al., Nature Comm, 12, 5615). These SMBHs are much quieter than a typical AGN as they accrete lower quantities of material. Since the plasma that forms around these bodies is less dense, it is far less efficient at radiating heat, and can reach temperatures of tens of billions of degrees. Under these conditions, protons within the plasma can be accelerated to extremely high energies, via processes including turbulence and magnetic field reconnection. As the protons collide with other baryonic particles, they can create neutrinos in the petaelectronvolt (PeV) range.

The *Swift* Guest Investigator (GI) program received 140 proposals in Cycle 18. Proposal review is underway, and results are expected to be announced in early 2022. *Swift* will continue to solicit proposals in GRB and non-GRB research during Cycle 19, with an estimated deadline of September 2022. Updates on the Cycle 19 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)

The Neutron Star Interior Composition Explorer (*NICER*) is an X-ray astronomy facility on the International Space Station dedicated to high-precision X-ray timing spectrometry of neutron stars, black holes, AGN, and other time-variable sources. In addition to absolute timing precision of better than 300 ns, *NICER* offers large effective area (1900 cm^2 at 1.5 keV), moderate spectral resolution (energy resolving power between 6 and 80), broad bandpass (0.2 – 12 keV), and a 30 arcmin^2 (non-imaging) field of view. *NICER*'s berth on the ISS provides real-time commanding of the facility, enabling flexible scheduling of observations and rapid followup of transients. Based at NASA's Goddard Space Flight Center, mission operations since March 2020 have been largely remote, including generation of observing schedules, commanding of the ISS payload, and pipeline processing and archiving of data.



Mass-radius relations for neutron stars. Dashed curve: lower limit from Earth-based laboratory experiments. Red, green and grey horizontal bars: ranges derived from NICER measurements; Blue horizontal bar: LIGO estimate from GW170817. Predicted stiff and soft neutron star equations of state are shown by the orange and gray bands, respectively. Credit: S. Reddy, U. of Washington; NASA

Observations proposed for Cycle 3 of *NICER*'s Guest Observer (GO) program began on March 1, 2021. Eight million seconds of science observing time were allocated for successful GO proposals, approved multi-cycle investigations from GO Cycle 2, and Cycle 2 investigations that were coordinated with other observatories but not carried out as a result of COVID-19 impacts at those facilities. Observations of targets from *NICER*'s Legacy Science program of neutron star studies were also conducted in Cycle 3. Selected Cycle 3 proposals, and the mission's short-term observing schedule are available at *NICER*'s website at the HEASARC. The proposal submission deadline for observations during *NICER* Cycle 4 was November 10; 107 proposals were received, and these will be reviewed in January 2022, with observations of accepted targets beginning on March 1, 2022.

NICER's scheduling flexibility allows it to observe a large number of target-of-opportunity (ToO) targets, which may be proposed by any observer for any target at any time. TOO requests are submitted via the *NICER* Target of Opportunity/Director's Discretionary Time Request form. Since last May, *NICER* has received 131 requests for Target of Opportunity requests for observations of important astrophysical transient phenomena and conducted 108 individual observations, which have resulted in 31 *NICER* Astronomer's Telegrams. *NICER* is currently capable of following up on Targets of Opportunity (ToO) within 4 hours during regular business hours and if the source is visible. *NICER*'s visibility windows for a given target can be complicated to determine because of occultation by structures (such as the large solar arrays) on the ISS. The *NICER* project recently released a web-based Enhanced Visibility Calculator to provide accurate near-term visibilities for any specified target.

The *NICER* team continues to implement more-responsive capabilities for the followup of new transients. The *NICER* project is maturing the ability to perform automatic raster scans of the localization uncertainty regions of new transients detected by JAXA's Monitor of All-sky X-ray Image (*MAXI*), which is also an ISS payload. An exciting automated triggering capability, dubbed "OHMAN" (for the On-orbit Hookup of *MAXI* And *NICER*), will allow *NICER* to respond to *MAXI* triggers on timescales of just a few minutes, similar to the rapid response of *Swift*, but with approximately 15 times the effective area of *Swift*'s X-ray Telescope. In late June, the OHMAN software underwent a successful verification test, and the final delivery of the OHMAN software for integrated verification testing was completed in October. OHMAN is expected to come online in March 2022 as ISS transitions to its next operational increment.

The *NICER* Users Group (NUG) was formed earlier this year, consisting of eight members with substantial expertise relevant to *NICER* science and instrumentation. Edward Cackett of Wayne State University is the NUG Chair. The NUG is expected to meet, independently of *NICER* mission leadership, in the spring and fall of each year. The community is encouraged to contact the NUG with comments and suggestions; contact information, the NUG Charter, and meeting information are available on the NUG webpage.

Some recent notable *NICER* science results follow.

- A joint *NICER-LIGO* analysis of the young pulsar PSR J0537-6910 shows that gravitational waves from the $l = m = 2$ mode account for less than 14% of the spin-down energy budget, and the fiducial equatorial ellipticity is constrained to be less than about 3×10^{-5}, the third-best constraint obtained for any young pulsar.
- *NICER* performed intensive monitoring of the outburst of RS Oph, a recurrent nova that went into outburst beginning on August 8. *NICER* observations started on August 10, when the emission was dominated by an evolving debris cloud that exhibited a strong thermal X-ray spectrum. By early September, the emission from the debris cloud faded and NICER was able to detect pulsed X-ray emission from a hot spot on the surface of the white dwarf, found to be spinning with a period of ~ 34 seconds.
- A recent analysis by Zhang & Li shows that the lower radius limit for PSR J0740+6620 found by *NICER* provides the best lower limit for the nuclear symmetry energy in the density range of 1 – 3 times the saturation density of nuclear matter.

NuSTAR

DANIEL STERN (JPL) & FIONA HARRISON (CALTECH)

As *NuSTAR* approaches the 10th anniversary of its launch next June, the mission continues to operate nominally on orbit and proudly crossed the threshold of >1000 refereed publications in the past month. A conference celebrating a decade of studying the high-energy universe in focus and exploring the range of astrophysics that *NuSTAR* is conducting will be held in Sardinia, Italy in June 2022. See the conference website for details about the conference, and registration information.

Artist's illustration of SS 433, a black hole or neutron star, as it pulls material away from its companion star. The stellar material forms a disk around SS 433, and some of the material is ejected into space in the form of two thin jets (pink) traveling in opposite directions away from SS 433. Credit: DESY/Science Communication Lab.

In late October, the *HEASARC* released a major update to the *NuSTAR* effective area calibration. Based on more than 9 years of observations of the Crab, utilizing both focused and stray light measurements, the newest CALDB files increase the flux of objects by approximately 5% on-axis, with a larger change for sources farther off-axis. The update also produces a better agreement between the two focal plane modules and more accurate high-energy and high off-axis angle corrections. For most *NuSTAR* observations, this calibration update will have little or no practical change, especially for analysis of low signal-to-noise spectra. Madsen et al. (2021, arXiv:2110.11522), which details the new calibrations, presents case studies investigating the changes for a sample of observations spanning a range of brightness and source types. Although the flux change is evident using the new calibration, the small changes seen in the fitted parameters did not result in a new interpretation of the observations.

On the science front, one highlight is a recent study published by Matt Middleton that shows that the Galactic source SS 433 is an Ultraluminous X-ray source, or ULX, even though it appears to be about 1,000 times dimmer than the minimum threshold to be considered one. ULXs, previously solely extragalactic, are sources whose luminosity exceeding the Eddington luminosity of neutron stars and stellar black holes, implying either super-Eddington accretion or an accreting intermediate mass black hole. With *NuSTAR*'s discovery of pulsations in the ULX M82 X-2, it was recognized that at least some ULXs are neutron stars. To date, nearly a dozen pulsating neutron star ULXs have been confirmed, with the brightest source having an implied peak luminosity greater than 500 times the Eddington limit.

At a distance of approximately 5.5 kpc, SS 433 is the only Galactic binary system known to persistently accrete at highly super-critical rates. It is at the center of, and likely associated with, the W50 nebula, also known as the Manatee Nebula, the remnant of a supernova that occurred about 20,000 years ago. The recent paper is based on *NuSTAR* monitoring of SS 433 across multiple phases of its 162 day superorbital period. Spectral-timing analysis shows that the hard X-ray emission from the inner regions is likely scattered towards us by the walls of a wind-cone: the high-energy X-rays from SS 433 are initially confined within two cones of gas extending outward from opposite sides of the central object, corralling the X-ray light into a narrow beam. Modeling shows that though *NuSTAR* only infers a peak intrinsic X-ray luminosity of 2×10^{37} erg/s, if viewed face-on, SS 433 would have a luminosity $> 10^{39}$ erg/s. This places it above the ULX threshold, making SS 433, by far, the closest confirmed ULX. The study also detects outflowing material travelling at least 0.14 – 0.29c, consistent with absorption lines recently reported in ULXs and confirming the expected association between ultrafast outflows and super-critical accretion. Finding a Galactic ULX provides a nearby laboratory to study these extreme sources, whose rapid growth might help us understand the supermassive black holes seen in the highest redshift quasars.

AstroSat

S. SEETHA (RRI) AND DIPANKAR BHATTACHARYA (IUCAA)

AstroSat completed six successful years in orbit in October 2021. A compendium of articles describing the experience, technical developments and science results during the first five years has recently been published in a special issue of the Journal of Astrophysics and Astronomy (vol. 42, 2021).

Recent science highlights from *AstroSat* include the discovery of three new star forming galaxies in the Bootes Void from a deep UVIT FUV survey of this region (ApJ 919, 101). The void galaxy sample displays a median star formation rate of $3.96\ M_{\odot}$ yr^{-1} with a weak effect of environment. This sample also shows dominant bluer galaxies compared to the field or denser environments and the red sequence galaxies are missing.

Broadband Spectral Energy Distributions have been constructed for four galaxies spanning the radio to UV band (MNRAS 504, 4143). Two of these galaxies, NGC 7590 and NGC 7599, were observed with the UVIT. While NGC 7590 provides some evidence of presence of cold dust, NGC 7599 shows signs of triggered star formation.

The high-energy peaked BL Lac object 1ES 1959+650 was observed on October 25 – 26, 2017, during its long flaring episode. Analysis of these data show that the soft and the hard X-ray emission are correlated. The broad-band X-ray spectra can be fit with a broken power law with a break energy of 2.86 keV. From time resolved analysis, the normalised particle density at an energy less than the break energy and the power law index before the break were found to be correlated with a delay of ~ 60 ks (MNRAS 504, 5485). Further analysis of the same source conducted over a longer duration spanning 2015 – 2021 and including data from *Swift*-XRT, *Fermi*-LAT and IR observations show significant spectral changes with an overall "harder when brighter" trend (ApJ 918, 67). The synchrotron peak energy exhibits positive correlation with X-ray flux, in a manner consistent with a geometric (changing Doppler factor) interpretation.

MAXI J1348−630, a new X-ray transient source discovered by the *MAXI*/GSC instrument has been studied using *AstroSat* and *NICER* during its outburst in 2019, in soft state and both faint and bright hard states (MNRAS 505, 713). Type A QPOs are detected at 6.9 Hz in the soft state and type C QPOs at 0.9 Hz and its sub-harmonic detected in the bright hard state. Time lags studies over the energy band $0.5 - 80$ keV exhibit hard time lag in the bright hard state and soft lag in the faint hard state. These observations can be explained using a single-zone stochastic propagation model, which however does not quantitatively match the *NICER* data, possibly due to the dominance of disk emission.

Another black hole X-ray transient, MAXI J0637-430, was detected in 2019 and was also observed by instruments on *AstroSat*, *NICER* and *Swift*. The source appears to exhibit a 'c' shaped trace in the Hardness-Intensity Diagram instead of the standard 'q' (MNRAS 508, 2447) . An upper mass limit of 19 $M_\odot$ with retrograde spin was estimated for the compact object.

The persistent high mass black hole X-ray binaries LMC X-1 and LMC X-3 in the disk-dominated soft state during 2016 – 2020 exhibited moderate variability. By continuum fitting of the spectra the mass of the black hole is estimated to be in the range of $7.64 - 10.00$ $M_\odot$ for LMC X-1 and $5.35 - 6.22$ $M_\odot$ for LMC X-3, The spin parameter is estimated to be $0.82 - 0.92$ for LMC X-1, consistent with previous values, and $0.22 - 0.41$ for LMC X-3, better constrained than earlier estimates (MNRAS 501, 5457). Cyg X-1, another persistent BHXB, has been observed at an extremely soft state in October 2017 and the spin parameter is estimated to be > 0.9981 at 99.7% confidence level (MNRAS 507, 2602).

Time resolved analysis of several bursts during 2016 – 2018 timeframe from the neutron star X-ray binary atoll source 4U 1636-536 show that three of the bursts exhibit burst oscillations at 581 Hz, two of them being in the decay phase of photospheric radius expansion (PRE) and the third predominantly in the rising phase of the burst (MNRAS 508, 2123). The time evolution of the rms fractional amplitude during the rise of the third burst provides observational support for a flame spreading model. The oscillations observed post-touchdown for the PRE bursts are attributed to spreading of a cooling wake originating at higher latitudes of the neutron star. Further spectral analysis of these bursts indicate a soft excess near the peak, possibly due to the burst emission illuminating the disk and being re-emitted, resulting in an extra black body component (MNRAS: arXiv:2109.14631). Five bursts and one burst-like event have been observed from the Z source Cyg X-2 in 2016 when it was in the early flaring branch. These thermonuclear events are short and are attributed to Helium dominated bursts (NewA 83, 101479). *AstroSat* LAXPC spectra have also been used to estimate the magnetospheric radius and the radius of the boundary layer of the atoll source 4U 1705-44 (ApSS 366, 87).

The Type-I X-ray burst of October 2019 of the intermediate-spin high mass X-ray binary pulsar IGR J19294+1816 has been studied during its decay and this source becomes the 10th pulsar in which a QPO and a cyclotron feature have been observed. A QPO with a centroid frequency of 0.032 ± 0.002 Hz, width of 0.012 ± 0.006 Hz and a Quality factor of ~ 2.7 has been detected for energies up to 30 keV. The spin period of this source was determined to be 12.485065 ± 0.000015 s, with a single peaked, broad, energy-dependent pulse profile. Spectral fits indicate a cyclotron feature at ~ 42 keV, indicative of a magnetic field strength of 4.6×10^{12} G (MNRAS: arXiv:2109.14022).

Insight-HXMT

Shijie Zheng, Shuangnan Zhang (IHEP, CAS)

Insight-Hard X-ray Modulation Telescope (*Insight-HXMT*) is China's first X-ray astronomy satellite. It was launched on June 15, 2017 and is currently in its extended operation phase. The updated *Insight-HXMT* CALDB (V2.05) was released in March 2021. Non-proprietary data can be downloaded freely from the *Insight-HXMT* on-line archive. More information about the progress, user support and results of *Insight-HXMT* can be found at the *Insight-HXMT* home page (in English and Chinese).

Some recent important *Insight-HXMT* results have been published:

- The first detection of the time lag of hard X-rays in the type-II X-ray bursts in MXB 1730-335 (Chen et al. 2021)
- Finding the physical origin of the non-physical spin evolution of MAXI J1820+070 (Guan et al. 2021)
- The first observational explanation to the "hysteresis effect" in MAXI J1348-630 (Weng et al. 2021)
- Anti-correlation and correlation between the CRSF and luminosity below and above the critical luminosity in the brightest giant outburst of 1A

0535+262 (Kong et al. 2021)

- Confirmation of the spin of Cygnus X-1 (Zhao et al. 2020)
- Detection of a 22-s quasi-periodic pulsation and a quite steady gyrosynchrotron source in the X9.3 flare of the Sun

Please visit *Insight-HXMT*'s publication list for more details.

Proposals for the AO-04 cycle have been evaluated and the list of accepted proposals announced. The AO-04 observations began on Aug 13, 2020. In total, 333 observations from 33 approved proposals, including 250 ToO observations, have been approved. These observations include programs from institutions and universities in China, Germany, France, Spain, Italy, UK and Greece, and other countries. The long-term and short-term observing plan and the list of observed sources and exposure times are available at the *Insight-HXMT* website.

The Fermi Gamma-Ray Space Telescope

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

The *Fermi* Gamma-ray Burst Monitor (GBM) and Large Area Telescope (LAT) continue to scan the gamma-ray sky. The Flight Operations Team and the Instrument Operations Teams manage the observatory and instruments, working mostly remotely due to the COVID-19 pandemic.

Fermi, together with *Swift*, provided the trigger for a dramatic gamma-ray burst discovery. GRB 190829A was one of the closest bursts, and the trigger allowed the ground-based *H.E.S.S* TeV observatory to measure its energies up to more than 3 TeV and to follow the afterglow for three days.

The *Fermi* GBM triggered another important multi-wavelength campaign, for GRB 200826A. This appeared to be a short burst, of the type associated with merging neutron stars, but follow-up observations revealed a supernova, a feature usually associated with long bursts. The combination of many observations led to the conclusion that this was a stellar collapse that almost failed to produce the jets associated with a gamma-ray burst.

Current *Fermi* software and documentation are available through the Fermi Science Support Center. The latest 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 . If you have job/research/degree opportunities relevant to the gamma-ray community, the LAT Collaboration has an Opportunity Board where those can be posted.

Guest Investigator Proposals for *Fermi* Cycle 15 are due on February 17, 2022. Please see the solicitation on NSPIRES for more information on the program and how to propose. Information about a virtual pre-proposal workshop scheduled for January 28, 2022, and additional details about the program can be found at the *Fermi* Science Support Center proposal page.

The *Fermi* Summer School was held virtually this year, spread over seven weeks. The program included lectures and analysis tutorials. Please see the 2021 Summer School webpage for more information.

The Tenth International *Fermi* Symposium will be held in Johannesburg, South Africa, from October 9 – 15, 2022. The symposium venue will be Misty Hills Country Hotel, Conference Centre & Spa located on the outskirts of the city of Johannesburg. Please save the dates. Preliminary information for the symposium is available on the symposium webpage.

INTEGRAL

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

INTEGRAL's last thruster firing to control angular momentum was on July 17, 2020. Since that time, control of the angular momentum has been done solely by balancing solar radiation pressure - the "Z-flip" strategy – which implies very stringent observation planning requirements. Richard Southworth, the *INTEGRAL* Spacecraft Operations Manager, shared his impressions of one year of exciting operations in an ESA/Enabling & Support/Operations web story and an "ESA Explores Space Operations" podcast.

Until the second half of September 2021, the spacecraft continued to operate nominally, without thruster usage and no reaction-wheel biasing. However on September 22, a Single Event Upset (SEU) impacted the functioning of one of the reaction wheels, which resulted in an uncontrolled slew that triggered an Emergency Safe Attitude Mode (ESAM#9). However, the Mode did not stabilize the spacecraft due to a severe underperformance of the Reaction Control Subsystem (RCS). Reaction wheels were re-activated but, as the Mode relied upon a fully functional RCS, the spacecraft kept spinning at a rate of about 10 degrees per minute in at least two axes, and the wheels became saturated with angular momentum. Telemetry was choppy, coming in for short periods due to the spinning of the spacecraft. Batteries were discharging, with only short charging periods when the panels briefly faced the Sun. There was only a three hour window before battery blackout and the loss of *INTEGRAL*.

Colleagues from the Mission Operations Centre (MOC) supported by industry experts first reduced the energy consumption by turning off various payloads. The second immediate challenge was to stop the spinning by commanding the reaction wheels to slow down the body rates (spinning), and thus stabilize the spacecraft to allow controlled rotation to a Sun-facing attitude and recharge of the batteries. This heroic effort was achieved in the early hours of the morning on September 23.

To everyone's surprise, upon perigee exit, the spacecraft was once again rotating with high reaction wheel speeds. The reason for this is still not completely understood (as during perigee gap some housekeeping data is unavailable), but it probably triggered an autonomous momentum dump (AMD) that relied on the usage of the (again underperforming) thrusters. The experience of the previous day guided the steps to recovery, and within 2.5 hours the spacecraft had been stabilized again and its angular momentum control regained once more.

To prevent such anomalies from happening again, the ESAM and AMD were both deactivated. The spacecraft has since remained in a well-controlled state and stable angular momentum configuration. *INTEGRAL* resumed routine pre-planned science operations on 1 October. All spacecraft subsystems and instruments are again operating nominally.

The *INTEGRAL* Spacecraft Operations Manager and Project Scientist discuss how *INTEGRAL* was saved and what the mission has been up to in this Space Rocks video. On October 17, *INTEGRAL* celebrated 19 years of operations in space.

The annealing (#37) of the spectrometer SPI took place September 4 – 21. The usual tests during the cooling down, however, were interrupted by the ESAM#9 described above. The recovery level of the energy resolution is slightly worse than usual, certainly as a consequence of the ESAM related issues. It is not clear yet if this is due to contamination transfer or a real degradation of the GeD. The next annealing (#38) will help to verify this and might have to be done before the "standard" six months.

The *INTEGRAL* Target Allocation Committee (TAC) completed the review of AO-19 observing proposals on 18-20 May. Out of the 49 proposals submitted, 46 were selected, including 28 Target of Opportunity (ToO) follow-up observations, 3 Gamma-Ray Bursts (GRB), and 1 multi-messenger data rights. Drawing on the existing agreements between *INTEGRAL* and *XMM–Newton*, NASA's *Swift*, and NASA's *NuSTAR*, the TAC also granted 150 ks of *XMM–Newton*, 60 ks of *Swift*, and 140 ks of *NuSTAR* observing time to a total of 3, 2, and 2 *INTEGRAL* proposals, respectively.

Apart from ESAM#9 and the subsequent investigation period, scientific observations during the reporting period were performed as much as possible following the AO-18 long-term plan. A coordinated calibration observation of 3C273 took place on June 9 – 11 with *Chandra*, *NuSTAR*, and *XMM–Newton* and of the Crab on 28/29 August with *NuSTAR* and *XMM–Newton*. Coordinated observations of Jupiter with *XMM–Newton* and the Juno space probe occurred in May and June. A ToO observation of the fast radio burst FRB 180916.J0158+65 took place on September 13 – 15 involving *INTEGRAL*, *NuSTAR* and *XMM–Newton*. The aim was to find hard X-rays/soft gamma-ray emission during the predicted bursting activity. Several radio facilities (such as NRT, CHIME, and Torun Radio Astronomy Observatory) had secured their participation, insuring good simultaneous coverage with INTEGRAL.

Demonstrating the recovery of the spacecraft from the critical anomaly of September 22 – 23, one of the fastest re-planning and executions of an unanticipated ToO observation (4.7 hours from time of trigger to start of observation) occurred from October 13 – 14, in response to the new rise in X-rays from the black-hole binary transient V4641 Sgr. Concurrent observations were carried out with *Swift* and *NICER*. Further coordinated *INTEGRAL* & *XMM–Newton* observations were performed on October 15 – 16. Two further unanticipated ToOs were performed on 4U 1820-30 (October 17 – 18) and Cygnus X-3 (October 25 – 26), the latter supported by multi-wavelength monitoring observations (RATAN-600 (radio), *Fermi* (high-energy gamma-rays), SMA (submillimeter), and MRO (optical). A software patch to the Attitude and Orbit Control Subsystem (AOCS) to allow for more stable gyro-less slews is expected to be deployed by November 2021. This will allow an even faster response time to ToOs.

During this reporting period three very-high-energy neutrino events were reported (IceCube-210629A, IceCube-210717A, IceCube-210730A), as well as delayed reports on two very-high-energy neutrino events from May (IceCube-210510A, IceCube-210516A). No hard X-ray/gamma-ray counterpart were found by *INTEGRAL*, with the usual upper limits (see GCN Circulars #30348, #30376, #30377, #30471, #30581). One (long) gamma-ray burst (GRB210707A) was detected by IBAS in *INTEGRAL*'s main instruments Field-of-View (see GCN Circular #30414).

The intended coordinated (ToO) observations between *INTEGRAL*, Swarm and Cluster, to investigate the high-energy response on the Earth to Solar flares, has been postponed to Autumn 2022.

There is a significant correlation between *INTEGRAL*-detected hard X-ray (or soft gamma-ray) sources and TeV sources. By comparing the *INTEGRAL*/IBIS 1000 orbit catalogue with an online TeV source list, it has been shown that 39 objects (about 20% of the very-high energy gamma-ray catalogue) have emission in both the soft gamma-ray and TeV wavelength bands – see Malizia et al., 2021, in the Special Issue "High-Energy Gamma-Ray Astronomy: Results on Fundamental Questions after 30 Years of Ground-Based Observations", Universe 7(5), 135. This provides an indication of the usefulness of combining information at these frequencies and preparing a legacy program for future very-high energy observations, such as with the Cherenkov Telescope Array (CTA).

The *INTEGRAL* scientific conference, "Towards the third decade of X and Gamma ray observations," took place during October 11 – 16, 2021 in Sardinia, Italy.

Out of slightly more than 100 registered participants, approximately 50 attended the meeting in person; the rest followed the presentations online.

Efforts are underway for setting up the *INTEGRAL* Science Legacy Archive (ISLA). One of the ideas to be explored are science-based portals, where data products can be found which are geared towards the specific source categories.

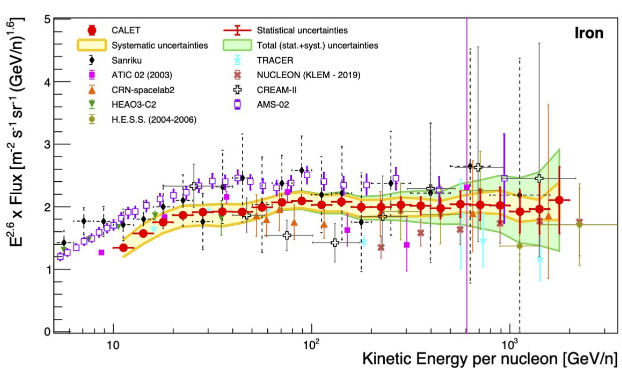
As of November 1, the number of refereed publications since launch is 1883; of these, 91 appeared in 2021.

CALET

JOHN WEFEL (LSU)

The CALorimetric Electron Telescope (*CALET*) mission continues to return high quality data from the International Space Station (ISS). The experiment has just passed its year six anniversary of data taking, mounted on port #9 of the Japanese Experiment Module – Exposure Facility (JEM-EF). Since the previous report, there have been several power outages to JEM-EF and ISS orbit/attitude problems, but *CALET* has recovered from all of these and returned, quickly, to data taking. One continuing problem that is being worked involves parking the robot arm within part of the *CALET* field-of-view. This can be handled during data analysis but that involves a reduction in the *CALET* exposure – so we are hoping for an operational "fix" for the problem.

The *CALET* team has now completed the detailed analysis of the IRON spectrum with the result shown in the figure, plotted as energy to the power 2.6 times the flux versus the kinetic energy per nucleon. Also shown are results from other balloon, satellite or ground based experiments (see a forthcoming PRL for details).



The flux of Iron nuclei $timesE^{2.6}$ plotted versus kinetic energy per nucleon for CALET (red) and previous experiments. The yellow band shows the total systematic uncertainties while the green band gives the total statistical + systematic uncertainty. Credit: CALET

The *CALET* results agree with ATIC-02 and TRACER at low energy and with CRN and *H.E.S.S* at high energy. Compared to AMS-02 , the *CALET* result is low by about 20%. Normalizing *CALET* to AMS-02 shows that the two results have the same spectral shape.

As suggested from our preliminary analysis, the Fe spectrum shows no spectral break. This behavior is different from the C and O spectra, which both show unmistakable spectral hardening as does the *CALET* result for Hydrogen. Now, the question becomes, 'what is the spectral shape of other elements such as Ni , heavier than iron, and the primary elements heavier than Oxygen, such as Ne, Mg, and Si.' These analyses are in progress and will illuminate the astrophysics involved in the spectral hardening that has been observed.

VERITAS

WYSTAN BENBOW (SAO) & AMY FURNISS (CAL-STATE EAST-BAY)

In September 2021, *VERITAS* began its fifteenth season of full-scale operations. After enduring the third rainiest monsoon season recorded since 1895, the array was brought back online after the annual $\sim$3-month pause without any major issues. Over the summer, several small upgrades to the *VERITAS* hardware were deployed, both to its gamma-ray and to its stellar intensity interferometry systems, while the usual major maintenance projects were performed. Project operations will continue in 2021 – 22 using the remote-operations model developed last season. This model successfully enabled data-taking at typical levels despite the ongoing pandemic. After one month of observing, it is clear the hardware systems continue to perform well and the collaboration anticipates a productive season.

The successful scientific operation of *VERITAS* and the development of the co-located prototype Schwarzschild-Couder Telescope (pSCT) for the next-generation Cherenkov Telescope Array (CTA) requires the dedicated efforts of its Project Office, as well as significant behind-the-scenes contributions which do not lead directly to corresponding-author publications. These contributions can be related to tasks such as instrument calibration, simulations, and data analysis software contributions, or to on-site service work. The *VERITAS* collaboration has two annual awards in order to formally recognize early-career collaborators who complete these critical service tasks. The awards are the Trevor Weekes and Simon Swordy Outstanding *VERITAS* Contribution Awards which recognize significant contributions by a post-doctoral researcher and a graduate student, respectively. The 2020 winners of these awards are Mireia Nievas Rosillo and Alisha Chromey. The Trevor Weekes Award was presented to Mireia Nievas Rosillo for "leading the effort ... to understand the change in response of the *VERITAS* instrument to Cherenkov light". Alisha Chromey (Iowa State University) received the Simon Swordy Award for her role in the Analysis and Calibration Working Group and in leading observing shifts. In 2021, the eligibility for awards is being extended to members of the SCT Consortium, a subgroup of the CTA Consortium. The winners of the awards for 2021 will be announced in January 2022. The awards website also lists the prior winners, and includes narrative details regarding their outstanding contributions.

The VERITAS collaboration's published highlights since Spring 2021 include:

- A search for TeV gamma-ray emission from pulsar tails (arXiv:2105.13911)
- An archival search for neutron-star mergers in gravitational waves and very-high-energy gamma rays:(arXiv:2106.01386)
- A study of the variability and spectral characteristics of three flaring FSRQs: (arXiv:2110.13181)
- Results from a 15-year (2004-2019) multi-wavelength observation campaign of the gamma-ray binary HESS J0632+057 (arXiv:2109.11894)
- Results from a 2019-20 multi-wavelength observation campaign of HESS J0632+057 with NuSTAR, VERITAS, MDM, and Swift (arXiv:2110.01075)

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.

With the recent release of the Astro2020 Decadal Survey, the PCOS Program Office, along with our counterparts in Cosmic Origins (COR) and Exoplanet Exploration (ExEP) will continue to engage with NASA HQ to prepare the implementation strategy for such a broad vision of the next decade in astronomy.

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 Cosmic Ray, Gamma-ray, Gravitational Wave, and X-ray SIGs. 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 3 years, and several members will be rolling off in December 2021, when a group of new members will be appointed.

In October of 2021, PCOS, COR, and ExEP teamed up with the Astrophysics Science Division at NASA/GSFC to organize a session at the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Diversity in STEM conference. In November, the same groups teamed up again to organize a session at the National Society of Black Physicists annual conference, the theme for which was "Grand Unification in the Diaspora". The PCOS Program Office will continue to seek out ways to engage diverse communities.

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 2022. You can submit an entry for these technology gaps using the Technology Gap Submission Form. With the release of Astro2020, the submission deadline has now been finalized as January 3rd, 2022.

A few personnel changes have recently occurred in the PCOS Program Office. Dr. Terri Brandt has returned to PCOS, where she, along with Dr. Brian Williams and Dr. Jake Slutsky perform the PCOS Chief Scientist duties. Thai Pham has announced his retirement as Technology Development Manager for the Astrophysics Projects Division at GSFC. We wish Thai well as he heads into retirement, effective at the end of 2021. Thai will be replaced by Rachel Rivera, who currently serves as the Director of the Instrument Design Lab at NASA/GSFC.

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), Grant Tremblay (CfA), & Jillian Bellovary (CUNY/AMNH)

The NASA PCOS X-ray Science Interest Group (XRSIG) continues to track and analyze science and mission development in X-ray astronomy, as well as providing a communication forum for the field. This year X-ray astronomy has seen more new and exciting science results, including the direct observation of light echoes from behind an accreting black hole, X-ray clues to the nature of the auroral emission on Jupiter, and possible X-ray evidence for a planetary transit in M51, the Whirlpool Galaxy.

The big upcoming mission news is the upcoming launch of the Imaging X-ray Polarimetry Explorer (*IXPE*) scheduled for December 2021. X-ray astronomy was also highlighted in the recommendations from the Astro2020 Decadal Survey, which include a probe-class X-ray mission with capabilities to complement ESA's *Athena* observatory, and development of an X-ray flagship mission as part of a Great Observatories Mission and Technology Maturation Program.

We are planning two XRSIG sessions coordinated with upcoming meetings. The XRSIG session in January will be held virtually, the week before this year's AAS Annual Meeting (date TBA), and plans to include a discussion of the Astro2020 Decadal Survey recommendations. The XRSIG also plans to host a session to coincide with the 19th AAS HEAD Meeting in Pittsburgh in March.

Other meetings of interest to the X-ray community include the *NuSTAR* Science Conference scheduled for Sardinia in June 2022, and the 2022 XMM-Newton Science Workshop on Black Hole Accretion Under the X-ray Microscope in Madrid, also in June 2022. We look forward to continuing to engage with the X-ray astronomy community!

The Gamma-ray Science Interest Group

MARCOS SANTANDER (UA), BINDU RANI (AU), JUSTIN FINKE (NRL)

We are happy to announce the selection of the Compton Spectrometer and Imager (COSI) for NASA's Small Explorer program. This mission, led by PI John Tomsick at the University of California, Berkeley, will study the origin of chemical elements in the Milky Way.

The recently released Astro2020 Decadal Review endorsed a Time Domain and Multi-Messenger Follow-Up program as its highest priority sustaining space-based program. The report further emphasizes the importance of "wide-field gamma-ray and X-ray monitoring, and rapid and flexible imaging and spectroscopic follow-up in the X-ray, ultraviolet (UV), and far-infrared (far-IR). In addition, space platforms can be designed to access much of the sky at any given time, essential for the study of short-lived transients or rapidly variable sources" (page 7-18).

The SIG is currently organizing a virtual mini-symposium at the upcoming 239th winter AAS meeting, focusing on the future of gamma-ray astronomy.

The SIG will continue organizing events at different national and international meetings and invite members of the gamma-ray community to contact the current chairs (Marcos Santander, Bindu Rani, and Justin Finke) with any inquiries or feedback regarding the GR-SIG program.

The Cosmic Ray Science Interest Group

MARCOS SANTANDER (UNIVERSITY OF ALABAMA), ANDREW ROMERO-WOLF (JPL)

The Cosmic-Ray Science Interest Group (CR-SIG) aims to act as a forum to discuss the current status of cosmic-ray and high-energy neutrino science and to provide input for NASA regarding future goals for the field. As such, the CR-SIG encourages members of the community to provide comments, questions and updates based on their present work and future plans for cosmic ray research relevant to NASA's mission.

The SIG is planning to host splinter meetings at upcoming national conferences in 2022, including the AAS meeting in January and the APS April meeting. The SIG chairs (Andres Romero-Wolf and Marcos Santander) invite the members of the CR community to contact them directly via email (andrew.romero-wolf@jpl.nasa.gov, jmsantander@ua.edu) with any inquiries or feedback regarding the NASA cosmic ray program. People interested in the activities of the group are also invited to join our mailing list available in the NASA PCOS website.

The Snowmass 2021 community planning exercise is underway in the U.S. and white papers are being prepared by the community to provide input for the process. As part of the "Cosmic Frontier 7" topic of Snowmass, a broad white paper on gamma-ray probes of fundamental physics is being prepared that describes the science case and technology drivers for future gamma-ray missions and observatories. We encourage members of the gamma-ray community involved in new mission concepts or future observatories to contact Tiffany Lewis to provide input for this white paper. Each mission or observatory team interested in participating in the white paper is invited to provide a 1-2 page contribution by February 4, 2022.

The Gravitational Wave Science Interest Group

JILLIAN BELLOVARY (CUNY/AMNH) AND SEAN MCWILLIAMS(WVU)

The GWSIG is excited to be organizing an in-person session at the 239th meeting of the AAS, to be held January 9 – 13, 2022 in Salt Lake City, Utah. The speakers for this session are yet to be selected, but topics will likely focus on recent results and future expectations in light of the Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020), "Pathways to Discovery in Astronomy and Astrophysics for the 2020s".

Potential talks may include recent Advanced *LIGO* results from the O3b run and plans for O4 and beyond, upcoming results from NANOGrav and the recent evidence of a potential gravitational-wave signal observed by the European pulsar timing array, prospects for NANOGrav's future in light of a strong decadal endorsement of the ngVLA, and a status update on *LISA* in light of the strong decadal endorsement for US participation in *LISA* science and data analysis. The GWSIG is also planning to organize a splinter session at this year's APS April Meeting, to be held April 9 – 12, 2022 in New York, NY, related to the "New Windows on the Dynamic Universe" science theme recommended by the Decadal Survey. Further information about upcoming GW SIG meetings can be found at the PhysPAG website.

The GWSIG was pleased to see theAstro2020 Decadal Survey strongly advocate for the emerging field of gravitational-wave astrophysics in one of its three broad science themes, New Messengers and New Physics. Within that theme, the Survey identified the priority science area "New Windows on the Dynamic Universe", and explicitly recommended "[u]pgrades to improve the sensitivity of current ground-based gravitational wave detectors, and development of technologies to enable next-generation facilities", as well as "[s]trong software and theoretical foundations to numerically interpret the gravitational wave signals from merging compact objects to extract new physics in the extremes of density and gravity, and ensure easy user access to the wealth of data on the dynamic universe and to model and interpret astronomical sources whose physical conditions cannot be replicated in laboratories on Earth". Although ground-based GW astronomy is funded by NSF PHY (not AST), and therefore was not part of the Survey's formal charge, the committee nonetheless "strongly endorse[d] gravitational wave observations as central to many crucial science objectives… The survey also strongly endorse[d] investments in technology development for advanced gravitational wave interferometers, both to upgrade NSF's Laser Interferometer Gravitational-Wave Observatory (LIGO), and to prepare for the next large facility".

In addition to the endorsements related to ground-based GW astronomy, the Survey further advised NASA to "[establish] funding for LISA science at a level that ensures U.S. scientists can fully participate in LISA analysis, interpretation, and theory". The Survey recommends that "NASA should work with the European Space Agency to ensure the Laser Interferometer Space Antenna (LISA) achieves the full scientific capability envisioned by [the Astro2010 Decadal Survey] New Worlds, New Horizons. NASA should continue calls for LISA Preparatory Science with a known cadence during the decade. After a jointly developed plan for LISA data analysis and management are clear, and a few years prior to launch, NASA should establish funding for LISA science at a level that ensures U.S. scientists can fully participate in LISA analysis, interpretation, and theory".

In addition to the broad recommendations contained in the main report, the reports of the individual topical panels (contained in the Astro2020 report as appendices) made additional strong recommendations for significant and specific investments in gravitational-wave astrophysics, including building upgraded facilities to improve *LIGO* and expand NANOGrav, and maximizing NASA's contribution to *LISA*.

The Imaging X-ray Polarimetry Explorer

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

Despite COVID-19, the Ball Aerospace has shipped the *IXPE* Observatory to Kennedy Space Center for encapsulation into a Falcon-9 and launch in December. Here we update the status of the mission since the previous Newsletter.

Significant events include completion of Assembly, Integration and Test of the Observatory. Observatory-level environmental testing—acoustic, shock, vibration, and thermal vacuum testing—concluded without incident. The *IXPE* Standing Review Board conducted the Operational Readiness Review (ORR) and recommended proceeding to launch. Turning to the ground system, the *IXPE* Team successfully completed radio-frequency compatibility tests and two mission rehearsals; a third rehearsal will occur a few weeks before launch.

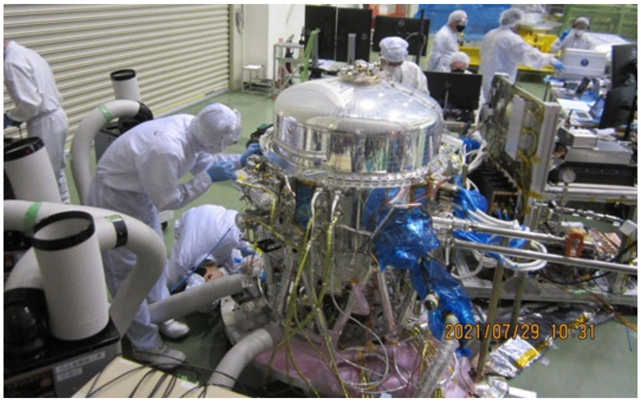
The Science Operations Center (SOC, at MSFC) has been extremely busy developing, testing, and verifying software to process the data. The SOC is already passing weekly target lists to the Mission Operations Center (MOC, at LASP), which converts these to appropriate command loads for transmitting to the Observatory. Finally, in addition to preparing the core pipeline, the SOC has purchased hardware to implement an enhanced pipeline, using Neural Network (NN) event reconstruction based upon code developed at Stanford. Meanwhile, the Italian Instrument Team has begun extensive validation of the NN code against calibration data. However, as the possibility of this enhancement occurred late in the program, the SOC will not implement the enhanced pipeline until after launch.

The X-ray Imaging and Spectroscopy Mission

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

Development continues on the *X-ray Imaging and Spectroscopy Mission* (*XRISM*). NASA personnel have been able to continue to support the integration and testing of the Resolve instrument both virtually and in-person. The in-person support, in particular, has happened as a result of extraordinary efforts on the part of both the NASA and JAXA project management teams. Travelers to Japan continue to face the most strenuous tasks of all with the requirement to quarantine upon arrival before beginning work on the instrument, though the requirements for the length of the quarantine are beginning to improve and look promising for 2022. At GSFC, work continues on the testing and calibration of the two identical X-ray mirror assemblies (one for the Resolve instrument, one for Xtend). These mirrors are expected to be delivered to Japan in early 2022. The target mission launch date is in Japanese Fiscal Year 2022 (April 2022 – March 2023).

The targets for the Performance Verification (PV) phase of the mission have been selected. The PV phase of the mission will last approximately 6 months (following the checkout and initial calibration phases), during which the performance of the instruments will be verified through observations of a wide variety of celestial targets, including (but not limited to): X-ray binaries, active galactic nuclei, clusters of galaxies, and supernova remnants. It is anticipated that a Call for Proposals will come out in early 2022 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 a reminder, once the PV phase of the mission is concluded, the mission will enter the General Observer phase, in which it will remain for the duration of the mission. Yearly calls for observing proposals will be issued, and funding will be available through NASA for successful proposers based at US institutions.



After completion of the dewar cool-down and checkout of the flight hardware, the dewar was reconfigured for the start of thermal balance tests at the end of July. Credit: NASA/JAXA

For those in attendance at the upcoming Winter Meeting of the American Astronomical Society, there will be a Special Session on *XRISM* on Monday, January 10th from 2:00 – 3:30 MST. There will be talks on the overall mission status, science with *XRISM*, the Guest Scientist Program, and more. Anyone registered for the meeting with an interest in the mission is encouraged to come to this session.

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 to give a colloquium or seminar on *XRISM* and the breakthrough science the mission will enable. We are also able to give virtual talks.

The Cherenkov Telescope Array

DAVID WILLIAMS (UCSC)

The Astro2020 Decadal Survey has recommended a significant U.S. role in the construction and operation of the Cherenkov Telescope Array Observatory (CTAO), reaffirming both the unique and important capabilities of CTAO for studying very high-energy gamma rays and the substantial beneficial impact that U.S. participation will have, as previously recognized by the 2010 Decadal Survey. CTAO is the first observatory in the very high-energy band that will accept and execute proposals from all scientists in countries contributing to its construction and operation. *Therefore, implementation of this recommendation will unlock access to CTAO for all U.S.-based scientists*. The Multi-Messenger Program for the 2020s endorsed by the Panel on Particle Astrophysics and Gravitation recommends $70M for CTA, a medium-scale project in terms of U.S. investment, with U.S. participation in CTAO as a vital part of the recommended strategy for multi-messenger astronomy in the coming decade. Astro2020 also recommends an increase in the overall support for medium-scale projects and highlights the critical role that multi-messenger observations play in time-domain astrophysics.

An international consortium of CTA members, led by the U.S., has developed and prototyped a 9.7-m-aperture Schwarzschild-Couder Telescope (SCT) designed as a Medium-Sized Telescope (MST) for CTAO. With an innovative dual-mirror design, it achieves higher resolution across the full 8°-diameter field of view than other gamma-ray Cherenkov telescopes of similar size. The Astro2020 recommendation would enable the addition of about ten of these telescopes to CTAO, which "would dramatically enhance many of CTA's Key Science Projects, ranging from studies of astrophysical sources to searches for dark matter annihilation signals." These telescopes would be an enhancement to the "Alpha Configuration" of CTAO, which is based on the funding secured from other nations and described below.

The Alpha Configuration defines the scope of initial construction at the two CTAO sites: in the northern hemisphere on La Palma (Spain) and in the southern hemisphere situated in the Atacama Desert (Chile). "The Alpha Configuration ensures the outstanding performance of the Observatory and its transformational science," says Roberta Zanin, CTAO Project Scientist. "Both telescope arrays will achieve 5 to 10 times better sensitivity than any current instrument, which will constitute a giant scientific leap in gamma-ray astronomy."

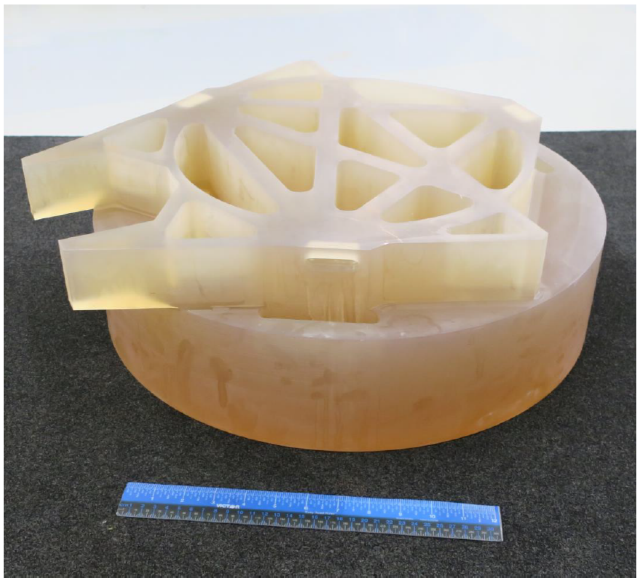
The Alpha Configuration consists of 4 Large-Sized Telescopes (LSTs; ~ 23-m aperture) and 9 Medium-Sized Telescopes (MSTs; aperture of 10 – 12 m) in the northern hemisphere array and 14 MSTs and 37 Small-Sized Telescopes (SSTs; ~ 4-m aperture) in the southern hemisphere array. The definition of these configurations is the result of a meticulous optimization process for each array's scientific capabilities, including a specialization of the northern array in extragalactic sources (CTAO's low and medium energy range) and that of the southern array in Galactic targets (CTAO's medium and high energy range) for this initial phase.

The Alpha Configuration was defined by the formal approval in June this year of the CTAO Cost Book and Scientific & Technical Description. At the same time, funding commitments for the construction of the complete Alpha Configuration were identified. Together, these set the stage for the final step in the application process to the European Union to form the CTAO European Research Infrastructure Consortium (ERIC). The CTAO ERIC is expected to be established in 2022, after which construction of the Alpha Configuration will take place for around five years.

LISA

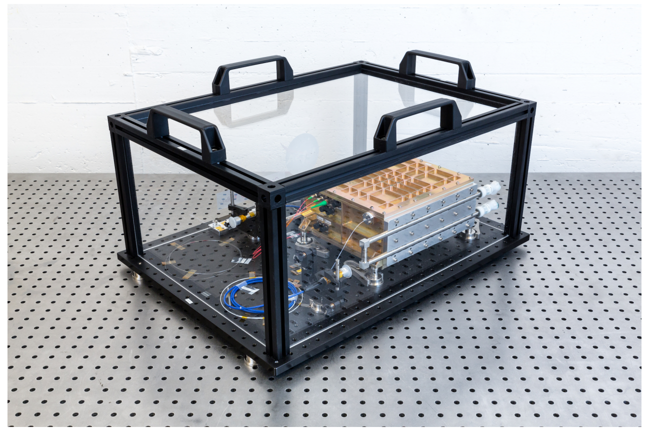
I. Thorpe (NASA/GSFC); G. Mueller (U. Florida); M. Vallisneri (JPL/Caltech); S. Barke (U. Florida)

LISA continues to make progress in its formulation phase: refining the design of the hardware and software, demonstrating the performance of key technologies, and consolidating the organizations and teams that will see the mission through its implementation phase.



Primary mirror blank for Engineering Development Unit of the LISA Telescope. Credit: L3 Harris; NASA/GSFC

A current focus of *LISA* activities is the Mission Formulation Review (MFR), an important system-wide review conducted by ESA. MFR kicked off in October 2021 and will complete with a Board meeting in early December. This review will consider aspects of the mission but focus particularly on the progress of two ESA-funded industrial studies developing the *LISA* flight system. Two industrial contractors have been working in parallel to develop designs for the *LISA* spacecraft. These designs will accommodate instrumentation provided by European national agencies and NASA which will perform the gravitational wave measurement. Based on ongoing progress reports from these contractors, no major technical or programmatic problems are anticipated that would negatively impact the review. Items of concern are the overall mass budget for the mission and the approach to assembly, integration, and test and its impact on mission schedule. Both of these items will be examined carefully by the review team with a goal of identifying potential strategies for improvement. The MFR review team will also assess progress on development of critical technologies as well as components of the *LISA* data analysis pipelines. Assuming a successful MFR, the ESA study of *LISA* should enter phase B1 in Spring 2022, with both industrial contractors finalizing their designs. The subsequent major ESA milestone is Mission Adoption, anticipated in 2024. At Adoption, the design is complete, critical technologies have been demonstrated, and roles and responsibilities of partners have been negotiated.



LISA laser "brassboard" demonstration unit being prepared for performance tests. Credit: NASA/GSFC

Substantial progress is also being made demonstrating key *LISA* technologies, an important criteria for the Mission Adoption review. NASA has consolidated its efforts on three systems: lasers, telescopes, and charge management systems. The first prototype (TRL4) laser system was delivered by NASA to CSEM, a Swiss metrology laboratory under contract with ESA, in July 2021. CSEM will run the NASA laser through a set of tests designed to demonstrate key performance metrics. In parallel, the laser team at NASA/GSFC is developing the TRL5 version of the laser, which will include a frequency stabilization cavity. The first prototype telescope structures are being fabricated by NASA's industrial partner, L3 Harris Corporation, and will be delivered in mid-2022 for test at GSFC. Lastly, the University of Florida is working under contract to NASA to develop a UV-LED based charge control system for integration with the Italian-led Gravitational Reference Sensor. A TRL4 version of the charge management unit was delivered to U. Trento for testing in 2019 and a TRL6 version is under development. NASA investments in other key *LISA* technologies, phasemeters and microthrusters, will be discontinued from NASA's *LISA* program in Fall of 2021 after two decades of investment. Both technologies have potential applications in other missions and may be applied in future GW missions.

ESA member states have also been pursuing technology development activities supporting their intended contributions to the *LISA* instrument. Italy will lead the Gravitational Reference Sensor (GRS) with contributions from Switzerland (front-end electronics) and the US (charge management system). The GRS, which is a direct descendant of the successful *LISA* Pathfinder design, will provide the reference points from which to measure the gravitational waves. The other primary functional component of the *LISA* instrument is the interferometric detection system (IDS), which will be led by Germany with contributions from several countries including optical benches from the UK, photoreceivers from the Netherlands and Belgium (with a possible alternative from Japan), a phase measurement system from Germany and Denmark, and integration and test support from France. Spain is leading development of a diagnostic subsystem and instrument control computer which will help monitor the spacecraft environment and its impact on *LISA*'s sensitive instrumentation.

Work is also underway in developing data processing algorithms for *LISA*. Particular focus is being placed on the first steps in the pipeline, which combine data from many different *LISA* subsystems and apply the time-delay interferometry (TDI) algorithms to produce an output which is sensitive to GWs. This "initial noise reduction pipeline" can be viewed as a part of the instrument system. A team within the *LISA* Consortium has been working to develop and simulate this pipeline with increasing levels of fidelity in order to validate its performance and identify any additional requirements on the flight system such as timing accuracy, etc.

The *LISA* science community, both within and outside of the *LISA* consortium, continues to refine and expand the science case for this exciting mission. Members of the Consortium science group supported ESA's Science Study Team in a study of the impact of mission duration on science return, requirements for absolute calibration, and other science requirements in support of the MFR. Several of the *LISA* Consortium working groups are preparing white papers that describe key elements of the *LISA* science case in detail. In the US, the NASA *LISA* Study Team (NLST) has been working to explore potential US contributions to *LISA* data analysis and science.

Organizationally, *LISA* is in a typical position for a late Phase-A project. The major partners have been identified and all major components have an identified provider who has already begun significant development activities. A few open elements remain, but the number continues to diminish and responsible partners for all items should be identified by Adoption. The technical teams are working closely together to define requirements and interfaces and management teams meet regularly to coordinate activities. As the Mission Adoption milestone is approached, formal agreements will need to be drafted and approved including a Multilateral agreement between ESA and its member states and a Memorandum of Understanding between ESA and NASA.

Looking further ahead beyond Mission Adoption, a single spacecraft design will be identified and a single prime contractor selected. The mission will then proceed through the implementation phase with launch occurring in the mid-2030s, depending on the details of the implementation schedule.

The Compton Spectrometer and Imager

John Tomsick & Andreas Zoglauer (UC Berkeley/Space Sciences Laboratory)

COSI is currently being developed as a Small Explorer (SMEX) satellite mission. It is a wide-field Compton telescope designed to survey the gamma-ray sky in the energy range from 0.2 to 5 MeV. *COSI* will have an instantaneous field of view of >25% of the sky and cover the whole sky every day. It consists of cryogenically cooled germanium cross-strip detectors which enable COSI's excellent energy resolution.

Science goals include uncovering the origin of Galactic positrons via measurements of the electron-positron annihilation line at 511 keV, studies of element formation by obtaining Galaxy-wide images of nuclear lines (26Al, 60Fe, and 44Ti), gaining insight into extreme environments with polarization measurements of accreting black holes and gamma-ray bursts, and probing the physics of multimessenger events.

Artist rendition of the Compton Spectrometer and Imager. Credit: UC Berkeley; NASA; NRL; Northrup Grumman

COSI began Phase A in March 2020 and its selection to move to Phase B was announced in October 2021. It is scheduled to launch in 2025 with a nominal mission life of 2 years.

HEAPoetry Corner

We Astronomers

We astronomers are nomads,
Merchants, circus people,
All the Earth our tent

We are industrious.
We breed enthusiams,
Honor our responsibility to awe.

But the universe has moved a long
way off.

Sometimes, I confess
Starlight seems too sharp.

And like the moon
I bend my face to the ground,
To the small patch where each foot
falls,

Before it falls,
and I forget to ask questions,
And only count things

— Rebecca Anne Wood Elson
(Physics Today 52, 9, 74)