The High Energy Astrophysics Division Newsletter

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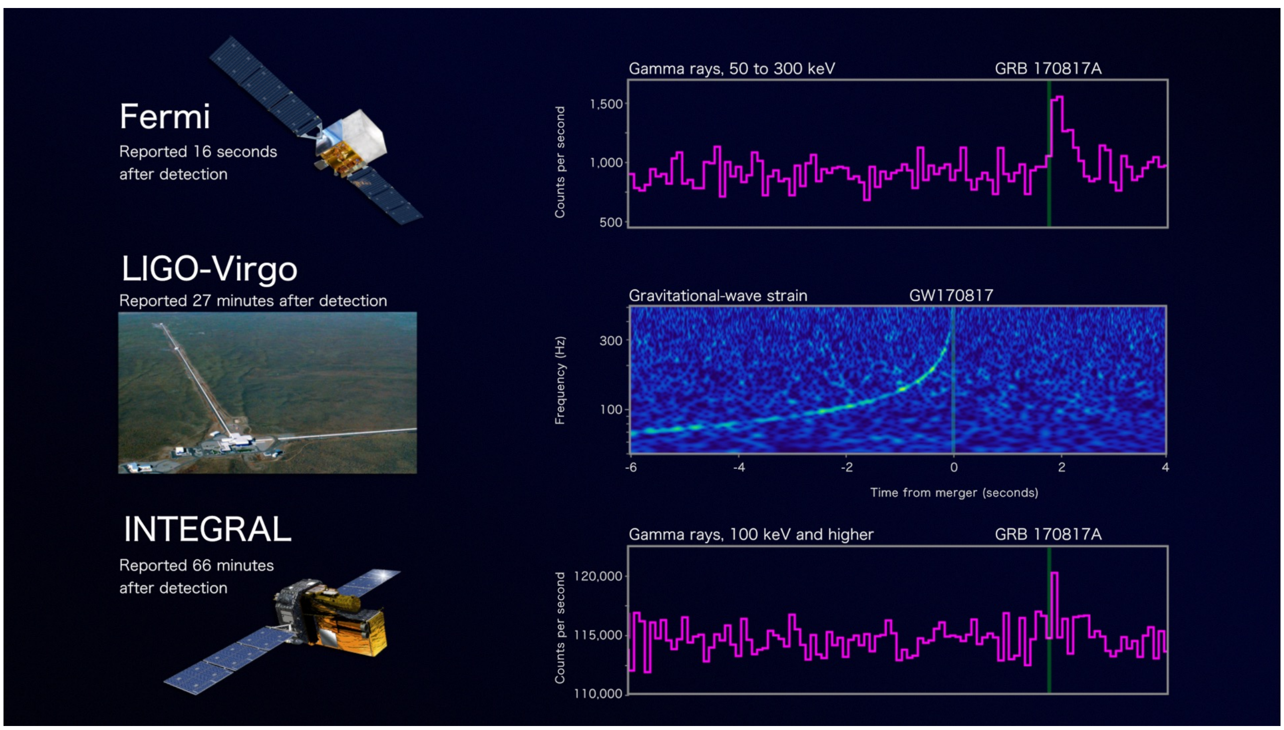


Multi-messenger signal from the "kilonova" GW170817/GRB170817A; the era of multi-messenger gravitational wave astrophysics has begun. (Credit: LIGO; VIRGO; NSF; NASA; ESA)

From the Chair

Chris Reynolds (U. MD & Cambridge)

With my term as Chair drawing to a close, it is inspiring to reflect on the scientific breakthroughs made by our community over the past two years. Thanks to *LIGO* (and now *Virgo*), we heard the song of gravitational waves for the first time as two 30 solar mass black holes merged in a distant galaxy, learning in the process that nature actually makes 30 solar mass black holes! Thanks to *LIGO*, *Virgo*, and *Fermi*, *INTEGRAL*, and many other observatories (and observers), we have both heard the gravitational waves and seen the light as two neutron stars spiraled together in the galaxy NGC4993, witnessing the creation of heavy elements including (most likely) gold. We have taken the pulse of the massive Perseus cluster of galaxies and its central AGN, giving a brief glimpse into the future made possible by high-resolution X-ray spectroscopy. The pace of discovery shows no signs of slowing — just since our last newsletter, we have had the launch of two high-energy astrophysics projects to the International Space Station, the Neutron star Interior Composition Explorer (*NICER*) and the Cosmic Ray Energetics and Mass (*ISS-CREAM*).

With this kind of backdrop, it is not at all surprising that the 16th Divisional HEAD meeting in Sun Valley was so successful. With almost 400 attendees, this was the largest HEAD meeting in recent history. We were treated to a spectacular public talk by Dr. Rachel Osten, who told a packed room about solar eclipses (and snuck in a little about the high energy Sun!). We honored our Prize winners, Dr. Eric Coughlin (Dissertation Prize), Prof. Jon Miller (Mid-Career Prize), and Dr. Nadia Drake (Schramm Prize). We enjoyed numerous and lively science and mission sessions. And, to top it all, it all kicked off with a beautiful total solar eclipse in the crystal clear Idaho sky. (Top that Rob!).

As is our recent tradition, we conducted a survey of those who attended the Sun Valley meeting — thank you to all of those who responded. We take these responses very seriously and they are very helpful in improving our members experience at HEAD meetings. We truly hear and appreciate your concerns about the increasing costs of these meetings and will continue to strive to make future meetings affordable but still high-quality. We are also very concerned that a small number of respondents felt they experienced harassment that violated the Society's anti-harassment policy. We stress that our Division does not tolerate harassment in any form, and we are working with the AAS to improve reporting procedures for such incidents going forward.

To ring in the new year, HEAD will have a strong presence at this January's AAS meeting at National Harbor near Washington-DC. Prof. Gabriela Gonzáles will deliver the Bruno Rossi Prize lecture, awarded for the opening up of gravitational wave astronomy and the discovery of binary black holes. We will also have two HEAD Special Sessions, one sharing the latest results from *NICER*, and a second on the famous merging neutron star binary GW170817. And if that's not enough, we will have our usual (raucous) HEAD business meeting where I officially get to turn over the reins to Dr. Rob Petre before fading into the background as the Past Chair.

Of course, this is a time when many of us start to prepare for the 2020 Decadal Survey which may formally start as early as a year from now. HEAD is committed to supporting our entire community during this process, and is planning a Special HEAD Meeting (*High Energy Astrophysics in the 2020's and Beyond*) to be held in the Hyatt Chicago-O'Hare March, 18-21 2018. This will be an exciting meeting, including a day of truly forward looking science talks as well as presentations from a very wide ranging set of proposed and planned space- and ground-based high-energy astrophysics and multi-messenger projects. We will also strive to create spaces for true community discussion and debate. We encourage all who are interested in the future of high-energy astrophysics to come to Chicago in March and participate — registration and accommodation information will be announced very shortly.

Before ending, I want to share a remembrance of our colleague and my friend, Dr. Jeff McClintock, who passed away on November 8th. Jeff was a true pioneer in the study of stellar-mass black holes, conducting some of the early measurements of compact object masses (thereby establishing them as black holes) for which he received the HEAD's 2009 Bruno Rossi Prize jointly with Charles Bailyn and Ron Remillard. More recently, working with Ramesh Narayan, he turned to the equally impactful issue of measuring black hole spins. As well as being a superb scientist, he was a kind and gentle man, and a dedicated mentor to many young astronomers. Rest in peace, Jeff.

I close this last Chair's Column of mine by thanking my colleagues on the Executive Committee and at the AAS main office — you have all made this job a distinct pleasure!

HEAD in the News

Megan Watzke (CXC)

Undoubtedly the biggest story in high-energy astrophysics – and all of astronomy – happened very recently: the announcement of both electromagnetic and gravitational radiation from a merger of two neutron stars in a binary system located at a distance of 40 Mpc. Several HEAD missions including *Fermi*, *Swift*, *INTEGRAL*, and *Chandra* played major roles in helping make this discovery of multi-messenger astronomy possible. HEAD contributions were featured in the press conference held at the National Press Club on October 16th and were part of the numerous press releases that went out about this result. The coverage from this story was literally world-wide and it would be impractical to list all of the stories here. Suffice it to say that this was a huge story not only for astronomy but science as a whole.

Though the neutron star merger captured the lion's share of science news in the last month, HEAD missions and topics certainly gained their share of attention. There were no formal press conferences at the HEAD meeting in Sun Valley, but several reporters did attend and were able to learn more about the exciting things happening in high-energy astrophysics. (Of course, they and the other meeting participants were treated to a spectacular view of the total solar eclipse!) Some recent HEAD news of note:

October 18, 2017: "*Fermi* Gamma-ray Burst Monitor Wakes the World to Smashing Neutron Stars"

October 4, 2017: "Mysterious Dimming of Tabby's Star May Be Caused by Dust"

September 6, 2017: "X-rays Reveal Temperament of Possible Planet-hosting Stars"

July 18, 2017: "Gamma-ray Telescopes Reveal a High-energy Trap in Our Galaxy's Center"

July 10, 2017 "A Large Fraction of Rapidly-Growing Supermassive Black Holes Evade Census"

June 13, 2017 "NuSTAR's First Five Years in Space"

May 31, 2017 "Early Black Holes May Have Grown in Fits and Spurts"

May 9, 2017 "Merging Galaxies Have Enshrouded Black Holes"

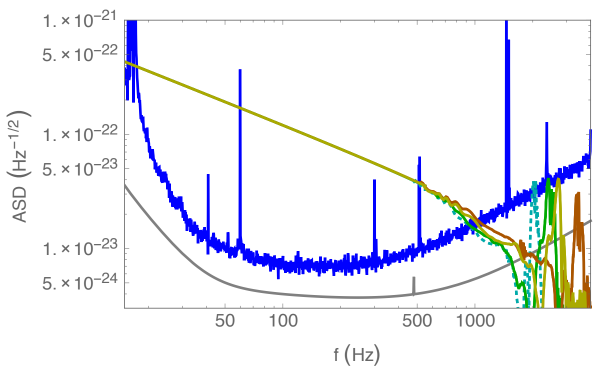
May 2, 2017 "Scientists Find Giant Wave Rolling Through the Perseus Galaxy Cluster"

The news offices of the various HEAD missions are always ready to help reporters trying to work on a story, or to help scientists prepare a press release for distribution. Please contact the relevant news office if you believe you potentially have a newsworthy result. If you don't know who to contact, please send me an email (mwatzke@cfa.harvard.edu) and I would be happy to point you in the right direction.

Laser Interferometer Gravitational-Wave Observatory

Jocelyn Read, CSU Fullerton; David Shoemaker, LSC Spokesperson

Ground-based gravitational-wave astronomy made several giant strides forward in the recent months. On 1 August 2017, the European Gravitational Observatory *Virgo* detector (located near Pisa, Italy) was added to the observing network. The *Virgo* detector had only undergone a short period of commissioning by that time, but had already reached a sensitivity sufficient to contribute to the ongoing 'O2' observing run by the two *LIGO* detectors. Soon thereafter, on 14 August 2017, the two *LIGO* detectors and *Virgo* jointly detected a gravitational-wave source, GW170814. This binary-black-hole coalescence was first detected by the more sensitive *LIGO* detectors, but then the position on the sky was considerably refined using Virgo. In addition, use of the three detectors verified that the polarization of the gravitational waves was consistent with General Relativity. Most excitingly, just 3 days later, on 17 August 2017, the three-detector *LIGO-Virgo* network unambiguously observed a binary neutron star coalescence, GW170817. The trigger was sent to roughly 100 observatories around the world, and an intense series of observations followed, from ground and from space, so that a very complete picture of the event was reconstructed. This event ushered in a new era of multi-messenger astrophysics, and confirmed the origin of short Gamma-ray bursts, among other ground-breaking results.



The approximate noise amplitude in the Livingston interferometer at the time of GW170817 is shown in blue; below it Advanced LIGO's full design sensitivity is shown in grey. A frequency-domain amplitude for a signal model compatible with GW170817 (in gold) sweeps across above the noise at the effective distance recovered by a LIGO/Virgo search. Above 500 Hz, the post-Newtonian amplitude is replaced by a set of numerical simulation data compatible with GW170817 but with varying neutron-star equations of state (solid green, gold, and brown lines); a disfavored equation of state simulation is shown with a dashed line. The post-merger oscillations produce peaks above 2000 Hz. Numerical data courtesy Tim Dietrich (AEI/FSU/BAM Collaboration) and is taken from results published in Phys. Rev. D95(12):124006 and Phys. Rev. D95(2):024029.

With several binary black hole mergers observed in the past two years, astronomers and relativists have become familiar with their general features: a quick chirp signal lasting seconds or less, a familiar inspiral-merger-ringdown pattern of waves, and a dark event in a distant galaxy, billions of light-years away. GW170817 is a little bit different. We've already seen systems like its presumed antecedent in our galaxy, where pulsars with neutron-star companions precisely map out their hours-long orbits with radio blips. We can imagine, then, the last 80 million or so years of the progenitor of GW170817. Two neutron stars, in a galaxy only 40 Mpc away, driven through a slow but steady inspiral by emission of gravitational radiation. For today's gravitational-wave observers, things become more interesting when the increasing orbital frequency sends the emitted gravitational waves into the sensitive range of our ground-based detectors. To give a sense of scale, we give a tour of some interesting way-points along the signal's path through that sensitive range of frequencies.

- 10 Hz: Calibration of *Virgo* and *LIGO* gravitational-wave detector data starts at frequencies of 10 Hz. A Keplerian orbit with a total mass of 2.74 solar masses (compatible with GW170817) has a separation somewhat over 700 km at the corresponding orbital frequency. Be patient: the neutron-star binary has more than 17 minutes left in its inspiral.

- 15 Hz: The automated template-based search that triggered *LIGO*'s transient notification for GW170817 started its comparison with incoming data at this frequency. This turns out to be roughly where the signal amplitude began to compare with background fluctuations from terrestrial sources. The source's corresponding Keplerian orbital separation hasn't changed too dramatically – the stars would have been roughly 550 km apart – but the inspiral has been slow: about 6 minutes remain.

- 20 – 24 Hz: Some analyses, like offline searches that determine the signal's significance and parameter estimation that checks what we can say about the masses and spins of a precessing system, don't begin until the signal reaches frequencies this high or higher. This is because of current computational and technical constraints. Only a very small fraction of the signal-to-noise has accumulated so far. There are about 100 seconds to go.

- 30 Hz: The core parameter estimation analysis for the gravitational-wave observation paper started to compare signal models with the data once the signal reached a frequency of 30 Hz. Tens of millions of waveforms need to be generated and compared to the data for each configuration, and the lower the starting frequency, the longer the waveform. About a minute of signal remains.

- 40 Hz: The signal begins to be visible by eye in the graphical representations of the data. But there's a lot of signal power that was hidden from view, contributing to the computational analysis before our eyes can pick out the chirp. It's easily possible that a future neutron-star signal, confidently detected, would be entirely invisible. Still 30 seconds before the end of the chirp.

- 60 Hz: By the time the signal reaches this gravitational-wave frequency, the chirp mass has been pinned down by the low-frequency evolution, which has so far been very much determined by that leading-order post-Newtonian dynamics. Roughly half of the signal-to-noise ratio should have accumulated in most analyses. There are about 9 seconds remaining.

- 100 Hz: A Keplerian estimate has the stars moving at more than 10% the speed of light, and higher order terms in the post-Newtonian expressions for the orbital evolution are coming into play. The mass ratio and spin parameters of the stars are measured through these higher order terms, with an impact on the signal that can be frustratingly correlated. The uncertainties of how dense matter behaves in the cores of neutron stars has so far been cloaked by their compactness, and the system has behaved like a pair of point masses. But things are going to get even more interesting in the final two seconds before the stars collide.

- 450 Hz: The size of the orbits approaches the size of the stars in these final orbits. The Keplerian separation of the centers of the neutron stars is 57 kilometres, but each neutron star's radius should be somewhere between 9 and 15 km, together covering almost half that distance. Each neutron star is tidally deformed by its companion, inducing a mass quadrupole moment that depends on the equation of state describing dense matter inside the star. The impact of this deformation on the orbital dynamics will drive the system to merge earlier than equivalent black holes or point masses. There are 30 msec remaining.

- 600 Hz: This is roughly the upper frequency limit of detectability for this source using today's *LIGO* and *Virgo* detectors. It also is where the analysis becomes tricky. We stopped our estimate of the radiated energy here, as the leading-order amplitude of the post-Newtonian waveform model used becomes unreliable. While consistent values of masses, spins, and tides compatible with the data allow are found, degeneracies and uncertainties allow for a spread of possibilities. Something like 16 milliseconds remain before the stars collide.

- 1024 Hz: The final milliseconds of the inspiral and merger of this source start to be masked by the detector noise, but the highest frequencies could contribute information about the parameters of the source system.

The details of the merger event in the final milliseconds is lost to detector noise, and is likely to remain a mystery for GW170817. But the analysis of this signal is continuing, and this may shed light on the final exotic phase of the merger – oscillations of the final object, whether a black hole or a neutron star.

The gravitational-wave story ends as the final object, whatever it may be, settles down to a steady long-term stable configuration. Of course, as we now know, the gravitational-wave story is only the first volume. This gravitational-wave leftover is the harbinger of the electromagnetic drama which followed: matter accreting onto the central remnant is about to launch the jet of a short gamma ray burst, and matter ejected during the final moments of the collision is now flying outward, to glow for days as a kilonova, ready to spark hundreds of astronomical investigations across the electromagnetic spectrum.

Laser Interferometer Space Antenna

Ira Thorpe (NASA/GSFC), Guido Mueller (U. Florida)

The long-running effort to realize a space-based gravitational wave observatory gained considerable momentum this summer with the successful completion of the LISA Pathfinder technology demonstration mission and a new start for the LISA mission. On June 20th, ESA's Science Program Committee formally selected the LISA mission concept for the 3rd Large-class opportunity in the Cosmic Visions programme. This selection was based on a proposal submitted to ESA in January of 2017 by an international consortium of scientists and the subsequent evaluation by ESA of that proposal's scientific capabilities, technical readiness, and cost. ESA immediately initiated a Phase 0 study of LISA with the goal of developing the top-level requirements that will be used to guide the formulation of the mission. A Science Study Team which will advise ESA during the formulation phase was stood up in September and includes three US members on its roster in anticipation of NASA's contribution to the mission. At the time of this writing, the ESA study is on track to enter Phase A by the end of calendar year 2017.

Stefano Vitale, Principal Investigator for LISA Pathfinder, sends the final command to the spacecraft at a ceremony at the European Space Operations Centre in Darmstadt, Germany on July 18th, 2017. Credit: ESA

NASA has been participating in the LISA development process through the LISA Study Office at the Goddard Space Flight Center. The Study Office is coordinating technology development activities for potential US contributions to the LISA payload, conducting engineering studies to define potential US contributions to the non-payload flight system, and organizing theory and modeling efforts that will support the eventual analysis and interpretation of LISA data. In addition, an independent NASA LISA Study Team was established in October with the primary purpose of refining and communicating the case for US involvement in LISA science to the Astrophysics community ahead of the 2020 Decadal Survey of Astronomy and Astrophysics.

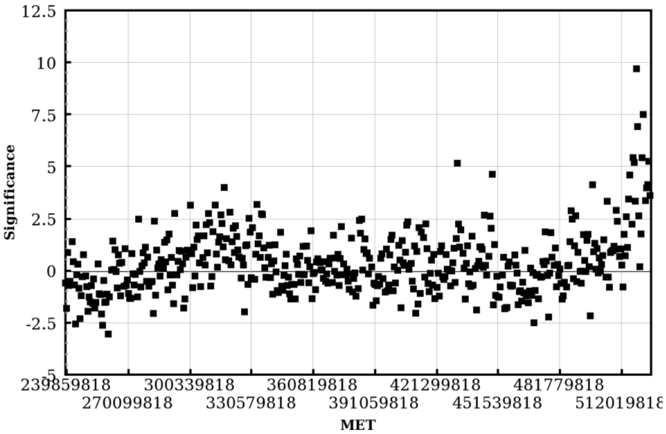
Just a few weeks after ESA's selection of LISA, the LISA Pathfinder mission was formally decommissioned on July 18th. At a ceremony at the European Space Operations Centre in Darmstadt, Germany, the LISA Pathfinder team gathered to say goodbye as Stefano Vitale, PI of the mission, issued the final command which would deactivate the spacecraft's communication systems. In its 18-month mission, Pathfinder demonstrated several key aspects of the LISA measurement system that were previously considered to be high-risk. Even in the initial published results, obtained just weeks into the science operations phase when the instrument had yet to be fully tuned or characterized, the performance exceeded the Pathfinder requirements (which had been deliberately relaxed from the LISA requirements) and approached the performance needed for LISA. In the ensuing year of operations, the Pathfinder team learned much more about the operation of individual components of the instrument as well as the performance of the system as a whole. Additional publications on subsystem performance have been starting to appear and work on a final analysis of the system-level performance is ongoing with publication expected in Spring of 2018. The experience with Pathfinder has been invaluable for the LISA team, and is already being applied in this early phase of LISA.

IceCube

Anna Franckowiak (DESY)

IceCube is the largest particle detector in the world. Comprising a volume of a cubic kilometer of clear Antarctic ice filled with over 5000 photo sensors, it is sensitive to neutrinos with energies above 100 GeV and down to about 10 GeV in the denser DeepCore subdetector. While cosmic rays are deflected by magnetic fields on their way from the source to us, high-energy neutrinos travel undeflected. In contrast to gamma rays, neutrinos are solely produced in hadronic interactions and are thus considered the smoking gun signature for cosmic-ray acceleration.

In 2013, the IceCube Collaboration announced the first detection of a diffuse flux of astrophysical neutrinos, opening a new window to the high-energy universe. The isotropic distribution of the arrival directions points to an extragalactic origin. While the flux measurement was refined over the last few years, no cluster in space or time has been identified yet. Identifying the astrophysical sources of the high-energy neutrinos is now the most pressing question in the young field of observational neutrino astronomy. Multimessenger studies correlating IceCube neutrinos with electromagnetic source catalogs can help to identify the sources. Dedicated searches for high-energy neutrinos from the direction of Gamma-ray bursts and Gamma-ray blazars did not find significant correlation and disfavor those sources as the main contributors to the measured neutrino flux.



Fermi all-sky variability light curve of TXS 0506+056. Credit: NASA/DOE

To increase the sensitivity to the detection of transient electromagnetic counterparts to the neutrino events, IceCube launched a real-time program, which identifies interesting neutrino candidates at the South Pole mere seconds after their interaction in the ice, and distributes their directional information through the Gamma-ray coordinates network (GCN) to the astronomy community in only 30 seconds or so. The program began releasing events to the public in April 2016, and published IceCube alerts have received great interest, resulting in rapid follow-up observations in many wavelength bands, ranging from radio to gamma-rays.

On September 22, 2017, the IceCube real-time program celebrated a jubilee by sending its tenth public alert. This jubilee alert proved to be a cause of jubilation — the large area telescope (LAT) on board the *Fermi* spacecraft reported the detection of a Gamma-ray flare coincident with the neutrino event. The identified Gamma-ray source is a known blazar, TXS 0506+056. Blazars are accreting supermassive black holes with a relativistic jet pointing at Earth. TXS 0506+056 is included in the third *Fermi* hard source list (3FHL), i.e., it is detected at Gamma-ray energies above 10 GeV. Its flux has increased over the past few weeks and has reached six times the flux emitted in its quiescence state.

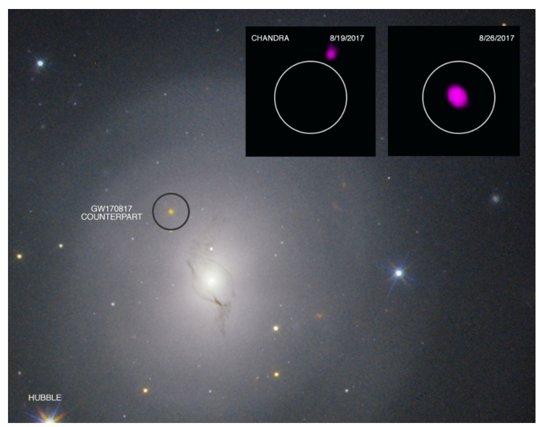
The outburst is seen not only in gamma rays, but also in radio and optical frequencies. Furthermore, the ground-based Cherenkov telescope MAGIC retrieved the flaring source in a 12-hour-long observation, showing that the emission extends to >100 GeV energies. The distance of the source is unknown. The Liverpool telescope recorded an optical spectrum of the blazar aiming for the measurement of the source redshift through the detection of shifted emission lines. Unfortunately, the bright jet emission washed out all spectral features, foiling the redshift measurement.

The most important question now is whether this is a chance alignment of the neutrino with an unrelated blazar in the line-of-sight, or a real physical connection. Archival *Fermi*-LAT data, which cover the entire sky every three hours for the past nine years, will be crucial to answer this question. The IceCube, *Fermi*, and MAGIC teams are working closely together to measure the chance probability. If the correlation exists, we should be expecting more neutrino–Gamma-ray coincidences in the future! Does IceCube see other blazars in its archival data? Stay tuned!

The Chandra X-ray Observatory

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

Chandra has carried out more than 18 years of highly successful and productive science operations. The *Chandra* X-ray Observatory is unique in its capability for producing the sub-arcsecond X-ray images that are essential to accomplish the science goals of many key X-ray and multi-wavelength investigations in current astrophysical research. The Project is looking forward to many more years of scientific productivity. NASA has chosen to continue the mission, and SAO and MSFC are working to extend the contract to operate the *Chandra* X-ray Center with options through September 2030.



First X-ray image of a kilonova, from Chandra. Credit: CXC

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 thermal control surfaces. Condensation on the filter reduces ACIS's sensitivity to low-energy X-rays (but does not affect the HRC). The decline in insulation effectiveness requires extra effort in scheduling observations but has not significantly affected *Chandra*'s observing efficiency.

In August, following the detection by the *LIGO* and *Virgo* observatories of gravitational waves from the merger of two neutron stars, *Chandra* achieved the first detection of X-rays from a gravitational wave source. A series of *Chandra* observations, the first of which did not detect the source, indicated that the X-ray emission is consistent with an off-axis view of the afterglow from a short Gamma-ray burst produced by the neutron star merger. This is the first X-ray detection of an off-axis short Gamma-ray burst, a so-called "kilonova".

An updated preliminary detection list for *Chandra* Source Catalog 2.0 was made available to the community in September 2017 (list CXC 2.0 pd2). The list provides an initial set of key data, including positions, likelihoods, amplitudes and associated errors, for all of the ~374,000 detections that will be included in the full catalog to be released in early 2018. A pre-release source list including ~316,000 unique X-ray sources on the sky is set for release by the end of October 2017.

In December 2016, the *Chandra* X-ray Center (CXC) issued a call for proposals for Cycle 19 observations, with a deadline for proposals in March 2017. Scientists worldwide submitted 574 proposals, including 462 proposals for observing and 112 for archive and theory research. The Cycle 19 peer review, held in June 2017, approved 122 observing proposals, including 7 Large Projects, 2 Very Large Projects, and 33 theory and archive investigations.

The call for proposals for Einstein fellowships attracted 163 applications for 2017. The 8 Fellows selected in January by the Einstein Fellows peer review will begin their three-year terms in the Fall of 2017. Because NASA is in the process of consolidating its named fellowships programs under the administration of the Space Telescope Science Institute, this is the final group of CXC-administered Einstein Fellows.

The CXC held a workshop, "From *Chandra* to *Lynx*: Taking the Sharpest X-ray Vision Fainter and Farther", in August 2017. *Lynx*, formerly known as the X-ray Surveyor, is one of the large strategic mission concepts being studied by NASA in preparation for the 2020 U.S. Decadal Survey. *Lynx* is the first future X-ray mission concept planned to match the spatial resolution of the *Chandra* X-ray Observatory. This workshop aimed to leverage *Chandra*'s legacy and maximize its impact on the development of *Lynx* science and design objectives.

The *Chandra* Press Office has been active in issuing image releases, science press releases and other communications of *Chandra* research results. The annual *Chandra* Newsletter (Issue #24) was released and distributed in April.

XMM-Newton

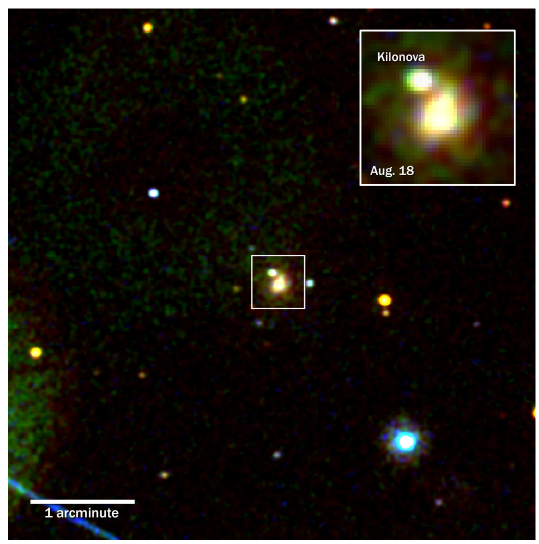
Lynn Valencic (JHU & NASA/GSFC)

The 17th Call for Proposals for *XMM–Newton* closed on October 6, 2017. There were 441 proposals submitted; 13 were for the new Fulfil Programs, 16 were for Multi-Year Heritage Programs, 64 were for Large Programs and 84 were for joint programs with *HST*, *Swift*, VLT, *Chandra*, or *NuSTAR*. Taking both principal and co-investigators into account, about 1500 scientists were involved in the response to the AO. The oversubscription rate was 6.4. Successful submissions will be announced in late December. Funding will be available for A/B-ranked proposals with US PIs; Phase II proposal submission for approved proposals will run from January 9 – February 2, 2018. Approved observations are planned to be performed starting in May 2018. Presentations shown at the XMM-Newton Science Operations Centre (SOC)'s symposium on "The X-ray Universe 2017" are now available online. The agenda, minutes, and presentations from the May 2017 Users Group Meeting are also available.

Swift

Eleonora Troja (NASA/GSFC), Brad Cenko (NASA/GSFC)

Approaching the 14th anniversary of its launch on November 20, 2004, the *Swift* mission continues to operate flawlessly. It supports four 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.



Swift's Ultraviolet/Optical Telescope imaged the kilonova AT 2017gfo produced by merging neutron stars in the galaxy NGC 4993 (box) on Aug. 18, 2017, about 12 hours after gravitational waves and a short Gamma-ray burst were detected. The source was unexpectedly bright in ultraviolet light. This false-color composite combine images taken through three ultraviolet filters. Inset: Magnified views of the galaxy. Credit: NASA

Swift participated in the worldwide campaign to identify and characterize the electromagnetic counterpart of the binary neutron star merger GW170817 discovered via its gravitational wave emission by the Advanced *LIGO* and *Virgo* collaboration. With its rapid response capabilities, *Swift* detected bright but rapidly fading ultraviolet (UV) emission from the counterpart, a surprising result with important implications for the composition and orientation of the neutron-rich ejecta. The short-lived UV pulse likely came from material blown away by the short-lived disk of debris that powered the Gamma-ray burst. The rapid fading of the UV signal suggests that this outflow was expanding with a velocity close to a tenth of the speed of light. Swift's sensitive X-ray limits beginning only 0.6 day after the merger placed tight constraints on the presence of any ultra-relativistic jet viewed directly on-axis. We look forward to many more such discoveries when *LIGO* and *Virgo* come back online in 2018. The era of multi-messenger astronomy is truly upon us! Lynn Cominsky developed a social media plan to highlight *Swift*'s contributions to this "golden binary" neutron star merger. The *Swift* GSFC home page was updated to showcase the discovery image of UV radiation by *Swift*, and to provide a link to the scientific paper. *Swift*'s highlights were posted on Facebook and Twitter throughout the day of the press conference. The final posting was a big thank you to Neil Gehrels, who would have really loved Swift's contributions to this amazing event.

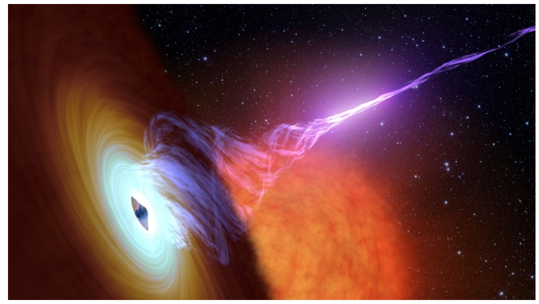
The *Swift* Cycle 14 GI program proposal deadline was September 28, 2017. NASA received 146 proposals for *Swift* Cycle 14, requesting a total observing time of 10.9 Ms and $5.2M in funds for 1,071 targets. The *Swift* Cycle 14 Peer Review will be held in December. Cycle 14 observations will commence on or around April 1, 2018, and will last 12 months.

NuSTAR

Daniel Stern (JPL), Fiona Harrison (Caltech)

NuSTAR is busy observing Cycle 3 approved targets, as well as Targets of Opportunity such as the recent binary neutron star merger gravitational wave event GW170817 (Evans et al., Science, in press; arXiv:1710.05437). *NuSTAR* didn't detect a counterpart to that event, but the non-detection was scientifically valuable, favoring a line of sight that avoided a direct view of any ultra-relativistic, highly collimated ejecta. The *NuSTAR* Guest Observer Cycle 4 Announcement of Opportunity was released in early October, with proposals due on January 19, 2018. Also, the mission has recently solicited self-nominations to join the recently created *NuSTAR* Users' Committee (NUC). The NUC will provide community advice and feedback to the project, to ensure that the interests of the guest investigator community are well-served by the project.

Recent mission highlights include a press release just prior to Halloween reporting on coordinated joint observations of the flaring Galactic black hole binary V404 Cyg by *NuSTAR* and the fast optical camera ULTRACAM on the William Herschel Telescope (WHT) in La Palma, Spain. The paper, led by Poshak Gandhi at Southampton University in the UK, reported small, 0.1-second delays between flaring at X-ray wavelengths and at optical wavelengths. Not only does this work demonstrate that the optical variations originate in the jet but it also sets a characteristic distance of 1000 Schwarzschild radii above the black hole for the main inner optical emission zone.



Artist's rendition of the acceleration zone of an X-ray jet from an accreting black hole binary. Credit: NASA/JPL-Caltech

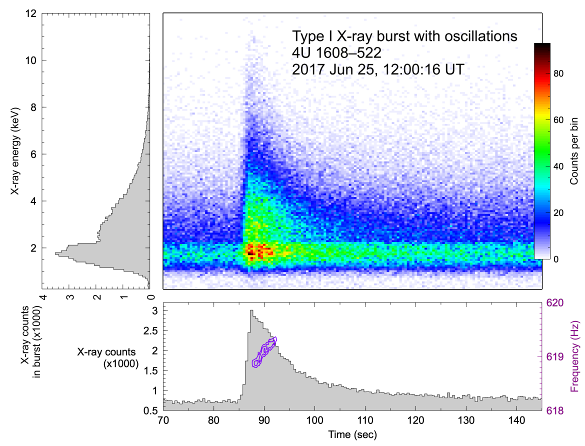
The Neutron Star Interior Composition Explorer

Keith Gendreau (NASA/GSFC), Zaven Arzoumanian (NASA/GSFC)

On June 3, 2017, NASA's Neutron Star Interior Composition Explorer (*NICER*) — an X-ray astrophysics mission with a focus on neutron stars — was successfully launched on board a SpaceX Falcon 9 rocket, together with supplies and other experiments destined for the International Space Station (ISS) on the company's 11th Commercial Resupply Services flight. One week later, the *NICER* payload was extracted from the Dragon vehicle by ISS robotic systems and, in an operation extending over three days, installed on the ExPRESS Logistics Carrier 2, a "roof rack" for ISS providing both storage for equipment as well as mechanical, power, and communication accommodations for experiments. *NICER*'s systems were activated, its launch locks released, and on June 14 NICER's X-ray Timing Instrument (XTI) had its first view of the sky.

Over the course of a month, the payload was subjected to a systematic set of commissioning tests and calibration activities, including verification of its critical performance metrics: in pointing accuracy and stability, effective area, background, energy resolution, photon time-stamping accuracy, throughput, and health-and-safety engineering parameters. We are pleased to report that *NICER* is working as designed, and is living up to its promise of providing a unique soft X-ray (0.2–12 keV) timing-spectroscopy capability.

NICER formally entered its Science Operations phase on July 17, 2017. Early observations resulted in a "first light" release that included measurement of 619 Hz burst oscillations from the neutron star in the low-mass X-ray binary 4U 1608−522. The *NICER* Science Team's continuing research efforts cover all aspects of rotation-, accretion-, and magnetically powered neutron stars, with key objectives — such as unique constraints on the equation of state of ultra-dense matter — anticipated within the 18-month baseline mission duration. Additional X-ray astrophysics investigations, of black holes, active stars, cataclysmic variables, and other high-energy phenomena, are being pursued as time and visibility permit. Targets of opportunity are actively pursued (although, for the time being, rapid response is not possible around the clock).



NICER first light observation of low-mass X-ray binary 4U 1608–522, revealing a serendipitous Type I X-ray burst. Credit: NASA

NICER data will become available in the HEASARC archive beginning mid-January 2018. Recent versions of the HEAsoft data analysis software package already contain a collection of NICER-specific tools.

Following NICER's baseline mission, a Guest Observer program is planned during a "bridge" mission phase, approximately from January to September 2019, with proposals due in Fall 2018. Any further extension of the *NICER* mission will be determined by the NASA Astrophysics Senior Review process.

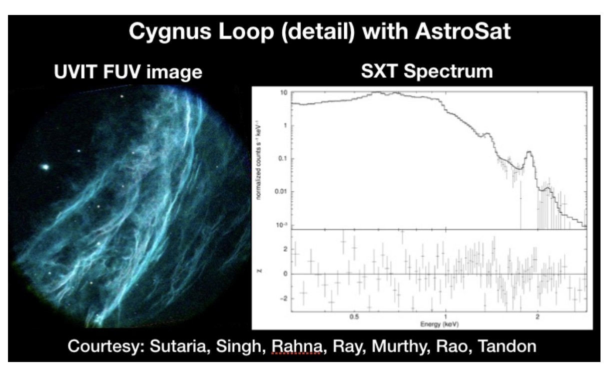
AstroSat

Dipankar Bhattacharya (IUCAA, Pune), K. P. Singh (IISER Mohali)

The Indian multi-wavelength astronomy mission *AstroSat* completed two years in orbit on September 28, 2017. After the first year of Performance Verification and Guaranteed Time observations, the Guest Observer program is currently under way. From October 2017 onwards some observing time has been made available to International Guest Observers. The next call for proposals will be due in January 2018. Target of Opportunity (ToO) proposals are also being accepted, with a minimum response time of about three days. ToO proposals can be submitted at any time. Detailed instructions and tools for proposal submission and data usage may be accessed from the *AstroSat* Science Support Cell.

All science payloads aboard *AstroSat* are operating satisfactorily, providing simultaneous spectral coverage from the visible band to hard X-rays (~150 keV). At even higher energies (up to ~400 keV) the Cadmium Zinc Telluride Imager (CZTI) operates as an all-sky open detector, particularly sensitive to Gamma-ray Bursts and other such high energy transients. More than 100 GRBs have so far been detected, and positive detection of hard-X-ray polarization has been made in seven of those cases. The CZTI GRB archive page provides details of *AstroSat* GRB detections. The CZTI has also been active in the follow-up of Gravitational Wave triggers. Another transient monitor instrument on *AstroSat*, the Scanning Sky Monitor (SSM), sensitive in the $2-10$ keV range, has been regularly monitoring the fluxes of over 300 X-ray sources, with derived light curves which are openly available to the community.

Pointed observations with *AstroSat* so far have largely targeted compact stars, both accreting and isolated; these observations make up nearly 50% of the observing time. Another $\sim 15\%$ of the allocated observing time has been devoted to observations of Active Galactic Nuclei. These observations utilize *AstroSat*'s broad-band timing capability. Important energy-dependent timing characteristics have been discovered in compact star sources like Cyg X-1, Cyg X-3, GRS 1915+105, 4U 0115+63, 4U 1728-34, 4U 1636-536 and several others, primarily by the Large Area X-ray Proportional Counter (LAXPC) instrument. Timing of some of the AGN sources have hinted at previously unknown cutoffs in their power spectra. The Soft X-ray Telescope (SXT) in conjunction with the Ultra-Violet Imaging Telescope (UVIT) has been used for simultaneous imaging and spectroscopy of diffuse hot gas, with clear detection of X-ray spectral lines. The excellent imaging capability of the UVIT, coupled with its wide field, is being used extensively to study nearby galaxies and star clusters, revealing hidden populations of young stars. The ability of UVIT to study intensity variations on timescales of milliseconds has also been demonstrated using the Crab pulsar. Broadband spectroscopy using multiple *AstroSat* instruments is currently possible for bright (>100 milliCrab) sources; response matrices, background models and analysis methods are being further improved to allow such studies for weaker sources.



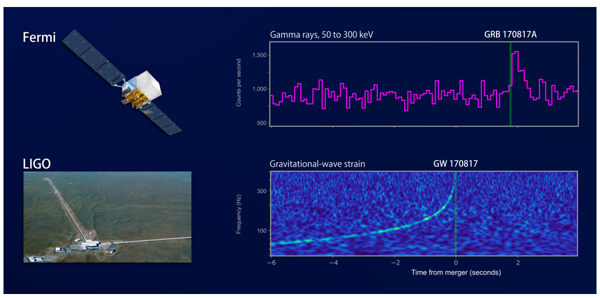
AstroSat observation of the Cygnus Loop. Credit: AstroSat

Links to publications which feature *AstroSat* data may be found at the *AstroSat* Science Support Cell website.

The Fermi Gamma-ray Space Telescope

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

The *Fermi* Gamma-ray Space Telescope played a prominent role in the discovery of the Gamma-ray signal from the neutron star merger gravitational wave event GW 170817. The signal from the Gamma-ray Burst Monitor (GBM) was in fact the first announcement of this event to be sent out. *Fermi* Project Scientist Julie McEnery discussed the GBM discovery at the historic discovery press conference on October 16, 2017. The *Fermi* instrument teams look forward to continued multimessenger cooperative efforts with the GW community.



Fermi and INTEGRAL observation of a short Gamma-ray Burst GRB170817A associated with the kilonova/gravitational wave source GW 170817 seen by LIGO/Virgo. Credit: LIGO; Virgo; NSF; NASA

Fermi results continue to span a broad range of topics, with studies carried out by the national and international *Fermi* community. In addition to the detection of the Gamma-ray burst that accompanied GW170817, there are a number of other *Fermi* science results of note. Among them:

- The *Fermi* Large Area Telescope (LAT) team released a new catalog of 1556 Gamma-ray sources seen at energies above 10 GeV (3FHL).

- Working from maps of unidentified Fermi-LAT Gamma-ray sources, a team using the radio Low-Frequency Array (LOFAR) discovered the second-fastest pulsar identified to date.

- CalTech radio astronomers, using the Owens Valley Radio Observatory that monitors many of the *Fermi* blazars, found a gravitational lensing event that revealed information about the inner jet of a blazar.

- The Gamma-ray excess in the Galactic Center region continues to be a puzzle, possibly related to Dark Matter, though two recent reports suggest alternatives to Dark Matter as the source of this excess.

- Terrestrial Gamma-ray flashes seen by the *Fermi*-GBM are often, it turns out, produced in the outer bands of tropical storms.

A total of 43 new guest investigations were selected for Cycle 10, out of 183 proposals received. Cycle 10 is currently under way, and will continue until August 2018. The call for Cycle 11 proposals was recently issued, and the proposal submission deadline is February 23, 2018. Additional information is available at the *Fermi* Science Support Center website. The spacecraft continues to operate nominally and to enhance the archive with new observations. Data access, current analysis software and analysis documentation and science threads are available from the *Fermi* Science Support Center.

Lynn Cominsky and Elizabeth Ferrara developed a social media plan to highlight *Fermi*'s role in the discovery of the GRB from GW170817, with live and scheduled postings to *Fermi*'s Facebook and Twitter accounts during the discovery press conference. In addition, the *Fermi* Goddard webpage was updated to feature the discovery, with links to some of the scientific publications. Scientists interested in reusing some of the animations and graphics that were created by NASA for this event can find them at GSFC's Science Visualization Studio. Lynn Cominsky also demonstrated some hands-on activities relevant to GW170817 through a Universe of Learning Science Briefing to museum and science center educators on November 2. As part of this continuing series, *Fermi* team members presented at previous Science Briefings on Pulsars (Paul Ray, August 2017) and Dark Matter (Simone Murgia, October 2017). The presentations and resource materials for these briefings can be downloaded from the Universe of Learning website.

INTEGRAL

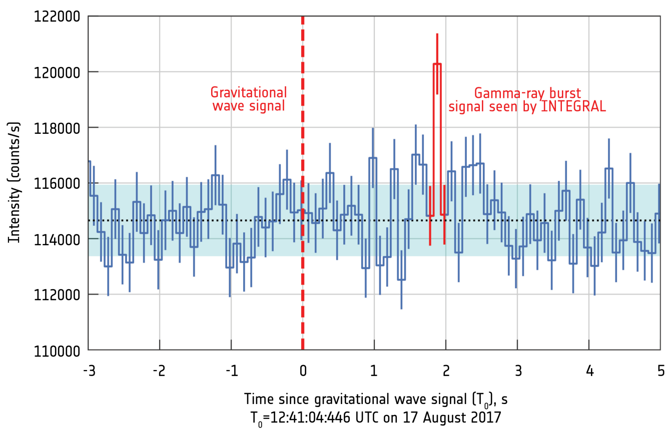
Erik Kuulkers (ESA/ESTEC) and Steve Sturner (CRESST/UMBC & NASA/GSFC)

There were two significant milestones for *INTEGRAL* in 2017. First, on 17 August 2017, multi-messenger gravitational-wave (GW) and electro-magnetic (EM) astrophysics was born. *INTEGRAL* played an important role in discovering the Gamma-ray flash linked to GWs. Both NASA's *Fermi*/GBM and ESA's *INTEGRAL*/SPI-ACS recorded a short Gamma-ray Burst (GRB170817A, Goldstein *et al.* 2017, ApJ 848, L14; Savchenko *et al.* 2017, ApJ 848, L15), which we now know was the tell-tale-sign of a binary neutron star merger. As discussed above, this led to an intense follow-up campaign by a large number of ground and space telescopes. Targeted follow-up observations were also carried out by *INTEGRAL*, starting 19.5 hr after the event, and lasting for 5.4 days; however, no high-energy (transient) afterglow emission was seen (Savchenko *et al.* 2017, ApJ 848, L15). First results were made public on October 16, 2017 in a press conferences broadcast around the world. This historic event has led to at least 84 papers, many of them appearing in the Astrophysical Journal Letters, as well as Science and Nature. The second round of *LIGO* and *Virgo* GW operations (O2) has just ended (25 August 2017) with a third round of *LIGO/Virgo* GW operations (O3), with improved sensitivities, expected to begin in the autumn of 2018. Therefore extending *INTEGRAL*'s operations beyond the end of 2018 is of the utmost importance in what is already now being referred to as the "golden age of GW astronomy." This is an opportunity that we should not miss.

The second memorable milestone occurred on October 17, 2017, which marked the 15th anniversary of *INTEGRAL* operations. From rare breeds of high-energy stars to the feeding habits of monster black holes and the annihilation of antimatter, *INTEGRAL* has been uncovering the secrets of the most energetic phenomena in the Universe. *INTEGRAL* remains highly productive: as of October 20, 2017, the total number of INTEGRAL-related refereed publications since launch is 1091. Thus far in 2017, 59 refereed papers have been published. *INTEGRAL* has begun to play a crucial role in new fields of astrophysics, such as follow-up observations of high-energy neutrinos, Fast Radio Bursts (FRBs), and the study of GW sources. To celebrate this anniversary, the "*INTEGRAL* Symposium 2017: Energetic Time Domain Astrophysics" meeting was held October 16–20, 2017 in Venice, Italy. The Symposium was dedicated to Neil Gehrels († February 6, 2017) and Nanni Bignami († May 24, 2017). The Symposium also saw the institution of the "Mikhail Revnivtsev Prize". This prize, established in honor of the renowned high-energy astrophysicist from the Russian Federation, is given to an outstanding early-career high-energy scientist. The inaugural prize was awarded to Volodymyr Savchenko, for his important scientific contributions to *INTEGRAL*.

In mission news, Matthias Ehle took over from Peter Kretschmar as *INTEGRAL* Mission Manager on July 1, 2017. For the immediate future, Peter will remain as *INTEGRAL* Science Operations Manager. Julie McEnery and Brad Cenko have been appointed as US Mission Scientists in the *INTEGRAL* Users Group (IUG) to replace Neil Gehrels. Final delivery to Guest Observers of the long-awaited, new data analysis software, OSA11, is expected to take place in the Autumn/Winter 2017 time frame. The spacecraft, payload and ground segment have been generally performing nominally over the period covered. The 29th SPI annealing was performed between July 25 – August 9, 2017. The camera switch-on was successful though the energy resolution seems higher than usual for some of the detectors. On September 6 and 10, the Sun produced a pair of X-class flares, the strongest observed in over 10 years. The first flare caused the OMC and JEM-X to go into safe mode for less than a day. During the second flare, all instruments were affected, but they were all active again within 5 days. The AO-15 Target Allocation Committee (TAC) meeting took place May 15–17, 2017 at ESAC, Spain. Fifty-four out of the 65 proposals were approved, including 22 Target-of-Opportunity (ToO) follow-up observations, and 4 GRB proposals. In addition, *XMM–Newton*, *Swift* and *NuSTAR* observing time was granted to a total of 12 proposals.

Scientific observations for the AO-14 cycle during this period were performed mostly as planned with the addition of a few ToO observations including observations of gravitational wave events and other sources. *INTEGRAL* conducted a number of coordinated observations during this reporting period as well, and detected 2 GRBs in the high-energy instruments.



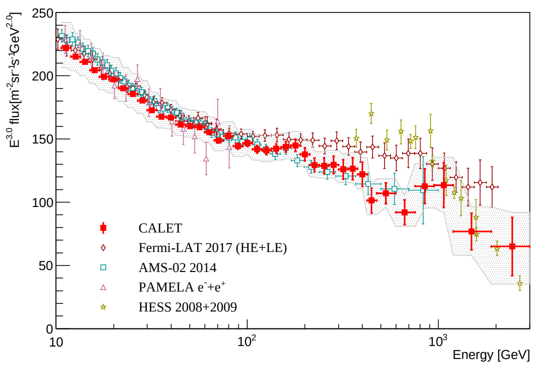
The intensity of gamma rays measured by ESA's INTEGRAL satellite on 17 August 2017. Less than two seconds after the Laser Interferometer Gravitational-wave Observatory (LIGO) experiment was triggered by the passage of gravitational waves, marked as T_0, the Anti-Coincidence Shield (ACS) on INTEGRAL's SPI spectrometer, recorded a burst of gamma rays for 0.1 sec. The flash was also detected for almost two seconds by NASA's Fermi satellite. Credits: ESA/INTEGRAL/SPI/ISDC.

In this new era of multi-messenger astrophysics, a core *INTEGRAL* team has been established to respond to alerts on Gravitational Wave (GW) events as well as ultra-high-energy neutrinos detections, performing near-real time analysis of the data from the omni-directional SPI and IBIS instrument shields. Whenever possible, these events are followed up with targeted observations. The *INTEGRAL*/SPI-ACS covered the full *LIGO* 90% confidence region of the black hole binary merger GW 170104, but no coincident EM signal was seen, providing stringent constraints on any electro-magnetic counterpart in the *INTEGRAL* energy range (Savchenko *et al.* 2017, ApJ 846, L23). *INTEGRAL* apparently detected a weak (3.5σ) Gamma-ray signal in the SPI-ACS data near the time of the binary black hole merger event GW170814 (which was the first GW event to be detected by *Virgo*). However, inspection by the *INTEGRAL* GW team of the SPI-ACS, IBIS/Veto, and IBIS/ISGRI data did not reveal evidence for any significant deviation from background (Savchenko *et al.*, GCN #21478).

CALET

John Wefel (LSU)

Following its successful launch and arrival at the International Space Station (ISS) on August 25, 2015, the CALorimetric Electron Telescope (*CALET*) mission has been returning excellent data since October, 2015. These data have been used for on-orbit testing, calibration, environment monitoring and science analysis. As of August 31, 2017, the total observation period is 689 days with a live time fraction of about 84%. A total of nearly 450 million events have been collected with the high energy trigger (E>10 GeV). In addition, periods are selected for the low energy trigger mode, for routine calibration, and for ultra-heavy nuclei studies.



The all-electron spectrum measured by CALET on the ISS from 10 GeV to 3 TeV, with systematic errors shown as a grey band. The results are compared to spectra from Fermi-LAT, AMS-02, PAMELA and HESS. (Credit: PRL, 119, 181101, 20017)

The main telescope of the *CALET* mission is a deep (30 radiation lengths) calorimeter composed of an Imaging section (IMC) followed by a total absorbing section (TASC). The calorimeter can contain an electron shower of 1 TeV. At the top is a scintillator-based charge detector (CHD) to separate electrons and protons from Gamma-rays and heavier cosmic rays. Combining the charge resolution of the CHD and the IMC allows all of the elements up to silicon to be well separated, and extension to the iron peak is in progress. Due to the broad dynamic range of the CHD, signals of trans-Ni (UH) cosmic rays are also separated up to Z=40. The mission complement also include a Gamma-ray burst monitor (CGBM), which has been observing events at a rate of about one every ten days (7 keV - 20 MeV), as well as studying transient sources and looking for counterparts to *LIGO-Virgo* gravitational wave observations as part of an agreement with the *LIGO-Virgo* collaboration.

The main science objective of *CALET* is the measurement of the total electron spectrum to as high an energy as possible to search for signatures of "nearby" sources (1 kpc) of particle acceleration. In addition, *CALET* studies the nuclei spectra (Z=1–40) and secondary to primary ratios to unravel particle transport in the Galaxy. Finally, *CALET* also measures high energy Gamma-rays, to about 10 TeV, for diffuse spectrum and source investigations. The *CALET* team has completed preliminary analysis for many of these science topics and results were presented at the 2017 International Cosmic Ray Conference held in Korea. Please consult the conference proceedings for details.

Analysis of the total electron spectrum has now resulted in a paper that has been accepted for publication in Physical Review Letters. The figure shows the results from 10 GeV to 3 TeV compared to previous data. From 10 GeV to several hundred GeV, all of the experiments are in reasonable agreement. For a single power law fit, *CALET* finds a spectral index of -3.152 ± 0.016, which includes both statistical and systematic errors. At higher energies, *CALET* agrees better with AMS-02 than with *Fermi*-LAT and also sees a fall-off at the highest energies as reported by *H.E.S.S*. However, the statistics are still meager at the highest energies and more data, plus refined analysis, are needed to assess the significance of the structure in the "TeV region".

Physics of the Cosmos News

T. J. Brandt (NASA/GSFC, PCOS Acting 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. To enable current and future missions to address these questions, the PCOS Program Office (PO) facilitates a number of community activities, including meetings and articles, and reviews strategic technology capability gaps, prioritization, and development yearly. Dr. Ann Hornschemeier stepped down as PCOS Chief Scientist on Oct 1, 2017 to focus on future X-ray missions, *LISA*, and scientific research; her outstanding service to the PCOS community is very much appreciated. I write to you now as Acting Chief Scientist.

Our recent meetings included a PCOS community town hall and X-ray and Gamma-ray Science Interest Group (SIG) meetings within the August HEAD meeting, with agenda and, as available, presentations. We invite you all to the upcoming PCOS/PhysPAG and SIG meetings at the January 2018 AAS meeting and at the APS meeting in April, 2018. We'll hold a day-long meeting, including a joint town hall with the Cosmic Origins (COR) PAG, and featuring a talk by Paul Hertz (Director of Astrophysics at NASA) on Monday, January 8, immediately preceding the official start of the AAS meeting, This will be preceded by morning meetings of the Cosmic Ray, Gravitational Wave, Gamma-ray, and X-ray

SIGs and followed by a PhysPAG Town Hall meeting. We are working to have remote connection available for all meetings for those who wish to attend remotely! Please check the PCOS website for updates closer to the event. We also encourage anyone attending the AAS to go to the Decadal Large and Probe Mission studies sessions during the meeting.

To capitalize on the increased excitement for Multi-messenger Astrophysics (MMA) generated by the gravitational wave event GW170817 this fall, the PhysPAG is currently chartering a new MMA Science Analysis Group (SAG). The MMA SAG will explore the breadth of science accessible in the coming decade(s). Please come give input during the community discussion time at the PhysPAG Town Hall at AAS and at APS.

The program office released the PCOS 2017 Program Annual Technology Report (PATR) on October 10, 2017. In addition to analyzing technology gaps related to strategic missions, the PO received a number of other gaps which were included in the PATR. Unlike the strategic gaps, these will not be automatically reevaluated the following year unless they are resubmitted with justification of their strategic role or are substantially different from the past year's gap. In addition to the PATR, the newly redesigned technology website includes a list of the prioritized gaps as well as a searchable database of all PCOS- and COR-managed technology development projects.

We welcome your input on PCOS science topics, particularly through the relevant PhysPAG Science Interest Groups, several of which have articles in this newsletter, and by submitting technology gaps by June. We also look forward to seeing you at the upcoming AAS January meeting, the Special HEAD meeting in March, and the APS April meetings and encourage you to join our email list and/or check our website in December for news, such as of the new PhysPAG Executive Committee members and our 2017 PCOS Newsletter!

The X-ray Science Interest Group

Ralph Kraft (CfA) and John Tomsick (UC Berkeley)

It has been a busy year for X-ray astronomy in the US with two missions under development and a third entering phase A. US participation in the X-ray Astronomy Recovery Mission (*XARM*) was confirmed, and an AO was released for Participating Scientists. The deadline for stage 2 proposals is December, with selections announced in early 2018. The Imaging X-ray Polarimetry Explorer (*IXPE*) was approved for flight, with launch scheduled for the last quarter of 2020. Finally, the *Arcus* mission concept, a large area X-ray spectroscopic mission, was one of the concepts approved for phase A study during the past MIDEX round, with final selection late in 2018. Accepted Missions of Opportunity proposals include *COSI-X*, a balloon-borne experiment to survey the Gamma-ray sky at 0.2-5 MeV and *ISS-TAO*, a wide-field X-ray transient detector to be berthed on the International Space Station.

This is a critical time for the future of X-ray astronomy as we approach the 2020 Decadal Survey. The *Lynx* flagship mission concept study is advancing (see below) with a paradigm-changing science program. The preliminary study report is due to NASA headquarters in March 2018. Last year, NASA funded ten probe mission concepts studies, several of which are of great interest to the HEAD community. Results from these studies will be presented to the Decadal. The HEAD community needs to be actively and energetically engaged in the Decadal process to ensure that both NASA and the broader astrophysics communities are informed about our science and our priorities. Several key questions are facing our community – what is the best balance between Explorers, Probes, and Flagship class missions? What are the key technologies our community must invest in to realize future missions? What other mission concepts should be presented to the Decadal?

The most recent XRSIG meeting was held at the AAS/HEAD meeting in Sun Valley, ID. We heard updates about US participation in *Athena*, the status of *XARM*, and summaries of the probe mission concept studies most relevant to the HEAD community: *TAP*, the Transient Astrophysics Probe, and *AXIS*, a high spatial resolution X-ray imager. *POEMMA*, a multi-messenger astrophysics mission and *STROBE-X*, an X-ray timing experiment, are the other accepted probe mission concept studies relevant to HEAD. At the Sun Valley meeting, we also bid a fond farewell to Wilt Sanders, for his many years at NASA Headquarters in the service and in strong support of high-energy astrophysics. Our next XRSIG meeting will be at the January, 2018 AAS meeting in the National Harbor, Washington, DC and is tentatively scheduled for Jan 8th at 10:30AM. The meeting agenda is being developed as of this writing, and the XRSIG chairs welcome any ideas and inputs. There will also be a special HEAD meeting in Chicago in March, 2018 devoted to preparations for the Decadal including future looking science talks and future project/mission talks. We hope to see you at both of these meetings!

The Gamma-ray Science Interest Group

Henric Krawczynski (Washington University, St. Louis), Sylvain Guiriec (CRESST/UMCP & NASA/GSFC), John Tomsick (UC Berkeley)

The big announcement on October 16, 2017 about the discovery of a short Gamma-ray burst associated with a binary neutron star gravitational wave event reverberated through the Gamma-ray community. The scientific impact of the multimessenger observations is enormous, including astrophysical results (proving the connection of short Gamma-ray bursts and neutron star - neutron star mergers, information about the production of r-process atomic nuclei), and fundamental physics results (a precision measurement of the relative velocities of electromagnetic and gravitational waves, a precision test of the equivalence principle involving gravitational waves, and information on the neutron star equation of state). The observations prove the viability of multimessenger observations of compact merger events and the important role that high-energy observations play. News from the Gamma-SIG include new bi-weekly telecons. The telecons will be used as a forum to discuss hard X-ray and Gamma-ray science, and detector and mission concepts. The next Gamma-SIG meeting will be held during the 231st AAS meeting, January 8–12, 2018 at the Gaylord National Resort & Convention Center, National Harbor, MD.

The Cosmic Ray Science Interest Group

IGOR MOSKALENKO (STANFORD), JAMES BEATTY (OHIO STATE)

The discovery of cosmic rays is formally associated with a series of balloon flights performed by Viktor Hess in 1912, for which he was awarded a Nobel prize in 1936. One of the flights reached an altitude of more than 5,000 m, where the ionization of the air was significantly larger than that at the sea level. He correctly concluded that the ionizing radiation is coming from the outer space. The discovery was later confirmed in many experiments and the term “cosmic rays” was coined by Robert Millikan.

Many studies of cosmic rays were performed in 20th century. In the pre-accelerator era, before the 1960s, cosmic rays were the only source of energetic particles. Observations of their interactions in emulsions helped discover many elementary particles. It was found that the spectrum of cosmic rays is almost featureless with the power-law index of about -3 in the energy range from about 1 GeV to more than 10^{20} eV, the highest energy ever observed. The only features observed in cosmic rays were the so-called “knee” at $\sim 5 \times 10^{15}$ eV, the “ankle” at $\sim 10^{18}$ eV, and a cutoff at $\sim 10^{20}$ eV predicted by Greisen and Zatsepin & Kuzmin in 1960s (GZK cutoff). A general understanding is that cosmic rays below the ankle are mostly Galactic and above it are mostly extragalactic. Cosmic rays include all known particles and isotopes, and perhaps yet unknown particles.

At the turn of the century it became clear that basic features of cosmic rays are well-established and that new studies would require new technology and very large detectors, but progress was expected to be rather incremental. Meanwhile, “a small positron flux of nonstandard origin above 5 GeV” was already noticed in balloon flights of the TS93, CAPRICE94, and HEAT instruments.

The eve of the centennial anniversary of the discovery of cosmic rays was marked by an explosion of new findings. There are so many of them discovered just in the last decade that it is easy to miss one or two. First in a series was a clear discovery of the raise in the cosmic ray positron fraction by PAMELA, contrary to the expected decline if positrons are secondaries produced in cosmic ray interactions. This discovery was confirmed by the Fermi-LAT, and with improved statistics and up to ?500 GeV by AMS-02. An observation of the flattening of the proton and Helium spectra at very high energies was discovered by the CREAM and confirmed by the ATIC-2 experiments, while observation of the break in the proton and He spectra at the same rigidity of ~ 300 GV came from PAMELA observations at lower energies. *Fermi*-LAT confirmed the flattening in the proton spectrum through the observations of the spectrum of cosmic-ray-induced Gamma-ray emission from the thin layer at the top of Earth’s atmosphere. Again, AMS-02 confirmed these observations with much higher statistics and accuracy. It looks like AMS-02 also sees a flattening in the spectra of heavier cosmic ray nuclei, Lithium through Oxygen, at the same rigidity as for protons and He.

Very well timed with the centenary of the discovery of cosmic rays, the Voyager 1 spacecraft (launched in 1977) crossed the heliospheric boundary in 2012. This first-ever interstellar probe is still in a good health, and continues to beam to us the details of the interstellar spectra of cosmic ray species at low energies.

Fermi-LAT obtained a spectacular first measurement of the all-electron spectrum in the range from 20 GeV to 1 TeV. It appears flatter than expected and has a power-law index ≈ -3 over the whole energy range, with a sharp cutoff above 1 TeV detected by H.E.S.S. It is now measured with much better accuracy by AMS-02 and the sharp cutoff at 1 TeV is confirmed by other experiments. The first all-electron data from *CALET* agree well with AMS-02.

Meanwhile, a signature of a relatively recent supernova or a series of supernovae in the solar neighborhood was observed by the ACE/CRIS instrument in the form of the excess in ^{60}Fe over the predicted amount of secondary isotope. The Boron to Carbon ratio (one of the major ratios in cosmic rays used to derive propagation parameters) is now measured up to several TeV and shows no sign of an expected flattening. This is all in contrast to predictions of the rise in the antiproton-to-proton and Boron-to-Carbon ratios, where the former is roughly constant from about 30 to 500 GeV. There are indications that the positron fraction starts to fall above 500 GeV (AMS-02), a long awaited signature that may be the key to understanding the origin of the excess positrons. The astrophysics and particle physics communities are thrilled by these developments and are closely watching for any new data coming from the cosmic ray experiments.

Observational astrophysics of cosmic rays has recently made a new leap to the International Space Station. Three dedicated experiments (AMS-02, *CALET*, *ISS*-

CREAM) are measuring the spectra of cosmic ray species in the energy range from 1 GeV up to the knee. There are even plans to extend the energy coverage of the ISS by adding a detector of ultra-high energy cosmic rays. AMS-02 was launched in 2011 and thus is the most mature of the three current cosmic ray detectors on the ISS. *CALET* was launched in 2015, and has started to deliver first results (as discussed above).

ISS-CREAM (the International Space Station version of the Cosmic Ray Energetics and Mass experiment) is the newest of the cosmic ray experiments on the ISS. *ISS-CREAM* was successfully sent to space on August 14, 2017 (after sitting at the Kennedy Space Flight Center for about two years) and is poised to deliver spectacular results. The goal of the mission is to extend the energy reach of direct measurements of cosmic rays to the highest energy possible to probe their origin, acceleration and propagation. Its long exposure above the atmosphere offers orders of magnitude greater statistics, without the secondary particle background inherent in cosmic ray balloon experiments.

The *ISS-CREAM* instrument consists of complementary and redundant particle detectors to measure elemental spectra of Z = 1–26 nuclei over the TeV to PeV energy range. An ionization calorimeter determines the energy of cosmic ray particles, and provides tracking and event triggering. The four-layer silicon charge detectors provide precise charge measurements. Top/bottom counting detectors provide shower profiles for electron/hadron separation. The boronated scintillator detector provides additional electron/hadron discrimination using thermal neutrons produced by particles that interact within the calorimeter. *ISS-CREAM* will (1) determine how the observed spectral differences of protons and heavier nuclei evolve at higher energies approaching the knee; (2) be capable of measuring potential changes in the spectra of secondary nuclei resulting from interactions of primary cosmic rays with the interstellar medium; (3) conduct a sensitive search for spectral features, such as a bend in proton and helium spectra; and (4) measure electrons with sufficient accuracy and statistics to determine whether or not a nearby cosmic-ray source exists. It will also contribute indirectly to dark matter searches by measuring electrons in addition to nuclei at energies beyond current direct measurements. Congratulations to the *ISS-CREAM* team! We are looking forward to seeing the first results!

The Universe of Learning

Lynn Cominsky (Sonoma State University)

NASA's Universe of Learning (UoL) Astrophysics Learning and Literacy program is coordinating a Special Session at the Winter 2018 AAS meeting entitled "Learning with NASA Astrophysics: How to Get Connected". UoL is one of the 27 awardees selected in 2015 that comprise NASA's STEM Activation network. This special session will feature representatives from several NASA Science Mission Directorate STEM Activation network groups. The main focus of the session is to discuss how to best connect scientists and engineers (aka Subject Matter Experts or SMEs) with NASA's STEM products and programs - and ultimately with learners of all ages. Included in this session will be short presentations, a panel discussion, and networking time to connect directly with practitioners of NASA STEM engagement. Confirmed speakers include Hashima Hasan (NASA), Dana Backman (SETI Institute), Pamela Harman (SETI Institute), Barb Mattson (NASA/GSFC) and Colleen Manning (Goodman Research Group).

"Learning with NASA Astrophysics: How to Get Connected" will occur on 1/9/18 at 2 PM at the Gaylord Center in National Harbor, MD. We are also inviting posters (late deadline is 12/3/17) to accompany this Special Session. Come join us to find out more about NASA's efforts to connect astrophysics SMEs with learners of all ages and how you can be involved!

Spectrum Röntgen Gamma/eROSITA

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

Since January 2017, both fully integrated scientific payloads, the eROSITA and ART-XC telescopes, are in Moscow's outskirts, in the assembly hall of NPOL Lavochkin Association. All hardware components are now in place, apart from an element of the "radiocomplex" (the downlink system of the Navigator Spacecraft) that needs replacement, and is currently on the critical path.

In the lab, electrical interface and functional tests of the two scientific payloads (eROSITA and ART-XC) together with the Navigator S/C platform are currently under way. The remaining preparations for the Proton launcher adapter, and the ground stations are also under way, and the project approaches its final stretch before launch. Launch is still expected in the September/October 2018 window.

The SRG components in the NPOL assembly hall just before the first round of electrical interface tests. In the foreground, the Navigator platform. In the background, the two scientific payloads (eROSITA, left and ART-XC, right) integrated onto the mounting structure, and connected to the S/C sub-system. Credit: IKI; SRG team

Athena: Revealing the Hot and Energetic Universe

Kirpal Nandra (MPE), Didier Barret (IRAP), Randall Smith (CfA), and Francisco J. Carrera (IFCA, CSIC-UC) for the *Athena* Science Study Team and the *Athena* Community Office

The mission continues to progress through an intensive Phase A study, with a detailed examination and consideration of all the technical issues and programmatic constraints. The coming six months will see a consolidation of this process, combining results from the ESA study team, the two industrial Prime contractors and the X-IFU and WFI instrument teams. By mid-2018, the mission is expected to have a sound baseline that meets the cost, mass, and schedule constraints that can be taken forward through the remainder of Phase A and beyond.

System-level studies of the spacecraft and conceptual design work for the instruments continue, with particular emphasis on the consolidation of the design of the Science Instrument Module (SIM). Significant progress has been made on the SIM design since this was identified as a key issue at the Mission Consolidation Review (MCR) and subsequently the delta-MCR (dMCR), via a series of dedicated design sessions in the ESA Concurrent Design Facility (CDF). Concerns over the overall system mass have also been addressed following mass consolidation work and the analysis of mass-saving options (the so-called “SIMO” exercise) performed by the *Athena* Working Groups.

A substantial issue identified at the MCR but still not fully resolved is the mission cost to ESA. Current estimates exceed the cap of €1.05bn specified by the ESA Science Program committee (SPC) at the time *Athena* was selected. A major design-to-cost exercise has therefore been initiated along with parallel efforts to identify cost-mitigation options and efficiency savings. The philosophy behind this is to define a mission with the best possible science performance while meeting the imposed programmatic constraints. The science community was fully involved in this via an activity entitled CORE (the Cost-driven Observation Reprogramming Exercise) which was set up to assess the science performance of a mission configuration expected to be within cost. The ESA *Athena* Study Science Team (ASST) proposed a number of options for this cost-constrained mission configuration. While some of these should have no impact on science, others which do were considered during CORE. These included the removal of 5 mirror rows (with a corresponding reduction in the effective area), a reduction in the field-of-regard requirement (saving hardware costs e.g. for the deployable sunshield and solar array drive mechanism), and reductions in operation costs (e.g. via a shorter mission lifetime and reduced ground system support for ToOs).

The ASST, based on inputs from its working groups, concluding that this cost-constrained mission still represents a major breakthrough in capabilities. An observing program was furthermore constructed that retains the breadth of the *Athena* science while still addressing the vast majority of the Hot and Energetic Universe science objectives. The main negatively affected cases were those relying on the field of regard and fast ToO response, and the ASST recommended that all steps be taken to retain those capabilities. In considering the possible reduction of effective area, the ASST concluded that if necessary it is preferable to remove the 5 outer rows of the mirror (compared to other possible reconfigurations) thus preserving the high-energy response of the mirror, while reducing the 1 keV effective area from $2m^2$ as proposed to $1.4m^2$ in the cost-constrained case. A reduction in nominal mission lifetime from 5 to 4 years was furthermore deemed acceptable. Further cost analysis and consolidation continues.

The 6th Meeting of the Wide Field Imager Consortium (WFI) was held from October 10–12, 2017 in the Nicolaus Copernicus Astronomical Center (CAMK), Warsaw, Poland. More than 70 consortium members attended to discuss the status of the instrument development, scientific activities, and plans for future work. The meeting started with a series of splinter sessions, dedicated to specific WFI subsystems such as the filters and filter wheel assembly and the detector electronics and instrument control electronics. In addition, the WFI Science Team assembled to review the latest updates to the science requirements and the ongoing science assessment activities. The Background Working Group discussed progress on the reduction and understanding of the instrumental background.

The plenary session started later the same day with a mission status report by WFI PI and ASST Lead Scientist Kirpal Nandra followed by an *Athena* study status overview given by ESA’s Payload Manager Alexander Stefanescu. Over the course of next two days, the instrument subsystems were discussed in detail. Highlights include the development of the DEPFET sensors, which is making excellent progress with the successful test of prototype detectors. The production of the proto-flight sensors has started. First vibration test of the supporting mesh for the large optical/UV light-blocking filters were also successful and the next tests with flight-like filters are in preparation. All other subsystems, e.g., electronics, filter wheel, thermal, and mechanical, are progressing well. François Pajot (IRAP) kindly provided a report on the X-IFU status. The plenary session also included an update on the end-to-end simulator by the SIXTE team as well as presentations on astrophysics with the WFI, in particular, the multi-tiered survey and the potential for the WFI Fast Detector to constrain the accretion geometry near the event horizon of stellar mass black holes.

Athena will form part of a suite of major multi-waveband facilities operating in the late 2020s which will work together to revolutionize astrophysics. To probe this topic more deeply, the ASST has initiated a series of synergy studies. The first such exercise was the ESO-*Athena* Synergy Workshop, with conclusions summarized in a public white paper.

Synergies between the Square Kilometer Array telescope and the *Athena* X-ray observatory mission were discussed at a workshop held April 24–25, 2017 at SKA Organisation Headquarters at Jodrell Bank, near Manchester, UK. *Athena* and SKA have some common science objectives, including studies of galaxy clusters and large-scale structure, AGN and surveys, X-ray binaries, accretion physics and transient phenomena. The identified synergies will be collected in a white paper (currently in draft for publication in early 2018) co-ordinated by the SKA-*Athena* Synergy Team (SAST): Rossella Cassano (INAF/IRA, Chair), Chiara Ferrari (OCA), Rob Fender (Oxford) and Andrea Merloni (MPE).

In June 2017 the *Athena* Community Office released the third issue of the *Athena* Community Newsletter. This newsletter contained detailed information on the expected *Athena* background as calculated by the AREMBES project as well as information on how particle backgrounds will impact the instruments. The newsletter also featured a science 'nugget' on how stellar mass black holes and neutron stars generate winds, and how Athena, together with ground-based IR and mm telescopes will be able to diagnose these effects. The *Athena* nuggets are aimed not only at the scientific community but also at non-experts. They are released on a monthly basis on the *Athena* Community Support portal under outreach/nuggets section as well as on social media.

In other outreach, the ACO prepared materials about X-ray astronomy for the European Researchers' Night on September 29, 2017, published under the outreach/material section. The ACO has also participated, together with Didier Barret and Edoardo Cucchetti from IRAP, in the creation of an Athena-themed board game, led by Yaël Nazé of the University of Liége (Belgium), which is also available in several languages from the outreach/material website.

In addition to the regular channels (web, @athena2028 Twitter, and the *Athena* X-ray *Athena* X-ray Facebook page) for the diffusion of news and resources (for instance, standard long and short presentations about Athena), urgent or important notifications have been sent to the *Athena* Community through bimonthly Brief News emails.

Athena has been well-represented at recent science meetings. A symposium entitled "The X-ray Universe 2017" was held in Rome, June 6–9, 2017. *Athena* was presented in two plenary talks by Xavier Barcons (ESO) and Matteo Guainazzi (ESA), on the *Athena* science case and concept, and in a special session on *Athena*, where Didier Barret and Arne Rau (MPE) presented the X-IFU and WFI instruments, respectively. In addition, there were several other talks and posters on several technical and scientific aspects of the mission. The scientific synergies enabled by the SKA, *CTA* and *Athena* were discussed in a dedicated symposium of the European Week of Astronomy and Space Science in Prague, June 26–30,2017. Some of the presentations can be found under the resources/presentations section. There was also a significant presence of *Athena* at the SPIE Optics and Photonics 2017 meeting in San Diego, 6-10 August 2017, with a session dedicated to *Athena* and several contributions related to the optics and the WFI now available in the proceedings of the meeting. Finally, Laura Brenneman (CfA) gave an overview talk on *Athena* at the conference "*Chandra* to Lynx: Taking the Sharpest X-ray Vision Fainter and Farther" August 8–10, 2017, in Cambridge (MA), and Matteo Guainazzi (ESA) also gave a talk on the status of *Athena* at the 16th Annual AAS HEAD meeting in Sun Valley.

Imaging X-ray Polarimetry Explorer

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

The Imaging X-ray Polarimetry Explorer (IXPE) was selected in January 2017 as a NASA astrophysics Small Explorer (SMEX) mission for launch in November 2020. Due to a significant funding reduction for FY2018, the IXPE Project was asked to replan the mission, resulting in a 5-month Phase-B extension, slipping the Mission Preliminary Design Review (PDR) to June, 2018 with launch now expected in April, 2021. Despite these perturbations, the Project has made significant technical and programmatic progress. Indeed, it supported the Mission System Requirements Review (SRR) conducted by the Standing Review Board at MSFC on September 18 and 19.

At MSFC, construction of a Mirror Module Assembly (MMA) engineering unit is underway. This unit will contain 6 of 24 flight mirror shells with dummy masses as surrogates for the remaining 18 mirror shells. The MMA engineering unit will be environmentally tested at MSFC next Spring to qualify its design, after which it will be used for verifying hardware and processes for the telescope end-to end calibration at MSFC. Meanwhile, detailed thermal modeling of the flight MMA is nearing completion, which will allow specification of the heater power requirements and design of the MMA thermal-control system.

In Italy, prototype polarization-sensitive gas pixel detectors, of a design very close to that of the flight units, have been built and are undergoing testing. The Italian Space Agency conducted the Instrument System Requirements Review (SRR) on October 30 and 31.

The IXPE Science Working Group held its first face-to-face meeting at MSFC on September 20, following the Mission SRR. In its role to counsel the IXPE Principal Investigator in the IXPE scientific investigation, the SWG received reports from various technical elements of the Project and from four recently-chartered scientific working groups.

The X-ray Astronomy Recovery Mission

Rich Kelley (NASA/GSFC)

The JAXA X-ray Astronomy Recovery Mission (*XARM*), designed to recover the essential capabilities of the *Hitomi* mission (that was lost to an operational mishap in March 2016) is making steady progress and will soon be officially underway. The mission will carry two instruments: The "Resolve" soft X-ray spectrometer based on an X-ray calorimeter array and high efficiency X-ray mirror, and the "Xtend" soft X-ray imager based on a CCD sensor and a duplicate X-ray mirror. These two instruments will be rebuilds of similar instruments on *Hitomi*, but with limited changes based on lessons learned from *Hitomi*. NASA is providing the key components of the Resolve instrument, including the calorimeter detector system and first-stage cooling components, electronics, the X-ray mirrors for Resolve and Xtend, and the Resolve data pipeline and data center. JAXA is responsible for the other components of the Resolve instrument, the Xtend instrument, the spacecraft, launcher (H-IIA), and mission operations center. By agreement, NASA will have a Project Office within the NASA Explorers Program Office that manages the hardware contributions that will also have a review and advisory role for the mission, and provide oversight and a communications path for Resolve development at the Goddard Space Flight Center. ESA will support the mission through agreement with JAXA, and will provide similar hardware and expertise as for *Hitomi*.

The JAXA side of the project entered a "pre-project" phase in October and issued a request for bids for the spacecraft. It is anticipated that the project will start official development in April 2018. On the NASA side, the project is conducting a combined PDR/CDR in mid-November 2017 and will proceed to a confirmation review in January 2018. NASA and JAXA are discussing a data share agreement and a framework for science participation. NASA has already issued a call for US science participants to the mission (due December 13, 2017), and is planning, with JAXA, to have additional members of the US community propose to participate in the early phase of the mission.

The Cherenkov Telescope Array

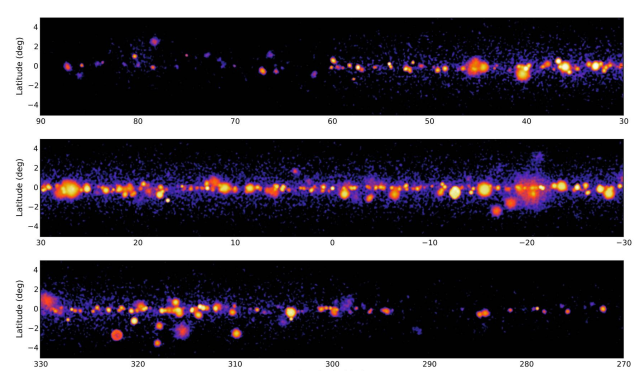
Megan Grunewald (CTAO)

The Cherenkov Telescope Array (*CTA*) is a global initiative to build the world's largest and most sensitive high-energy Gamma-ray observatory with more than 100 telescopes located in the northern hemisphere (at the Roque de los Muchachos astronomical observatory on the island of La Palma, Spain) and the southern hemisphere (near the existing European Southern Observatory site at Paranal, Chile). More than 1,400 scientists and engineers from 32 countries are engaged in the scientific and technical development of *CTA*. The planning for the construction of the Observatory is managed by the CTAO gGmbH, which is governed by Shareholders and Associate Members from a growing number of countries.

It has been a decade since science planning for *CTA* started, resulting in a series of publications in a special edition of Astroparticle Physics in 2013. The current work began that same year with an organized effort by the *CTA* Consortium to develop *CTA*'s Key Science Projects (KSPs) in 2013. After three years of development and refinement that included internal and external reviews, the KSPs were incorporated into a single document: "Science with the Cherenkov Telescope Array". The latest iteration of "Science with the Cherenkov Telescope Array" was made available at the *CTA* on-line library and arXiv (1709.07997) and will be published in a special edition of the International Journal of Modern Physics D. The work includes more than 200 pages that introduce and elaborate *CTA*'s major science themes and place *CTA* in the context of other major observatories.

"The release of this document represents a major milestone for *CTA*, and it details the breadth and the richness of the science that will be done with the observatory over the next decade," says *CTA* Co-Spokesperson Prof. Rene Ong. "The document would not have been possible without the hard work of literally hundreds of *CTA* Consortium members over a period of many years."

CTA will be the foremost global observatory for very high-energy Gamma-ray astronomy over the next decade and beyond. The scientific potential of *CTA* is extremely broad: from understanding the role of relativistic cosmic particles to the search for dark matter. *CTA* will explore the extreme Universe, probing environments from the immediate neighborhood of black holes to cosmic voids on the largest scales. With its ability to cover an enormous range in photon energy (from 20 GeV to 300 TeV), *CTA* will improve on all aspects of performance with respect to current instruments. And its wider field of view and improved sensitivity will enable *CTA* to survey hundreds of times faster than previous TeV telescopes.



Simulated sky map that will be obtained during the CTA galactic plane survey. Credit: CTA

CTA will seek to address a wide range of questions in astrophysics and fundamental physics that fall under three major study themes: understanding the origin and role of relativistic cosmic particles, probing extreme environments and exploring frontiers in physics. Some of the most promising discoveries will come from a survey of the Milky Way, which should discover more Galactic sources for improved population studies and advance our understanding of the origin of cosmic rays; the search for the elusive dark matter with models not accessible by other experiments; and the detection of transient phenomena like Gamma-ray bursts and gravitational wave events associated with catastrophic events in the Universe.

The project to build *CTA* is well advanced: working prototypes exist or are under construction for all the proposed telescope designs and significant site characterization has been undertaken. Construction is expected to begin in 2018. When it is complete, *CTA* will serve as an open observatory to the world-wide physics and astrophysics communities. To learn more and to sign up for the *CTA* Newsletter please visit the *CTA* website.

Lynx

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

The *Lynx* X-ray Observatory is a large mission concept under study to aid the 2020 Astrophysics Decadal Survey Committee in formulating their recommendations for future NASA strategic missions.

The *Lynx* study is being performed under the leadership of a Science and Technology Definition Team (STDT) selected from the astrophysics community with support from a joint Marshall Space Flight Center-Smithsonian Astrophysical Observatory study office and with participation by over 250 scientists worldwide dedicated to the success of *Lynx*. The STDT holds regular weekly meetings and several face-to-face workshops annually. These meetings are open to the public and are announced on the *Lynx* website. The most recent meetings include an STDT workshop in April and a joint technology interchange meeting and instrument/optics working group conference in May.

The STDT has established key science questions to be addressed by *Lynx*: How and when do the first black holes in the universe radiate? How do they affect their surroundings? How do feedback processes shape galaxies? What are the properties of the gas that resides outside of galaxies? The observatory hardware requirements needed to answer these science questions were identified to be a large collecting area, high angular resolution, X-ray ($\sim$0.15$-$10 keV) mirror assembly, with two orders of magnitude increase in sensitivity over *Chandra*, and a science instrument suite that is capable of fine imaging, high-resolution dispersive grating spectroscopy at low energies, and imaging spectroscopy across the *Lynx* waveband.

The *Lynx* study team is currently preparing an interim report describing in detail credible hardware configurations that will achieve *Lynx* science goals. In addition to a thorough description of the scientific goals, this report also presents a discussion on a design reference mission; schedule, risk and related programmatic considerations; and a technology development roadmap. The report recently underwent an external review and recommendations from that review are being incorporated. An open forum on the optics and science instruments being considered for *Lynx* was held at the 2017 SPIE Optics and Photonics conference, which coincided with the kickoff of a *Lynx* Optics and Instrument Working Group collaboration to define the process for developing the *Lynx* technology development plan.

Also over the summer, intensive studies of the *Lynx* science instruments were undertaken by the Instrument Design Lab at GSFC and by the Advanced Concepts Office at MSFC. These studies refined the subsystem conceptual designs; evaluated system performance and attributes including mass, power, and data rates; assessed technology risks; and provided preliminary cost estimates.

The next STDT face-to-face meeting is being planned for mid- to late-January 2018. *Lynx* public outreach activities are underway for the winter AAS meeting in Washington, DC.

The 2017 Eclipse: Sun Valley and Vicinity

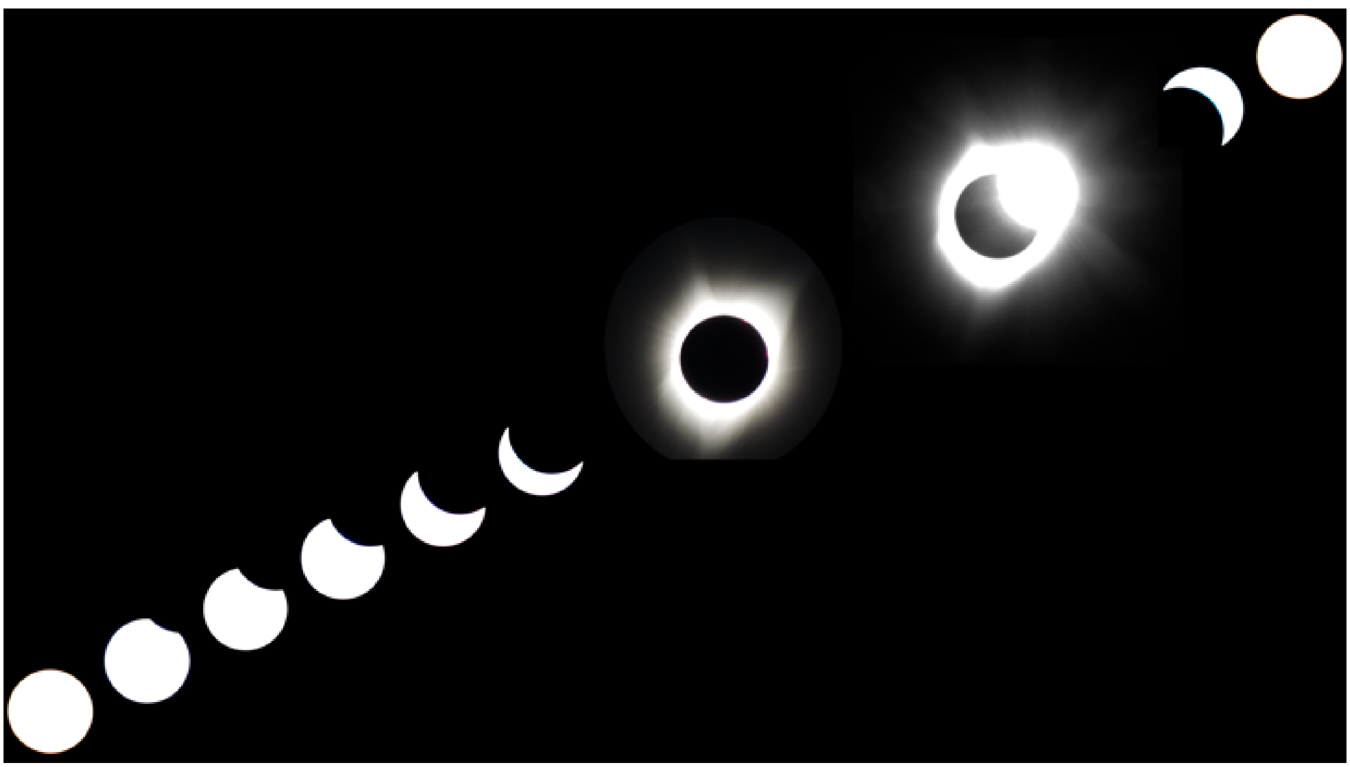
Mike Corcoran (CRESST/CUA & NASA/GSFC)

Once the sun did shine / And lord it felt so fine / The moon a phantom rose / Through the mountains and the pine / And then the darkness fell ...

— “The Moon’s a Harsh Mistress”, by Jimmy Webb[1]

Some images of the 2017 eclipse by participants at the 16th Divisional Meeting of the High Energy Astrophysics Division. More beautiful photos can be seen on the Facebook photo album.



Top, left: Partial Eclipse by Chris Mauche; Top, Middle: H-α Partial by Damian Christian; Top, Right: Diamond Ring by Scott Wolk; Bottom: Eclipse Montage by Pat Slane.

[1]Not that James Webb