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Physics of the Cosmos Newsletter

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Physics of the Cosmos Program Update

Peter Bertone, *PCOS Program Deputy Chief Scientist*
Ann Hornschemeier, *PCOS Program Chief Scientist*
Mansoor Ahmed, *PCOS Program Manager*

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Welcome to this special edition newsletter devoted to suborbital projects related to high energy astrophysics and cosmology under the Physics of the Cosmos (PCOS) science themes. We highlighted suborbital projects in our 2014 PCOS newsletter and plan to do this approximately every 2 years or so given that for many areas in PCOS there is a great amount of activity going

NASA's Fermi Satellite Kicks Off a Blazar-detecting Bonanza

In April, 2015 NASA's Fermi Gamma-ray Space Telescope observed a flood of high-energy gamma rays from a blazar outburst, which helped two ground-based gamma-ray observatories detect some of the highest-energy light ever seen from a galaxy so distant. The observations provide a surprising look into the environment near a supermassive black hole at the galaxy's center and offer a glimpse into the state of the cosmos 7 billion years ago.

Black-hole-powered galaxies called blazars are the most common sources detected by NASA's Fermi Gamma-ray Space Telescope. As matter falls toward the supermassive black hole at the galaxy's center, some of it is accelerated outward at nearly the speed of light along jets pointed in opposite directions. When one of the jets happens to be aimed in the direction of Earth, as illustrated here, the galaxy appears especially bright and is classified as a blazar. Credits: M. Weiss/CfA

"When we looked at all the data from this event, from gamma rays to radio, we realized the measurements told us something we didn't expect about how the black hole produced this energy," said Jonathan Biteau at the Nuclear Physics Institute of Orsay, France.

Astronomers had assumed that light at different energies came from regions at different distances from the black hole. Gamma rays, the highest-energy form of light, were thought to be produced closest to the black hole. "Instead, the multiwavelength picture suggests that light at all wavelengths came from a single region located far away from the power source," Biteau explained.

The gamma rays came from a galaxy known as PKS 1441+25, a type of active galaxy called a blazar. At its heart lies a monster black hole with a mass estimated at 70 million times the sun's and a surrounding disk of hot gas and dust.

In April, PKS 1441+25 underwent a major eruption. Luigi Pacciani at the Italian National Institute for Astrophysics in Rome was leading a project to catch blazar flares in their earliest stages in collaboration with the Major Atmospheric Gamma-ray Imaging Cerenkov experiment (MAGIC), located on La Palma in the Canary Islands. Using public Fermi data, Pacciani discovered the outburst and immediately alerted the astronomical community. Fermi's Large Area Telescope revealed gamma rays up to 33 billion electron volts (GeV), reaching into the highest-energy part of the instrument's detection range. For comparison, visible light has energies between about 2 and 3 electron volts.

Read the full article: **http://www.nasa.gov/feature/goddard/nasas-fermi-satellite-kicks-off-a-blazar-detecting-bonanza**

Glow from the Big Bang Allows Discovery of Distant Black Hole Jet

Astronomers have used NASA's Chandra X-ray Observatory to discover a jet from a very distant supermassive black hole being illuminated by the oldest light in the Universe. This discovery shows that black holes with powerful jets may be more common than previously thought in the first few billion years after the Big Bang.

The light detected from this jet was emitted when the Universe was only 2.7 billion years old, a fifth of its present age. At this point, the intensity of the cosmic microwave background radiation, or CMB, left over from the Big Bang was much greater than it is today.

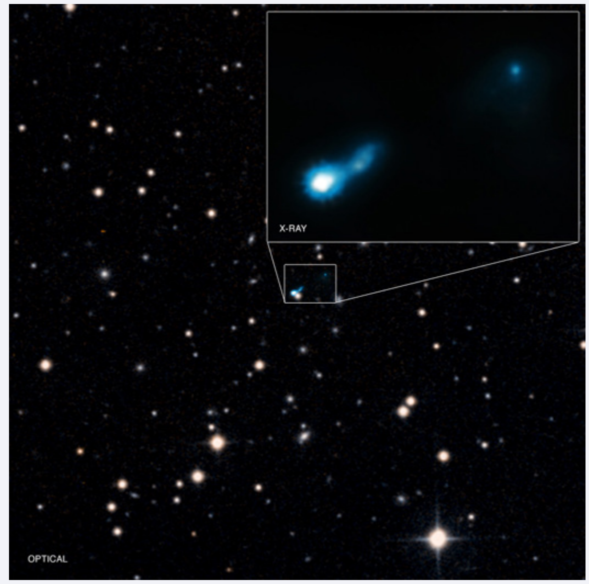
The length of the jet, found in the system known as B3 0727+409, is at least 300,000 light years. Many long jets emitted by supermassive black holes have been detected in the nearby Universe, but exactly how these jets give off X-rays has remained a matter of debate. In B3 0727+409, it appears that the CMB is being boosted to X-ray wavelengths.

Electrons in black hole jets usually emit strongly at radio wavelengths, so typically these systems are found using radio observations. The discovery of the jet in B3 0727+409 is special because so far almost no radio signal has been detected from this object, while it is easily seen in the X-ray image.

"We essentially stumbled onto this remarkable jet because it happened to be in Chandra's field of view while we were observing something else," explains co-author Lukasz Stawarz of Jagiellonian University in Poland.

Scientists have so far identified very few jets distant enough that their X-ray brightness is amplified by the CMB as clearly as in the B3 0727+409 system. But, Stawarz adds, "if bright X-ray jets can exist with very faint or undetected radio counterparts, it means that there could be many more of them out there because we haven't been systematically looking for them."

Read the full article: **http://chandra.harvard.edu/press/16_releases/press_021616.html**



A jet from a very distant black hole being illuminated by the leftover glow from the Big Bang, known as the cosmic microwave background (CMB), has been found as described in our latest press release. Astronomers using NASA's Chandra X-ray Observatory discovered this faraway jet serendipitously when looking at another source in Chandra's field of view. X-ray: NASA/CXC/ISAS/A.Simionescu et al, Optical: DSS

on in the suborbital program. Beyond the critical maturation of technologies for eventual use on spaceflight missions, these projects train future principal investigators and produce great science results—all at relatively low cost. A regular edition newsletter with full articles on program elements that are not covered in depth here will be released in fall 2016.

The year 2015 marked the centennial for the publication of Einstein's theory of General Relativity. We also witnessed two watershed events in the history of gravitational-wave (GW) astrophysics. Of course, they were the direct detection of gravitational waves on September 14, 2015 (announced February 11, 2016) by LIGO and the launch of ESA's LISA Pathfinder (LPF) on December 3, 2015. LISA Pathfinder was the first NASA PCOS mission to launch since the PCOS Program was created. The NASA contribution to the ESA LPF mission, consisting of the Disturbance Reduction System (DRS) and drag-free control software, is managed through the JPL-based ST-7 project office. On March 1 science operations began to characterize acceleration noise performance and validate physics-based models of the instrument that will be used in the design of a future LISA-like GW mission. The team held a press event on June 7, 2016 announcing results from the European phase of the mission and publication of an article in *Physical Review Letters*. The article reports that the measured acceleration noise performance on LISA Pathfinder far exceeds its requirements and approaches those of a full-scale observatory such as LISA. This represents a major step toward realizing a LISA-like observatory. The transition to operations for the US DRS payload will begin in late June to early July 2016. NASA participation in an extended mission of 7–8 months has been formally approved by NASA HQ Astrophysics Division Director Paul Hertz pending final confirmation of the proposal by ESA. The purpose of the extended mission will be to gain deeper understanding of instrumental performance by undertaking experiments deemed too risky for prime mission operation. Lastly within the realm of GW astrophysics, in November, 2015 NASA chartered a study to investigate how the US might contribute to the future ESA GW mission (L3, launch in 2034). An interim report was delivered to Paul Hertz on June 20 and the final report is due on September 30. The study team has held nine teleconferences and a face-to-face meeting. More detail can be found in the "L3 Study Activity" box later in this edition and on the **PCOS website**.

Study activities related to NASA-ESA collaboration on the next ESA X-ray astronomy mission, Athena (L2, launch in 2028) continue. In September 2015, the first Athena

Science Meeting was held at the European Space Astronomy Center (ESAC), outside Madrid, Spain and highlighted the breakthrough science to be performed by Athena. Approximately 200 scientists from around the world attended, including 25 from the US. A one-day Athena Science Study Team meeting followed, which was attended by NASA delegate Randall Smith (SAO), NASA Study Scientist Rob Petre (GSFC) and NASA Program Scientist Michael Garcia (HQ). Topics of discussion included the Science Management Plan and the Science Ground System. In November, the Athena Science Requirements Review was held in Garching, Germany with the participation of several US scientists who were selected to serve as NASA representatives on the Athena science working group panels. In December, NASA HQ held a meeting of the NASA-sponsored Athena science working group panel chairs in Washington, D.C. The purpose of the meeting was to update the panel chairs of the ongoing NASA activities and to seek suggestions about US participation in the mission. The NASA contribution continues to center around providing the calorimeter array for the X-ray Integral Field Unit (X-IFU). Discussion is ongoing about US providing part of the Wide Field Imager (WFI). In February, 2016 representatives from the WFI instrument team met at NASA Headquarters to address this topic.

There have been several milestones for the ESA Euclid Mission (M2, launch in 2020) and the NASA Euclid Project. In December 2015, the mission passed Preliminary Design Review. The NASA Euclid Project, which is responsible for delivering 16 flight near-infrared detectors and 4 flight spares, successfully reached KDP-C (Key Decision Point C, entering final design and fabrication phase) in March of this year. The final contracts with Teledyne Imaging Sensors (TIS) were signed in January 2016 and the first two flight candidate detectors were delivered to JPL in March for environmental testing (a total of eight have since been delivered and completed initial vibration testing), while in April GSFC received another two flight candidate detectors for response characterization. In January, the annual Euclid Science Peer Review was held at the AAS Meeting and a tri-agency Memorandum of Understanding (MOU) for cosmological simulations using Department of Energy (DOE) supercomputer facilities was initiated. A working Group of National Science Foundation (NSF), NASA, and DOE scientists has been established. The annual Euclid Consortium Meeting was held in Lisbon, Portugal May 30–June 3, 2016.

Preparations are underway for the National Research Council (NRC) 2020 Astrophysics Decadal Survey. The PhysPAG update article in this edition describes in some detail the process used for selecting candidate large-scale (>$1B total cost) mission concepts to study for consideration by the Decadal Survey committee. Also included in the article are PhysPAG activities toward gathering input on candidate Probe-class (total cost approximately between $400M and $1B) mission concepts for study and prioritization by the Decadal Survey. One of the four candidate large mission concepts is for an X-ray astronomy mission, following the terminology of the 2013 **NASA Astrophysics Roadmap**, called “X-ray Surveyor” (XRS). The XRS study effort began in March, 2016 with the kickoff telecon of the Science and Technology Definition Team (STDT). More information can be found in the “X-ray Surveyor Study” box later in this newsletter and by following the link to the XRS study website. For important details on technology development related to Decadal Survey planning, please see the article by PCOS Program Technology Development Manager Thai Pham and Program Technologist Opher Ganel.

The Program Office welcomes Harley Thronson as the new Program Chief Technologist, replacing Bernie Seery who will remain at GSFC as Assistant Director for Advanced Concepts. Harley is also Senior Scientist for Advanced Concepts in Astrophysics at GSFC. He has served in many roles in his 20-year distinguished career at NASA including HQ Program Scientist for the Hubble, Spitzer and James Webb space telescopes and for the SOFIA airborne observatory. We thank Bernie for his valuable service and dedication to the PCOS Program.

As always, we greatly appreciate your comments and questions. Contact information for all program officers can be found in the “PCOS Organization” box near the end of the newsletter.

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Cosmic Microwave Background Radiation Polarization Experiments

Shaul Hanany, *University of Minnesota*
Bill Jones, *Princeton University*
Al Kogut, *NASA Goddard Space Flight Center*

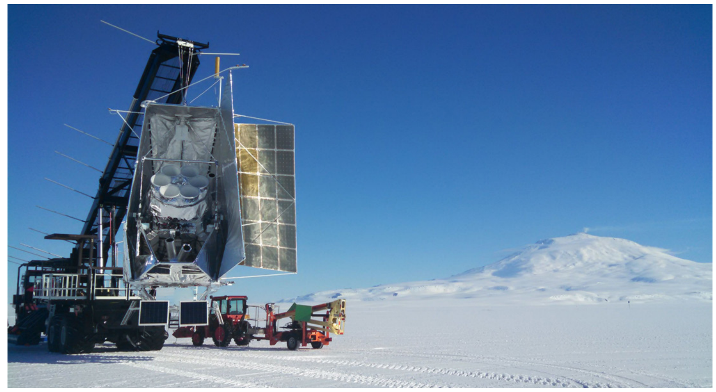
Introduction

The spectrum and anisotropy of the cosmic microwave background (CMB) have provided phenomenally rich cosmological information over the last 50 years. Arguably the most exciting information contained in the CMB is still to be uncovered through measurements of its polarization properties. Gravitational waves produced in the early universe would leave a signature on the CMB polarization at characteristic angular scales larger than ~1 degree. Detecting or constraining the magnitude of these signatures, also called “B-modes,” provides a direct probe of fundamental physics at energy scales a trillion times higher than accessible to ground-based accelerators. The 2010 New Worlds New Horizons (NWNH) Decadal Survey panel stated: “The convincing detection of B-mode polarization in the CMB would represent a watershed discovery.” Polarization signatures on smaller angular scales that arise from gravitational lensing of the CMB photons by the distribution of matter in the universe are sensitive to, and can thus constrain, a host of cosmological parameters, and in particular can provide strong constraints on the sum of neutrino masses.

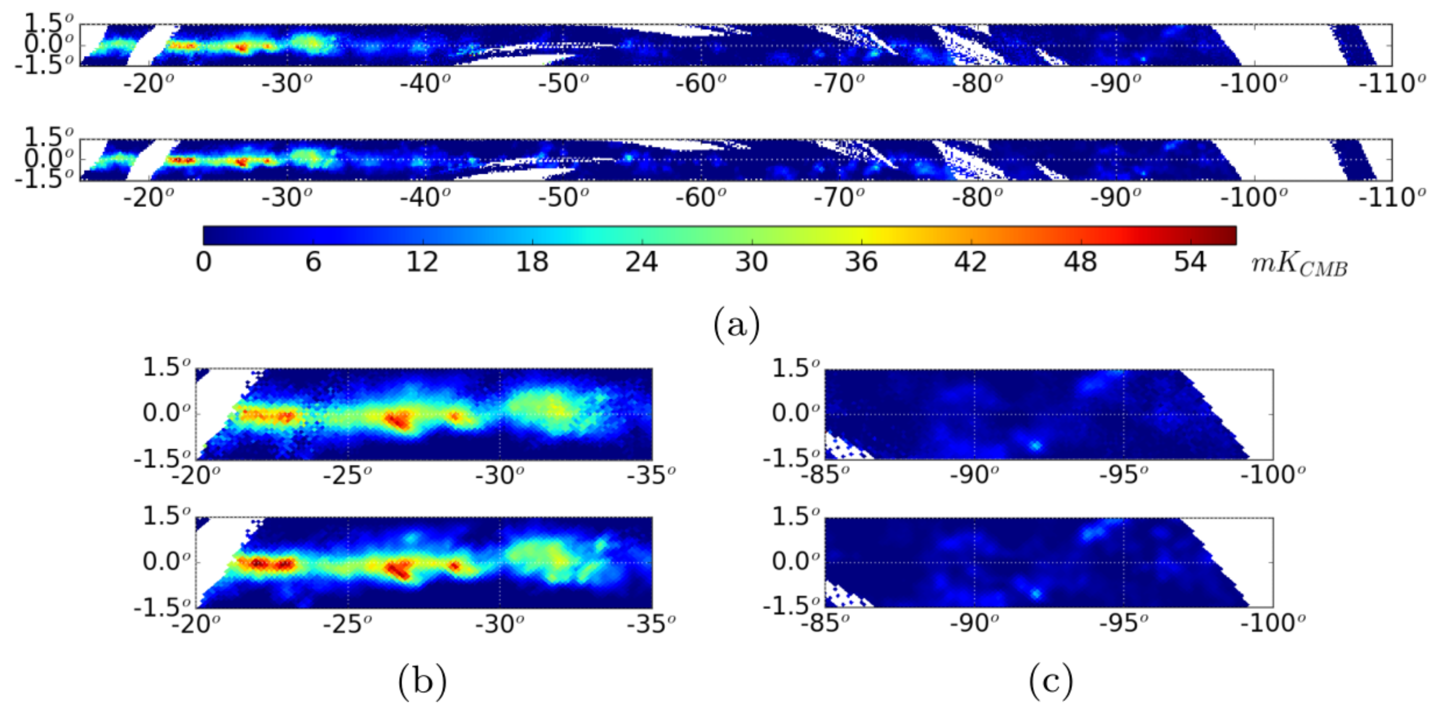
Three Complementary Balloon Payloads

This science fits under the PCOS theme, however much of the action is outside the PCOS program in APRA (Astrophysics Research and Analysis) program balloon experiments. Currently NASA supports three balloon-borne experiments that probe the polarization properties of the CMB: the E and B experiment (EBEX; P.I. Shaul Hanany), the Suborbital Polarimeter for Inflation Dust and the Epoch of Reionization (SPIDER; P.I. Bill Jones), and the Primordial Inflation Polarization Explorer (PIPER; P.I. Al Kogut). Their design and science deliverables are complementary: they are serving as a test-bed for key technologies that are candidates for a future space mission, and they are excellent training grounds for future space scientists and engineers. All three experiments are attempting to either detect or set progressively more stringent bounds on the B-mode from Inflation.

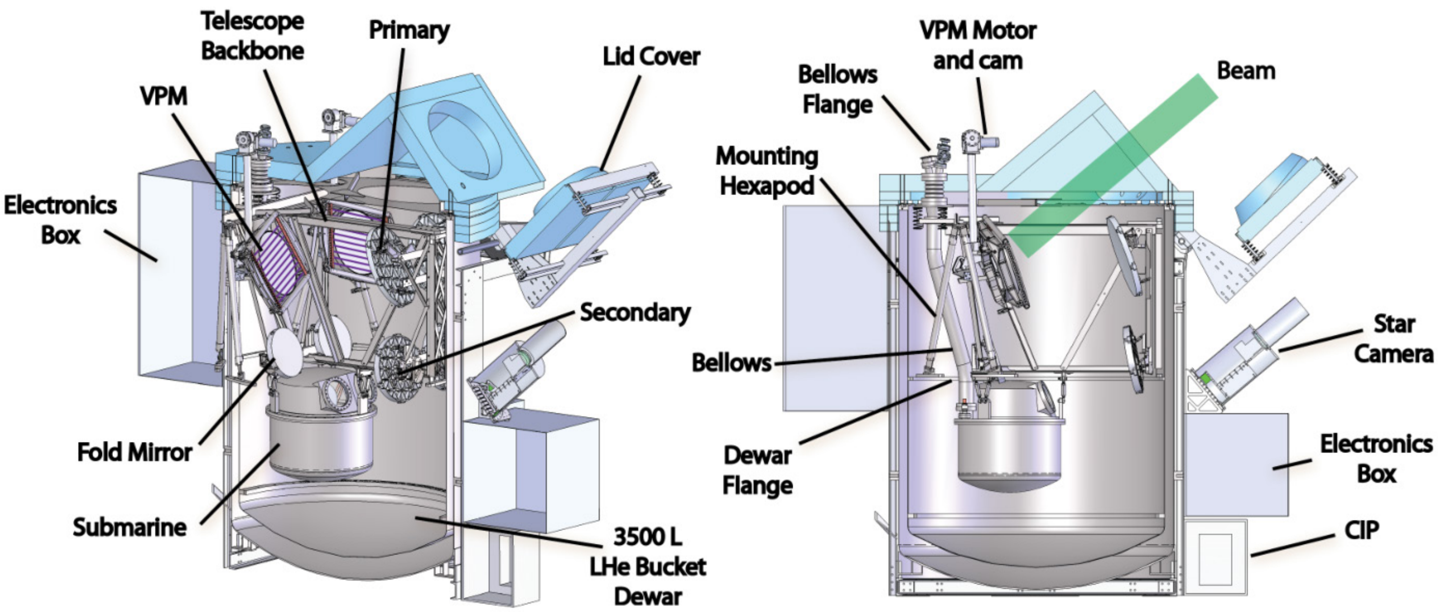
Some also have sufficiently high angular resolution to detect the small scale gravitational lensing signal. They are probing a broad range of frequencies between 90 and 600 GHz with overlapping frequencies: 90–285 GHz for SPIDER, 150–410 for EBEX, and 200–600 GHz for PIPER. The three payloads use transition edge sensor (TES) bolometers for detecting the incident radiation. TES bolometers are suitable for fabrication and readout in large array format, which is required for achieving the extreme sensitivity necessary to detect the Inflationary B-modes. Both the detailed design of the TES and the coupling of the radiation between the sky and the detector differ, providing useful information about the different technical approaches, and giving rise to completely different systematic uncertainties. Each of the polarimetric approaches is also different. EBEX uses a continuously rotating broad-band half-wave plate and a stationary grid; SPIDER has a stepped half-wave plate and the detectors are inherently polarization sensitive; PIPER is relying on a variable-phase polarization modulator. During its Antarctic long duration flight in 12/2012 EBEX was the first of the current round of balloon experiments to collect science data. This flight also marked the first time that a kilo-pixel array of TES bolometers, read-out using superconducting quantum interference device (SQUID) amplifiers, was used on a balloon-borne platform. An intensive data analysis effort has since been undertaken and this year the EBEX team completed an initial temperature calibration for all detectors. SPIDER's inaugural Antarctic flight, in January 2015, lasted 17 days before landing in a remote region of West Antarctica. The hardware has yet to return, but the data from that flight has produced a survey of CMB polarization over 4500 square degrees at each of 94 and 150 GHz that is more sensitive than that produced by the Planck spacecraft. The SPIDER team is in the midst of the cosmological analysis, and is preparing for a second flight



The SPIDER CMB balloon payload on the launchpad in Antarctica prior to its first flight. Credit: W. Jones.



(a) The Galactic plane in the 250 GHz EBEX frequency band. Top panel: the optimized EBEX temperature map using 236 detectors. Bottom panel: the corresponding processed reference map smoothed to 15.0 arcminutes. (b) & (c) Zoom on two different areas from (a). Credit: From arXiv:1601.07923v1



CAD rendering of the optical configuration used for PIPER CMB balloon experiment. Credit: Adapted from arXiv:1407.2584v1

that will extend the frequency coverage to 285 GHz. PIPER is planning a series of 8 short (0.5–3 days) flights, alternating launches between North American and Australian sites to observe both the northern and southern sky. The combined flights achieve nearly full-sky coverage otherwise possible only from satellite platforms. This summer, the PIPER team plans to conduct a brief trial flight, using an engineering test unit, from NASA's Columbia Scientific Balloon Facility in Palestine, Texas. An overnight science flight from Fort Sumner, New Mexico is scheduled for September 2016.

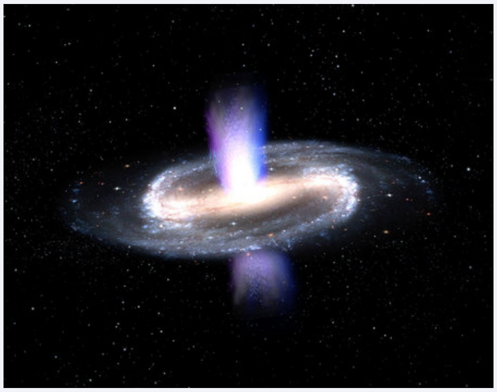
The Broader Context

A number of ground-based experiments and the Planck satellite are also making significant advances in mapping the po-

A Milky Way Twin Swept by an Ultra-fast X-ray Wind

ESA's XMM-Newton has found a wind of high-speed gas streaming from the center of a bright spiral galaxy like our own that may be reducing its ability to produce new stars.

It is not unusual to find hot winds blowing from the swirling discs of material around supermassive black holes at the center of active galaxies. If powerful enough, these winds can influence their surroundings in various ways. Their primary effect is to sweep away reservoirs of gas that might otherwise have formed stars, but it is also possible that they might trigger the collapse of some clouds to form stars.



Winds from a spiral galaxy. Artist's impression depicting a wind flowing from around a supermassive black hole at the center of a bright spiral galaxy. Credit: ESA

Such processes are thought to play a fundamental role in galaxies and black holes throughout the Universe's 13.8 billion years. But they were thought to affect only the largest objects, such as massive elliptical galaxies formed through the dramatic collision and merging of two or more galaxies, which sometimes trigger the winds powerful enough to influence star formation.

Now, for the first time, these winds have been seen in a more normal kind of active galaxy known as a Seyfert, which does not appear to have undergone any merging. When observed in visible light, almost all Seyfert galaxies have a spiral shape similar to our own Milky Way. However, unlike the Milky Way, Seyferts have bright cores that shine across the entire electromagnetic spectrum, a sign that the supermassive black holes at their centres are not idle but are devouring their surroundings.

The supermassive black hole at the heart of this particular Seyfert, known as IRAS17020+4544 and located 800 million light-years from Earth, has a mass of nearly six million Suns, drawing in nearby gas and making it shine moderately. Because the galaxy is broadly similar to our own, it raises questions about the history of the Milky Way and the role that our own central black hole may have played.

Read the full article: **http://www.esa.int/Our_Activities/Space_Science/A_Milky_Way_twin_swept_by_an_ultra-fast_X-ray_wind** larization of the CMB. Planck is scheduled to release its final polarization results in mid-2016. The ground-based Keck, Polarbear, ACTPol,and SPTPol are also expected to release results within the next year. NWNH recommended that a new CMB satellite mission be considered if the existing combined space and ground-based program is successful in detecting B-modes from the epoch of inflation. The community is expecting a very exciting period.

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High Energy Ballooning: Going Above and Beyond!

Terri Brandt, *NASA/GSFC*

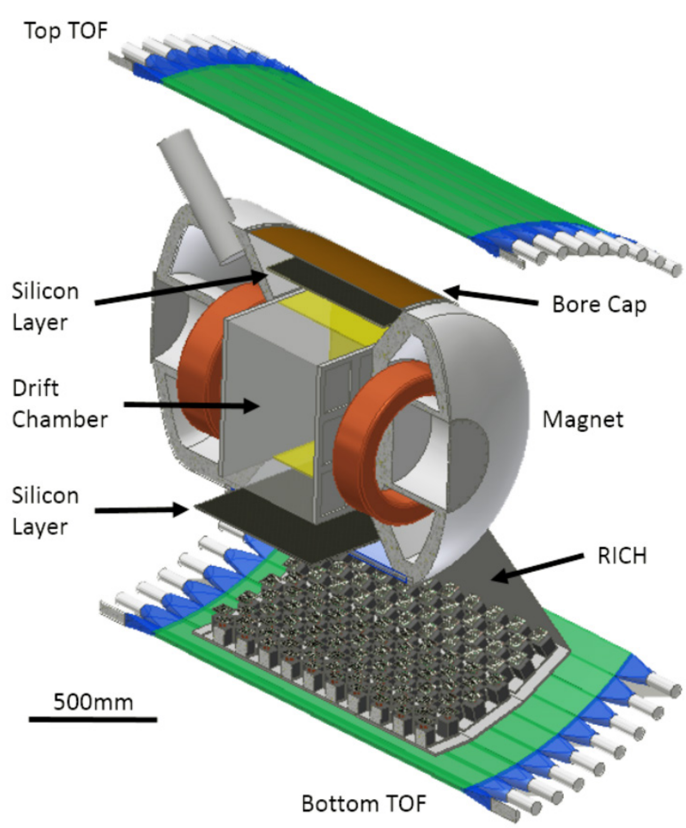
Cosmic Ray (CR) and γ-ray experiments have a rich history of discovery on the balloon platform that have yielded significant insight into the high energy universe. Today, a number of novel solutions to address sometimes century old questions are currently funded and are in development or flying. The variety of payloads proposed each year to delve into a wide range of questions now also including neutrinos, demonstrates the vibrancy afforded by the balloon platform at high energies.

BACCUS (P.I. Eun-Suk Seo, Univ. of Maryland): Boron And Carbon Cosmic rays in the Upper Stratosphere (BACCUS) continues the previous six CREAM (Cosmic Ray Energetics and Mass) balloon flights to measure the charge and energy spectra of protons through iron from 10^{12} to 10^{15} eV. The nuclear composition at these energies provides insight into the highest energy Galactic CRs. Comparing the number of primary nuclei such as carbon, primarily created at the source, to secondary nuclei such as boron, created via spallation during propagation, gives insight into CRs' journey through the Galaxy. BACCUS is currently scheduled to launch from McMurdo Station in Antarctica during the December 2016 season.

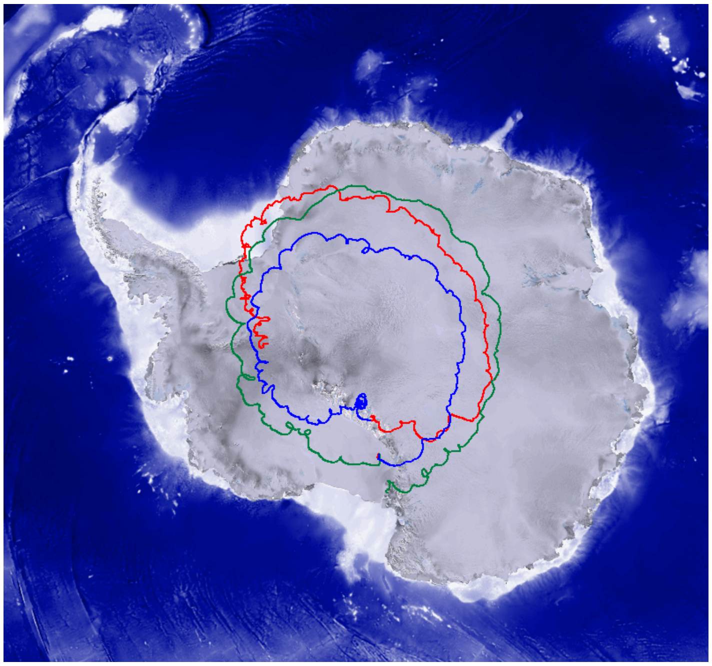
HELIX (P.I. Scott Wakely, Univ. of Chicago): The High Energy Light Isotope Experiment (HELIX) aims to use light isotopes such as ^{10}Be and ^{9}Be to investigate Galactic CR propagation models not fully constrained by nuclear charge data, e.g., B:C. Flying a ~1 Tesla magnet will enable determination of isotopic mass of CR nuclei for energies of a few – 10 GeV/n. The diffusion of primary cosmic rays in a halo around the Galaxy creates secondaries such as Beryllium, which has the stable ^{9}Be isotope, while ^{10}Be has a half-life of 1.39 Myr. Combining measurements of ^{10}Be:^{9}Be at > ~GeV/n with secondary/primary CR measurements such as B:C will allow scientists to determine both the halo size and the diffusion coefficient rather than just their ratio. Constraining the propagation model this way is crucial for linking the particle CR populations observed directly on Earth to those, such as positrons, inferred from Galactic photon sources such as γ-rays. The HELIX collaboration is currently expanding the magnet's liquid helium capacity to enable a 14 day flight.

Boron And Carbon Cosmic-rays in Upper Stratosphere (BACCUS) experiment payload during integration at the University of Maryland. Credit: E. Seo.

SuperTIGER (P.I. Robert Binns, Washington Univ. in St Louis): Reaching to the highest nuclear charges yet measured, the Super Trans-Iron Galactic Element Recorder (SuperTIGER) is optimized for unprecedented individual element resolution and statistical precision for nuclei above iron. The first flight, in December 2012 on a long duration balloon, gathered a record breaking 55 days' data. Along with the ~4x collection area, this increased statistics for nuclei with charge 30 ≥ Z ≥ 40 by an order of magnitude from previous measurements. These heavy nuclei point to CRs originating in massive



Partially-sectioned 3D model of the High Energy Light Isotope eXperiment (HELIX) detector systems, showing superconducting magnet, hybrid tracking system, two time-of-flight layers and ring-imaging Cherenkov detector. Credit: PoS(ICRC2015)682.

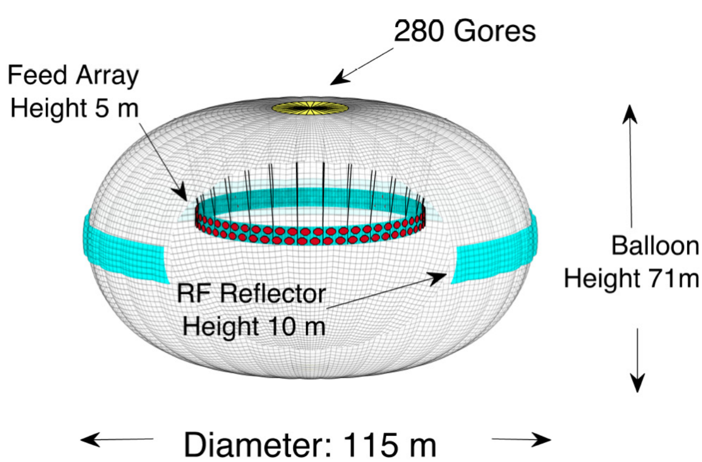


Record-breaking 55 day triple circumpolar flight path of SuperTIGER long-duration balloon payload. Credit: Columbia Scientific Balloon Facility.

ANITA-III balloon payload during hang test prior to launch at McMurdo Station Antarctica. Credit Columbia Scientific Balloon Facility.

(OB) star associations. The data from this and a second SuperTIGER flight planned for December 2017 will test and clarify both the OB association origin model and models for atomic processes which appear to preferentially accelerate elements residing primarily on dust grains, "refractories," over more volatile elements. Such preferential acceleration of refractories would have intriguing implications for, e.g., the distribution of massive elements throughout the Galaxy.

EUSO-SPB (P.I. Angela Olinto, Univ. of Chicago): The Extreme Universe Space Observatory on a Super Pressure Balloon (EUSO-SPB) is pushing boundaries to measure ultra high energy (UHE) CRs, thought to come from outside the Milky Way, likely from the most energetic objects in the universe. The EUSO-SPB telescope will be the first telescope to observe UHECR fluorescence from above, by using a Fresnel lens refractor with an ultrafast UV camera to record transient light events from UHECR showers in the atmosphere. The flight, planned for spring 2017, should measure dozens of UHECR events against a background of UV emission from varying cloud coverage and ocean conditions. In addition to exploiting the new SPB capability, researchers may leverage this balloon platform experience to enhance proposals such as JEM-EUSO for the International Space Station (ISS).



Schematic model of the ExaVolt Antenna (EVA) full-scale 18.7 Mcft super-pressure balloon. The reflector panels (light blue) are shown as a cut-away in the front portion, to reveal the internal feed array. Credit: PoS(ICRC2015)1151.

ANITA (P.I. Peter Gorham, Univ. of Hawaii): Aiming to measure the highest energy (> ~10^{19} eV) cosmic neutrinos produced in interactions of particles from the highest energy sources in the universe, the ANtarctic Impulsive Transient Antenna (ANITA) observes the Antarctic ice sheet looking for bursts of radio waves from neutrino interactions in the ice. ANITA measurements have provided some of the most stringent limits on cosmogenic neutrino production models, complementary to lower energy (< ~PeV) IceCube measurements of astrophysical (and atmospheric) neutrinos. The novel technique also detected some 16 UHECRs interacting in the atmosphere. The launch of ANITA IV is planned for December 2016.

EVA (P.I. Peter Gorham, Univ. of Hawaii): Building on the ANITA approach, the ExaVolt Antenna (EVA) will increase sensitivity to the neutrinos' coherent radio Cherenkov signals, extending the neutrino energy threshold down to ~$10^{17.5}$ eV, by exploiting the surface of a SPB. A toroidal reflector around the equator of the balloon focuses the plane wave onto a set of feed antennas arranged in a cylinder near the center of the balloon. In September 2014, the EVA collaboration successfully tested a 1/20th scale model which functioned as predicted. Development is ongoing for a special silvered-polyethylene thin film material required for the reflectors on the full scale balloon.

COSI (P.I. Steven Boggs, UC Berkeley): The Compton Spectrometer and Imager (COSI) was the first major scientific instrument flown on a SPB. The novel Compton telescope design utilizes a compact array of cross-strip germanium detectors to resolve individual γ-ray interactions with high spectral and

COSI launch operation from Wanaka Airport, New Zealand on May 17, 2016. Credit: Columbia Scientific Balloon Facility.

spatial resolution. Mechanically cooling the instrument rather than using liquid Nitrogen enables long-duration balloon operations. The soft γ-ray telescope (0.2–5 MeV) will probe the origins of Galactic positrons, uncover sites of nucleosynthesis in the Galaxy, and perform pioneering studies of γ-ray polarization of a number of source classes. Due to a balloon leak, the December 2014 flight ended after only 2 days. On 16 May 2016, COSI was successfully launched from Wanaka Airport, New Zealand on a SPB heading around the world. The COSI balloon payload successfully completed a 47-day flight and recovery of the payload is underway in Peru.

GRAPE (P.I. Mark McConnell, Univ. of New Hampshire): The Gamma Ray Polarimeter Experiment (GRAPE) is designed to measure γ-ray Burst (GRB) polarization across the entire sky, in the energy range of 50–500 keV, on a series of long duration balloon flights. GRAPE performed well during test flights in 2011 and 2014 from Ft. Sumner, New Mexico. A new design leveraging the GRAPE experience will take advantage of a robust balloon platform for future flights.

ASCOT (P.I. Peter Bloser, Univ. of New Hampshire): Reaching again towards higher energies, the Advanced Scintillator Compton Telescope (ASCOT) balloon project seeks to demonstrate that modern scintillator materials and light readout devices can be used to create a sensitive Compton telescope for observing cosmic and solar γ-ray sources at 0.5–20 MeV. ASCOT will use newer commercially available scintillators and silicon photomultiplier light sensors to create a compact, efficient, low background prototype telescope. A 1-day demonstration flight from Ft. Sumner, planned for the fall of 2017, aims to image the Crab Nebula, which will pave the way for longer duration flights to study γ-rays from solar flares, GRBs, black holes, and other sources.

Summary: As evidenced by these experiments, measuring the unknown often requires seeking novel solutions to low fluxes, from collecting the heaviest or most energetic nuclei and isotopes, to seeking radio signals from the lightest particles known, to looking for polarized light from the highest energy objects in the universe. The various balloon platforms provide the opportunities to test and develop technologies in short flights, to spend weeks viewing from the largest ice sheet in the world, and soon, to spend similar durations for making more statistically significant measurements at mid-latitudes. Balloons have also been a platform for proving technologies and expanding to even bigger venues, such as the ISS. For example, the CALorimetric Electron Telescope (CALET), which arrived at the ISS on 24 Aug 2015, has heritage from the BETS, ATIC, and TIGER balloon projects. With a 5-year mission baseline, the instrument is poised to add to the CR and γ-ray data sets at energies above Fermi and AMS-02. CREAM for the ISS (ISS-CREAM) is scheduled for launch on a SpaceX rocket in June 2017. It aims to measure the charge and energy spectra of CR electrons and nuclei from the ISS, above the balloon platform's ~3g/cm^2 residual atmosphere, removing this source of systematic error.

Balloons are agile platforms with a solid heritage of record-breaking high energy astrophysics discoveries. They provide proving grounds for novel detectors and techniques, often later deployed in space missions. We eagerly await results from the current array of CR, neutrino, and γ-ray detectors and anticipate that the future will bring more novel instruments which will deepen our understanding of the universe and fundamental physics.

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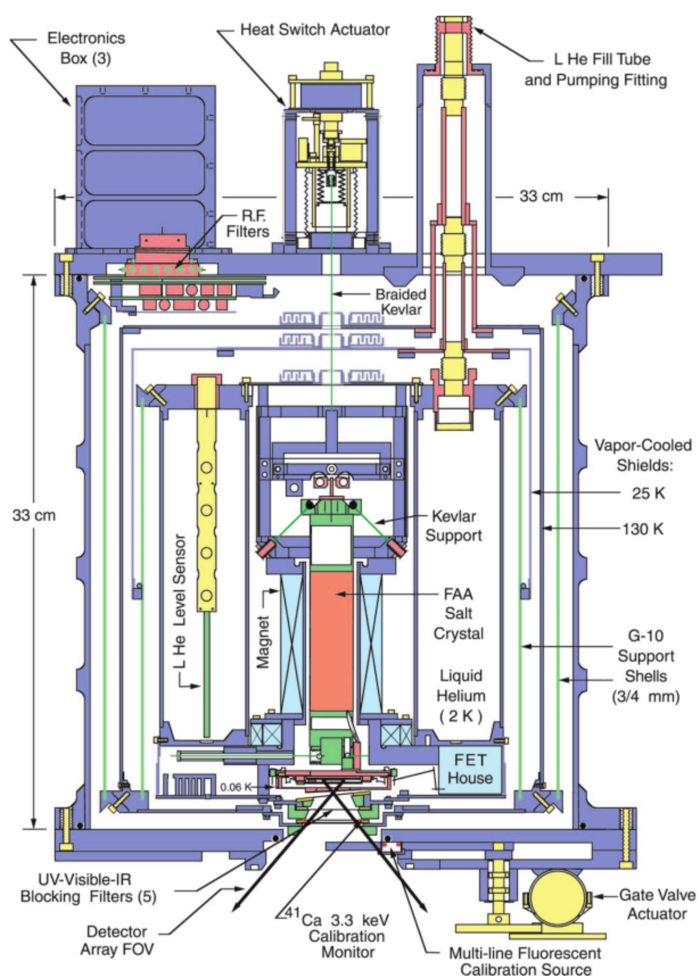
X-ray Suborbital Sounding Rockets

Scott Porter, *NASA/GSFC*
Wilton Sanders, *NASA HQ*

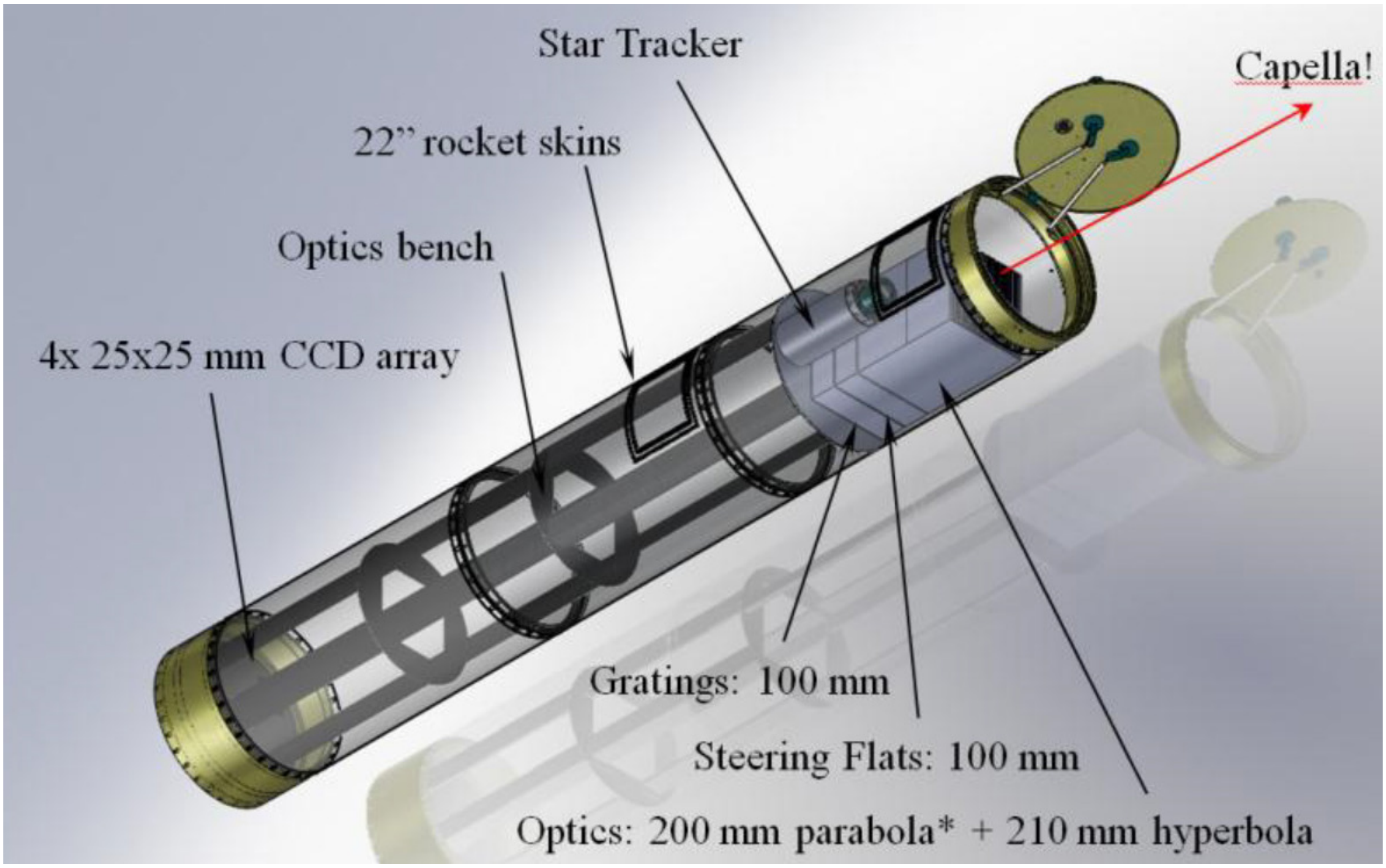
There is a rich tradition of X-ray sounding rocket experiments going back more than 50 years, beginning with the discovery of extra-solar X-rays using an Aerobee 150 sounding rocket in 1962. Sounding rockets are named for the nautical term "to sound," which means to take measurements. Even in the current era of large X-ray observatories, X-ray sounding rockets continue to play an important role in both X-ray observational science and technology development. Investigations which involve building an X-ray sounding rocket payload are funded through NASA's Astrophysics Research and Analysis (APRA) program and utilize NASA's Sounding Rocket Program, operated out of Wallops Flight Facility in Virginia. Currently there are 5 funded investigations that include a sounding rocket payload for X-ray astronomy. All of these projects have significant science goals and many of them demonstrate new technology. In fact, many of these new technologies are relevant to PCOS, including cryogenic X-ray detectors, very low temperature cryogenic systems, precision X-ray grating spectrometers, light-weight high-efficiency X-ray optics, wide field-of-view X-ray optics, X-ray polarimeters, and on-board modulated X-ray calibration sources. Below are brief descriptions of the five currently funded investigations. There are generally many more proposed each year than can be funded, demonstrating a rich and vibrant field.

XQC (P.I. Dan McCammon, Univ. of Wisconsin): The X-ray Quantum Calorimeter (XQC) payload has flown 6 times since 1995, most recently in 2013, to observe the diffuse soft-X-ray background at high spectral resolution. The science goals of the XQC are to differentiate, spectrally, the various solar-system and extra-solar contributions to the soft X-ray background. The XQC is also a key technology development platform incorporating cryogenic X-ray calorimeters and ultra-cold cooling systems that were a key predecessor of the SXS instrument on Hitomi. In 2016, the XQC payload received a major upgrade to its data collection and storage system. XQC is scheduled to fly again during an upcoming campaign in Australia.



Cross section of the XQC sounding rocket cryostat. Total weight is 27 kg with electronics and vibration mounts. Credit: Adapted from ApJ,576:188-203, 200

The OGRESS team stands in front of the sounding rocket during its spin balance test. Credit: NASA/OGRESS



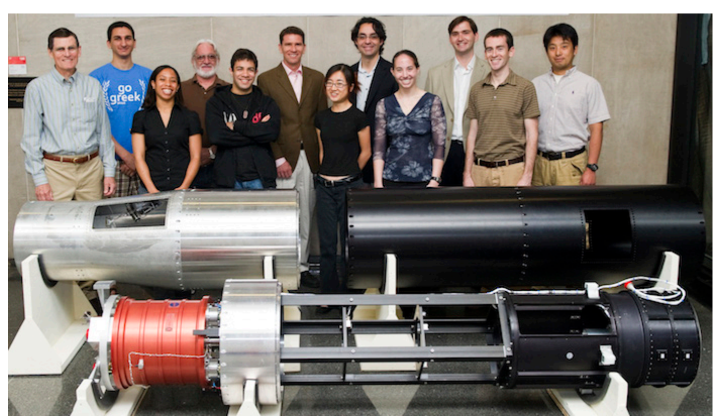
CAD rendering of the OGRE sounding rocket payload. Credit: R McEntaffer

DXL (P.I. Massimiliano Galeazzi, Univ. of Miami): The Diffuse X-ray emission from the Local galaxy (DXL) experiment was designed to spatially differentiate local diffuse emission, produced by the interaction of the solar wind with solar system neutral atoms, from more distant contributions to the soft X-ray background. The payload consists of two large soft-X-ray proportional counters and a novel new instrument (STORM) to demonstrate the in-flight performance of slumped micropore "Lobster-eye" optics. DXL was first launched in 2012. The second successful launch of the payload, dubbed DXL-2, occurred on December 5, 2015.

OGRESS (P.I. Randall McEntaffer, Univ. of Iowa): The Off-plane Grating Rocket for Extended Source Spectroscopy (OGRESS) has successfully flown three times (twice as the Extended X-ray Off-plane Spectrometer, EXOS) to observe the Cygnus Loop supernova remnant, most recently in May 2015. OGRESS uses a wire grid collimator, an off-plane grating, and a GEM detector for high spectral resolution measurements in the Band 100–750 eV. OGRESS is scheduled to fly again in 2018.

Micro-X (P.I. Enectali Figeuroa-Feliciano, Northwestern Univ.): The Micro-X payload includes next generation, transition-edge calorimeters coupled with a lightweight nested-foil X-ray optic and is designed to image bright knots in galactic supernova remnants with high spectral resolution. Micro-X is also a key technology demonstrator for the next generation

The DXL-2 payload is prepared for launch in the NASA payload assembly building at the White Sand Missile Range in New Mexico. Credit: NASA/Ted Gaceki



The Micro-X sounding rocket payload with group members and supporters. Credit: E Figueroa of high spectral resolution X-ray calorimeters. The initial flight of Micro-X is scheduled for November 2016.

OGRE (P.I. Randall McEntaffer, Univ. of Iowa): The Off-Plane Grating Rocket Experiment (OGRE) is a very high resolution (R>1500) spectrometer coupled to a slumped glass X-ray optic to resolve line blends in Capella, a bright, line-rich, binary star, often used as a spectral calibrator for high resolution X-ray spectrometers. OGRE also demonstrates key future technologies including high-resolution off-plane gratings and high throughput, precision, slumped-glass X-ray optics. The initial flight of OGRE is scheduled for 2017.

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Physics of the Cosmos Program Analysis Group (PhysPAG) Report

Jamie Bock, *PhysPAG Chair (Caltech)*
Mark Bautz, *PhysPAG Vice Chair (MIT)*

At the Joint PAG meeting during the January 2016 AAS conference, NASA's Astrophysics Division Director, Paul Hertz, charged the PAGs with evaluating two options for Decadal Survey preparation concerning medium-scale aka Probe-class missions (total cost approximately between $400M and $1B). In discussing these options during the PhysPAG meeting at the conference later the same day, the PhysPAG decided to issue a **call to community** for input in the form of two-page white papers describing possible Probe mission concepts. Fourteen white papers were received and are **posted on the PCOS website**. The **PhysPAG response** to the charge was released in March of this year. The report included a joint statement from all three PAGs concurring with the PhysPAG preference for the option of issuing a solicitation through the ROSES system for study proposals where about 10 would be competitively selected and funded at a level of approximately $100k each for one year. The results would then be presented to the Decadal Survey Committee which would have the option of asking NASA to conduct further studies at higher cost and level of detail for a smaller number (~3) of candidate mission concepts.

Last October, the PhysPAG released its **final report** on flagship mission studies in preparation for the 2020 Astrophysics Decadal Survey. The report was in response to the charge given to the three PAGs by Dr. Hertz in a **January 2015 white paper**. The three PAGs concurred in the report's joint statement that all four large missions identified in the white paper as candidates for concept maturation prior to the 2020 Decadal Survey should be studied in detail. The PhysPAG, in addition, expressed strong support for NASA participation in ESA's L2 and L3 missions, a future Inflation Probe mission, and the importance of Probe-class missions in general.

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PCOS Technology Gaps and the Four Large Mission Concept Studies Starting this Year

Thai Pham, *Program Technologist*
Opher Ganel, *Program Technologist*

In January 2016, NASA Astrophysics Division Director Paul Hertz, **kicked off Science and Technology Definition Teams (STDTs) to study four large mission concepts to inform the 2020 decadal survey**. He announced that NASA is initiating mission concept studies of the following four large mission concepts:

- Far-IR Surveyor;
- Habitable Exoplanet Imaging Mission;
- Large UV/Optical/IR (LUVOIR) Surveyor; and
- X-ray Surveyor.

He charged the STDTs to develop the science case, flow that science case into mission requirements, vet the technology gaps list, and direct trades of science vs. cost/capability.

Study deliverables include the following that affect astrophysics technology development:

- "Deliver Initial Technology Gap Assessment" by June 30, 2016 (optional)
- "Complete Concept Maturity Level 2 Audit… Identify, quantify and prioritize technology gaps for 2017 technology cycle" by February 2017 (required)

Physics of the Cosmos Program Analysis Group (PhysPAG) Executive Committee			
Name	**Affiliation**	**Expertise**	**Term Expiration Date**
J. Bock, Chair	Caltech/JPL	CMB	December 2016
M. Bautz, Vice Chair	MIT	X-rays	December 2016
R. Bean	Cornell University	Dark Energy	December 2016
J. Conklin	University of Florida	Gravitational Waves	December 2017
N. Cornish	Montana State University	Gravitational Waves	December 2016
O. Doré	JPL	Dark Energy	December 2017
R. Kraft	SAO	X-rays	December 2018
H. Krawczynski	Washington University in St. Louis	Gamma-rays	December 2017
M. McConnell	University of New Hampshire	Gamma-rays	December 2016
A. Miller	Columbia University	CMB	December 2017
I. Moskalenko	Stanford University	Particle astrophysics	December 2018
E. Seo	University of Maryland	Particle astrophysics	December 2016
E. Wollack	NASA/GSFC	CMB	December 2017

- "Update Technology Gap Assessments" by June 2017 (optional)
- "Interim report…Deliver initial technology roadmaps" by early December 2017 (required)
- "Update Gap Assessments… In support of 2018 technology cycle" by June 2018 (required)
- "Final Report… Finalize technology roadmaps, tech plan and cost estimates for technology maturity" by January 2019 (required)

As described in our **2015 PCOS Program Annual Technology Report** (PATR), our technology development and maturation process revolves around inputs from the community. This includes input to the decadal survey, submission of technology gaps for prioritization, responding to PCOS Strategic Astrophysics Technology (SAT) calls, and maturing technologies that will enable the future of PCOS science. None of this changes as a result of the STDTs' work. At the same time, the above deliverables will likely have a significant and gradually growing impact on PCOS technology gap prioritization in 2016–2019.

In terms of technology planning, the STDT process concentrates community effort and expertise relevant for each mission concept. However, this should not be seen as precluding community contributions from non-STDT members. It takes a joint NASA/community effort to identify and prioritize technology gaps, and then solicit, fund, and manage the technology maturation projects that will close them.

As in 2015, our Technology Management Board (TMB) considers in July gaps submitted prior to June 1, while those missing that cutoff date are deferred to the following year. This June 1 deadline applies to gaps proposed outside of the STDT process, allowing the PCOS Program Analysis Group (PhysPAG) Executive Committee (EC) the time needed to consolidate new gaps with last year's list, crafting a comprehensive, compelling, and non-redundant set of gaps for TMB prioritization in July. Gaps submitted by the STDTs are due by June 30, and are considered in parallel to non-STDT gaps. Note that given the level of expertise residing in the PhysPAG EC, we would not be surprised to see significant overlap between STDT-submitted gaps and those in the EC's list. The TMB evaluates gaps according to their **Strategic Alignment**, **Benefits and Impacts**, **Scope of Applicability**, and **Urgency**. We expect to use the same criteria in prioritizing STDT-identified gaps and those submitted by others. We will publish this year's priority ranking in our 2016 PCOS PATR, to be released in October.

Refer to the PCOS **PATR** or **PCOS Program website** for more details on PCOS science, technology development program and process, recent gap submissions, priority recommendations for this year's SAT solicitation, and status and plans of all current PCOS SAT projects. Questions or comments on our process or any other aspect of the Program are also welcome and can be directed to **thai.pham@nasa.gov**.

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X-ray Surveyor Study

The X-ray Surveyor is a concept for a scientifically compelling X-ray observatory that would revolutionize our understanding of the physics of astronomical systems and enable frontier science from first accretion light in the Universe to solar system objects. X-ray Surveyor should provide a great leap forward in capability including high angular resolution and throughput for orders of magnitude gains in sensitivity, a large field of view, and high resolution spectroscopy.

X-ray Surveyor is one of four Decadal Survey Mission Concept Studies initiated in January 2016. The study will extend over three years and executed by the Marshall Space Flight Center under the leadership of a Science and Technology Definition Team (STDT) drawn from the community.

More information may be found on the **X-ray Surveyor website**.

Community Chairs of the STDT	
Feryal Özel	University of Arizona
Alexey Vikhlinin	Smithsonian Astrophysical Observatory
Study Scientist and co-chair of the STDT	
Jessica Gaskin	NASA/Marshall Space Flight Center
Members of the STDT	
Steven Allen	Stanford University
Mark Bautz	Massachusetts Institute of Technology
W. Nielsen Brandt	The Pennsylvania State University
Joel Bregman	University of Michigan
Megan Donahue	Michigan State
Ryan Hickox	Dartmouth University
Tesla Jeltema	UC Santa Cruz
Juna Kollmeier	Carnegie Institution for Science
Laura Lopez	The Ohio State University
Piero Madau	UC Santa Cruz
Rachel Osten	Space Telescope Science Institute
Frits Paerels	Columbia University
Michael Pivovaroff	Lawrence Livermore National Laboratory
David Pooley	Trinity University
Andrew Ptak	NASA/Goddard Space Flight Center
Eliot Quataert	University of California Berkeley
Christopher Reynolds	University of Maryland
Daniel Stern	Jet Propulsion Laboratory
Ex-Officio observers of the STDT	
Ann Hornschemeier	NASA/Goddard Space Flight Center (PCOS Program Office Chief Scientist)
Daniel Evans	NASA Headquarters (X-ray Surveyor Program Scientist)
Robert Petre	NASA/Goddard Space Flight Center (Chief, GSFC X-ray Astrophysics Laboratory)
Randall Smith	Smithsonian Astrophysical Observatory (Athena Liaison)

L3 Study Activity

NASA intends to partner with ESA on the third Large-Class mission (L3) in ESA's Cosmic Vision 2015-2025 Programme, planned for launch in 2034. ESA has selected a gravitational wave observatory as the science theme. To this end, NASA is starting a study conducted by selected members of the community by forming an L3 Study Team (L3ST). A Dear Colleague Letter was issued on December 7, 2015, soliciting nominations and self-nominations for the L3ST, with due date December 21, 2015. Submitted applications were reviewed by members of the NASA HQ Astrophysics Division and of the PCOS Program office, who then made selection recommendations.

The purpose of the "L3 Study" is to understand how NASA might participate in ESA's L3 Gravitational Wave mission, to inform our engagement through its earliest stages and to prepare for the 2020 decadal survey. The following individuals have been appointed to serve on the L3ST:

Members of the L3ST

Name	Affiliation
Baker, John	NASA Goddard Space Flight Center
Bender, Peter	University of Colorado at Boulder
Berti, Emanuele	University of Mississippi
Conklin, John	University of Florida
Cornish, Neil	Montana State University
Cutler, Curt	Jet Propulsion Laboratory
Holley-Bockelman, Kelly	Vanderbilt University
Hughes, Scott	Massachusetts Institute of Technology
Larson, Shane	Northwestern University
McWilliams, Sean	West Virginia University
Miller, Cole	University of Maryland
Robertson, Norna	California Institute of Technology
Shoemaker, David (Chair)	Massachusetts Institute of Technology
Thorpe, Ira	NASA Goddard Space Flight Center
Vallisneri, Michele	Jet Propulsion Laboratory

Note: Ex-Officio NASA members of the L3ST: R. Sambruna, A. Hornschemeier. In addition, A. Parmar has been appointed by ESA as an observer on the L3ST.

The L3ST will be assisted by a Technology Analysis Group (TAG) who will provide expert knowledge of the technology associated with NASA's possible hardware contributions to ESA.

Members of the Technology Analysis Group (TAG)

Name	Affiliation
Camp, Jordan	NASA Goddard Space Flight Center
Klipstein, William	Jet Propulsion Laboratory
Livas, Jeffrey	NASA Goddard Space Flight Center
McKenzie, Kirk	Jet Propulsion Laboratory
Mueller, Guido	University of Florida
Ziemer, John	Jet Propulsion Laboratory

Message from the Astrophysics Division Director

Paul Hertz, *Astrophysics Division Director, NASA Headquarters*

The NASA Science Mission Directorate (SMD) saw a major leadership change with the departure of Associate Administrator for SMD, John Grunsfeld, in May 2016. Geoffrey Yoder, formerly the Deputy Associate Administrator for SMD, has been appointed the Acting Associate Administrator for SMD. Mr. Yoder is committed to continuing to advance all SMD missions in formulation, development, and operations; integrating strategic planning across all Divisions to further advance NASA objectives and Decadal Surveys; making NASA's technical and capability management more efficient to free up resources for missions and science; and continuing to base NASA's decisions firmly on community input and peer review.

As I described during the NASA Town Hall at the 228th meeting of the American Astronomical Society in San Diego, CA, the Astrophysics Division continues to execute a portfolio that can be broadly divided into Strategic Missions, Explorer Missions, Research and Analysis (R&A), and other cross-cutting activities. We rely on our advisory committees and expert community groups to provide NASA guidance in strategic planning and in the smooth execution of our programs. The fiscal year (FY) 2017 President's budget request, which was submitted to Congress in February 2016 and is the subject of discussion by the Congressional appropriations committees this summer, would provide funding for NASA astrophysics to continue its planned programs, missions, projects, and supporting research and technology; for the operating missions continue to generate important and compelling science results; for the new missions under development for the future; and for continuing progress toward implementing the recommendations of the 2010 Decadal Survey (**http://www.nasa.gov/news/budget/**).

Conditional on Congressional appropriations that support the President's budget request, a modest funding growth in the R&A program will continue in FY2017. In addition to R&A, NASA also funds the community through the mission Guest Observer (GO) programs. The selection rate for proposals in 2015-2016 was 23% for R&A proposals and 28% for GO proposals. 100% of the 2015 selections were announced within 150 days of proposal submission. This year, in addition to the regular research opportunities solicited through the Research Opportunities in Space and Earth Science (ROSES) NASA Research Announcement and through the mission GO programs, a late summer/fall 2016 release date is targeted for Medium-class Explorer (MIDEX) and Explorers Mission of Opportunity solicitations (**http://explorers.larc.nasa.gov/APMIDEX2016/**).

The NASA 2016 Astrophysics Senior Review was held during February and March 2016. Eight missions (Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Swift, and

XMM-Newton) were evaluated in three review panels. The Hubble Space Telescope and the Chandra X-Ray Observatory were reviewed in standalone panels, as these are core facilities for the community, mature and stable missions with no operational changes. The Senior Review panels found no scientific reason to discontinue or significantly reduce any of the missions under review and that the scientific value of the complete operating mission portfolio is greater than the sum of its parts. The panels encouraged NASA to continue all of these missions. Based on the report of the 2016 Astrophysics Senior Review, and conditional on Congressional appropriations that support the President's budget request, NASA approved all eight missions for continued operations through FY2017 and FY2018. The full reports of the 2016 Astrophysics Senior Review panels and NASA's response can be found at **http://science.nasa.gov/astrophysics/2016-senior-review-operating-missions/**.

With the spring 2016 New Zealand Super Pressure Balloon (SPB) campaign completed, NASA has demonstrated a new capability for ultra-long duration balloon (ULDB) missions at mid-latitudes. Launched on May 11, 2016, from Wanaka, New Zealand, the SPB circumnavigated the globe for ~46 days, terminating in a remote area of Peru on July 2, 2016. Aside from the technology test of the balloon itself, the SPB carried the Compton Spectrometer and Imager (**COSI**) gamma ray telescope (PI: Steven Boggs, U.C. Berkeley) as a science payload-of-opportunity. Information on the SPB campaign, including the round-the-world flight track of the mission and a link to the **COSI** team's home page, is available at **http://www.csbf.nasa.gov/newzealand/wanaka.htm**. Additional balloon campaigns are planned this year from Palestine, Texas, Ft. Sumner, New Mexico, and McMurdo Station, Antarctica.

Operating mission news includes:

- The LISA Pathfinder mission began science operations on March 1, 2016, with a successful performance of the ESA test package. Commissioning of the NASA experiment, the Disturbance Reduction System (DRS), started at the end of June.
- Following successful activation of the observatory and instruments, Hitomi (ASTRO-H) suffered a mission-ending spacecraft anomaly on March 26, 2016. Prior to mission failure, the NSA-provided Soft X-ray Spectrometer (SXS) demonstrated a spectral resolution of ~4.7 eV, significantly exceeding the science requirement. The SXS completed several science observations, including a scientifically important observation of the Perseus Cluster, before the anomaly.
- The Stratospheric Observatory for Infrared Astronomy (SOFIA) started conducting Cycle 4 observations in February 2016, and is in New Zealand through mid-July 2016 for southern hemisphere observations. The German second generation instrument, upGREAT, a multi-pixel heterodyne spectrometer, has been commissioned, and the testing and commissioning of the U.S. second generation instrument, HAWC+, a far infrared imager & polarimeter, is under way. The downselect for a third generation instrument will be made in September 2016.

Missions in development news includes:

- The Neutron star Interior Composition Explorer (NICER) and Cosmic Ray Energy and Mass (CREAM) payloads are in storage at Kennedy Space Center awaiting launches to the International Space Station in 2017.
- The Transiting Exoplanet Survey Satellite (TESS) project has begun fabrication and integration of all flight systems; TESS is planning a December 2017 launch.
- The James Webb Space Telescope has achieved major milestones during the past year, including installation of all 18 telescope mirrors into the telescope backplane and integration of all four science instruments into the telescope at Goddard Space Flight Center, completion of the cryocooler for the Mid-Infrared Instrument (MIRI) at Jet Propulsion Laboratory, first powering of the spacecraft bus at Northrup Grumman, and completion of the second test of the pathfinder telescope and ground support equipment at Johnson Space Center. Planning has begun for early release observations and the Cycle 1 GO call in late 2017. More information on Webb is at **http://jwst.nasa.gov/** and **https://jwst.stsci.edu/**.
- The Wide-Field Infrared Survey Telescope (WFIRST), the highest large mission priority of the 2010 Decadal Survey, became a new NASA project when it entered the formulation phase (Phase A) in February 2016. The Formulation Science Working Group has begun meeting under the leadership of Neil Gehrels (Goddard Space Flight Center), David Spergel (Princeton U.), and Jeremy Kasdin (Princeton U.). The next milestones for WFIRST are the System Requirements Review (SRR) in June 2017 and starting Phase B (KDP-B) in October 2017. More information on WFIRST is at **http://wfirst.gsfc.nasa.gov/**.

NASA has initiated large mission concept studies to serve as input to the 2020 Decadal Survey. NASA has appointed Science and Technology Development Teams (STDT) and initiated four large mission concept studies: Far Infrared Surveyor, Habitable Exoplanet Imaging Mission, Large Ultraviolet/Optical/Infrared Surveyor, and X-ray Surveyor. The STDTs have a significant role and responsibility to develop a science case, flow the science case into mission parameters, vet the technology gap list, and direct trades of science versus cost/capability for the missions. NASA is also planning to issue a call later in 2016 for medium-size mission concept studies (Astrophysics Probes). Full information on NASA's planning for the 2020 Decadal Survey is at **http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/**.

My entire Town Hall Presentation from the June 2016 AAS meeting is available at **http://science.nasa.gov/astrophysics/documents/**.

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Meet the Einstein Fellows: Wen-fai Fong

Wen-fai Fong grew up in a quaint suburb outside of Rochester, NY. She received double Bachelor's degrees in Physics and Biology at MIT (2008), her Ph.D. in Astronomy & Astrophysics from Harvard University in May 2014, and is currently pursuing her Einstein Fellowship at the University of Arizona in Tucson.

Wen-fai's research focuses on the electromagnetic signatures of compact object mergers, involving either two neutron stars or a neutron star and a black hole. Such systems are the most promising candidates for gravitational wave detections with Advanced LIGO/VIRGO, and are also likely sites for the production of heavy elements in the Universe. For her dissertation research, she showed that short-duration gamma-ray bursts, a class of extremely energetic explosions, likely originate from compact object mergers. As an Einstein Fellow, Wen-fai will build a multi-wavelength observational campaign to characterize gamma-ray burst afterglows, "kilonovae", and other more exotic electromagnetic signatures from compact object mergers to assess their joint detectability with gravitational waves. Such research will be crucial prior to the upcoming era of gravitational wave discovery.

Apart from research, Wen-fai is also passionate about mentoring. Recognizing the importance of her own mentors, Wen-fai started a peer and faculty mentoring program for graduate students while at Harvard. She plans to make such mentoring initiatives an integral part of her career.

PCOS Organization

Program Office

Program Manager:
Mansoor Ahmed, mansoor.ahmed@nasa.gov
Deputy Program Manager:
Azita Valinia, azita.valinia-1@nasa.gov
Chief Scientist:
Ann Hornschemeier, ann.hornschemeier@nasa.gov
Deputy Chief Scientist:
Peter Bertone, peter.bertone@nasa.gov
Chief Technologist:
Harley Thronson, harley.a.thronson@nasa.gov
Technology Development Manager:
Thai Pham, bruce.t.pham@nasa.gov

Headquarters

Program Executive:
Shahid Habib, shahid.habib-1@nasa.gov
Program Scientist:
Rita Sambruna, rita.m.sambruna@nasa.gov
Deputy Program Scientists:
Daniel Evans, daniel.a.evans@nasa.gov
Wilt Sanders, wilton.t.sanders@nasa.gov

Newsletter Editorial Team
Antara Basu-Zych, antara.r.basu-zych@nasa.gov

Calendar of Upcoming PCOS/PhysPAG Events

October 2016	Einstein Fellows Symposium Harvard-Smithsonian Center for Astrophysics Cambridge, Massachusetts
January 3-7, 2017	AAS 229th Meeting Gaylord Texan Hotel & Convention Center Grapevine, Texas PhysPAG, SIG sessions TBD
January 28-31, 2017	APS 'April' Meeting 2017 PhysPAG, SIG sessions TBD
August 16-20, 2017	AAS/HEAD Sixteenth Divisional Meeting Sun Valley, Idaho SIG sessions TBD

To stay up to date on PCOS and the PhysPAG
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