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Physics of the Cosmos Newsletter

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Astrophysics Programs: Where PCOS Fits

Mansoor Ahmed, *PCOS Program Manager*

A great deal has progressed in the PCOS Program since you last heard from us! First and foremost, it is my great pleasure to welcome John Nousek as the new Chair of the PCOS Program Analysis Group (PhysPAG) Executive Committee. The Program Office (PO) is looking forward to continuing to work closely with the PhysPAG in advancing PCOS science and relevant technologies (see John's **PhysPAG Report**)

The PCOS science objectives are best achieved when critical activities such as theoretical research, technology maturation and space mission development are well coordinated. Some of these activities occur outside of the PCOS Program per se, and it is critical that the Program stays abreast of progress made in these activities. The theme for this issue of the newsletter is "PCOS Science and Technology that is NOT in the PCOS Program". We hope this will better inform the community that much of what we do is broader than the program

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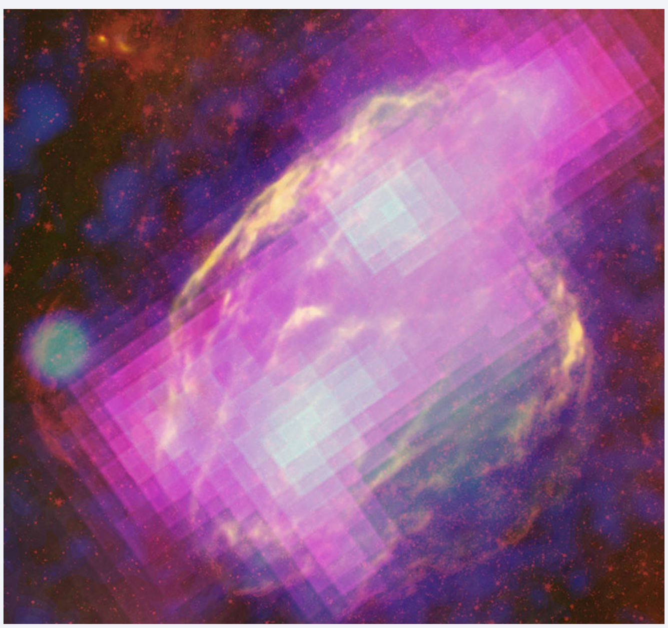
NASA's Fermi Proves Supernova Remnants Produce Cosmic Rays



The W44 supernova remnant is nestled within and interacting with the molecular cloud that formed its parent star. Fermi's LAT detects GeV gamma rays (magenta) produced when the gas is bombarded by cosmic rays, primarily protons. Credit: NASA/DOE/Fermi LAT Collaboration, NRAO/AUI, JPL-Caltech, ROSAT

A new study using observations from NASA's Fermi Gamma-ray Space Telescope reveals the first clear-cut evidence the expanding debris of exploded stars produces some of the fastest-moving matter in the universe. This discovery is a major step toward understanding the origin of cosmic rays, one of Fermi's primary mission goals.

The Fermi results concern two particular supernova remnants, known as IC 443 and W44, which scientists studied to prove supernova remnants produce cosmic rays. IC 443 and W44 are expanding into cold, dense clouds of interstellar gas. These clouds emit gamma rays when struck by high-speed particles escaping the remnants.

Scientists previously could not determine which atomic particles are responsible for emissions from the interstellar gas clouds because cosmic ray protons and electrons give rise to gamma rays with similar energies. After analyzing four years of data, Fermi scientists see a distinguishable feature in the gamma-ray emission of both remnants. The feature is caused by a short-lived particle called a neutral pion, which is produced when cosmic ray protons smash into normal protons. The pion quickly decays into a pair of gamma rays, emission that exhibits a swift and characteristic decline at lower energies. The low-end cutoff acts as a fingerprint, providing clear proof that the culprits in IC 443 and W44 are protons.

Read the full article at **http://www.nasa.gov/mission_pages/GLAST/news/supernova-cosmic-rays.html** itself. Here, I provide a reminder on what is and is not within the PCOS program.

On the research front, the PCOS program includes the Einstein Fellows program, which is administered through the Smithsonian Astrophysical Observatory. The Program Office remains apprised of the scientific achievements of our Fellows (see the feature story on one of the new Fellows, **Selma de Mink**).

The PCOS program includes the Strategic Astrophysics Technology (SAT) awards. To facilitate a fair and open competition, selections are made by NASA HQ through an independent peer review process. The PO plays an important role in informing the technology developers as well as the HQ selection committee of the PCOS technology needs and priorities via the PCOS **Program Annual Technology Report**, released each October.

The Astrophysics Research and Analysis Program (APRA) is not part of PCOS, although it enables a lot of interesting technology development—including a vibrant suborbital program—that is extremely relevant to PCOS science objectives (see contributions on **cosmic microwave background balloons** by Shaul Hanany et al., and on **X-ray sounding rockets** by Scott Porter). The PO interactions with the PhysPAG play a critical role in staying current with the progress in these areas.

On the space missions front, **Planck**, **Chandra**, **XMM-Newton,** and **Fermi** are formally within the PCOS portfolio (see the boxes containing science highlights from these missions). **Euclid**, which is ready to enter its Implementation phase, also falls within the PCOS portfolio (see the contributed piece by Jason Rhodes and Michael Seiffert). ESA is the lead agency for Euclid, Planck, and XMM-Newton.

Several other missions conduct PCOS-related science, funded under the Explorers Program and including partnerships with ESA, JAXA and other NASA programs like the International Space Station (see Angela Olinto's piece on **cosmic ray experiments** on the ISS). The recently launched NuSTAR mission and upcoming Astro-H and NICER Explorer Missions of Opportunity are "related missions," and the PCOS program stays well connected with these missions through interactions with the PIs and Program Scientists (see the **NuSTAR** science highlight, and boxes on **Astro-H** and **NICER**).

The articles in this issue of the newsletter will further expand on the role of the Program across all crosscutting activities that are valuable in achieving PCOS science goals. We hope you enjoy the newsletter and find it informative about the program (what is within the program and what isn't). As ever, please do not hesitate to **contact us** with questions.

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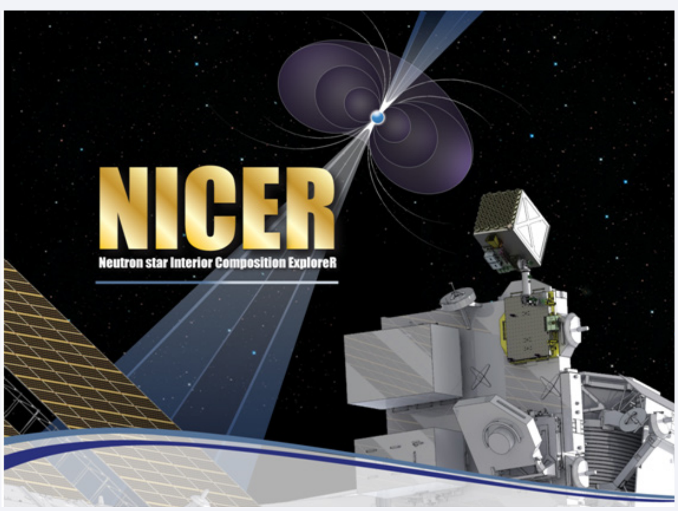
PCOS Science That Isn't in the Program

Ann Hornschemeier, *PCOS Chief Scientist*
Alan Smale, *PCOS Deputy Chief Scientist*

As you can see, the theme of this newsletter is "PCOS Science and Technology that is not in the PCOS Program." We had a little bit of fun with this. You will notice we have added many more "boxes" this time to include all our related missions, both operating (**Suzaku**, **Swift**, **NuSTAR**) and in development (**Astro-H** and **NICER**) in addition to our regularly featured in-program missions (**Chandra**, **XMM-Newton**, **Fermi**, and **Planck**). For completeness we've also included our in-development missions (**Euclid** and **LISA Pathfinder/ST-7**).

The breadth of science PCOS covers is staggering and to some degree is always within the program. As scientists we must remain apprised of progress in all areas. For example, the cosmic microwave background results from Planck and from both ground-based and **balloon payload experiments** feed directly into plans for an eventual Inflation Probe study. Under "behavior of matter at extremes," the action is currently in two places, in one of our program operating missions, Fermi, and on the **ISS**, well outside the PCOS program, where revolutionary cosmic-ray experiments are operating and many new experiments will be installed in years to come.

Neutron star Interior Composition ExploreR (NICER): PCOS Science on the Space Station



A recent addition to the PCOS "related mission" list is the Neutron star Interior Composition Explorer (NICER), which is planned for a 2016 deployment onto the International Space Station via the Explorers program as a Mission of Opportunity. NICER will explore the exotic states of matter within neutron stars, where density and pressure are higher than in atomic nuclei, confronting theory with unique observational constraints. Energy-resolved timing in the 0.2–12 keV X-ray band holds the key to understanding the extraordinary gravitational, electromagnetic, and nuclear-physics environments embodied by neutron stars.

NICER will feature grazing-incidence optics coupled with silicon drift detectors, actively pointed over nearly a full hemisphere of sky, providing photon-counting spectroscopy and timing—registered to GPS time and position—with high throughput and low background. With its unprecedented sensitivity, NICER will probe the interior structure of neutron stars, the physics of dynamic phenomena such as thermonuclear bursts, and the mechanisms at work in neutron star magnetospheres, among the most powerful cosmic particle accelerators known.

NICER's robust design is compatible with the ISS visibility, vibration, and contamination environments, allowing the mission to exploit established infrastructure with low risk. In addition to advancing a vital multi-wavelength approach to neutron star studies through coordination with radio and gamma-ray observations, NICER will have a response time on the order of a few minutes several times a day for targeting of transients.

More information can be found at **http://heasarc.gsfc.nasa.gov/docs/nicer/**

Of course science performance is inherently linked to technology development and we often have to look broadly to maximize the science yield from our missions. Our understanding of the performance of a future gravitational wave observatory—and indeed the U.S. capability for participating in a future space-based gravitational wave mission—demands we understand well the **LISA Pathfinder experiment,** both the U.S.-contributed ST-7 payload and the European experiment. Details of the performance of the NASA-contributed H2RG detectors that will be part of the **ESA's Euclid experiment** connect to survey design and science yield of the mission. As we explore the possibilities for U.S. participation in a Euclid Data Center, we must remain cognizant of both current and future ground-based Dark Energy surveys. After Euclid, revolutionary dark energy science will be conducted with WFIRST (which is in the Exoplanets portfolio). Again, the dark energy *science* is in the PCOS portfolio as are parts of **the H4RG detector** development.

Another area of science that crosses programs and themes is the evolution of black holes and how they link to galaxy evolution. While our X-ray observatories continue to make progress on this topic for black holes large and small (see **Chandra** and **NuSTAR** releases), X-ray detectors also enable important discoveries in stellar evolution including what powers pulsars and the nature of Type Ia supernova explosions (see **XMM** and **Suzaku** releases). And as we sit on the threshold of Advanced LIGO making gravitational wave detections, awareness is building that another powerful probe of SMBH growth at $z > 10$ would be a space-based gravitational wave facility. As we must consider black hole and galaxy growth together, this takes us to "cosmic origins" topics of galaxy evolution.

One science nugget in this newsletter isn't in the PCOS program at all. Some of the same laser interferometric technology developed for LISA is being put to use on **GRACE follow-on**, an earth science mission.

It makes things exciting when *everything* is relevant. Choosing sessions at American Physical Society meetings is next to impossible as we run between cosmic ray, cosmology and gravitational wave sessions. We hope this newsletter gives you a feel for all the great high energy astrophysics and cosmology going on in NASA astrophysics, whether it is formally sorted into PCOS or not.

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Cosmic Microwave Background Radiation Polarization Experiments

Shaul Hanany, *University of Minnesota*
Bill Jones, *Princeton University*
Al Kogut, *NASA/GSFC*

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 released during the epoch of inflation 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 'Inflationary B-modes', is a direct probe of Inflation and of fundamental physics at energy scales a trillion times higher than accessible to ground-based

NuSTAR: Black Hole Naps Amidst Stellar Chaos

Nearly a decade ago, NASA's Chandra X-ray Observatory caught signs of what appeared to be a black hole snacking on gas at the middle of the nearby Sculptor galaxy. Now, NASA's Nuclear Spectroscopic Telescope Array (NuSTAR), which sees higher-energy X-ray light, has taken a peek and found the black hole asleep.

NGC 253 (Sculptor Galaxy) image. Color (red/orange) overlay shows NuSTAR hard X-ray data. Background black and white image is in the optical band. Credit: NASA/JPL-Caltech/JHU

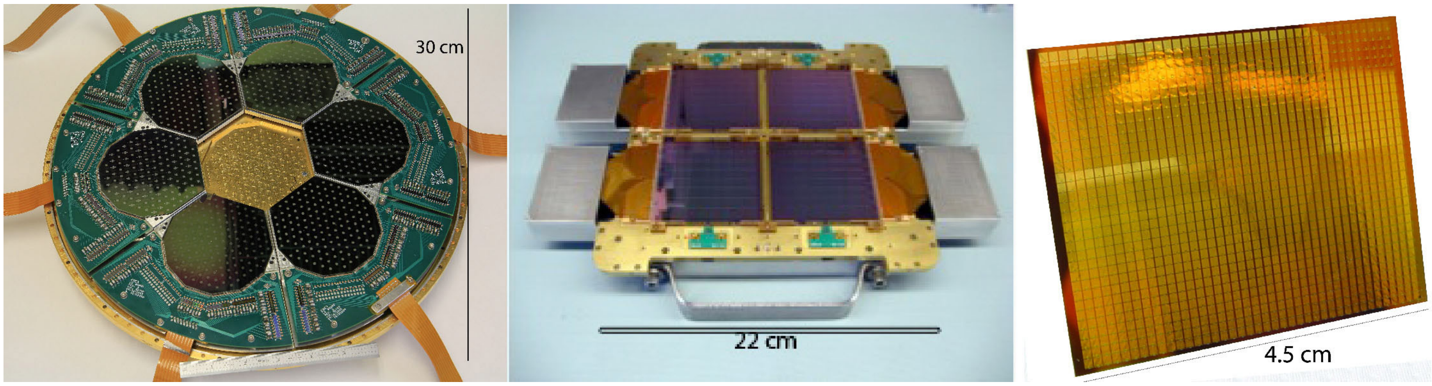
The slumbering black hole is about 5 million times the mass of our sun. It lies at the center of the Sculptor galaxy, also known as NGC 253, a so-called starburst galaxy actively giving birth to new stars. At 13 million light-years away, this is one of the closest starbursts to our own galaxy, the Milky Way, which is all around quieter than the Sculptor galaxy. It makes far fewer new stars, and its behemoth black hole, about 4 million times the mass of our sun, is also snoozing.

The findings are teaching astronomers how galaxies grow over time. Nearly all galaxies are suspected to harbor supermassive black holes at their hearts. In the most massive of these, the black holes are thought to grow at the same rate that new stars form, until blasting radiation from the black holes ultimately shuts down star formation. In the case of the Sculptor galaxy, astronomers do not know if star formation is winding down or ramping up.

Chandra first observed signs of what appeared to be a feeding supermassive black hole at the heart of the Sculptor galaxy in 2003. Then, in September and November of 2012, Chandra and NuSTAR observed the same region simultaneously. The NuSTAR observations—the first-ever to detect focused, high-energy X-ray light from the region—allowed the researchers to say conclusively that the black hole is not accreting material. NuSTAR launched into space in June of 2012.

In other words, the black hole seems to have fallen asleep. Another possibility is that the black hole was not actually awake 10 years ago, and Chandra observed a different source of X-rays. Future observations with both telescopes may solve the puzzle.

Read the full article at **http://www.jpl.nasa.gov/news/news.php?release=2013-198**



Focal planes with thousands of transition edge sensor bolometers are now moving to TRL6 through use on balloon borne payloads that measure the polarization of the cosmic microwave background radiation. Different design approaches are being tested by different experiments providing valuable information about technical trade-offs and giving rise to different systematic uncertainties. Left: for its flight launched in 12/2012 EBEX used two focal planes, each with seven wafers (dark decagons) and 140 bolometers/wafer (white dots). (The central wafer is missing in this photograph.) Center: One of the six focal planes that will be used by SPIDER in the upcoming 12/2013 flight. This focal plane has 512 polarization sensitive bolometers. Right: Focal plane for the PIPER experiment containing 1280 bolometer. Each flight will use 4 such focal planes

accelerators. The recent New Worlds New Horizons Decadal Survey panel stated: "The convincing detection of B-mode polarization in the CMB produced in the epoch of reionization would represent a watershed discovery". Polarization signatures on smaller angular scales that arise from gravitational lensing of the CMB photons by the distribution of mass 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 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. 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 an excellent training ground for the nation's future space scientists and engineers.

All three experiments are attempting to either detect or set progressively 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: 90–220 GHz for SPIDER, 150–410 for EBEX, and 200–600 GHz for PIPER. The three payloads use transition edge sensor 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

Astro-H: An Interagency Cross-Program Collaboration

The joint JAXA/NASA Astro-H mission will investigate the physics of the high-energy universe using high-resolution, high-throughput spectroscopy. NASA participation in Astro-H is funded as a Mission of Opportunity under the Explorers Program and is thus a PCOS "related mission" in a manner similar to Suzaku. Astro-H is comprised of four complementary instruments spanning 0.3–600 keV. The Soft X-ray Spectrometer (SXS), developed jointly by the NASA/GSFC and JAXA's Institute of Space and Astronautical Science (ISAS), is a high-resolution, non-dispersive X-ray spectrometer sensitive over 0.3–12 keV. It consists of a ~ 1 arcmin X-ray mirror and a 6 × 6 microcalorimeter array (3' × 3') operating at 50 mK using a multi-stage cooling system designed to operate more than three years. The system will have an energy resolution of 5–7 eV and a collecting area > 200 cm^2 at 7 keV. Three additional instruments, provided by ISAS/JAXA, extend the band pass to create an observatory with extraordinary capabilities. The Soft X-ray Imager (SXI) covers a large field of view CCD operating at 0.3–12 keV. The Hard X-ray Imager (HXI) will perform sensitive imaging spectroscopy in the 5–80 keV band using specially coated X-ray optics while the non-imaging Soft Gamma-ray Detector (SGD) extends the observatory's energy band to 600 keV. Astro-H is under construction now and will be launched into low-Earth orbit in 2015 from the Tanegashima Space Center on a H-IIA rocket. A U.S. Data Center is also being developed to support a funded Guest Investigator program.

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 transition-edge sensor bolometers, readout using SQUID amplifiers, was used on a balloon-borne platform. SPIDER is scheduled to deploy to Antarctica this year. At the time of this writing the team is in a NASA base in Texas for integration and testing prior to shipping the payload. PIPER is planning a series of 8 short (0.5–3 days) flights, alternating launches between North America and Australia sites to observe both the northern and southern sky. The combined flights achieve nearly full-sky coverage otherwise possible only from satellite platforms. The first flight of PIPER is planned for 2014.

The Broader Context

A number of ground based experiments and the Planck satellite are also making significant advances in mapping the polarization of the CMB. Planck is scheduled to release its polarization results in mid 2014. The ground-based Background Imaging of Cosmic Extragalactic Polarization (BICEP), Polarbear, and South Pole Telescope Polarization experiment (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. Within the next 18 months all of NASA's current CMB balloon payloads should have flown for the first time and a stream of new results from many CMB polarization experiments are forthcoming. The community is expecting a very exciting period.

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The Synergy between Manned Space Flight and PCOS: The Example of Cosmic Ray Experiments on the Space Station

Angela Olinto, *University of Chicago, Chair Cosmic Ray Study Analysis Group*

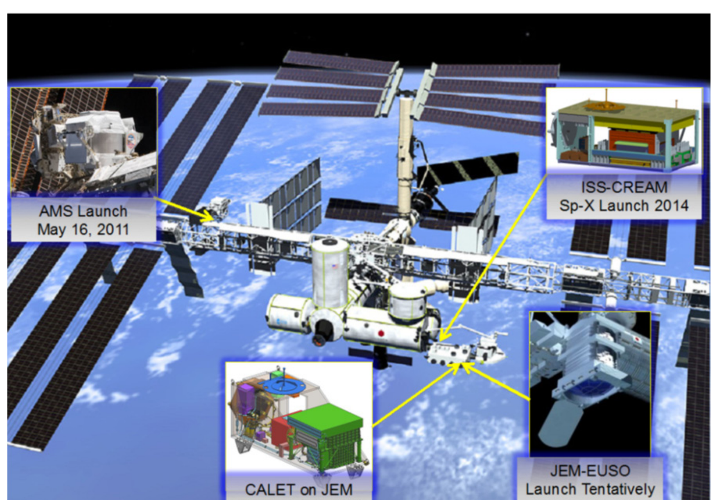
Among the most anticipated scientific results at the 33rd International Cosmic Ray Conference (ICRC) were a series of high-statistics measurements announced by the Alpha Magnetic Spectrometer (AMS) collaboration. This biennial meeting that took place July 2–9, 2013, in Rio de Janeiro, Brazil, is the most important conference in the field of cosmic rays. As a reminder, scientifically, cosmic rays fit into the PCOS portfolio under the "Behavior of Matter under Extreme Conditions".

AMS is a versatile, state-of-the-art cosmic ray instrument operating on the International Space Station (ISS) since May 2011. Programmatically, this experiment is not within the PCOS portfolio because it is scientifically led by Department of Energy and major NASA funding comes from Human Exploration and Operations Mission Directorate. AMS released their first results in March 2013: a measurement of the positron fraction from 0.5 to 350 GeV (PRL 110, 14, 2013). This confirmed, and extended to higher energy, the puzzling excess of the high-energy positron to total electron fraction compared to expectations from current models of secondary nuclear production and galactic transport that was reported earlier by the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA). This may result from a nearby cosmic-ray accelerator such as a pulsar or the annihilation of dark matter particles. Other astrophysical explanations are also possible, including propagation effects. AMS may settle this open question as its measurements extend to yet higher energies, facilitated by long-term operation on the ISS. At the ICRC, AMS also reported the spectra of cosmic ray protons, helium nuclei, positrons, and electrons, the boron to carbon ratio, and tests of anisotropy.

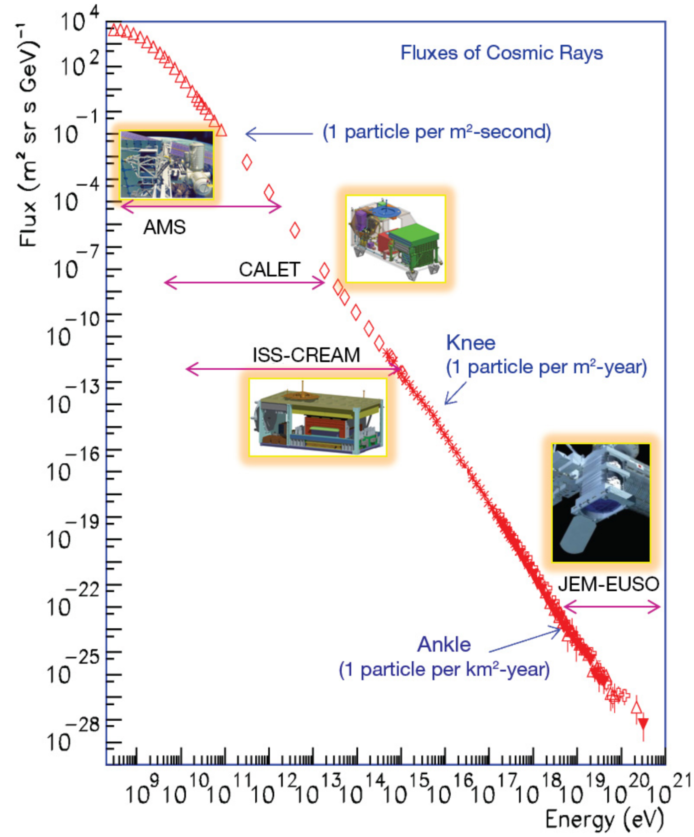
Cosmic ray instruments do not require fine pointing and the ISS is an excellent platform with a fairly high inclination, low Earth orbit and supplying power, cooling, and telemetry. The success of AMS confirms that the ISS is as an outstanding site for fundamental research in cosmic rays. Two more cosmic ray payloads are already scheduled to join AMS on the ISS. In 2014, the CALorimetric Electron Telescope (CALET) and the Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) will be deployed to the Japanese Experiment Module (JEM) of the ISS. The Extreme Universe Space Observatory (JEM-EUSO) has also been planned for the ISS and could join CALET and ISS-CREAM on the JEM as early as 2017. It should be expected that other cosmic ray instruments will be proposed for the ISS.

CALET will measure the total electron spectrum up to ~20 TeV, complementing the AMS electron-positron study and extending Fermi and AMS electron measurements to search for electron sources at energies above the limit of the distant source spectrum. It will also measure nuclei to energies approaching the "knee" in the cosmic ray spectrum at ~PeV total energy and TeV gamma rays. The CALET payload also includes a gamma-ray burst monitor (CGBM).

ISS-CREAM will study the acceleration of Galactic cosmic rays by extending to knee energies direct measurements of the flux of different cosmic ray components from protons to iron nuclei. This ISS experiment builds on experience with six balloon flights in Antarctica, which provided 161 combined days of exposure and gave the CREAM instrument exceptional reach for measuring nuclear cosmic ray spectra. Reconfigured



Location of current and pending cosmic ray experiments on the International Space Station.



Cosmic ray spectrum with energy ranges of current and pending experiments shown.

for the ISS, it can reach much higher energies than would be possible even with many more balloon flights, by taking advantage of the long-term exposure provided by the ISS platform.

JEM-EUSO will search for the powerful, and as yet unidentified, sources of the highest energy cosmic rays, which have been detected at greater than 10^{20} eV, the energy of a fast baseball possessed by a single subatomic particle. JEM-EUSO is a downward looking ultraviolet telescope with a very wide field of view. It will monitor the night atmosphere from above to detect and measure fast fluorescence light traces produced by cosmic ray induced extensive air showers, and so use the atmosphere as a vast calorimeter to determine the energies and arrival directions of the particles. The mission will reach the unprecedented annual exposure of 60,000 km^2 sr yr, which is about nine times the annual exposure of the largest ground based observatory at the highest energies.

The combination of AMS, CALET, and ISS-CREAM will make the ISS the most capable observatory to date for cosmic ray research. In the future, JEM-EUSO may expand this further to the highest energies. From understanding the origins of Galactic and extragalactic cosmic rays, and perhaps to unveiling the nature of the dark matter, this combined effort is certain to lead to fundamental discoveries.

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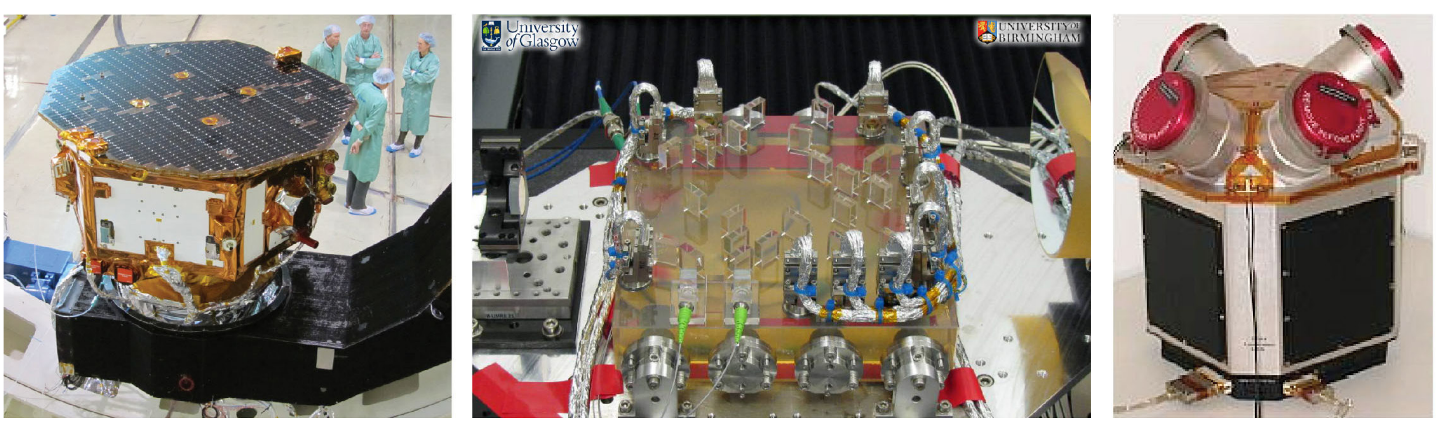
Paving the Way for Gravitational Wave Detection in Space: LISA Pathfinder, the LISA Technology Package, and ST7-DRS

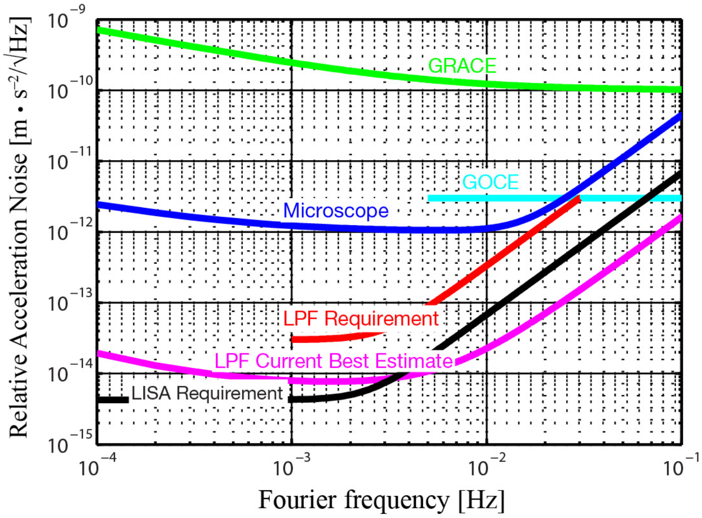
Ira Thorpe, *NASA/GSFC*
Curt Cutler, *NASA/JPL*

LISA Pathfinder (LPF) is a dedicated technology demonstration mission for a future space-based observatory of gravitational waves in the milliHertz band. Although the formal NASA/ESA partnership on the LISA mission was dissolved in the Spring of 2011, both agencies are actively pursuing concepts for LISA-like gravitational wave observatories that take advantage of the significant technology development efforts that have already been made, especially those of LPF. Led by the European Space Agency, LPF includes major hardware contributions from several European national agencies as well as a contribution from NASA in the form of the Space Technology 7 Disturbance Reduction System (ST7-DRS). LPF will validate a number of key technologies for LISA-like gravitational wave detectors, including inertial reference sensors, ultra low-noise drag-free flight, and micro-Newton thrusters. The heart of LPF is the European-provided LISA Technology Package (LTP), whose main components are two gravitational reference sensors, an interferometric measurement system, and cold gas micro-thrusters.

The LPF spacecraft, which was completed more than a year ago, has recently exited a hibernation phase in preparation for the delivery and integration of the cold gas micro-thrusters. A number of technical issues that have contributed to launch delays for LPF have recently been successfully addressed including the launch-lock mechanism for the test masses and the micro-propulsion system. Following delivery of the payload, the LTP will join ST7-DRS, which was integrated with the



Left: The completed LPF spacecraft undergoing an on-station thermal test prior to integration of the science payloads. Center: The LTP optical bench generates the optical signals required to measure picometer changes in the test mass positions. Right: ST7's colloidal microthrusters will be used to precisely control the position and attitude of LPF.



Performance comparison of various implemented and proposed space missions with low-acceleration environments.

LPF spacecraft in 2011. Launch is planned on a VEGA rocket from Kourou, French Guiana in July of 2015. After approximately 90 days of cruise and commissioning, LTP will begin science operations in a Lissajous orbit around the Earth-Sun L1 point. After 90 days of LTP operations, ST7-DRS will conduct 60 days of operations followed by a possible joint-operations phase targeting additional technology studies and fundamental physics experiments.

Once LPF reaches its operational orbit, each gravitational reference sensor will release a 46 mm cube of Au-Pt alloy into free flight. A combination of capacitive and interferometric sensors will measure the position and attitude of these test masses relative to the spacecraft and to one another. The drag-free control loop will command the spacecraft to follow one of the test masses by activating the micro-Newton thrusters. In this way, the spacecraft acts as a sort of 'flying shield', isolating the test mass from external disturbances such as solar radiation pressure. The second test mass, electrostatically suspended in its housing, will act as a low-disturbance witness to measure the residual acceleration of the drag-free test mass. LTP intends to demonstrate a residual acceleration of ~3×10^{-14} m/s^2/Hz$^{1/2}$ at a Fourier frequency of 1mHz, or about 10^{-16} g. This represents a roughly two orders of magnitude advance over inertial reference systems in other existing or planned missions.

In addition to the LTP, LPF carries the NASA-provided ST7-DRS payload consisting of alternative micro-Newton thrusters based on a technology known as colloidal micro-propulsion as well as a computer implementing an independently-developed drag-free control system. ST7-DRS will use the sensor input provided by the LTP to complete the drag-free control loop, validating both the control algorithms as well as the micro-thruster technologies. The colloidal micro-thrusters, developed through a partnership of JPL and Busek Co, Inc., produce thrust by electrically charging small droplets of propellant and accelerating them through an electric field. This is similar to ink-jet printer technology, except that a typical ink-jet printer head produces a thrust that is approximately 100x larger. Demonstrating precise control and reliability of the colloidal microthrusters in an operational environment is a major goal of ST7-DRS.

A key objective of LPF is to validate a physics-based model for the residual acceleration on the drag-free test mass. Such a model can be used to extend the results of LPF to future LISA-like GW missions, which will operate at lower frequencies and with increased performance in different orbital environments. This validation will be accomplished by conducting

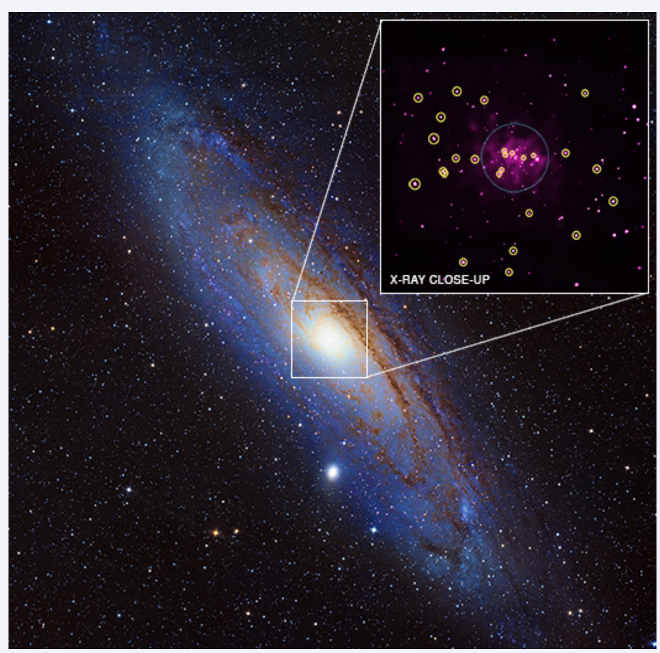
NASA's Chandra Turns up Black Hole Bonanza in Galaxy Next Door

Using data from NASA's Chandra X-ray Observatory, astronomers have discovered an unprecedented bonanza of black holes in the Andromeda Galaxy, one of the nearest galaxies to the Milky Way. From more than 150 Chandra observations, spread over 13 years, researchers identified 26 black hole candidates, the largest number to date, in a galaxy outside our own.

The black hole candidates belong to the stellar mass category, meaning they formed in the death throes of very massive stars and typically have masses five to 10 times that of our sun. Astronomers can detect these otherwise invisible objects as material is pulled from a companion star and heated up to produce radiation before it disappears into the black hole.

The first step in identifying these black holes was to make sure they were stellar mass systems in the Andromeda Galaxy itself, rather than supermassive black holes at the hearts of more distant galaxies. To classify those Andromeda systems as black holes, astronomers observed that these X-ray sources had special characteristics: that is, they were brighter than a certain high level of X-rays and also had a particular X-ray color. Sources containing neutron stars, the dense cores of dead stars that would be the alternate explanation for these observations, do not show both of these features simultaneously. Sources containing black holes do.

The European Space Agency's XMM-Newton X-ray observatory added crucial support for this work by providing X-ray spectra, the distribution of X-rays with energy, for some of the black hole candidates. The spectra are important information that helps determine the nature of these objects.



M31 (Andromeda Galaxy) image. Credit: X-ray (NASA/CXC/SAO/R.Barnard, Z.Lee et al.), Optical (NOAO/AURA/NSF/REU Prog./B.Schoening, V.Harvey; Descubre Fndn./CAHA/OAUV/DSA/V.Peris)

Read the full article at **http://chandra.harvard.edu/press/13_releases/press_061213.html.**

a series of experiments to measure various contributions to the overall acceleration noise. PCOS scientists Ira Thorpe (NASA/GSFC) and Curt Cutler (NASA/JPL) are involved in developing the data analysis pipeline for one of LTP's most crucial experiments, known as the "drift mode". Here, the witness test mass is periodically released from its electrostatic suspension, electrostatically kicked, and allowed to drift ballistically for a few microns before being kicked again. In LISA-like missions, it is crucial that both test masses are free-falling (in the sensitive direction), and the drift-mode experiment is the only LPF experiment that allows one to measure the acceleration noise under this condition.

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NASA's Contribution to the Euclid Mission, an ESA-NASA Partnership

Michael Seiffert, *JPL*
Jason Rhodes, *JPL*

A major new development since the last PCOS newsletter is NASA's participation in the ESA Euclid mission. On January 10, 2013 a Memorandum of Understanding was signed for NASA to officially join ESA's Euclid mission. Euclid is pushing ahead and is on schedule for a 2020 launch, leading to a ~6-year photometric and spectroscopic survey of about a third of the sky. Euclid's science objectives to better understand dark energy, gravity, and dark matter are aligned with those of NASA's PCOS Program and the scientific themes outlines in the Astro2010 Decadal Survey.

NASA will provide detectors and associated electronics for one of Euclid's two instruments, the Near Infrared Spectrometer Photometer (NISP). The Sensor Chip Systems (SCSs) delivered by NASA will each include a Teledyne H2RG (2K by 2K) near infrared detector, a flexible cryogenic cable, and associated cryogenic readout electronics (see figure). NASA will provide 20 such systems (16 for flight and 4 flight spares) to ESA for integration into the NISP. The Goddard Space Flight Center's Detector Characterization Laboratory (DCL) will validate and characterize the performance of the SCSs and their components before delivery to ESA. The NASA contribution will be managed by the Jet Propulsion Laboratory (Project Manager Ulf Israelsson).

In exchange for NASA's hardware contribution, the MoU with ESA specified that NASA would be invited to nominate 40 individual scientists for membership in the ~1200 member Euclid Consortium (EC). The EC is the scientific body set up to provide the NISP and a visible camera (VIS) to ESA and to perform the Euclid scientific analyses. Following the NASA Research Announcement in 2012, peer review selection and final endorsement by ESA and the EC in February 2013, 40 new US scientists joined 14 US scientists who were already part of the EC. These 54 scientists will participate in the full range of Euclid science activities. The three teams, led by Jason Rhodes (JPL), Alexander Kashlinsky (GSFC) and Ranga-Ram Chary (Caltech/IPAC) will pursue science programs in dark energy science as well as science related to galaxy evolution. The NASA Euclid Project Scientist Michael Seiffert, was given the 40th NASA slot.

As part of NASA's contribution to Euclid, NASA was given a seat on the 18-member Euclid Consortium Board, the governing body of the EC and a seat on the 12-member ESA Euclid Science Team, which monitors the overall implementation of Euclid. Jason Rhodes (JPL) is the NASA representative on those bodies.

The NASA hardware contribution to Euclid is proceeding on schedule, and up to-date information on the mission

Participants at the Euclid Consortium (EC) meeting in May 2013 in Leiden, Netherlands. This was the first venue for 40 new NASA-funded science team members to participate in the EC.

The NASA-provided "triplets" for the Euclid NISP instrument each include an H2RG near infrared detector, a cryogenic cable, and a cryogenic readout electronics module based on Teledyne's SIDECAR™ (system image, digitizing, enhancing, controlling, and retrieving) ASIC (Application Specific Integrated Circuit)

can now be found at NASA's Euclid website (**http://euclid.jpl.nasa.gov**). A contract is being negotiated with Teledyne to deliver hardware to NASA for testing and a successful Preliminary Design Review (PDR) for the NASA hardware contribution was held July 17–18, 2013. NASA is currently studying the possibility of the US joining Euclid's Science Ground Segment (SGS). Implementation of the Euclid mission has been proceeding on schedule in Europe as well. The Euclid visible instrument (VIS), NISP, and SGS have all passed recent detailed reviews. ESA has also chosen Thales Alenia Space as the prime contractor for Euclid and EADS Astrium to provide the payload module (including the telescope).

The Euclid Consortium publishes newsletters several times a year. These are archived at **http://www.euclid-ec.org/Documents/Newsletter/.**

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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. 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. X-ray sounding rocket payloads 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 6 funded X-ray payloads in development or being flown. All of these programs have significant science goals and many of them demonstrate new technology. In fact, many of the new tech-

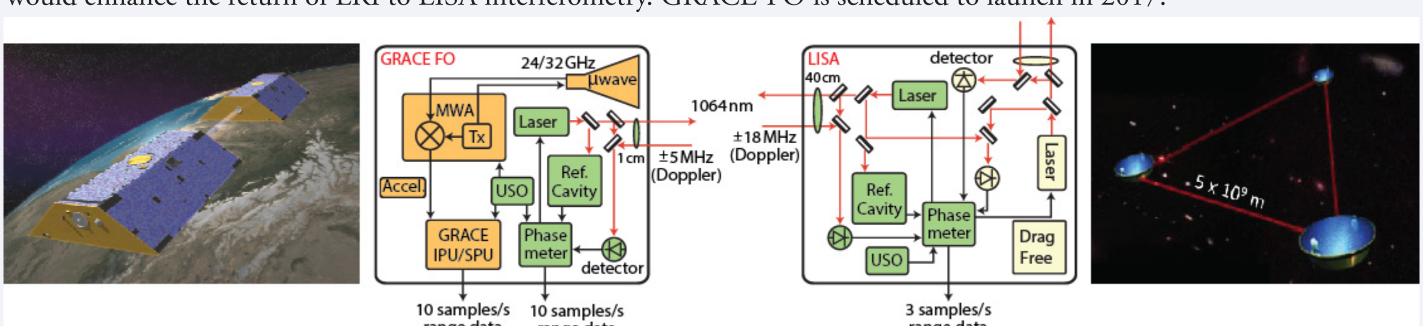
Earth Science Gravity-Sensing Mission to Fly Inter-spacecraft Laser Interferometer

Bill Klipstein, *NASA/JPL*

The GRACE Follow-On (GRACE-FO) mission will include the first-ever inter-spacecraft laser interferometer leveraging off of technology investments from PCOS in support of LISA. The Laser Ranging Interferometer (LRI) will measure fluctuations between two spacecraft in a following polar low-Earth orbit caused by variability in the mass distribution of the Earth. The Gravity Recovery and Climate Experiment (GRACE) mission has used a K and Kα-band microwave link since 2002 to measure these fluctuations with micrometer precision, revealing dramatic effects of climate change; the LRI will demonstrate 20x improvement in this measurement.

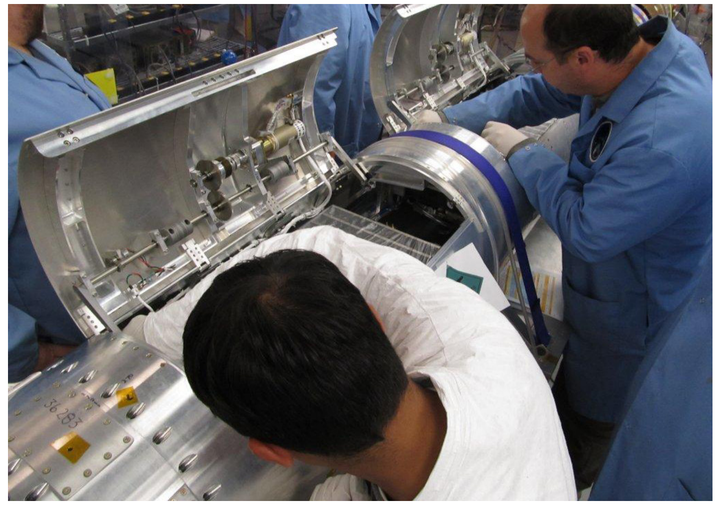
The LISA interferometry team has developed LRI as a simplified version of the LISA interferometer based on component technologies and measurement strategies developed for LISA in the US and Germany. Component technologies include precision phase meters, quadrant photoreceivers, and frequency-stabilized lasers. Component and concept validation for the LRI have relied on capabilities developed in the LISA interferometer testbed and through Earth Science Technology Office funding.

Demonstration of an inter-spacecraft interferometer represents an exciting risk reduction opportunity for LISA even with the simplified optical system and measurement precision 1000x less than LISA. In addition, NASA's APRA program has funded the LISA Experience from GRACE Optical Payload (LEGOP) proposal to explore the possible implementation of LISA interferometry experiments on the LRI hardware. Implementation of the LEGOP experiments during LRI operations would enhance the return of LRI to LISA interferometry. GRACE-FO is scheduled to launch in 2017.



An Earth science mission will use inter-spacecraft interferometer developments from LISA. Spacecraft images for GRACE and LISA shown with schematic of LASER interferometer experiments for each mission

The XQC payload during recovery after landing in the desert at White Sands Missile Range in November 2011.



The DXL payload during horizontal integration testing at White Sands Missile Range in December 2012.

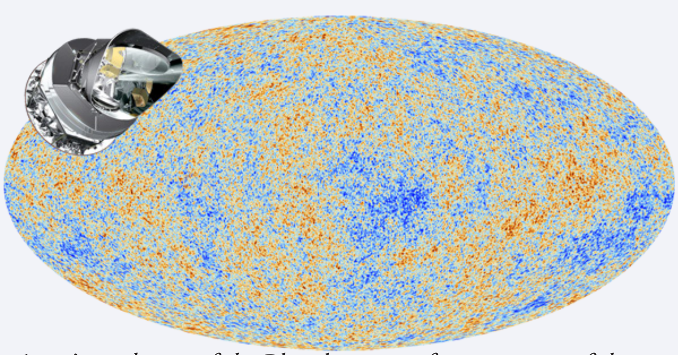
nologies in the current programs are relevant to PCOS including cryogenic X-ray detectors, very low temperature cryogenic systems, precision X-ray grating spectrometers, light-weight high-efficiency X-ray optics, wide field-of-view X-ray optics, X-ray polarimeters, and on-board modulated X-ray calibration sources. Below is a brief description of the currently funded X-ray payloads. There are generally many more payloads proposed each year than can be funded, demonstrating a rich and vibrant field.

XQC (Univ. of Wisconsin): The X-ray Quantum Calorimeter (XQC) payload has flown 5 times since 1995, most recently in 2011, 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 Astro-H**. XQC is scheduled to fly again in 2013.

DXL (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.

OGRESS (Univ. of Iowa, Univ. of Colorado): The Off-plane Grating Rocket for Extended Source Spectroscopy (OGRESS) has successfully flown twice (as the Extended X-ray

Planck Mission Brings Universe into Sharp Focus



Artist's rendering of the Planck spacecraft over a map of the cosmic microwave background observed by Planck. (Spacecraft image: ESA and the Planck Collaboration - D. Ducros)

The Planck space mission has released the most accurate and detailed map ever made of the oldest light in the universe, revealing new information about its age, contents and origins.

The map, based on the mission's first 15.5 months of all-sky observations, reveals tiny temperature fluctuations in the cosmic microwave background, ancient light that has traveled for billions of years from the very early universe to reach us. The patterns of light represent the seeds of galaxies and clusters of galaxies we see around us today.

The age, contents, and other fundamental traits of our universe are described in a simple model developed by scientists, called the standard model of cosmology. These new data have allowed scientists to test and improve the accuracy of this model with the greatest precision yet. At the same time, some curious features are observed that don't quite fit with the simple picture. For example, the model assumes the sky is the same everywhere, but the light patterns are asymmetrical on two halves of the sky, and there is a spot extending over a patch of sky that is larger than expected.

The findings also test theories describing inflation, a dramatic expansion of the universe that occurred immediately after its birth. In far less time than it takes to blink an eye, the universe blew up by 100 trillion trillion times in size. The new map, by showing that matter seems to be distributed randomly, suggests that random processes were at play in the very early universe on minute "quantum" scales. This allows scientists to rule out many complex inflation theories in favor of simple ones.

The map results suggest the universe is expanding more slowly than scientists thought, and is 13.8 billion years old, 100 million years older than previous estimates. The data also show there is less dark energy and more matter, both normal and dark matter, in the universe than previously known. Dark matter is an invisible substance that can only be seen through the effects of its gravity, while dark energy is pushing our universe apart. The nature of both remains mysterious.

Complete results from Planck, which still is scanning the skies, will be released in 2014.

Read the complete article at **http://planck.caltech.edu/news20130321.html**

Off-plane Spectrometer, EXOS) to observe the Cygnus Loop supernova remnant, most recently in 2009. 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 schedule to fly again in 2014.

Micro-X (MIT): 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 of high spectral resolution X-ray calorimeters. The initial flight of Micro-X is scheduled for 2014.

XACT (GSFC): The X-ray Advanced Concepts Testbed (XACT) payload will demonstrate many key technologies that benefit future orbital observatories including time-projection chamber X-ray polarimeters, high throughput, lightweight X-ray concentrators, and modulated X-ray sources. The initial flight of XACT is scheduled for 2015.

OGRE (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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Detector Development For Future Wide-Field Infrared Surveys

Thai Pham, *PCOS Technology Development Manager*

A key technology need that was highly ranked in prioritization by the 2012 PCOS **Program Annual Technology Report (PATR)** is a large-format near-infrared detector. Such detectors would be of use across multiple projects and programs, and would enable very-large-pixel-count surveys that are impracticable or cost-prohibitive using existing technology.

One example is the ongoing study on the Wide-Field Infrared Survey Telescope (WFIRST) dark energy and microlensing mission that is the highest ranked large mission in the most recent Decadal Survey. This concept (**http://arxiv.org/abs/1305.5425**, **http://arxiv.org/abs/1305.5422**, and **http://www.thespacereview.com/article/2304/1**) uses a set of Teledyne Imaging Sensors' HAWAII-4RG 10 µm pixel pitch (H4RG-10) near-infrared sensors (about 0.6–2.5 µm) to provide the wide area coverage required for the surveys. These 4K × 4K format detectors are a reasonable extension from the current-generation H2RG 2K × 2K detectors (in use in many projects, including for the **Euclid** mission), additional development is required to bring them to the same level of maturity so that they can confidently be used on a high-profile mission.

In this spirit, two Strategic Astrophysics Technology (SAT) proposals were funded last year to support this development (Principal Investigators: Bernie Rauscher/GSFC and Selmer Anglin/Teledyne). While the WFIRST project is under the Astrophysics Exoplanet Program, the development for this

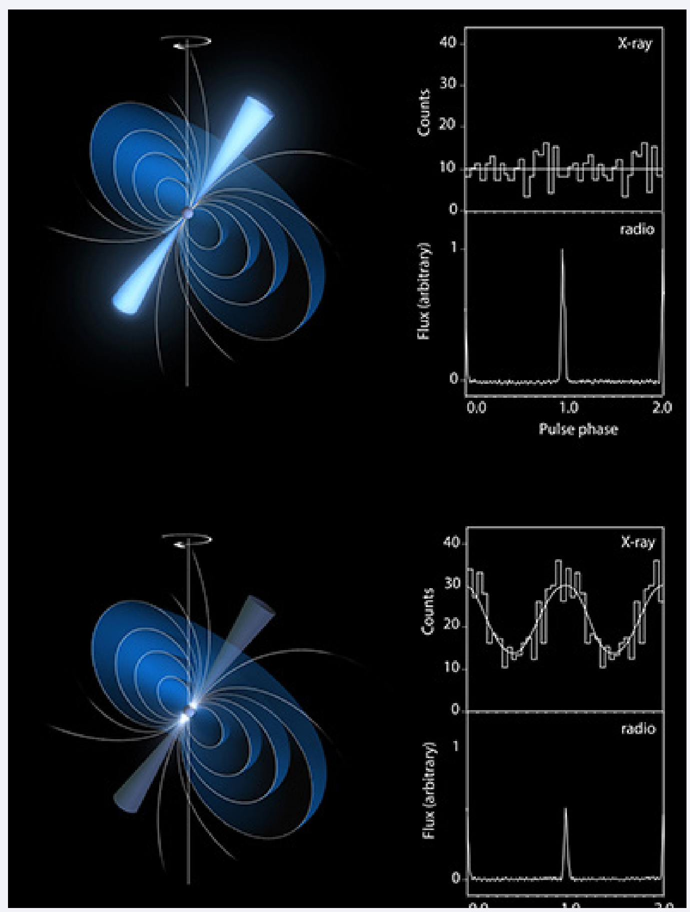
XMM-Newton: Baffling Pulsar Leaves Astronomers in the Dark

New observations of a highly variable pulsar using ESA's XMM-Newton are perplexing astronomers. Monitoring this pulsar simultaneously in X-rays and radio waves, astronomers have revealed that this source, whose radio emission is known to 'switch on and off' periodically, exhibits the same behaviour, but in reverse, when observed at X-ray wavelengths. It is the first time that a switching X-ray emission has been detected from a pulsar, and the properties of this emission are unexpectedly puzzling.

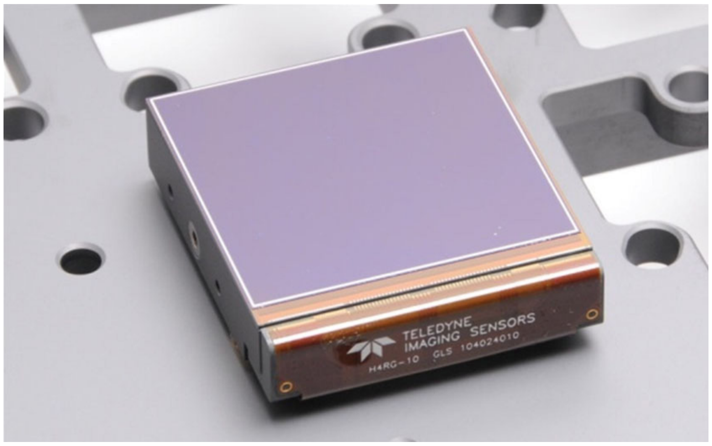
Wim Hermsen, from SRON, led a new study based on observations of the pulsar known as PSR B0943+10, which were performed simultaneously in X-rays, with ESA's XMM-Newton, and in radio waves. By probing the pulsar emission at different wavelengths, the study had been designed to discern which of various possible physical processes take place in the vicinity of the magnetic poles of pulsars. Instead of narrowing down the possible mechanisms suggested by theory, however, the results of Hermsen's observing campaign challenge all existing models. "The X-ray emission of pulsar PSR B0943+10 beautifully mirrors the switches that are seen at radio wavelengths, but to our surprise, the correlation between these two emissions appears to be inverse: when the source is at its brightest in radio waves, it reaches its faintest in X-rays, and vice versa," said Hermsen.

These observations will keep theoretical physicists busy investigating possible physical mechanisms that could cause the sudden and drastic changes to the pulsar's entire magnetosphere and result in such a curious emission.

Read the full article at **http://sci.esa.int/xmm-newton/51314-baffling-pulsar-leaves-astronomers-in-the-dark/**



The two states of pulsar PSR B0943+10 as observed with XMM-Newton and LOFAR. Credit: ESA/ATG medialab; ESA/XMM-Newton; ASTRON/LOFAR



Shown is an H4RG-10 consisting of 4K x 4K pixel array of HgCdTe pixels mated to a silicon readout on a 10 μm/pixel pitch.

crosscutting technology is currently covered by the Astrophysics Cosmic Origins (COR) Program. These SAT proposals have been programmatically combined, with the concurrence of the Principal Investigators, to provide a focused effort that is aimed towards maturing the technology for the Wide-Field InfraRed Survey Telescope-Astrophysics Focused Telescope Assets (WFIRST-AFTA) concept.

In concert with developments funded directly by the WFIRST-AFTA study team, this work will enable developing and characterizing a set of new devices that could be used to bring the technology to Technology Readiness Level 6 by approximately 2015. The specific areas of concentration for development are: 1) improvement of the readout noise to support short integration times for an agile survey, and 2) improvement of the persistence to reduce inter-scene crosstalk that will be introduced by the continuous survey. Ideally, the larger pixel count will enable covering the same area with 4x fewer devices, making for a more practicable and simplified integration and test program. The per-pixel cost should also be lower than with the current H2RG 18 μm pixel pitch technology because the detector area is almost the same for this increased pixel count. These aspects make this technology a key enabler of the ambitious surveys envisioned for WFIRST-AFTA.

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Physics of the Cosmos (PhysPAG) Report

John Nousek, *Chair of the PhysPAG Executive Committee*

PhysPAG conducted a very successful experiment by holding dual Town Hall meetings at both the AAS High Energy Astrophysics Division meeting (in Monterey, CA, on April 9), and at the APS meeting (in Denver, CO, on April 16). Even though held over the lunch hour in both cases there was a very substantial turnout of interested astronomers and physicists.

The Monterey HEAD Town Hall was chaired by me, with NASA presentations by Richard Griffiths (NASA HQ) and Ann Hornschemeier (PCOS Program), and SAG presentations by Daniel Stern (Euclid), Guido Mueller (GW-SAG), and Jay Bookbinder (X-ray SAG). The Denver APS DAP Town Hall was chaired by Ann, with SAG presentations by Shaul Hanany (Inflation Probe SAG), Neil Cornish (GW-SAG), Liz Hays (GammaSAG) and Angela Olinto (CosmicSAG).

The agenda and digital copies of most of the presentations are available at **http://pcos.gsfc.nasa.gov/physpag/meetings/physpag-meetings-April2013.php**

Coming Soon!

Technology Development Roadmaps for:

- **A Near Term Probe Class X-ray Astrophysics Mission**
- **A Future Space-Based Gravitational Waves Observatory**

The PCOS Program Office expects to announce the public release of these Roadmap documents in the coming weeks, via the PCOS mailing list and website.

The X-ray SAG also held a full-day workshop on the day following the HEAD meeting in Monterey, CA.

The Executive Committee is considering ways to encourage participation in the activities of PhysPAG, in particular to serve as a conduit for community response to the relevant plans of the NASA Astrophysics Division. Please let me or any of the Executive Committee know your views as to whether the best vehicle for communication may be sessions at large meetings (such as the AAS or APS meetings), at topical meetings (such as the HEAD or eLISA workshops) or at dedicated PhysPAG open sessions (such as WebEx or telecons). All of the PAGs organized in the Astrophysics Division are receiving charters to standardize their makeup. For PhysPAG the largest change is that currently named 'SAG' (for Science Analysis Group) will become 'SIGs' for Science Interest Group. The reason for the change is that the term SAG is reserved for groups assembled on an ad hoc basis, and with a short term to study specific questions posed to them by Headquarters. SIGs are persistent groups that provide on-going support and community outreach to Headquarters.

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Message from NASA Astrophysics Division Director

Paul Hertz, *Director, NASA Astrophysics Division*

Since fall 2012, NASA has been studying potential uses of the 2.4-meter telescope assets that were made available to the Agency by the National Reconnaissance Office (NRO) in mid-2012. The Astrophysics Focused Telescope Assets (AFTA) study showed that for approximately the same costs, the telescope assets would enable a Wide-Field Infrared Survey Telescope (WFIRST) mission with significantly improved science capabilities relative to the design described in the Astrophysics Decadal Survey. Use of the telescope assets would also enable the addition of an exoplanet imaging instrument to WFIRST that would enable imaging and characterization of planets around nearby stars up to a decade earlier than contemplated in the Decadal Survey. The results of the studies were presented to the NASA Administrator and other senior officials across the Agency on May 30, 2013. The Administrator directed the Science Mission Directorate to continue pre-formulation activities for a mission using the 2.4-meter telescope assets to prepare for a later decision as to whether a WFIRST mission would be undertaken with these optics. No decision on a future wide-field infrared survey mission is expected until early 2016. The study report by the AFTA Science Definition Team is available at **http://wfirst.gsfc.nasa.gov/science/**.

Although this remains a time of opportunity for NASA Astrophysics, the budgetary future remains uncertain. The FY13 rescission and sequestration has an impact. The rescission (~1.8%), sequestration (~5%), and other budget adjustments will result in an FY13 Astrophysics budget significantly lower than planned. The President's FY14 Budget Request supports several NASA decisions that have been previously announced, including a new Explorer mission (TESS; **http://web.mit.edu/newsoffice/2013/nasa-selects-tess-for-mission-0405.html**) and a new Explorer Mission of Opportunity (NICER; **http://heasarc.gsfc.nasa.gov/docs/nicer/**) downselected for development leading to flight, a new Euclid project to fund hardware procurement and a US science team for our partnership with the European Space Agency (ESA), and mission extensions for Spitzer, Planck, Chandra, Fermi, XMM, Kepler, Swift, and Suzaku per the recommendation of the 2012 Senior Review. The FY14 Budget Request also requires efficiencies in Fermi mission operations to be implemented in FY14, ahead of schedule and resulting in a significant reduction of operating costs, and it does not support selections for the 2012 Astrophysics Explorer Mission of Opportunity AO. Impacts of these revised budget planning numbers also include lowered research and analysis (R&A) selection rates in 2013 (for FY14 funding), delays in future Explorer AOs, and other reductions in FY14 where funding requirements were deferred from FY13. The constrained budget request for FY14 and constrained planning budget for FY15-FY18 means priorities must be set and choices must be made.

Within these budgetary constraints, NASA will continue to be guided by the goals of the 2010 Astrophysics Decadal Survey; we have developed an implementation plan to do so, and it is available at **http://science.nasa.gov/astrophysics/documents/**. A task force of the Astrophysics Subcommittee (APS), led by Chryssa Kouveliotou, is developing an Astrophysics Roadmap to create a compelling, 30-year vision for Astrophysics at NASA. The team has received community input through abstracts on science and technology challenges, as well as through invited talks from experts. The Roadmap team is maintaining communication with the astrophysics community through their webpage at **http://science.nasa.gov/science-committee/subcommittees/nac-astrophysics-subcommittee/astrophysics-roadmap/**.

NASA is compelled to make the short-term sacrifices necessary to meet this vision. The impacts of a reduced budget include a change in the pace of the Explorer program and putting on hold selections from the 2012 Announcement of Opportunity for Explorer Missions of Opportunity; lowered R&A selection rates in 2013 (for FY14 funding); and other reductions in FY14 where funding requirements have been deferred, such as funding of accepted Cycle 7 proposals to the Fermi Guest Observers program, which will be deferred until early FY15. We continue to look for scientists who would like to join the NASA staff for a few years and bring their talent and ideas to influence the nation's space Astrophysics program.

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

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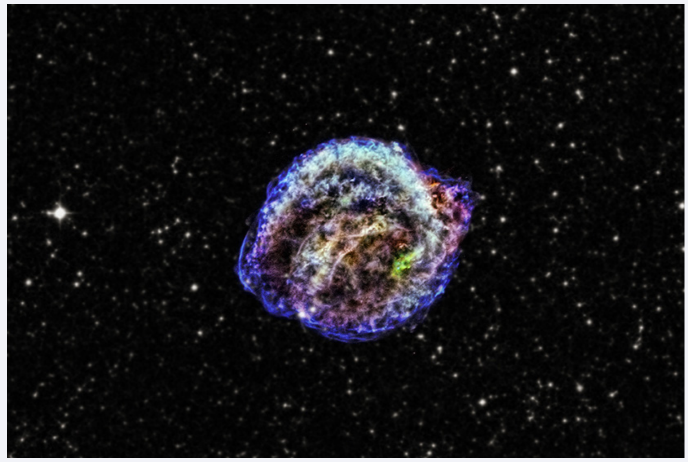
Suzaku 'Post-mortem' Yields Insight into Kepler's Supernova

An exploding star observed in 1604 by the German astronomer Johannes Kepler held a greater fraction of heavy elements than the sun, according to an analysis of X-ray observations from the Japan-led Suzaku satellite. The findings will help astronomers better understand the diversity of type Ia supernovae, an important class of stellar explosion used in probing the distant universe.



This composite of images from NASA's Chandra X-ray Observatory shows the remnant of Kepler's supernova in low (red), intermediate (green) and high-energy (blue) X-rays. Credit: X-ray: NASA/CXC/NCSU/M.Burkey et al.; optical: DSS

"The composition of the star, its environment, and the mechanism of the explosion may vary considerably among type Ia supernovae," said Sangwook Park, an assistant professor of physics at the University of Texas at Arlington. "By better understanding them, we can fine-tune our knowledge of the universe beyond our galaxy and improve cosmological models that depend on those measurements."

The best way to explore the star's makeup is to perform a kind of post-mortem examination on the shell of hot, rapidly expanding gas produced by the explosion. By identifying specific chemical signatures in the supernova remnant, astronomers can obtain a clearer picture of the composition of the star before it blew up.

"Kepler's supernova is one of the most recent type Ia explosions known in our galaxy, so it represents an essential link to improving our knowledge of these events," said Carles Badenes, an assistant professor of physics and astronomy at the University of Pittsburgh.

Using the Suzaku satellite's X-ray Imaging Spectrometer (XIS), the astronomers observed the remnant of Kepler's supernova in 2009 and 2011. With a total effective XIS exposure of more than two weeks, the X-ray spectrum reveals several faint emission features from highly ionized chromium, manganese and nickel in addition to a bright emission line from iron. The detection of all four elements was crucial for understanding the original star.

The findings provide strong evidence that the original white dwarf possessed roughly three times the amount of metals found in the sun.

Read the full article at **http://www.nasa.gov/mission_pages/astro-e2/news/post-mortem.html**

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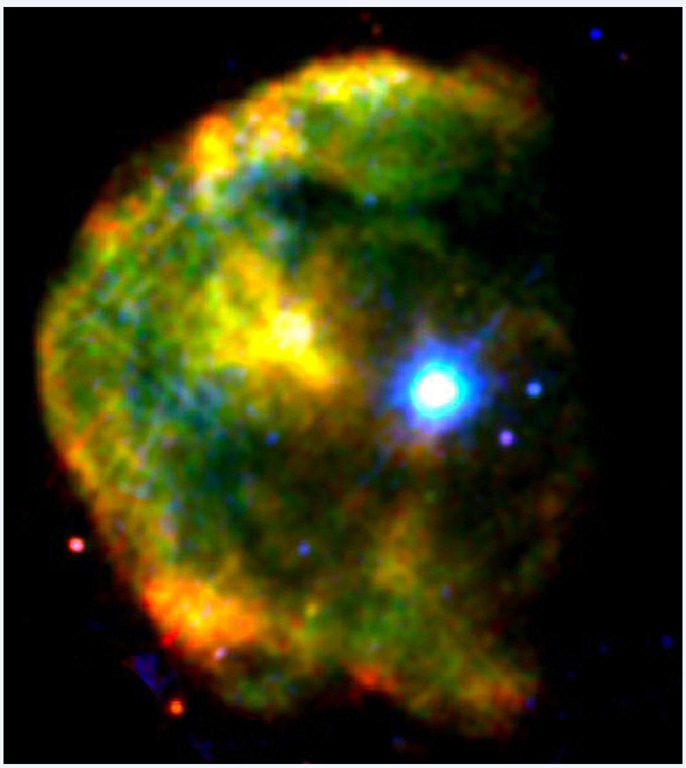
NASA's Swift Reveals New Phenomenon in a Neutron Star



The magnetar 1E 2259+586 shines a brilliant blue-white in this false-color X-ray image of the CTB 109 supernova remnant, which lies about 10,000 light-years away toward the constellation Cassiopeia. CTB 109 is only one of three supernova remnants in our galaxy known to harbor a magnetar. X-rays at low, medium and high energies are respectively shown in red, green, and blue in this image created from observations acquired by the European Space Agency's XMM-Newton satellite in 2002. Credit: ESA/XMM-Newton/M. Sasaki et al

Astronomers using NASA's Swift X-ray Telescope have observed a spinning neutron star suddenly slowing down, yielding clues they can use to understand these extremely dense objects.

This neutron star, 1E 2259+586, is located about 10,000 light-years away toward the constellation Cassiopeia. It is one of about two dozen neutron stars called magnetars, which have very powerful magnetic fields and occasionally produce high-energy explosions or pulses.

Observations of X-ray pulses from 1E 2259+586 from July 2011 through mid-April 2012 indicated the magnetar's rotation was gradually slowing from once every seven seconds, or about eight revolutions per minute. On April 28, 2012, data showed the spin rate had decreased abruptly, by 2.2 millionths of a second, and the magnetar was spinning down at a faster rate.

"Astronomers have witnessed hundreds of events, called glitches, associated with sudden increases in the spin of neutron stars, but this sudden spin-down caught us off guard," said Victoria Kaspi, a professor of physics at McGill University in Montreal.

Astronomers dubbed the event an "anti-glitch," said co-author Neil Gehrels, principal investigator of the Swift mission at NASA's Goddard Space Flight Center in Greenbelt, Md. "It affected the magnetar in exactly the opposite manner of every other clearly identified glitch seen in neutron stars."

On April 21, 2012, just a week before Swift observed the anti-glitch, 1E 2259+586 produced a brief, but intense X-ray burst detected by the Gamma-ray Burst Monitor aboard NASA's Fermi Gamma-ray Space Telescope. The scientists think this 36-millisecond eruption of high-energy light likely signaled the changes that drove the magnetar's slowdown.

The discovery has important implications for understanding the extreme physical conditions present within neutron stars, where matter becomes squeezed to densities several times greater than an atomic nucleus. No laboratory on Earth can duplicate these conditions.

Read the full article at **http://www.nasa.gov/mission_pages/swift/bursts/new-phenom.html**

Meet the Einstein Fellows: Selma E. de Mink

Although massive stars are rare and short-lived, they played a major role in transforming the pristine Universe left after the Big Bang to the modern Universe in which we live today. With their high luminosities, strong stellar winds and violent explosions they heat, stir and enrich and surroundings, in which new stars and their planets form.

Massive stars do not live their lives alone. Practically all have at least one nearby companion, often more. Recent work indicates that the large majority of massive stars (70%) will experience severe interaction with a companion star, for example mass accretion and spin up or a merger of the two stars. It is clear that this drastically changes the evolution and final fate of both stars.

Even though major progress has been made over the last decades in sophisticated stellar modeling, we are only beginning to explore how the effects of binarity affect entire stellar populations.

In her work, Selma de Mink is particularly improving our understanding of how binarity affects the role that massive stars play as "cosmic engines," i.e., their mechanical, radiative, and chemical feedback, and their role as "cosmic probes" of star formation nearby and at high redshift. Her expertise is in theoretical modeling of the internal structure and evolution of massive stars, but she actively participates in a variety of observing programs, with the VLT, HST, and Chandra.

Selma de Mink obtained a B.Sc. in physics and mathematics at the University of Utrecht in The Netherlands, getting her first research experience during a summer internship at the Instituto d'astrofisica de Canarias, in Tenerife, Spain. She continued with a M.Sc. and PhD in astrophysics in Utrecht. After a few months at the Argelander Institute in Bonn, Germany, she came to the US in 2010 as a Hubble Fellow at the Space Telescope Science Institute and Johns Hopkins University in Balimore, Maryland. In August 2013 she has started as an Einstein Fellow at Carnegie Observatories in Pasadena, California.

Calendar of Upcoming PCOS/PhysPAG Events

Note that some arrangements are sensitive to sequester restrictions on NASA travel and expenditures. Currently, for instance, PCOS is not permitted to send a booth to the January AAS. Should the situation change, we will send a booth if we are able.

October 29-30, 2013	Einstein Fellows Symposium Cambridge, MA
January 5, 2014 (Sunday)	PhysPAG Workshop at the AAS Meeting Washington, D.C.
January 7, 2014 (Tuesday)	"Reports from NASA's Astrophysics Program Analysis Groups" session at the AAS Washington, D.C.
April 5-8, 2014	PCOS/PhysPAG Town Hall at the American Physical Society Meeting Savannah, GA

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