National Aeronautics Space Administration

Cosmic Origins Newsletter

September 2014 Volume 3 Number 2

Summer 2014 Cosmic Origins Program Update

Mansoor Ahmed, *COR Program Manager*
Susan Neff, *COR Program Chief Scientist*

Welcome to the September 2014 Cosmic Origins (COR) newsletter. In this issue, we provide an update on several activities relevant to the COR objectives. Some of these activities are not under direct purview of the program office but are relevant to the COR objectives, therefore the program office tries to stay abreast of their progress.

A key part of the COR Program is managing development of the technologies required for future COR discoveries. While the Astrophysics Research and Analysis Program (APRA) program provides funding to explore new technology ideas, the Strategic Astrophysics Technology (SAT) program is intended to bring important technologies to a level of development that could be infused into a flight mission. We thank the community for their input helping the COR Porgram identify current technology gaps. The COR program office is updating the Technology Gaps list, which will be released in October as part of the 2014 Program Annual Technology Report (**PATR**) and will influence the next SAT call for proposals. Please see the article by HQ Program Scientists Mario Perez and Mike Garcia, which reviews the **achievements of the SAT program** since its inception in 2009, and the **article on the suborbital program**, yet another key piece of the technology maturation process, that involves flight-testing of new technology with sounding rockets or balloon flights.

Results from the 2014 Senior Review for Astrophysics Operating Missions were announced in May. The review, held every two years, develops recommendations to maximize scientific productivity from the missions. NASA uses the review's findings to prioritize funding of operating missions. The Review Panel noted that all proposals had excellent science cases, and that in their opinion, the US future of space astrophysics is threatened with irreparable damage in the current funding climate. The panel suggested that *Hubble* should not be considered for diminished support until the James Webb Space Telescope (JWST) is fully operational. The warm *Spitzer* mission was initially not considered for continuation; later it was continued for the next two years, subject to Congressional appropriation. The committee's full report, and NASA's response can be found at **http://science.nasa.gov/astrophysics/2014-senior-review-operating-missions/**. An **overview of *Spitzer*'s achievements and status** is presented later in the newsletter.

The *Hubble* and *Spitzer* space telescopes continue to produce science breakthroughs. *Hubble* recently selected new investigations for its 22nd observing cycle, and *Spitzer* is accepting proposals now for its 11th cycle of Guest Observers. Both observatories continue to be heavily oversubscribed, by factors of 6–7, with proposals for exciting new experiments. Discoveries also continue to be announced from COR missions that have stopped making new observations: *Herschel*, GALEX, and WISE. We include highlights of a few recent results in boxes throughout the newsletter.

Excellent progress is being made in missions that are not formally part of the COR program. The Stratospheric Observatory for Infrared Astrophysics (SOFIA) offers a unique capability in the mid- and far-infrared parts of the spectrum, and it also provides the option of updating instrumentation. The airborne observatory was declared fully operational in May. After some budget turmoil, it appears likely that SOFIA will move into routine operations in the near future. We **report on SOFIA's status** later in the newsletter. JWST development continues on schedule and on budget. The Wide-Field Infrared Survey Telescope (WFIRST) pre-formulation work continues on the WFIRST Astrophysics Focused Telescope

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Assets (AFTA) concept, and is supported in the current Congressional budget plans for 2015.

The Cosmic Origins community is beginning to plan for the future with JWST and eventually WFIRST. In particular, the Cosmic Origins Program Analysis Group (COPAG) has been very active in the past six months in WFIRST studies, as you will see in the **article by Ken Sembach, COPAG chair**. We also report on our May **Workshop on the Future of Far IR Space Astrophysics**.

We would like to be sure all interested scientists are involved in planning for the future of Cosmic Origins science, as practiced from above the Earth's surface. We need your expertise and knowledge. The COPAG (Cosmic Origins Program Analysis Group) is open to all interested individuals—if you participate, you're in. Right now, four Science Analysis Groups (SAGs) and one Science Interest Group (SIG) are very involved in science and technology planning, as described later in the newsletter. They want your input and involvement. For more information about recent COPAG activities, see: **http://cor.gsfc.nasa.gov/copag** To join the COPAG, to indicate interest in specific SAGs or SIGs, or to suggest new activities, please visit: **http://cor.gsfc.nasa.gov/copag/joinCOPAG.php**

Young scientists are key to the future of Astrophysics—they will be the researchers who use future observatories for breakthrough discoveries. We introduce one of the recently selected *Hubble* fellows, **Dr. Fabienne Bastien**, who is exploring how stellar activity can be used to improve estimates of exoplanet sizes, and to determine stellar masses

The COR office has had several personnel changes in the past six months. We welcomed Lia LaPiana in May who replaces John Gagosian as the new COR Program Executive. Lia is also Program Executive for the PCOS program and for the WFIRST study. Dr. Deborah Padgett has been appointed as the Deputy Chief Scientist for COR. Her background is as an infrared astronomer, with a particular interest and expertise in star formation. She brings her extensive experience with the *Spitzer* and WISE missions to the COR program. Dr. Mark Clampin has left the Cosmic Origins program to lead GSFC work developing a viable concept for a very large UVOIR space telescope. Mr. Bernie Seery is the new Chief Technologist for COR and PCOS. He has extensive experience in mission formulation and development, in technology development and implementation, and in strategic collaboration, and is Assistant Director for Advanced Concepts at GSFC.

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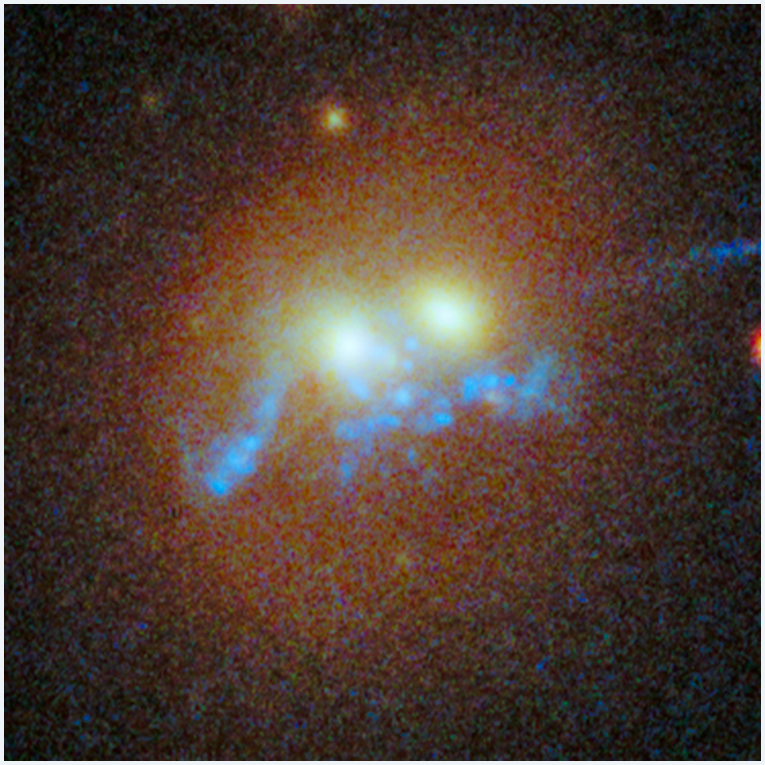
Hubble Sees Corkscrew Bridge of Young Stars Between Two Ancient Galaxies

Astronomers routinely use the exquisite resolution of the *Hubble* Space Telescope to study intricate details in galaxy clusters. Recent observations revealed a peculiar structure that resembles a string of pearls twisted into a corkscrew shape, extending 100,000 light years and winding around the cores of two colliding galaxies. Astronomers are scrambling to explain the origin, and ultimate fate of the object.

The slinky-structure's unique morphology is expected to provide new insight into formation of super-star-clusters, merger-driven galaxy growth, and gas dynamics in a rarely-seen merging collision of two giant elliptical galaxies. "The stunning morphology must be very short-lived, perhaps about 10 million years, which is a fraction of the time it takes the galaxies to merge" said Grant Tremblay, of the European Southern Observatory.

The blue superclusters of young stars are evenly spaced along the chain at separations of 3,000 light years from one another.

The underlying physical processes that give rise to the 'beads-on-a-string' morphology are related to the "Jeans instability", describing the behavior of self-gravitating clumps of gas. It is analogous to the process that causes a falling column of water to disrupt, explaining why rain usually falls in drops rather than in long filaments. "This is a beautiful demonstration of the profound scale-invariance of the fundamental laws of nature" Tremblay added. "We see the same physics on 100,000-light-year scales that we see in our kitchen sinks and inkjet printers."



Hubble image of a 'string of pearls", or super-clusters of blue-white newly formed stars, winding around the cores of two merging elliptical galaxies. Image Credit: NASA, ESA, and G. Tremblay (ESO).

Scientists are working to understand the chain's origin. One possibility is that cold molecular gas fueling the recent burst of star formation was native to the two merging galaxies. Another possibility is that the star-forming gas cooled from the ultra-hot plasma that surrounds the galaxies, and a third is that the gas results from a shock wave created when the two giant galaxies crash together.

Full story at **http://hubblesite.org/newscenter/archive/releases/2014/26/full/**

Message from the Astrophysics Division Director

Paul Hertz, *Director, HQ Astrophysics Division, NASA Science Mission Directorate*

As we approach the end of the 2014 fiscal year, it is time to reflect on our achievements and shortcomings, and plan for challenges ahead. We have been extremely fortunate that our space-based missions, both large and small, have continued to make headlines with spectacular scientific discoveries that capture the mind of the public. We have learned more about the way the universe works, have studied the birth of stars and galaxies, and have made great strides in discovering and understanding exoplanets.

As I described during the NASA Town Hall at the American Astronomical Society meeting in Boston on June 2, 2014, we continue to make progress addressing the priorities of the 2010 Decadal Survey for Astronomy and Astrophysics. The appropriation that NASA Astrophysics received for FY 2014 and the Administration's FY 2015 budget request both support our plans for continued progress. The progress we are making toward the major recommendations of the 2010 Decadal Survey includes:

- A goal of the Astrophysics Division is to be prepared to start a new strategic NASA Astrophysics mission to follow JWST as soon as funding becomes available. Preformulation and focused technology development for a 2.4m version of the Wide-Field Infrared Survey Telescope (WFIRST), a mission concept referred to as the Astrophysics Focused Telescope Assets (AFTA), are underway. NASA received $56M in directed funding for FY 2014 for WFIRST/AFTA to continue preformulation activities and technology development. A recent National Research Council (NRC) study on WFIRST/AFTA offers a positive view of WFIRST/AFTA in the context of the Decadal Survey with concerns about technology and cost risks. The Administration's FY 2015 budget request supports an Agency/Administration decision for formulation of WFIRST/AFTA to begin no earlier than FY 2017, should funding be available.
- A new ROSES element, WFIRST Preparatory Science, was announced on April 21, with a goal to bridge from basic theory to observational modeling for WFIRST/AFTA; and more than 50 proposals were received on July 11. Investigators selected will coordinate efforts with the WFIRST Study Office and the WFIRST/AFTA Science Definition Team.
- The Administration's FY 2015 budget request includes augmentation of the Explorer program to enable more frequent flight opportunities, including a planned SMEX AO later this year (see the draft AO at **http://nspires.nasaprs.com/** and the community announcement at **http://explorers.larc.nasa.gov/APSMEX/**) and a MIDEX around FY 2017.
- Strategic technology investments are being made and partnerships are being discussed with the European Space Agency in their gravitational wave and X-ray observatories. NASA has joined ESA in supporting the ESA Science Study Team for the recently selected mission concept, "Advanced Telescope for High-ENergy Astrophysics" (Athena).
- Strategic technology investments are being made to advance the medium scale programs including technology for exoplanet

Hubble is turning 25!

On April 24, 2015, the *Hubble* Space Telescope will reach a major milestone—25 years in space. *Hubble* provides stunning views of the universe and makes discoveries that time and again alter our understanding of astronomical phenomena. Even as the mission looks forward to operations out to 2020 or beyond, one can't help but reflect on the impact that *Hubble* has had on science, popular culture, and the education of millions of students. In celebration of this anniversary, NASA, the European Space Agency, the *Hubble* Team, and others are planning a variety of educational and celebratory activities throughout the coming year that will showcase great science, the people who operate *Hubble*, and the creativity that *Hubble* has inspired in generations of students and the public. Examples include a large *Hubble* presence at the next South by Southwest festival in Austin Texas, new exhibits and events at the Intrepid museum in New York City, and multiple opportunities for public involvement in online activities relating to *Hubble*'s amazing images and science.

The Space Telescope Science Institute's 2015 Spring Symposium will be one of many events occurring in the anniversary year. That meeting, "*Hubble* 2020: Building on 25 years of Discovery" (http://www.stsci.edu/institute/conference/hubble25/), will be held April 20–23, 2015. Additional information will be provided on other activities as it becomes available. If you or your host institution have ideas or plans to celebrate *Hubble*'s silver anniversary, please share them with the *Hubble* Team by sending email to hubble25th@stsci.edu

missions and technology for detection of polarization of the cosmic microwave background.

• Modest augmentations have been made to small programs including R&A.

The FY 2014 appropriation for NASA provides $658M for JWST and $668M for the rest of NASA astrophysics. The FY 2015 Administration's budget request would provide $645M for JWST and $607M for the rest of NASA astrophysics. Both budgets support the continued development of JWST on plan toward its launch in 2018, and both budgets include funding for continued preformulation of WFIRST as described above. Both budgets also include funding for several new missions including the Transiting Exoplanet Survey Satellite (TESS), the next Astrophysics Explorer mission, the Neutron Star Interior Composition Explorer (NICER), the next Astrophysics Explorer Mission of Opportunity, and the NASA contribution to the European Space Agency's Euclid mission.

The Administration's FY 2015 budget proposes to place SOFIA into storage by FY 2015 unless partners are able to support the U.S. portion of SOFIA costs. The NASA appropriation subcommittees in both houses of Congress, however, have proposed continued funding for SOFIA at a level sufficient to continue operations. NASA has continued to conduct the SOFIA program as planned during FY 2014.

Other program highlights since my last Newsletter include:

• SOFIA formally entered the Operations Phase in May. Second generation instruments, HAWC+ (U.S.), and upGREAT (German) are under development. In late June, SOFIA was flown to Germany for a Heavy Maintenance Visit.

• Astrophysics research funding remains flat, retaining the growth realized since the Decadal Survey, with the success rate of proposals hovering between 15% and 24%. This is caused by a sharp increase in the number of proposals received.

• A Senior Review of operating missions was conducted in April. At that time, all operating missions other than *Spitzer* were approved for continued operation. The NEOWISE-R data analysis proposal, MaxWISE, was not approved for funding. A full report of the Senior Review may be found at **http://science.nasa.gov/astrophysics/2014-senior-review-operating-missions/**.

• In July, the Science Mission Directorate made the decision to extend *Spitzer* operations for the next two years. The *Spitzer* observatory is an important resource for on-going infrared observations for research programs across the Science Mission Directorate, and, subject to the availability of Congressional appropriations in FY2015, it will be continued.

• Astrophysics approved some funds for education activities in FY2014 and has continued a limited number of high impact activities.

Major activities planned for FY 2015 include confirmation of the TESS Explorer mission, launch of the ISS-CREAM experiment to the Space Station, Step 1 selection of the next Small Astrophysics Explorer and Explorer Mission of Opportunity Phase A studies, launch of ESA's LISA Pathfinder with NASA's ST-7, completion of the WFIRST/AFTA science definition team report, conduct of the Astrophysics Archives Senior Review, start of the NRC Mid-Decade Review, and celebration of twenty five years of operation of the *Hubble* Space Telescope. All Astrophysics programs flow from the recently completed *NASA 2014 Science Plan*, which is available at **http://science.nasa.gov/about-us/science-strategy/**

My entire presentation to the American Astronomical Society meeting is available at **http://science.nasa.gov/astrophysics/documents/**

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Herschel Finds New Molecules Around Old Stars

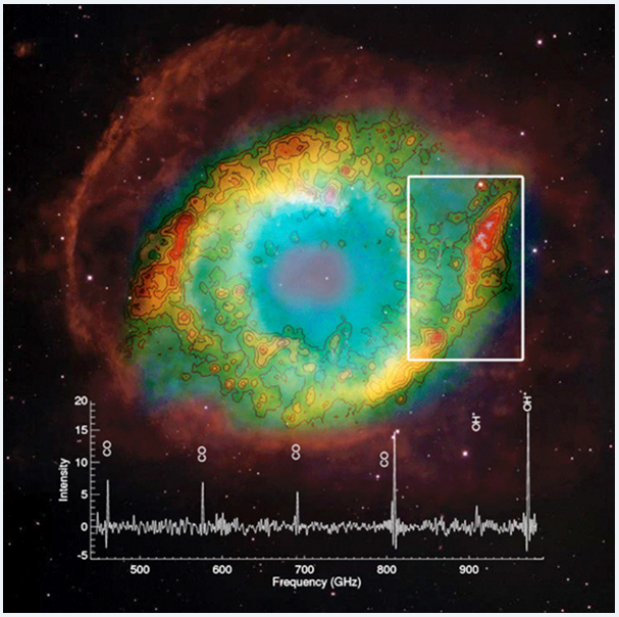
Astronomers using *Herschel* have discovered that a molecule vital for creating water exists in the gaseous castoffs of dying stars.

A star like the sun burns hydrogen in its core steadily for billions of years. However, once the fuel is exhausted in the center, the star swells into a red giant, becoming unstable, and shedding its outer layers. The ionized gas forms a kaleidoscope of ionized gas, known as a planetary nebula. The remaining stellar core contracts to become a hot white dwarf star, pouring out ultraviolet radiation into its surroundings. The intense UV radiation is likely to destroy molecules previously ejected by the star, and radiation was also thought to restrict formation of new molecules in the nebula.

However, in two separate studies, astronomers using *Herschel* have found that a molecule essential to the formation of water seems to thrive in this harsh radiation environment, and may even require the radiation to form. The molecule, known as OH+, is a positively charged combination of one oxygen and one hydrogen atom. In a study of planetary nebulae, those in the most intense radiation fields, were found to contain significant amounts of OH+. The central stars have temperatures higher than 100,000°C.

The two studies are the first to identify this critical molecule, needed for the formation of water, in the ejecta of dying stars.

Full story at **http://www.esa.int/Our_Activities/Space_Science/Herschel/New_molecules_around_old_stars**



The Helix planetary nebula, showing the location where OH+, a precursor molecule for water, was detected by Herschel space observatory. Image credit: ESA/Herschel Science Center and M. Etxaluze/Instituto de Ciences de los Materiales de Madrid

Spitzer Status and Achievements

Deborah Padgett, *COR Deputy Chief Scientist*

Spitzer Space Telescope is the fourth in NASA's series of great observatories and the most powerful mid-infrared telescope launched thus far. *Spitzer* is an 85 cm telescope, which was initially cooled by liquid helium. It was launched into an Earth-trailing orbit to simplify observing strategy, and to help the telescope remain cold by staying far away from the warm, bright Earth. During *Spitzer*'s nearly six-year of cryogenic operations, its Infrared Spectrograph (IRS), Infrared Array Camera (IRAC), and Multi-band Imaging Photometer for *Spitzer* (MIPS) provided images and spectroscopy between 3.6–160 μm, revealing the full glory of the cool infrared universe. Although *Spitzer*'s current warm mission is limited to observing at the shortest IRAC wavelengths, its unsurpassed sensitivity and stability keeps current demand for *Spitzer* observations high.

Spitzer's scientific accomplishments as a general-purpose infrared observatory span locales from our celestial neighborhood to the cosmological frontiers.

Spitzer observations led to the discovery of Saturn's enormous Phoebe ring, millions of miles in diameter. The observatory has observed cold and dusty Solar Systems objects targeted by in-situ NASA missions, such as Comet Tempel/1 (Deep Impact) and Pluto (upcoming New Horizons flyby).

The observatory has revolutionized our understanding of star formation in our own and nearby galaxies. The Spitzer image (right), of the Christmas Tree Nebula and the star cluster NGC 2264, exemplifies the spectacular images obtained by *Spitzer*, which pierce the dusty shroud of molecular clouds and reveal newborn stars within. Such data have enabled an unparalleled inventory of many thousands of young stars with planet-forming dusty disks in the galaxy, yielding current star-formation rates of nearby molecular clouds. *Spitzer* observations have traced the evolutionary path of these disks, from gas-rich, opaque structures feeding onto wildly active protostars to ephemeral, translucent debris disks sustained by asteroid collisions and cometary debris. *Spitzer* spectra have demonstrated the presence of water and organic molecules in young stellar disks where planets form, have found buckyballs in space and have shown the ubiquity of polycyclic aromatic hydrocarbons throughout the cosmos, even in the very early Universe.

Some of *Spitzer*'s most important work is ongoing. Cosmological redshift causes galaxies undergoing intense star-formation early in their history to appear brightest at *Spitzer*'s remaining 3.6 and 4.5 μm bands. Recent work combining *Spitzer* and *Hubble* observations have constrained masses for several z > 10 galaxies (close to the beginning of the Universe). Joint *Spitzer-Hubble* "Frontier Fields" of lensing galaxy clusters promise to uncover more of these very distant objects, paving the way for future JWST projects.

Spitzer's photometric stability makes it ideal for time domain astrophysics. This capability has come to the forefront during the warm mission with synoptic studies of brown dwarfs, young stellar objects, and, most prominently and unexpectedly, extrasolar transiting planets. *Spitzer* was the first observatory to detect planetary transits in the mid-infrared and is the only one thus far to detect the atmospheres of exoplanets directly during secondary occultation. *Spitzer* continues to determine radii, temperature maps, and

Spitzer image of the "Christmas Tree Nebula." Recently-formed stars appear as pink and red specks, still-forming protostars are yellow dots, and organic molecules mixed with dust appear green. Blue points are older foreground stars. More information at http://www.spitzer.caltech.edu/images/2412-sig05-028-Stellar-Snowflake-Cluster Image credit: P.S. Teixeira (CfA); NASA/JPL

to constrain atmospheric composition of super-Earth-sized exoplanets. Roughly a third of warm *Spitzer*'s time is currently devoted to exoplanets, a third to observational cosmology, and a third to general astrophysics.

Despite its slow drift away from the Earth, *Spitzer* is technically capable of operating through 2018, although budgetary constraints may be more limiting. Current funding is expected to extend through 2016. The Cycle 11 Call for *Spitzer* Proposals **http://ssc.spitzer.caltech.edu/warmmission/propkit/cp/** is soliciting proposals, due on October 29, 2014, providing ample opportunity for amazing new discoveries from *Spitzer*.

Spitzer is managed by JPL with the support of the spacecraft engineering team at Lockheed-Martin in Denver, and the science program is administered by the *Spitzer* Science Center at IPAC on the Caltech campus.

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SOFIA is Declared Fully Operational

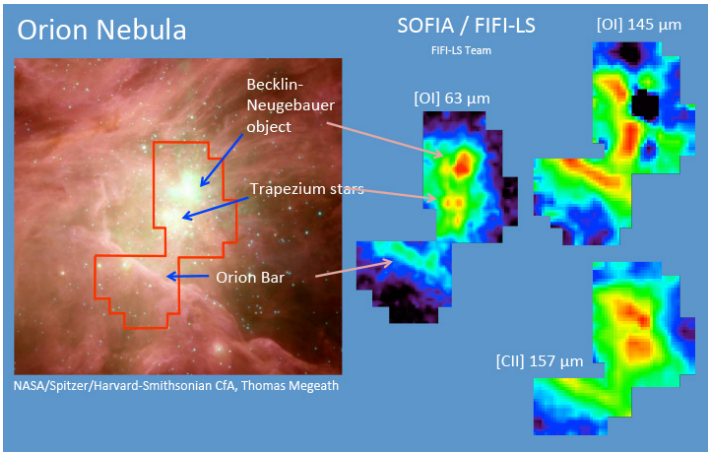
Susan Neff, *COR Chief Scientist*

NASA declared SOFIA fully operational on 2 June 2014; this is SOFIA's equivalent to successfully launching a spacecraft! Technical criteria were met in February 2014 and the formal review was completed at the end of May 2014. SOFIA is in Germany for the summer, undergoing a decadal inspection and telescope maintenance.

In February 2014, SOFIA completed commissioning the first four science instruments (FORCAST, GREAT, HIPO, and FLITECAM). In April, commissioning was completed for the observatory's fifth instrument, the Field-Imaging Far-IR Line Spectrometer (FIFI-LS) and commissioning began for the sixth instrument, the Echelon-Cross-Echelle Spectrograph (EXES), a very high spectral resolution that will operate in the mid-infrared (4.5–28.3 μm). In May, the H-band channel of the German Receiver for Astronomy at Terahertz Frequencies (GREAT) began commissioning. FIFI-LS, EXES, and GREAT (with the new H channel) were all offered in SOFIA's Cycle 3 proposal call, and will be available to the science community starting in March 2015. All of the first generation instruments are now operating on SOFIA. More information about SOFIA's instrument suite may be found at: **http://www.sofia.usra.edu/Science/instruments/**

Development work continues on two second-generation instrument upgrades, the High Resolution Airborne Wideband Camera-Plus (HAWC+), a far infrared camera with polarization capabilities, and enhancements to the GREAT spectrometer.

The SOFIA Cycle 3 Call for Proposals closed on July 18, 2014. A total of 153 proposals were received—122 from 14 different countries through the US/NASA queue and 31 from German institutions through the German/DSI queue. Results of the proposal review and selection are expected to be announced in October, and Cycle 3 observations will begin in March 2015, offering 450 hours of observing time.



(Left) Spitzer image of the Orion nebula, a massive star- forming region located 1300 light years from Earth. (Right) SOFIA Field-Imaging Far-IR Line Spectrometer (FIFI-LS) mosaics of the heart of the nebula, showing the same field observed in the light of neutral oxygen and singly ionized carbon. The relative brightnesses of the various features in different bands will allow astronomers to investigate heating and cooling processes in the nebula, and how they relate to star formation. Full story at http://www.nasa.gov/mission_pages/SOFIA/SpectrometerFinishesCommissioningTest.html

The SOFIA science community forum participates in a series of teletalks about SOFIA science and instruments. More information about the talks can be found at: **http://www.sofia.usra.edu/Science/SCF/index.html**

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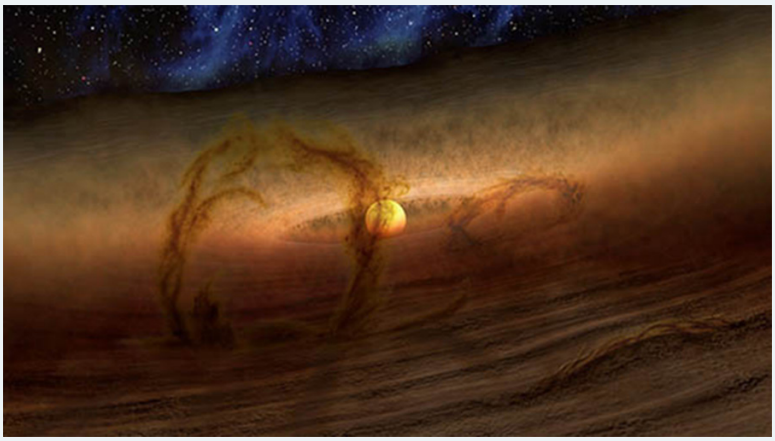
Spitzer May Detect Magnetic Storms in Circumstellar Disks



An artist's conception of magnetic loops carrying dust and gas above a disk of planet-forming material around a recently formed star. The loops are thought to account for excess infrared emission detected by Spitzer. Image credit NASA/JPL-Caltech/R.Hurt (IPAC)

Researchers using *Spitzer* to study developing stars have had a hard time figuring out why stars give off more infrared light than expected. Planet-forming disks that circle the young stars are heated by starlight, and radiate at infrared wavelengths, but *Spitzer* detected additional infrared emission coming from an unknown source, that was not explained by the disk alone.

Recently, three-dimensional computer modeling of disk turbulence showed that the disks were expected to have fuzzy surfaces, with layers of low-density gas supported by magnetic fields.

The idea of magnetic atmospheres associated with protoplanetary disks is not new, but this is the first time a connection has been suggested to the observed infrared excess.

According to Neal Turner (at NASA's Jet Propulsion Laboratory), the magnetic atmospheres behave similarly to the surface of our sun, where moving magnetic field lines can spur tremendous solar prominences to flare up in big loops. The new theory suggests that gas and dust are suspended above and below the planet-forming disks on giant magnetic loops. The loops are similar to prominences seen on the surface of the sun. Dust associated with the loops is thought to absorb the starlight, and to reradiate the energy in the infrared, providing enough extra infrared radiation to account for all the extra infrared light.

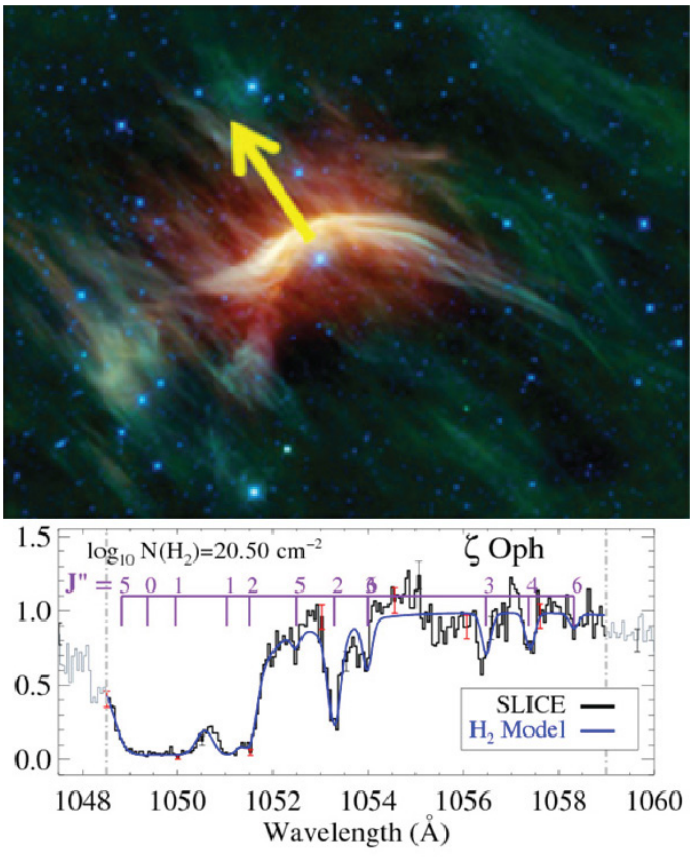
For full story, see: **http://www.spitzer.caltech.edu/news/1621-feature14-05-Mystery-of-Planet-forming-Disks-Explained-by-Magnetism**

Cosmic Origins Suborbital Program: Sounding Rockets

Susan Neff, *COR Program Chief Scientist*

Suborbital experiments were the beginning of space astrophysics, and experiments first developed as rocket (or balloon) payloads have been precursors to many of NASA's astrophysics instruments. Sounding rockets continue to play an important role in Cosmic Origins. In addition to carrying out forefront science investigations, they provide great flexibility, with short development times, the potential for fast access to space for one-time events, an opportunity to flight-test new technologies, and an invaluable training ground for future Principal Investigators. Sounding rocket experiments are funded through NASA's Astrophysics Research and Analysis (APRA) program and are part of NASA's Sounding Rocket Program, operated at Wallops Flight Facility in Virginia. Currently there are five funded rocket programs relevant to the Cosmic Origins.

• SLICE and CHESS (Principal Investigator (PI): Kevin France, University of Colorado): The Suborbital Local Interstellar Cloud Experiment (SLICE) and the Colorado high-resolution Echelle Stellar Spectograph (CHESS) experiments perform Far-ultraviolet (far-UV) spectroscopy of the interstellar medium (ISM). The telescope optics use coatings optimized for observing the hydrogen and carbon budgets of the ISM between 1020Å and 1060Å.



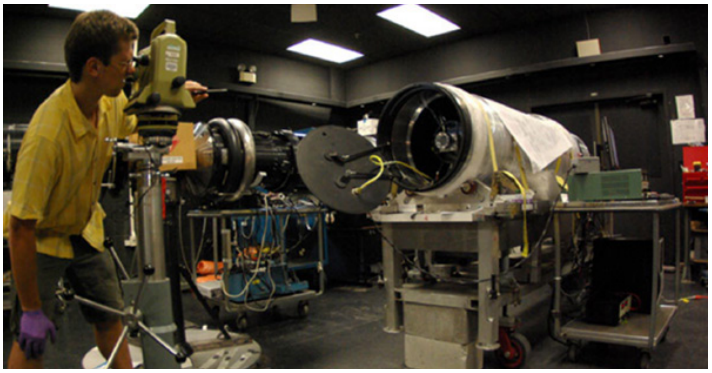
WISE image of Zeta Ophiuchi, showing the direction of motion, and the bow shock formed around the massive runaway star as it moves through the diffuse gas in our Galaxy. SLICE observed molecular gas along the sightline to the star, and may have detected the evolution of the molecular abundances of this material owing to the motion of the star through the nebula.

The CHESS experiment prior to launch at White Sands Missile Range in May 2014. A Terrier-Black Brant rocket motor delivered CHESS to an altitude of about 320 km to make the science observation.

SLICE flew in April 2013, and used four nearby hot stars to study sightlines through the intervening gas. The resulting spectra probed the various phases of the interstellar medium, ranging from cool molecular gas that will form the next generation of stars, to hot gas driven into the interstellar gas when massive stars die in supernova explosions. SLICE also characterized the interaction between a massive runaway star and the ambient ISM, which forms a bow shock in front of the fast-moving star. Former undergraduates Robert Kane and Nico Nell had hands-on roles with SLICE, and now carry out mechanical design, structural analysis, and detector analysis with Dr. France's group at the University of Colorado.

The higher resolution CHESS payload flew in May 2014, and incorporated several significant technology advances. New cross-strip Microchannel Plate (MCP) detectors by J. Vallerga (University of California and Sensor Systems), supporting very large global count rates were flight-tested. Two new grating technologies were also flown for the first time: the echelle grating was an experimental approach with square-ruled grooves intended to suppress scattered light, and the cross-dispersing grating was holographically ruled onto a toroidal powered optic. The echelle did not meet expectations, resulting in a significant efficiency loss, while the powered cross-disperser performed better than anticipated. On their next flight, the CHESS team plans to flight-test a different new-technology echelle grating, in collaboration with NASA's Jet Propulsion Laboratory. Graduate student Keri Hadley, who joined CHESS during instrument design and worked on almost all aspects of instrument development, will use the resulting data as part of her doctoral thesis.

• FORTIS (PI: Stephan McCandliss, Johns Hopkins University): The Far-Ultraviolet Off-Rowland Telescope for Imaging and Spectroscopy (FORTIS) is designed to obtain images and spectra simultaneously, over a wide field (30 arcminutes, the size of the full moon), using a microshutter array similar to the one planned for JWST. The microshutter array, which flew in space for the first time on FORTIS, can be used to obtain simultaneous spectra of multiple selected locations (up to 43), greatly increasing the observing efficiency relative to earlier Far-UV instruments. The payload is designed to observe hydrogen gas radiating in the Far-Ul-



Former graduate student Brian Fleming measures the alignment of the telescope prior to a shake test at NASA's Wallops Flight Facility. Dr. Fleming is now a postdoctoral fellow at University of Colorado, working with Dr. France's rocket program.

traviolet part of the spectrum, and is optimized for observations between 800–1950Å, providing a factor six increase in throughput over previous Far-UV instruments. Former graduate student Brian Fleming worked with McCandliss on every phase of the FORTIS payload; graduate student Scott Redwine joined the effort in 2009, and undergraduate students have also gained hands-on experience with the rocket payload.

• FORTIS has flown twice so far. In May 2013, on its first flight, FORTIS successfully observed the nearby star-forming galaxy M61, but did not obtain scientifically useful data because scattered geocoronal hydrogen emission saturated the detectors. Moreover, the flight ended with a rough landing. Immediately after the May 2013 flight, the FORTIS team plunged into rebuilding the telescope to respond to an exciting target: the apparition of Comet ISON. In November 2013, FORTIS flew again, and successfully observed the breakup of the comet as it approached the sun. FORTIS was used to look for hydrogen, oxygen, and carbon monoxide emission at different locations in and around the comet nucleus. Since ISON came from the outer reaches of our Solar System, the new data are expected to provide information on the composition of the primordial solar nebula. FORTIS is now being readied for a flight in Summer 2015, to observe hydrogen emission from a star-forming galaxy.

Three other currently funded sounding rocket experiments are relevant to Cosmic Origins and will be featured in future editions of the newsletter:

• ACCESS (PI: Mary Beth Kaiser, Johns Hopkins University): The Absolute Color Calibration Experiment for Standard Stars (ACCESS) will provide an absolute flux calibration scale, to better than 1%, tied to NIST standards, with a resolving power of ~500 for wavelengths $0.35 < l < 1.7$ microns. Increased precision and accuracy, to 1% or better, in the astrophysical flux scale is necessary for reducing systematic errors associated with the photometric redshift based flux measurements of the SNeIa used to generate the SNeIa *Hubble* diagram that discriminates between dark energy models.

• CIBER (PI: Jamie Bock, Caltech): The Cosmic Infrared Background Imager (CIBER) uses the integrated light from all infrared sources in the Universe, to determine constraints on the stellar content of the Universe and to search for signatures of the first generation of stars and galaxies.

Sometimes the landing is rougher than expected! FORTIS payload recovery, at White Sands Missile Range.

• IMAGER (PI: Timothy Cook, University of Massachusetts, Lowell): The Interstellar Medium Absorption Gradient and Extinction Rocket (IMAGER) is exploring how dust grains are affected by their surrounding radiation field, and how the presence of dust affects astrophysical observations at all wavelengths.

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Cosmic Origins Technologies, NASA HQ

Mario Perez, *COR Program Scientist*
Michael Garcia, *COR Program Scientist*
Lia. S. LaPiana, *COR Program Executive*

The Strategic Astrophysics Technology (SAT) program for all three themes (Cosmic Origins: Technology for Cosmic Origins (TCOR), Physics of the Cosmos: Technology for Physics of the Cosmos (TPCOS), and Exoplanet Exploration: Technoogy Development for Exoplanet Missions (TDEM) has completed three full selection cycles since its inception in 2009. This program was established as a technology maturation tool to fill the needed gap for mid-Technology Readiness Levels ($3 \leq TRL < 6$). If we exclude new SAT selections, to be announced before the end of FY2014 (which include only selected investigations for TDEM and TPCOS), these three selection cycles have resulted in 43 meritorious investigations selected for funding, of which 11 are relevant TCOR technologies. Some of these investigations are still active and the research teams report periodically to technologists within the three program offices, who are in charge of mid-TRL technology management. A list of COR SAT investigations is at **http://cor.gsfc.nasa.gov/technology/**

Although the SAT program is still in the initial phases of development some early successes can be singled out by the recent incorporation of some of these funded investigations into space missions in formulation. This is the case of the starlight suppression technologies funded by TDEM that competed for the down select process in the internal coronagraph concepts of WFIRST/AFTA for further technology maturation. The WFIRST/AFTA study office has developed a plan for maturing coronagraph technology and retiring major engineering risks by late 2016. STMD is co-funding the WFIRST/AFTA coronagraph technology development starting in FY 2014 after the technology downselect. Similarly, the new H4RG near-IR (0.7–2.0 μm) detectors, originally selected and funded by TCOR, were also adopted as the detectors to be matured

by WFIRST/AFTA for the Wide-Field Imager instrument. Current progress on these detectors indicate that this technology is capable of delivering the required performance for WFIRST. Within the TPCOS theme, the SAT program supported the development of the antenna-coupled transition-edge superconducting (TES) bolometer, which was used in the BICEP2 experiment, and was central to the Cosmic Microwave Background (CMB) polarization measurements recently reported. The antenna-coupled detector arrays provided a 10-fold increase in measurement speed compared with the BICEP1 predecessor experiment.

SAT funded grants are intended to move these concepts up the TRL ladder, to make them viable as components in flight mission concepts. Ideally, all SAT-selected technology concepts should move into technology development plans within missions under study or development. The natural next step for these technologies, after the SAT program, is to be adopted as technologies of choice within strategic missions in formulation, and continue their maturation with technology funds allocated for these missions. A more detailed paper recently presented at the SPIE 2014 meeting on *Astronomical Telescopes and Instrumentation*, includes additional background information and a list of the funded investigations. This paper is available at: **http://cor.gsfc.nasa.gov/docs/**

We also continued collaborating with the Space Technology Mission Directorate (STMD) and these collaborations have resulted in the selection of two investigations under the Early Stage Innovation (ESI) solicitation on the topic of "*Thin-Film Physics or Optical Coatings*." Two far-infrared antireflective (AR) coatings targeted for CMB applications were funded for two years starting at the end of 2013: "*Bioinspired Broadband Antireflection Coatings at Long Wavelengths for Space Applications*" by Peng Jiang, U. of Florida, and "*Broad Bandwidth Metamaterial Antireflection Coatings for Measurement of the Cosmic Microwave Background*" by Jeff McMahon, U. of Michigan. These AR coatings are expected to reach absorption levels of about 90% across the bandwidth of relevant CMB frequencies.

For next year, we look forward to the new competition cycle for all three themes of the SAT solicitation, which was already issued via the Research Opportunities in Space and Earth Sciences (ROSES) on February 18, 2014 (Appendix D.8). The due date for the Notice of Intent to propose (NOI) is on January 23, 2015 and full proposals are due on March 20, 2015. It is likely that this solicitation will be amended with necessary updates during the month of December 2014.

As usual we always welcome your comments, thoughts, questions, and suggestions to any of us at NASA HQ.

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Cosmic Origins Program Analysis Group (COPAG) Update

Kenneth Sembach, *COPAG Chair*

The Cosmic Origins Program Analysis Group (COPAG) solicits and coordinates community input for issues related to NASA's Cosmic Origins (COR) program. The COPAG Executive Committee coordinates the various activities of the COPAG, which include articulating and prioritizing key science drivers for COR research, evaluating capabilities of potential missions for achieving COR science goals, and identifying focus areas for technologies needed to advance COR science. We recently solicited nominations for new members of the COPAG Executive Committee, and we expect to announce the results of this search in late September.

The COPAG uses Science Analysis Groups (SAGs) and Science Interest Groups (SIGs) to foster topical conversations and analysis of COR-relevant science and technology issues. Membership in the SAGs and SIGs is freely open to any interested parties, and we encourage community participation in all of these activities. The COPAG currently has three active SAGs. These include: SAG#6 (**Cosmic Origins Science Enabled by the WFIRST-AFTA Coronograph**) coordinated by Dennis Ebbets, SAG#7 (**Science Enabled by Operations Overlap of HST and JWST**) coordinated by James Green, and SAG#8 (**Science Enabled by the WFIRST–AFTA Data Archive**) coordinated by Sally Heap. These three SAGs are expected to conclude in late 2014, with reports to the Astrophysics Subcommittee soon thereafter. Input from the community is still possible and desirable, so if you would like to participate in these SAGs or contribute your ideas to the SAGs, please contact either the SAG leads or COPAG chair. A newly commissioned SAG, SAG #9 (Science Enabled by Dedicated *Spitzer* Observing Campaigns Prior to the Launch of JWST), will soon start identify compelling science with JWST enabled by, or benefitting from, large blocks of dedicated *Spitzer* observing time prior to JWST launch (late 2018).

The COPAG currently has one active SIG: (**Science Interest Group (SIG) #1: Far Infrared Science and Technology**) led by Paul Goldsmith and David Leisawitz. Activities for this SIG were jumpstarted by the successful workshop, "Bringing Fundamental Astrophysical Processes Into Focus: A Community Workshop to Plan the Future of Far-Infrared Space Astrophysics", held May 12–13, 2014 at the Goddard Space Flight Center. The program and presentations for that workshop can be found at **http://asd.gsfc.nasa.gov/conferences/FIR/**.

The COPAG was active at the June 2014 AAS meeting in Boston. In addition to open sessions for the active SAGs and SIG, the COPAG and ExoPlanet Analysis Group (ExoPAG) continued the tradition of holding a joint session at AAS meetings. Topics of that joint meeting included summaries of the COPAG SAG and SIG sessions, an update on the status of the "JWST and Beyond" study being conducted by the Association of Universities for Research in Astronomy, status presentations for the two ongoing Exoplanet probe studies, the status of *Spitzer* and 2014 Senior Review recommendations, a discussion of technology needs for future missions, and a presentation on the ATLAST study.

The COPAG and ExoPAG plan to hold a joint meeting at the January 2015 AAS meeting in Seattle to discuss items of common interest to the Cosmic Origins and Exoplanet communities. That joint meeting will take place on Sunday, January 4. An agenda will be posted soon on the COPAG and ExoPAG websites. We encourage all interested parties to attend. Come listen and contribute to the future of ExoPlanet and Cosmic Origins science!

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An Overview of the May 2014 Far-Infrared Community Workshop

D. Leisawitz, *NASA/GSFC*
P. Goldsmith, *Caltech/JPL*

A workshop called "Bringing Fundamental Astrophysical Processes Into Focus: A Community Workshop to Plan the Future of Far-Infrared Space Astrophysics" was held on May 12–13, 2014 at the Goddard Space Flight Center. The workshop brought together 147 scientists, technologists, instrument developers and program managers from academia, the private sector, NASA Centers, and NASA Headquarters. Twelve nations including the United States were represented.

The workshop achieved most of its objectives, which were to summarize recent successes in science and technology, identify the most pressing science questions that a far-infrared space mission is best placed to answer, inform the community about technical and programmatic status and possible future directions, and renew consensus regarding the future of far-IR space astrophysics. Secondary objectives were to energize the community by building awareness of the importance of far-IR astrophysics in the broader context of multi-wavelength astronomy, and to engage early-career scientists and technologists in the discussion.

The workshop included oral presentations, posters, splinter group discussions, a panel discussion, and audience participation. There were oral presentations on single aperture telescope and interferometry mission measurement capabilities; astrophysical processes and objects of interest on a distance scale ranging from the solar system to high-redshift galaxies and cosmology; and enabling technology. Each of the science talks included a table of measurement capabilities desired in a future space-based far-IR mission. Most of the talks and posters can be viewed on the workshop web site, **http://asd.gsfc.nasa.gov/conferences/FIR/** .

The programmatic landscape was discussed and factored into early planning for the 2020 Astrophysics Decadal Survey. The Japanese mission Space Infrared Telescope for Cosmology and Astrophysics (SPICA), in which ESA and its member nations will play a major role, will be proposed to ESA as a candidate for its fourth Medium (M)-class mission, with a final selection expected in 2017. US planning will have to allow for two possible outcomes: the SPICA proposal will be accepted by ESA and the mission will enter development, or the proposal will not be accepted and SPICA will be delayed or cancelled. SOFIA's future will also factor into planning for a future NASA far-IR space mission.

The Far-IR Science Interest Group (SIG) will engage all interested members of the science community in workshop followup activities. The SIG is co-led by Paul Goldsmith (JPL; paul.f.goldsmith@jpl.nasa.gov) and Dave Leisawitz (NASA GSFC; david.t.leisawitz@nasa.gov). Please feel free to contact us for further information.

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Meet *Hubble* Fellow Fabienne Bastien

Power outages, satellite safe events, and spectacular aurorae on Earth all result from magnetic flares on the Sun. High resolution movies of the solar photosphere show that even during quieter time, the Sun's surface is literally boiling, with huge parcels of ionized gas hundreds of kilometers in diameter constantly rising and falling. These convection cells induce small but rapid changes, or "flicker" in measured brightness and relative velocity for all Sun-like stars. In the current era of extremely high precision measurements, this flicker provides a fundamental limitation to techniques for finding new planets. Fabienne Bastien and her collaborators are working to understand and challenge this constraint.

Fabienne earned her B.S. in Astronomy from the University of Maryland at College Park, where she used HST images to study the asteroid Vesta and analyzed data from Deep Impact at Comet Tempel/1. She obtained a M.A. at Fisk University, expanding her interest in time-domain astronomy by exploring fast moving knots in the Cass A supernova remnant and outbursts from young FU Ori stars. She earned her Ph.D. in astronomy at Vanderbilt University, on "Empirically Interrelating Stellar Chromospheric Activity, Photometric Variability, and Radial Velocity Variations to Enhance Planet Discovery." Fabienne and her collaborators found that the amplitude of the flicker is correlated with stellar surface gravity, a key property used to determine a star's physical properties and evolutionary state. She is currently en-route to Pennsylvania State University, where she will expand her work to determine the effects of age, spectral type, and magnetic activity on flicker.

Fabienne's discovery led to revised size estimates for 289 Kepler planets. Her future work may enable optimized selection of stars likely to have small planets, and could lead to modeling and removal of the flicker signal, effectively lowering the noise floor for future exoplanet detection. She is enthusiastic about expanding exoplanet surveys to new spectral types suggested by her previous work.

As a four-year old child, Fabienne was told by her mother to look for angels in the night sky. When she peered out her bedroom window on a clear night, she was hooked on astronomy forever. Fabienne reads voraciously and loves to buy books.

Information about the *Hubble* Fellows Program may be found at **http://www.stsci.edu/institute/smo/fellowships/hubble/**

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Upcoming Events

October 29, 2014	*Spitzer* Cycle 11 proposals due
November 6, 2014	Nancy Grace Roman Technology Fellowship proposals due
November 6, 2014	2014 *Hubble* Fellow applications due
November 17–20, 2014	"Widefield Infrared Surveys" Pasadena, CA
January 4, 2015	COPAG meeting at AAS meeting Seattle, Washington
March 20, 2015	APRA and SAT proposals due
April 20–23, 2015	"*Hubble* 2020: Building on 25 Years of Discovery" STScI, Baltimore, MD
April 2015	*Hubble* proposals due

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