National Aeronautics Space Administration

Cosmic Origins Newsletter

July 2013 Volume 2, Number 1

Welcome from the Program Office

Mansoor Ahmed, *COR Program Manager*

It is my great pleasure to welcome Dr. Kenneth Sembach as the new chair of the Cosmic Origins Program Analysis Group (COPAG) Executive Committee. The Program Office (PO) is looking forward to working closely with the COPAG in advancing the Cosmic Origins (COR) science and relevant technologies.

It has been more than a year since the joint Physics of the Cosmos (PCOS)/COR Program Office was established. In February 2013, our Standing Review Board (SRB) assessed the progress made by the PO since entering the implementation phase. The Board was impressed by the PO's achievements, especially in the area of engaging the science community. According to the SRB:

"The Joint Program Office (JPO) is to be commended for catalyzing respective communities to 'reinvent their future' via PhysPAG [PCOS Program Analysis Group] and COPAG:

- Increasingly effective science outreach, led by PCOS/COR Program Scientists
- Increasing attendance at PhysPAG and COPAG public meetings
- Useful & easy-to-navigate Web sites established by JPO"

To achieve the COR scientific objectives, our efforts will be closely coordinated with those of the scientific communities. Mission concept studies can serve as anchors for specific enabling technologies to be funded this decade. Budget permitting, the PO will focus on building upon the Request for Information (RFI) results from last year, for ultraviolet/visible (UV/visible) science investigations, as well as an observatory in the far-IR domain instead of our participation in the Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission of Japanese space agency, JAXA, in this decade. In the near future, we plan to invite the larger community to suggest new ideas for concept studies and technology development that will enable COR science.

The SRB also commended the PO for concluding a comprehensive study on how to minimize the cost and associated risk of disposing of the *Hubble Space Telescope* (*Hubble*), when the time comes. "Impressive progress [has been] made in studying options for [*Hubble*'s] Disposal," the Board stated. On a brighter note, I am happy to announce that *Hubble* continues to operate at the peak of its scientific potential, without any technical issues.

We continue to implement our Technology Management Plan, where we engage the community in prioritizing technology needs and invest in the technologies on a competitive basis. COPAG and community participation in the listing of these needs is very important to ensure an accurate assessment. You will read more about our progress and our needs for COPAG interaction later in this newsletter in a section dedicated to technology investments.

The PO plans to continue its face-to-face interaction with the community, despite the sequestration guidelines that have impacted the ability of the PO to attend conferences where we can engage with a significant portion of the science community. The new limited-interaction philosophy is quite different from our current practice of active engagement, so we are working on alternatives to achieve the same goals and to minimize any impact to our community engagement activities. Stay tuned.

Inside this Issue

PO Personnel Update

I am pleased to welcome Gabe Karpati to our Program Office, as the Program System Engineer, replacing Steve Leete and Alan Cohen. Mr. Karpati's areas of expertise include mission design and concurrent engineering. He has been involved in the development of both *Hubble* and *Spitzer*, among other missions. Most recently, as the Chief Engineer of the GSFC Integrated Design Center, he has led the formulation of over 100 space flight mission designs and systems architecture concepts. Also joining the PO as Program Business Manager is Kevin Miller; he brings experience from *Hubble* and other missions. Finally, I am sorry to announce that Mark Brumfield, Deputy Program Manager for Advanced Mission Concepts, is leaving the PO. He will be missed. ✳

COR Science

Dominic Benford, *COR Chief Scientist*

The science scope of the Cosmic Origins Program is so broad that it is possible to touch on only a few of the many recent science highlights in this newsletter. The past year has seen *Hubble* reaching its 23rd birthday, the completion of *Herschel*'s cryogenic operations, the beginning of the *Stratospheric Observatory for Infrared Astronomy*'s (SOFIA) first full cycle of science flights, and the end of the *Galaxy Evolution Explorer* (GALEX) science data collection.

One major COR-led effort has been defining a path toward a future UV/visible mission to follow *Hubble*, as recommended in the 2010 New Worlds, New Horizons decadal survey. In June 2012, we released an RFI on science investigations using a future UV/visible wavelength space telescope. We received 34 substantial and compelling science ideas with 219 people contributing to these submissions. In September 2012, we hosted a workshop attended by most of the submission leads, who presented abbreviated versions of their proposed science visions. These constitute a broad and representative sampling of potential high-impact science investigations that could be addressed by a future UV/visible mission. All 34 submissions are available on the COPAG website, and a workshop summary and detailed analysis is being prepared for publication in the near future. We refer the interested reader to our webpage at: http://cor.gsfc.nasa.gov/RFI2012/rfi2012-responses.php, where this will be made available.

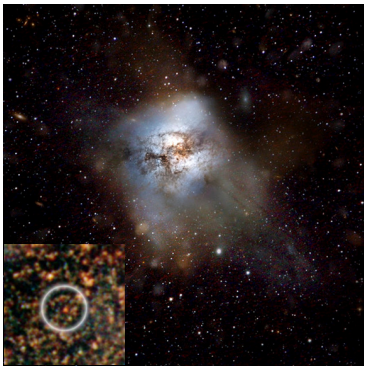
The RFI posed the question: "What observing proposal will you write in the next decade?" Answers to this question range from the science of star and planet formation to achieving a fundamental understanding of large-scale structure and galaxy formation and evolution. In this regard, the responses delineated the boundaries of the COR science portfolio and underlined the broad range of science a future UV/visible mission might fulfill. We intended that the mission concepts flowing from such questions should not be confined by prior mission concepts. We found that some performance parameters naturally grouped together around certain specifications. While these should not be construed as a definitive determination of required capabilities, they will help guide technology developments during the coming decade. For instance, more than half of all *imaging* science cases can be met by missions with a *Hubble*-scale mirror, wavelength range, and/or angular resolution. This provides a testimony that *Hubble*'s capabilities will remain competitive for many years to come. For *spectroscopy*, however, the desire is for efficient wavelength coverage into the far-UV with an aperture of at least *Hubble*'s class and, often, requirements include multi-object or other multiplexing capability.

We intend to build on this work by sponsoring a second workshop in 2014. The concept study capabilities will be traced to the requirements of the science investigations, in order to develop a plan for the technological capabilities needed for flight readiness in the decade of the 2020s. Investments in these technologies through the Strategic Astrophysics Technology (SAT) line will be shaped by this knowledge, in accordance with the recent Astrophysics Implementation Plan.

Herschel Discovers Earliest Starburst Galaxy

April 17, 2013

The European Space Agency (ESA)/NASA *Herschel* space observatory has discovered an extremely distant galaxy making stars more than 2000 times faster than our own Milky Way. Seen at a time when the Universe was less than a billion years old, its mere existence challenges our theories of galaxy evolution. The galaxy, known as HFLS3, appears as little more than a faint, red smudge in *Herschel* images.



Artist's impression of starburst galaxy HFLS3, which appears as little more than a faint, red smudge in the inset image from Herschel. Credit: ESA–C. Carreau

"Looking for the first examples of these massive star factories is like searching for a needle in a haystack," says Dominik Riechers of Cornell University, who led the investigation. "This particular galaxy got our attention because it was bright, and yet very red compared to others like it," says co-investigator Dave Clements of Imperial College London.

HFLS3 has one of the highest star formation rates ever seen in any galaxy. We see it as it existed in the infant Universe, but even at that young age, HFLS3 was already close to the mass of the Milky Way. This makes the object an enigma. According to current theories of galaxy evolution, galaxies as massive as HFLS3 should not be present so soon after the Big Bang. The first galaxies to form are expected to be relatively small and lightweight, and to form their first stars at rates of a few times that experienced by the Milky Way today.

See full article here

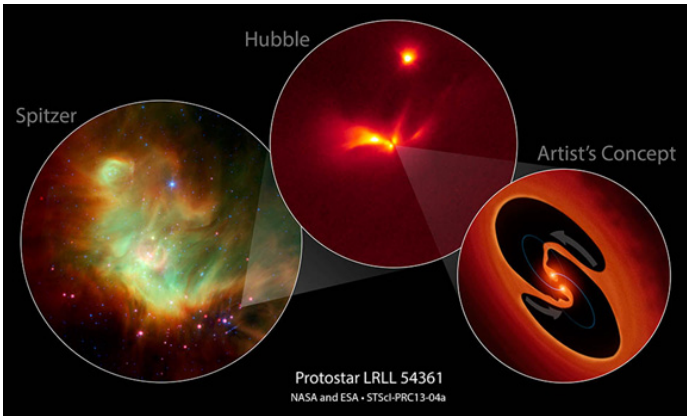
The decadal survey also recommended involvement, if possible, in the SPICA mission of Japanese space agency, JAXA. Present circumstances provide little opportunity for U.S. participation in SPICA, so it is prudent to consider how to advance the science goals behind the prominent decadal survey placement. We believe that a favorable path would be to plan for a stand-alone activity in the coming decade. This implies pursuing a plan similar to that currently under way for the UV/visible, but offset by roughly a year.

The sequester has prevented the COR Program Office from engaging the community in further workshops in FY 2013. However, we anticipate a return to a higher level of interaction in 2014. Until then, we look for more community involvement (via open COPAG telecons) to pursue the important work of advancing COR science and technology plans. Please don't hesitate to approach us with your interests and concerns! Contact us here.

Spitzer and *Hubble* Discover a Stellar Strobe Light

February 7, 2013

Two of NASA's great observatories, the *Spitzer* and *Hubble* space telescopes, have teamed up to uncover a mysterious infant star that behaves like a strobe light. Every 25.34 days, the object, designated LRLL 54361, unleashes a burst of light.



NASA's Spitzer and Hubble space telescopes have teamed up to uncover a mysterious infant star that behaves like a strobe light. Credit: NASA/ESA/JPL-Caltech/STScI/NOAO/ University of Arizona/Max Planck Institute for Astronomy/ University of Massachusetts, Amherst.

Astronomers propose that the light flashes are caused by periodic interactions between two newly formed stars that are gravitationally bound to each other. LRLL 54361, estimated to be no more than a few hundred thousand years old, offers insights into the early stages of star formation when gas and dust is rapidly accreted to form a new binary star.

"This protostar has such large brightness variations with a precise period that it is very difficult to explain," said James Muzerolle of the Space Telescope Science Institute (STScI) in Baltimore, Md., lead author.

The *Spitzer* infrared data showed unusual outbursts in the brightness of the suspected binary protostar, recurring every 25.34 days. Astronomers used NASA's *Hubble* Space Telescope to reveal the detailed stellar structure around LRLL 54361. *Hubble* observed two cavities above and below a dusty disk, and a spectacular movement of light away from the center of the system, an optical illusion known as a light echo. The disk, and surrounding natal envelope of gas and dust, prevent a direct view of the central stars.

Muzerolle and his team hypothesize the pair of stars in the center of the dust cloud orbit one another in a very eccentric orbit. As the stars approach each other, dust and gas are dragged from the inner edge of a surrounding disk. The material ultimately crashes onto one or both stars, which triggers a flash of light that illuminates the circumstellar dust. This is likely a brief, transitory phase in the birth of a star system.

See full article here

WISE Discovers Closest Star System Found Since 1916!

March 11, 2013

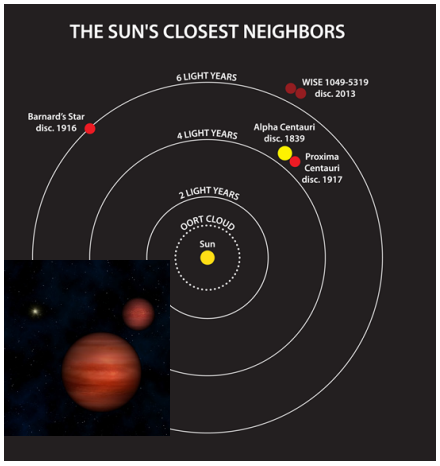
NASA's *Wide-field Infrared Survey Explorer* (WISE) has discovered a pair of stars that now holds the title for the third-closest star system to the sun. The duo is the closest star system discovered since 1916. Both stars in the new binary system are brown dwarfs, which are stars that are too small in mass ever to become hot enough to ignite hydrogen fusion. As a result, they are very cool and dim, resembling a giant planet like Jupiter more than a bright star like the sun.

"The distance to this brown dwarf pair is 6.5 light-years—so close that Earth's television transmissions from 2006 are now arriving there," said Kevin Luhman, Penn State University. "It will be an excellent hunting ground for planets because the system is very close to Earth."

The star system, named "WISE J104915.57-531906," is only slightly farther away than the second-closest star, Barnard's star, which was discovered 6 light-years from the sun in 1916.

Edward (Ned) Wright, the principal investigator for the WISE satellite at the University of California, Los Angeles (UCLA), noted, "One major goal when proposing WISE was to find the closest stars to the sun. ...the close-up views of this binary system we can get with big telescopes like...the future *James Webb Space Telescope* [JWST] will tell us a lot about the low-mass stars known as brown dwarfs."

WISE completed its all-sky survey in 2011, after surveying the entire sky twice at infrared wavelengths. The maps have been released to the public, but an ongoing project called "AllWISE" will combine data from both sky scans. AllWISE will provide a systematic search across the sky for the nearby moving stars such as WISE J104915.57-531906, and also uncover fainter objects from the distant universe. Those data will be publicly available in late 2013.



The binary system WISE J104915.57-531906 is the third nearest system to the Sun, and the closest one found in a century. Inset: an artist's conception of the binary system WISE J104915.57-531906 with the Sun in the background. Credit: Janella Williams, Penn State University.

See more about this image here

Message from NASA's Astrophysics Division Director

Paul Hertz, *Astrophysics Division Director, NASA Headquarters*

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 U.S. science team for our partnership with ESA, and mission extensions for *Spitzer*, *Planck*, *Chandra*, *Fermi*, *XMM-Newton*, *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 Announcement 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 pace of the Explorer program and putting on hold selections from the 2012 AO 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

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Strategic Astrophysics Technologies (SAT) Program, NASA HQ

John Gagosian, *COR Program Executive*
Michael Garcia, *COR Program Scientist*
Mario Perez, *COR Deputy Program Scientist*

As part of the initiative that started 3 years ago, we are prepared to run the peer-review evaluation process of the third set of proposals submitted to the SAT Research Opportunities in Space and Earth Sciences (ROSES)-12 element, which were submitted on March 22, 2013. This year we received a total of 40 SAT proposals across all three themes (COR, PCOS, and Exoplanets); 13 were self identified as being relevant to the COR Program. These proposals represent investigations on mirror technologies, UV and far-IR detectors, and materials for optical components. The SAT investigations support technology maturation at or beyond the Technology Readiness Level (TRL) 3 to higher-level, demonstrable, and repeatable milestones. These key technologies are expected to become feasible for implementation in future space flight missions.

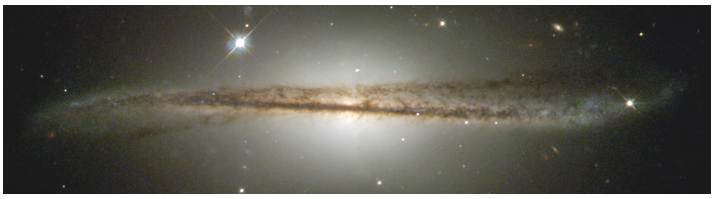
In the prior 2 years of competing the SAT portfolio, eight COR-related grants have been funded and the COR PO has managed the technology aspects of these projects by identifying milestones and the current TRL status of these investigations. All of these technical presentations are public and they are part of the 2012 COR Program Annual Technology Report (PATR) available at http://cor.gsfc.nasa.gov.

Within this process, the COR Technology Management Board (TMB) will start meeting this summer to re-evaluate the different technology needs, and their relative ranking, by prioritizing these needs to guide future SAT solicitations. The individual technology needs, and the rationale for their rankings, will be included in the 2013 PATR. It is important for the scientific community to be a part of this process by participating in the community meetings of the COPAG, since their deliberations are the initial input of this prioritization process. We invite you to read the PATR and to contact any member of the COPAG Executive Committee (EC) in order to provide input to this process.

We always welcome your comments, thoughts, questions, and suggestions. Contact us here. ✳

What Are Our Technology Needs?

Thai Pham, *ACTO Chief Technologist*



A key product of the COR Program's technology management process is our PATR. The PATR describes the Program's technology management activities and technology development progress over the past year. The PATR also defines the technology needs and their priorities for investment consideration during the upcoming year.

You are encouraged to read the 2012 COR PATR, which is available online at http://cor.gsfc.nasa.gov/docs/2012_COR_PATR_final.pdf, to learn about our technology development projects and their progress and our technology needs. In this report, the Program technology needs that were submitted by the community are prioritized using a set of criteria (described in the report) that reflects the goals of the COR Program. As future calls for technology development for the Program are drafted and investment decisions are made, the priorities established in the PATR are referenced. The prioritization process begins with your input regarding the technologies that you feel are needed to enable or enhance future COR missions. The COPAG is the main conduit for collecting technology needs identified by anyone in the community. These inputs can also be provided directly to the Program by submitting the "Technology Needs Form" at http://cor.gsfc.nasa.gov/technology/.

We look forward to receiving your technology needs input. The annual prioritization process begins in July, and we will release the next PATR in October 2013. Your insights and suggestions are important to us! Whether you develop cutting-edge technology or use that technology to expand our understanding of the universe, we encourage you to read the PATR and tell us what you think. This is your opportunity to take an active role in shaping the future of COR science. Feel free to comment on the prioritization process and please help us identify technology needs to prioritize. We would like to receive your technology needs inputs no later than July 19, so they can be incorporated into our 2013 technology planning process. If you have any questions, please contact me at thai.pham@nasa.gov. ✳

... "Message from Paul Hertz" Continued from page 4

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/. ✳

Status of the COPAG

Susan Neff, *COR Deputy Chief Scientist*

Dr. Kenneth Sembach, Head of the HST Mission Office at the STScI, has been appointed as the new chair of the COPAG. His scientific interests include evolution and baryonic content of the Inter-Galactic Medium (IGM), physical conditions and properties of gaseous material in galaxies, and feedback related to the Inter-Stellar Medium and IGM. Dr. Sembach is an expert in all aspects of *Hubble* instrumentation and operations, and an active participant in planning for future COR-oriented space missions including and beyond JWST.

Former COPAG chair Chris Martin completed his term in February 2013, after more than 3 years of dedicated work to advance COR science goals. The COPAG currently has nine members in the EC working across five Science Analysis Groups (SAGs). Three members of the COPAG Executive Committee will rotate off the committee in late 2013, and nominations (including self-nominations) for new members will be solicited through the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES), American Astronomical Society (AAS) announcements, and the COR e-mail exploder. Nomination information will be posted on the COR website, at http://cor.gsfc.nasa.gov/.

On September 19, 2012, the COPAG sponsored a community workshop at STScI in Baltimore to explore the possibility of using "probe-scale" missions (defined as under $1B) to execute the science investigations submitted to the UV/visible RFI. The workshop was attended by about 50 participants, and the discussion was lively. The workshop also featured presentations on future directions for far-infrared (FIR) COR science, and included discussions of missions both larger and smaller than "probe scale." Presentations are available at http://cor.gsfc.nasa.gov/copag/.

On January 6, 2013, preceding the 221st AAS meeting in Long Beach, the COPAG sponsored another community workshop, which was attended by about 35 people. This workshop presented a science analysis of the responses to the UV/visible RFI and a summary of the FIR technology needed for the future health of the field. These areas are likely to form the main focus for COPAG activities in the near future.

Recently, the COPAG executive committee has been reviewing the various SAGs, with the intent of closing out or revising the goals for some of the SAGs and possibly starting new SAGs. Suggestions from the community for high-priority analysis areas are welcome. Contact us here.

The COPAG had hoped to hold a community meeting in late summer/fall, ideally in conjunction with the Exoplants Program Analysis Group (ExoPAG). NASA restrictions on meeting participation and on travel are forcing a reexamination of this idea. The COPAG is currently investigating online community meeting possibilities; updates will be announced on the COR website and news mailer (http://cor.gsfc.nasa.gov/cornews-mailing-list.php).

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COR-related Conferences and Workshops

Susan Neff, *COR Deputy Chief Scientist*

Two very interesting science conferences in the past year have addressed the present state and desired future of astrophysics requiring ultraviolet wavelength observations. The first, "HST and Beyond: The Future of UV Astronomy," took place June 17–21, 2012, in Kauai, Hawaii. The second meeting, "GALEXFest: Exploring the UV Universe," occurred September 3–7, 2012, in Pasadena, Calif. The Kauai meeting was largely inspired by results from HST, particularly from the spectrographs, while the Pasadena meeting celebrated the breadth of science studies enabled by GALEX's (mostly imaging) observations. Both meetings included sessions dedicated to the next big science questions posed by current observations, and discussions of what facilities might be needed to address those questions. Agendas and many of the presentations from the conferences may be found, respectively, at http://uvastro2012.colorado.edu/program.shtml and http://galex.caltech.edu/galexfest/.

The COR program sponsored a community workshop September 18, 2012, at the STScI, to present and discuss responses to the RFI for "Science Objectives and Requirements for the next UV/visible Astrophysics Mission," as discussed on page 2. The workshop's agenda, presentations, and responses are available at http://cor.gsfc.nasa.gov/RFI2012/rfi2012-responses.php.

NASA organized a workshop in February 2013, in Huntsville Alabama, to present RFI responses for "Concepts for Applications of Large Space Optics." The workshop provided a plethora of ideas for creative re-use of the telescope assemblies donated to NASA. Thirty-four concepts were presented, with the majority addressing astrophysics goals. The COR Program's architecture study for combining a Hubble-like telescope launch with the HST de-orbit mission was presented by D. Benford. The workshop's agenda and abstracts are available at http://science.nasa.gov/salso/workshop-information/. ✳

..."COPAG" Continued from page 5

Another community workshop will occur just prior to the 223rd AAS meeting to be held in Washington, D.C., in January 2014.

We invite you to be part of the COPAG membership and be an active part of this dialogue. COPAG executive telecons are open to all interested parties, as are community meetings such as the COPAG community meeting prior to the 223rd AAS meeting. Please learn more and participate in enunciating the science drivers, technologies, and mission concepts relevant to the COR theme. ✳

Meet Hubble Fellow Joshua Peek

Joshua Peek
Hubble Fellow

How does matter flow into and out of galaxies, and how does that cycling affect the galaxies' evolution? All galaxies, small and large, accrete material from their environments, as well as return it to the surrounding volume of space. Episodes of star formation are associated with infusions of fresh gaseous material. However, details of the inflow/outflow, and locations, extents, and natures of the gas reservoirs are only beginning to be understood. Joshua Peek and his collaborators are pioneering a new method for determining the structure, content, and possibly the history of gaseous haloes around galaxies.

Josh earned his B.A. from Harvard University. He then moved to the University of California, Berkeley, where he earned an M.S. and a Ph.D., the latter focused on "High Velocity Clouds" (HVCs), which are thought to be falling onto our Milky Way. As a postdoctoral researcher at Columbia University, he continued work on HVCs and developed his "Standard Crayon" technique for characterizing dust properties. He is now a *Hubble* Fellow at Columbia University, and is using dust observations to explore galaxy evolution.

Josh uses brightness measures in 10 or more wavelength combinations ("colors") to determine how much dust is in a galaxy's halo, how that dust is distributed, and how violently it was ejected from the galaxy. Because dust and gas are often well mixed, dust can tell us about what processes may have affected the gas. Josh and his collaborators are beginning to learn which kinds of galaxies have what sorts of dust around them (e.g., sizes of grains, composition), to test their models against simulations of galaxy growth, and to decipher the different histories of different types of galaxies.

In addition to his work on galaxy haloes, Josh is also using his method with HVCs to explore their relative gas and dust content, and possibly to determine their origin. For both galaxy and HVC work, he uses a complementary collection of: space-based observations in the UV, visible, and infrared wavelengths (*Hubble*-Cosmic Origins Spectrograph, GALEX, *Herschel);* ground-based observations at visible, infrared, and radio wavelengths (Sloan Digital Sky Survey, Arecibo, Expanded Very Large Array, Green Bank Telescope); and large galaxy evolution simulations.

Josh has a strong interest in science communication, especially in effective data visualization techniques for complex data sets or concepts. He also likes the technical aspects of large-scale interactive art projects; he has been technical director of a small theater company and has participated in the annual Burning Man event at least a half-dozen times. He enjoys roller skating and rock climbing, but these days he is spending most of his non-astronomy time teaching his 16-month-old child how to visualize the universe.

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