National Aeronautics and Space Administration

Cosmic Origins Newsletter

September 2017 Volume 6 Number 2

Summer 2017 Cosmic Origins (COR) Program Update

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

Welcome to the September 2017 Cosmic Origins (COR) newsletter. In this issue, we provide updates on several activities relevant to COR Program objectives. Although some of these activities are not under the direct purview of the program, they are relevant to COR goals; therefore we try to keep you informed about their progress.

The article by **Paul Hertz** (Director, NASA Astrophysics) provides an overview of the state of the NASA Astrophysics Division and the current plan for moving forward. Two of the four studies being conducted for input to the decadal 2020 review address COR science goals: the Large UV-Optical-near IR mission (LUVOIR) and the *Origins Space Telescope* (OST, formerly *Far-Infrared Surveyor*). Both teams have made great progress in the past year, identifying initial key science drivers, selecting architecture concepts to study, and developing instrument requirements. Articles by the Community Chairs of the **LUVOIR** and **OST** studies summarize team accomplishments, status, and plans. More information on the studies may be found at the **LUVOIR** and the **OST** study websites.

The Astrophysics Division is also studying mission concepts that would bridge the gap between Explorer-class Principal-Investigator-led missions (<~$300M), and larger strategic missions (generally > ~$1B). Ten concepts were chosen for study in March 2017. We provide an introduction to the **three Astrophysics Probe mission concepts** with science goals directly addressing COR science goals.

The *James Webb Space Telescope* (*Webb*) is not formally part of the COR program, but much of the science that *Webb* will address sits firmly in the COR arena. The observatory continues towards its planned launch in 2018 on time and on budget. Calls for proposals have begun! We provide a brief **status of Webb** and an article on the **test chamber at Johnson Space Center**.

WFIRST is proceeding well towards completion of Phase A. A mid-term assessment of NASA's progress towards the 2010 Decadal Study's recommendations noted the compelling science goals of WFIRST; the mid-term assessment also recommended an independent, external, review of cost, technical progress, and management. We present an **overview of these**.

Many of NASA's advances are made through partnerships with other countries' space agencies. We provide an introduction to the process used to select, plan, and build missions at the **European Space Agency** (ESA).

SOFIA continues to operate well; it has started its fifth cycle of observations, commissioned a new instrument, and is planning for a next-generation instrument call.

The *Hubble Space Telescope* (*Hubble*) continues to obtain breathtaking images and fundamental spectroscopic measurements of our Universe. The *Spitzer Space Telescope* (*Spitzer*) recently was fundamental in the discovery of seven (!) exoplanets around a nearby ultra-cool dwarf star, and continues to obtain data that will

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help optimize the science program for *Webb*. The *Galaxy Evolution Explorer* (GALEX) and *Herschel* data archives continue to support new science discoveries. Science results from (current and former) COR missions are scattered through the newsletter.

Technology development is a crucial part of planning for future missions, large or small, and a key part of the COR Program is managing technology development needed for future COR discoveries. We also include an article about the new **COPAG Technology Interest Group** (TIG) and its role in helping with assessment of COR technology needs. The TIG's goal is to bring scientists and technologists together in thinking about the future of space-based COR science.

We introduce ***Hubble* fellow Anne Medling**, who studies interactions of gas with black holes at the centers of merging galaxies

We are pleased to welcome Erin Smith to the COR program office as the new COR Deputy Chief Scientist. Erin's background is in infrared instrumentation, and in studies of warm dust, the InterStellar Medium (ISM), and star formation and evolution. She will be a great asset to the program.

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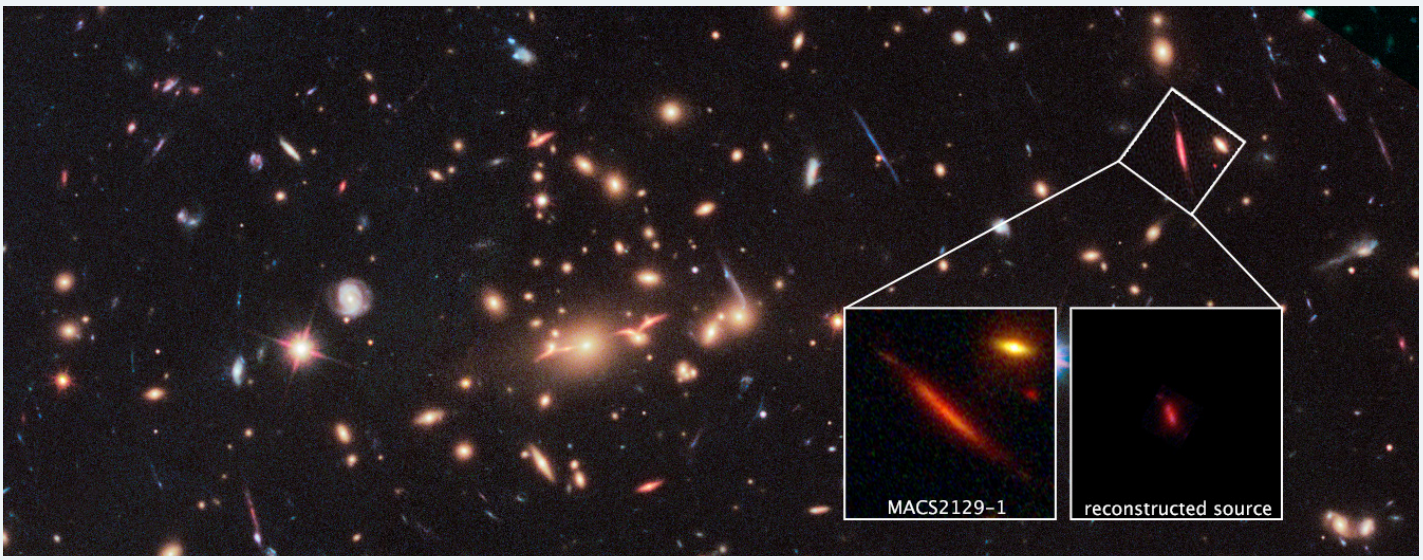
Hubble Captures Massive Dead Disk Galaxy that Challenges Theories of Galaxy Evolution

By combining the power of a "natural lens" in space with the capability of NASA's *Hubble Space Telescope*, astronomers made a surprising discovery—the first example of a compact yet massive, fast-spinning, disk-shaped galaxy that stopped making stars only a few billion years after the big bang. Finding such a galaxy early in the history of the Universe challenges our understanding of how massive galaxies form and evolve.



Hubble image of the galaxy cluster MACS J2129-0741, showing several "stretched" images of background galaxies. The inset red galaxy stopped forming stars very early in the history of the Universe, but velocity measurements show that it is a spinning disk, not an elliptical ball of stars. Credit: NASA, ESA, S. Toft (University of Copenhagen), and M. Postman (CLASH team)

When *Hubble* imaged the galaxy, astronomers expected to see a chaotic ball of stars formed through galaxies merging together. Instead, they saw evidence that the stars were born in a pancake-shaped disk. This is the first direct observational evidence that at least some of the earliest so-called "dead" galaxies—where star formation stopped—evolve from a Milky Way-shaped disk into the giant elliptical galaxies we see today.

This is a surprise because elliptical galaxies usually contain older stars, while spiral galaxies typically contain younger blue stars. At least some of these early "dead" disk galaxies must have gone through major makeovers. They not only changed their structure, but also the motions of their stars to make a shape of an elliptical galaxy.

"This new insight may force us to rethink the whole cosmological context of how galaxies burn out early on and evolve into local elliptical-shaped galaxies," said study leader Sune Toft of the Dark Cosmology Center at the Niels Bohr Institute, University of Copenhagen, Denmark. "Perhaps we have been blind to the fact that early "dead" galaxies could in fact be disks, simply because we haven't been able to resolve them."

Previous studies of distant dead galaxies assumed that their structure is similar to the local elliptical galaxies they will evolve into. Confirming this assumption in principle requires more powerful space telescopes than are currently available. However, through the phenomenon known as "gravitational lensing," a foreground cluster of galaxies acts as a natural "zoom lens" in space, magnifying and stretching images of far more distant background galaxies. By joining this natural lens with the resolving power of *Hubble*, scientists were able to see into the center of the dead galaxy.

For more information, see **http://hubblesite.org/news_release/news/2017-26**

Message from the Astrophysics Division Director

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

As I described during the NASA Town Hall at the 230th meeting of the American Astronomical Society (AAS), June 2017 in Austin, TX, the Astrophysics Division is continuing to execute a broad portfolio of research activities and missions for the community, many of which were the subject of sessions at the AAS meeting. In order to maximize the science return from the NASA astrophysics program, we rely on community participation at every level of the program. This includes the Astrophysics Advisory Committee (formally the Astrophysics Subcommittee), the Program Analysis Groups (PAGs), Science and Technology Development Teams for future missions, mission and archive User Groups, and peer review panels. I invite you to self-nominate yourself to participate in any of these community groups.

The FY17 appropriation and FY18 budget request provide funding for NASA astrophysics to continue its planned programs, missions, projects, research, and technology. The operating missions continue to generate important and compelling science results, and new missions are under development for the future. The next Senior Review of operating missions is in 2019. SOFIA is adding new instruments: the High-resolution Airborne Wideband Camera-plus (HAWC+) instrument has been commissioned; the High-Resolution Mid-Infrared Spectrometer (HIRMES) instrument is in development; a next generation instrument call is planned for early 2018. The *Neutron Star Interior Composition Explorer* (NICER), an Explorer Mission of Opportunity, was launched to the International Space Station (ISS) on 03/06/2017 (June 3, 2017), with the science program starting in mid-July. NASA missions under development making progress toward launches: ISS-*Cosmic Ray Energetics and Mass* (CREAM) (2017), *Transiting Exoplanet Spectroscopic Survey Satellite* (TESS) (2018), *James Webb Space Telescope* (2018), *Imaging X-ray Polarimetry Explorer* (IXPE) (2020), and Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) (2021), *Wide Field Infrared Survey Telescope* (WFIRST) (mid-2020s). Partnerships with ESA and JAXA on future missions create additional science opportunities: *Euclid* (ESA; 2020), *X-ray Astronomy Recovery Mission* (XARM) (JAXA; 2021), *Athena* (ESA; 2028), LISA (ESA; 2034). Explorer AOs are being released every 2–3 years: MIDEX/MO selections are targeted for Summer 2017, and the next SMEX/MO Announcement of Opportunity in 2019.

NASA supports the astrophysics community through a number of competed programs, including Guest Observer/Guest Investigator (GO) programs, Research and Analysis (R&A) programs, and Postdoctoral Fellowship (Hubble, Einstein, and Sagan) programs. Funding for R&A has been increased by 20% since the 2010 Decadal Survey. However, proposal numbers have grown faster than funding over this period, so selection rates have fallen. The 2017 Research Opportunities for Space and Earth Science (ROSES) solicitation was released on 14/02/201 and posted at **http://nspires.nasaprs.com/**.

NASA continues to make progress developing the *James Webb Space Telescope* according to plan during the integration and test phase. The ambient testing of the science payload has been completed at Goddard Space Flight Center, and it has been shipped to Johnson Space Center where end-to-end performance testing of the telescope and instruments are being conducted in space-like conditions within Chamber A; the spacecraft assembly is nearly complete at Northrup Grumman Space Park in Redondo Beach, CA; the spacecraft and sunshields will be completed and integrated this year. 2017 is also the year that the science community begins developing the *Webb Telescope*'s science program. The call for Early Release science was issued in January 2017, and the call for Cycle 1 General Observer proposals will be issued in November 2017. *Webb* remains on cost and on schedule for an October 2018 launch. Information on the *Webb Telescope* is at **https://jwst.nasa.gov/**, and information on the proposal opportunities is at **https://jwst.stsci.edu/**.

Two critical mission technologies for the *Wide-Field Infrared Survey Telescope* (WFIRST) have successfully completed three-year technology demonstration activities. NASA is conducting a WFIRST Independent External Technical/Cost/Management Review (WIETR) in response to findings and recommendations in the National Academies' Midterm Assessment. Information on WFIRST is at **https://wfirst.gsfc.nasa.gov/**.

The National Academies conducted a review of NASA's progress during the first half of the decade, and NASA's plans during the second half of the decade, for implementing the 2010 Decadal Survey. This Midterm Assessment, available at **http://www.nap.edu/download/23560**, made recommendations to NASA regarding its implementation of WFIRST, the Explorers Program, and U.S. contributions to the European Space Agency's *Euclid*, *Athena*, and gravitational wave missions. NASA will be implementing all of the Midterm Assessment's recommendations; the full details can be found in the 2016 Astrophysics Implementation Plan Update at **https://science.nasa.gov/astrophysics/documents/**.

NASA is sponsoring community-based studies in preparation for the 2020 Decadal Survey. Four mission concept studies for large missions are underway. Each study is being led by a Science and Technology Development Team supported by the engineering capabilities of a NASA Center. The entire community is invited to get involved with one or more of these studies; links to each of the studies is at **http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/**. NASA has solicited proposals to conduct mission concept studies for medium-size missions (probes), and selected ten proposals for mission concept studies. The probes implementation plan is available at **https://science.nasa.gov/astrophysics/2020-decadal-survey-planning**.

My entire Town Hall presentation from the June 2017 AAS meeting, which includes information on additional topics across the breadth of NASA astrophysics, is available at **http://science.nasa.gov/astrophysics/documents/**.

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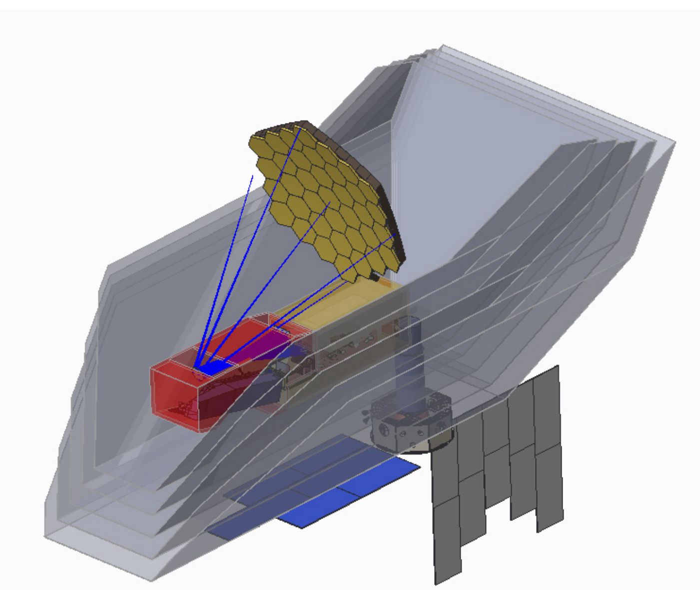
The *Origins Space Telescope* (OST) Mission Study

Margaret Meixner (STScI), co-Chair
Asantha Cooray (UC Irvine), co-Chair

The *Origins Space Telescope* (OST) is an evolving concept for the *Far-Infrared Surveyor* mission, and the subject of one of the four science and technology definition studies supported by NASA Headquarters to prepare for the 2020 *Astronomy and Astrophysics Decadal Survey*. The OST will measure biosignatures and find conclusive evidence for the presence or absence of life on exoplanets, measure the buildup of heavy elements and dust in distant galaxies, study feedback mechanisms in nearby galaxies and protoplanetary and debris disks in the Milky Way, and characterize cold objects in the outer reaches of our solar system.

The OST team will complete the Mission Concept 1 study in September 2017. In Concept 1, the telescope is a ~9 m off-axis, segmented telescope that is cryogenically cooled to ~4 K (see figure). A baffle (not shown) and cryocoolers ensure the telescope environment is maintained at ~4 K. The primary is deployed and the secondary is fixed inside the instrument accommodation module. Five instruments covering wavelengths from 6 to 660 μm enable the broad range of scientific activity: a Medium Resolution Scanning Spectrometer, with spectral resolving power R~500 and R~40,000 in the 30–660 μm range; a Far-Infrared Imaging Polarimeter, with 40, 80, 120, and 240 μm simultaneous imaging capability; a High Resolution Spectrometer, with R~10^5 and R~10^6 in the 25–200 μm range; a Heterodyne Instrument, with R~10^6–10^7 at wavelengths 63 μm and 111 to 566 μm; and a Mid-Infrared Imager, Spectrometer, and Coronagraph, covering 5 to 38 μm, with R~300, 1000, and 20,000, and equipped with a special transit spectrometer channel. The telescope, instrument accommodation module, sunshield, and spacecraft would be launched in NASA's Space Launch System with an 8.4 m diameter fairing, or in a similarly capable launch vehicle to L2.



Origins Space Telescope mission Concept 1, with a 9m cold telescope and five science instruments. (4 K baffle omitted to enable unobstructed viewing of the telescope and Instrument Accommodation Module).

Contribute your ideas!

All members of the scientific community are encouraged to participate in future discussions. There are biweekly telecons (**https://asd.gsfc.nasa.gov/firs/events/**) and six science working groups (**http://origins.ipac.caltech.edu/page/participate**) that continue to collect science cases. You can also email us at **ost_info@lists.ipac.caltech.edu**.

Our next face-to-face meeting will be 14–15/09/2017 at the Space Telescope Science Institute in Baltimore, at which we will discuss the second mission concept. We will be presenting at the January AAS meeting in National Harbor, MD (near Washington, DC) a talk in the Decadal Special Session, a talk in a special session on transiting exoplanets and talks and discussion in a Far-Infrared Science Interest Group (FIR SIG).

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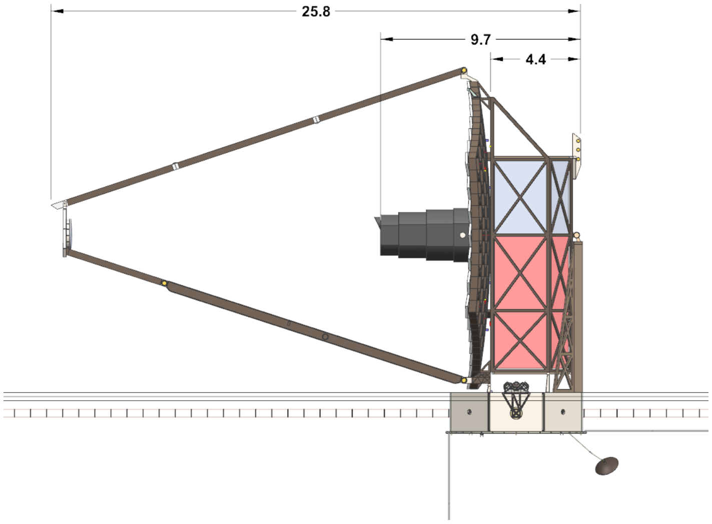
The Large Ultraviolet/Optical/Near-IR Telescope Study

Brad Peterson (OSU and STScI), co-Chair
Debra Fischer (Yale), co-Chair
Mark Postman (STScI), Wide-Field Imager Lead

The Large UV/Optical/IR Surveyor (LUVOIR) is one of four ambitious mission concepts being studied under the auspices of the NASA Astrophysics Division in preparation for the upcoming NRC Decadal Survey in 2020. The study is being carried out by a 24-member Science and Technology Definition Team (STDT) plus 9 international associates, supported by a number of science and technical working groups and NASA Goddard Space Flight Center. LUVOIR is envisaged as a general purpose, multiwavelength observatory whose science program will be driven by its guest observer program, in the tradition of NASA's Great Observatories including the *Hubble Space Telescope* as well as its successor, the *James Webb Space Telescope*. Like *Hubble*, LUVOIR is intended to be serviceable and upgradable to enable a long operational lifetime. Like *Webb*, LUVOIR will be in a halo orbit at Sun-Earth L2.

The task of the STDT is to define the compelling science that can be done uniquely with a large space-based telescope and identify the key technologies that will enable these science investigations: the goal is to demonstrate that engineering solutions to every technical challenge either exist or can be expected to be achieved on the near-term horizon with proper allocation of resources.

One of the more challenging science goals is to characterize atmospheres of nearby Earth-sized exoplanets that are in the habitable zone of their stars. LUVOIR will be uniquely able to conduct a systematic exploration of hundreds of star systems within 50–70 light years of the Sun. This requires a large aperture size, a coronagraph that can deliver at least 10^{-10} contrast and an ultra-stable optical system. A recent decision to actively position LUVOIR's 120 mirror segments using edge-sensor metrology, as is done with the ground-based Keck Telescopes, helps achieve the stability requirement.



The 15.1-m LUVOIR (Architecture A) as seen from the side. The blue and red areas show the positions of the instruments. The linear structure across the bottom is the three-layer sunshade: below this are the spacecraft bus, solar panels, and communications. The telescope is fully gimbled so that it can observe the entire down-Sun hemisphere and in special cases with a Sun-avoidance angle as small as 30 degrees.

To accommodate a wide range of science programs, the operational wavelength range of LUVOIR will be 100nm to ~5 µm, though the background for observations at wavelengths longer than about ~1.8 µm will be dominated by thermal emission from the telescope rather than sky background. The decision to operate LUVOIR near room temperature was made to both to avoid contamination on LUVOIR's sensitive UV optics and to avoid the much higher fabrication, testing, and operational costs of a cryogenic telescope. The short-wavelength limit is required for spectroscopic observation of oxygen emission spectral lines with wavelengths of 1032 and 1038 Ångstroms, which is crucial for study of the high-ionization interstellar medium (ISM) and the circumgalactic medium. It is important to note that UV-reflecting surfaces can now be made compatible with optical coronagraphy.

The LUVOIR team has decided to study two distinct mission architectures. Architecture A is based on the largest segmented mirror that can be packaged into a SLS Block 2 fairing, which has an inner diameter of 7.5 m. The mirror has diameter of 15.1-m and a collecting area of 135 m^2. Architecture B will be an alternative 9.2-m design that can fit into a 5-m launch fairing. The design for the 15.1-m LUVOIR concept is largely complete.

The LUVOIR STDT met for the fifth time at Caltech at the beginning of August. The final day of the three-day meeting was held jointly with the HabEx STDT, as the two teams have some overlapping science goals and technical requirements. Close interaction between the two teams is intended to ensure adherence to common standards, such as predictions of exoplanet yields, so that meaningful relative performance metrics are possible.

Exposure time calculators are available on the LUVOIR website at **https://asd.gsfc.nasa.gov/luvoir/**. The LUVOIR STDT strongly encourage members of the Cosmic Origins community to experiment with these tools. The STDT is currently writing up the LUVOIR science case for submission as part of the interim report due to NASA in December—additional contributions from the community are strongly encouraged.

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Astrophysics Probe Studies

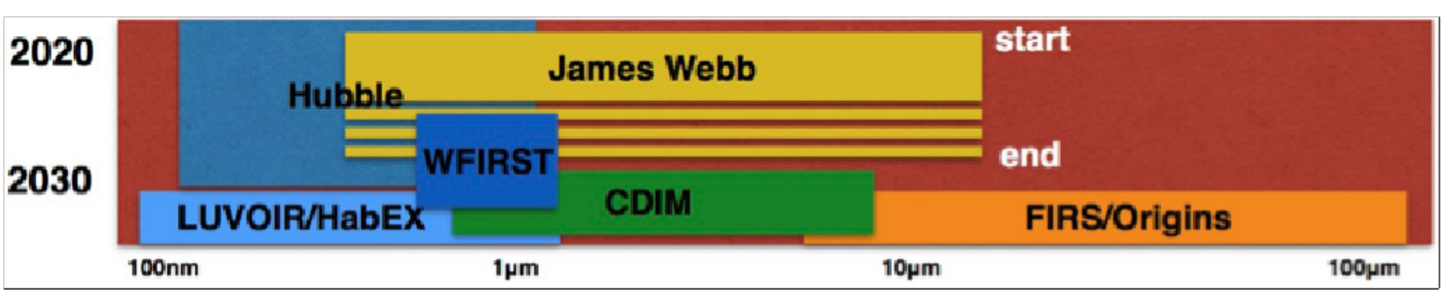
Susan Neff, *Chief Scientist*, COR Program

In the current Astrophysics mission portfolio, there are small, PI-led experiments (sub-orbital payloads, CubeSats, and Explorers), and larger strategic missions (*Hubble*, *Chandra*, *Spitzer*). However, there is currently no path to propose for an in-between class Astrophysics mission, similar in scope to FUSE, *Fermi*, or *Kepler*. Therefore, in 2016 NASA solicited proposals to study Astrophysics Probe mission concepts. These are intended to be PI-led missions, with a notional cost between ~$400M and ~$1B. The studies will be submitted to the 2020 Decadal Survey, as exemplars of possible Astrophysics Probe class missions. Three of the (ten) proposals selected for further NASA study address science questions directly relevant to the COR Program.

Cosmic Dawn Intensity Mapper (CDIM)

Asantha Cooray, University of California, Irvine

We are investigating a low-cost Probe-Class mission as the premier vehicle for a fundamental breakthrough in our knowledge of the reionization of the Universe following the big bang. We will explore the questions: When did the first UV-bright stars form from primordial gas? What is the history of stellar, dust, and metal build-up during reionization? What is the contribution of quasars to the reionization of the Universe?



In the 2025–2035 timeframe, CDIM will fill the capability gap between LUVOIR/HabEx (operating out to 1–2 µm), and the Origins Space Telescope (OST, with a minimum wavelength around 7–9 µm). (Completion dates for Hubble and Webb are uncertain.) Image Credit, A. Cooray

Cosmic Dawn Intensity Mapper (CDIM) is 1.5m-class infrared telescope capable of three-dimensional spectro-imaging observations over the wavelength range of 0.75 to 7.5 μm, spectral resolving power $\lambda/\Delta\lambda$ of 500. CDIM will use linear variable filters (LVFs) sitting on top of a focal plane of 36 2048^2 detectors to achieve an instantaneous field-of-view of 10 deg^2 instantaneously. A shift-and-stare survey strategy will produce 1360 independent narrow-band spectral images of the sky at each pointing. Currently prioritized science programs, taking over three-years of a five-year mission, will be accomplished with a two-tiered wedding cake survey (combined wide/shallow and narrow/deep surveys) with the shallower survey spanning close to 300 deg^2 and the deepest tier of about 25 deg^2. The remaining two years could be used for additional survey programs (the wide tier can be expanded to 1000 deg^2) or could be used for a General Observing (GO) program.

CDIM survey data will allow us to (i) determine spectroscopic redshifts of WFIRST-detected Lyman-break galaxies (LBGs) out to a redshift of 10; (ii) establish the environmental dependence of star-formation during reionization through clustering and other environmental measurements; (iii) establish the metal abundance of first-light galaxies during reionization over two decades of stellar mass by spectrally separating NII from Hα and detecting both Hβ and OIII; iv) measure 3D intensity fluctuations during reionization in both Lyα and Hα; and (v) combine intensity fluctuation measures with 21-cm data to establish the topology of reionization bubbles.

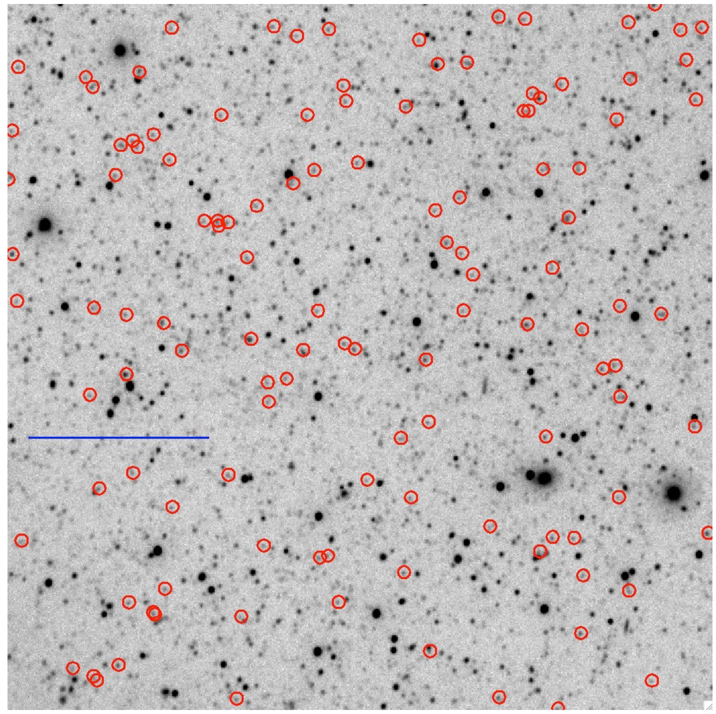
Cosmic Evolution Through UV Spectroscopy (CETUS)

Bill Danchi and Sally Heap, NASA/GSFC

In the 2020s, current and future wide-deep telescopes will be surveying the sky at wavelengths ranging from gamma rays to radio waves. These telescopes include E-ROSITA, Subaru's Prime Focus Spectrograph (PFS), LSST, WFIRST, *Euclid*, and the Square Kilometer Array. These surveys will be highly synergistic leading to new, important discoveries. But there is a glaring hole in this vision: it lacks a UV-sensitive telescope. This will hinder all astronomy, because the UV spectral region is so rich in diagnostics that it has become a natural and necessary companion to space and ground-based telescopes observing at all wavelengths. NASA has selected for study a Probe mission concept called CETUS to fill that hole.

The Cosmic Evolution Through UV Spectroscopy (CETUS) concept comprises a 1.5m wide-field telescope with a near-UV multi-object slit spectrograph (MOS), far-UV and near-UV wide-field cameras, and far-UV and near-UV spectrographs with both low and high spectral resolution. The goals of the CETUS mission concept are (1) to understand the processes operating in galaxies at cosmic noon that led to the decline in star formation and black-hole growth that has persisted to the present day, and (2) to provide an ultraviolet capability for use by the astronomical community after *Hubble* is retired.

As part of our study, we will soon be forming a Design Reference Mission (DRM) for CETUS with scientific rationale, real(istic) targets, exposure times, etc. for each scientific program. We welcome scientists of all nationalities to join us in formulating the DRM.



Sample image to be obtained by CETUS's near-UV camera, 1044" on a side. A far-UV image of the field will be obtained simultaneously by the camera. The near-UV multi-object spectrograph (MOS) has same field of view as the far-UV and near-UV cameras but is offset by ~600". It will observe in parallel with the UV cameras. The red circles enclose all ~100 z=0.8–1.3 galaxies that are bright enough for the MOS to observe, and the blue bar shows the length of the resulting spectrum covering 200-400 nm. (Image credit based on GALEX near-UV observation of a field in the COSMOS survey. The resolution of a CETUS image (~0.5") will be much finer than that of GALEX (~5"). Image credit: S. Heap

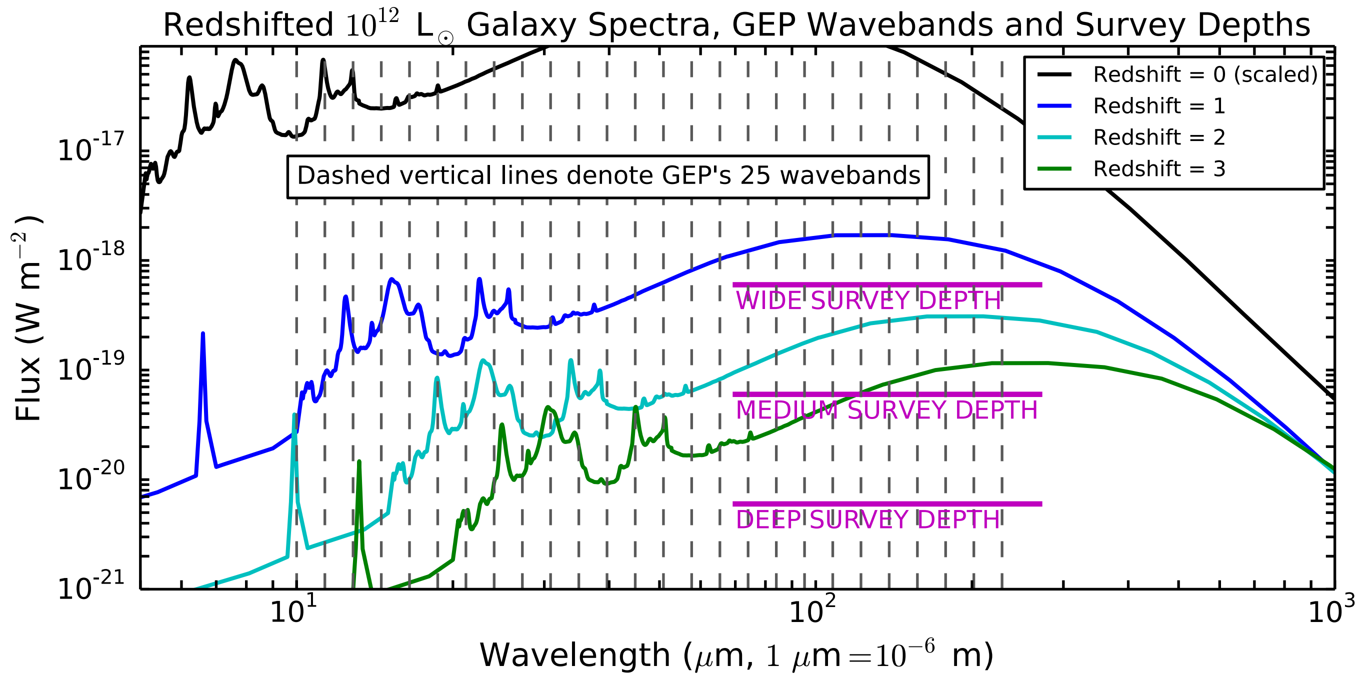
Please contact Bill Danchi (PI) at **William.C.Danchi@NASA.gov** or Sally Heap (Science PI) at **sara.heap@gmail.com**.

Galaxy Evolution Probe

Jason Glenn, University of Colorado

The Galaxy Evolution Probe (GEP) concept is a cryogenic, two-meter-class, far-infrared observatory designed to survey large regions of the sky. It will identify star-forming galaxies, assess their star formation rates, and measure the growth rates of their central, supermassive black holes (SMBH). Both star formation rates and SMBH accretion rates peaked at redshifts between z = 2–3, when the Universe was only 2–3 billion years old, and both have declined steeply since then. The reasons for the declines are not clear, but it seems likely that feedback into galaxies' interstellar media regulates and suppresses both star formation and accretion.

In the first year of the Galaxy Evolution Probe's nominal two-year lifetime, it will identify nearly of order a hundred million galaxies by mid- and far-infrared radiation from small, warm (10s - ~100 K) interstellar dust grains. The dust is heated by star formation, deeply embedded in molecular clouds and therefore obscured from detection with visible and ultraviolet radiation. However, the infrared radiation enables astronomers to identify dusty star-forming galaxies and to infer their rates of



The Galaxy Evolution Probe will use a 2 meter mirror to detect star-forming galaxies, from redshifts >3 to 0, thanks to new, sensitive MKID detectors. The mission will measure star formation rates, central SMBH accretion rates and redshifts, using 25 separate photometric bands. Image credit: J. Glenn

star formation. Uniquely, GEP will detect galaxies using mid-IR emission from polycyclic aromatic hydrocarbons (PAHs, small dust grains, or large molecules—strong indicators of star formation), while simultaneously using PAH bands to measure the redshifts of the galaxies photometrically. Redshifts will be determined using 25 photometric bands at wavelengths ranging from 10 µm to ~300 µm; each band will have spectral resolution R ~8 R = λ/Δλ. In the second year of the survey, spectroscopy of atomic fine structure lines will be obtained of a carefully selected sample of thousands of galaxies found in the first-year survey, and will be used to identify embedded active galactic nuclei. In addition to quantifying star formation rates and nuclear accretion rates, GEP will characterize the galaxies' interstellar media and probe their dark matter environments. Measuring key aspects of the physical conditions in galaxies and their environments will help astronomers understand star formation and SMBH growth.

Transformative innovations in detector technology have recently made a far-infrared space observatory such as the GEP feasible for the first time, specifically the ability to fabricate large arrays of sensitive kinetic inductance detectors (KIDs) that have a high frequency multiplex factor. These detectors, coupled with a cold (4 K) ~2 meter telescope, will allow the GEP to detect galaxies that are similar to how the Milky Way appeared 10 billion years ago, thus giving us important knowledge about our origins. The Galaxy Evolution Probe can serve as a technological and scientific pathfinder for the *Origins Space Telescope*, mentioned elsewhere in this newsletter.

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Cosmic Origins Suborbital Program: Balloon Program – Stratospheric Terahertz Observatory (STO)

Susan Neff, COR *Chief Scientist*
Chris Walker, University of Arizona

NASA's scientific discoveries depend on new observational capabilities and on access to space (with little or no atmospheric attenuation). Instruments developed as balloon or sounding rocket payloads are often precursors to larger NASA astrophysics missions. The Astrophysics suborbital program uses sounding rockets and balloons for access to space and near space. The program is flexible, low cost, and allows short development cycles. Suborbital payloads

STO-2 launch team, LDB facility on Ross Ice Shelf, 09/12/2016. From left to right back: C. Walker, K. Davis, W. Peters, C. Groppi, A. Young, M. Carpenter, J. Siles. kneeling: E. Jacklin, B. Duffy, E. Rodberg. Others instrument team members not shown: C. Kulesa, P. Bernasconi, H. Eaton, J. R. Gao, R. Dominguez, A. Stark, J. Gorczyca, C. Honniball, P. Thompson, B. Swift. Image Credit: Scott Battaion, NSF are used to demonstrate or flight-test new technologies, as well as to prototype or execute exciting new science investigations. The program is key as a rigorous training ground for the students and postdocs who will become future Principal Investigators. For some investigations a balloon-borne platform can provide higher scientific return than an orbital platform. Astrophysics balloon and rocket payloads are funded through NASA's Astrophysics Research and Analysis (APRA) program and are part of NASA's Balloon Program, managed by NASA's Wallops Flight Facility. Currently there are five funded balloon programs and four rocket programs relevant to Cosmic Origins.

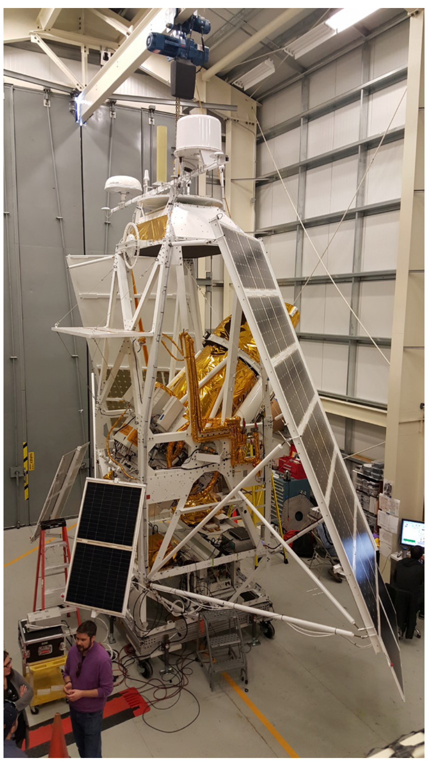
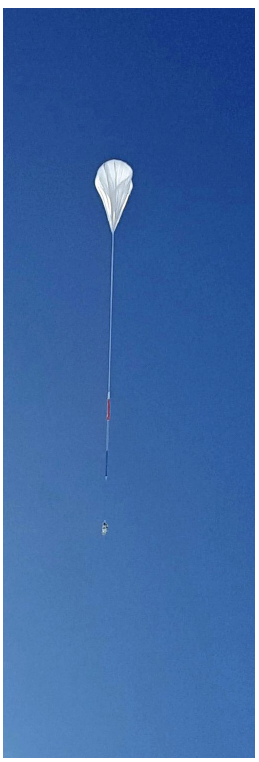
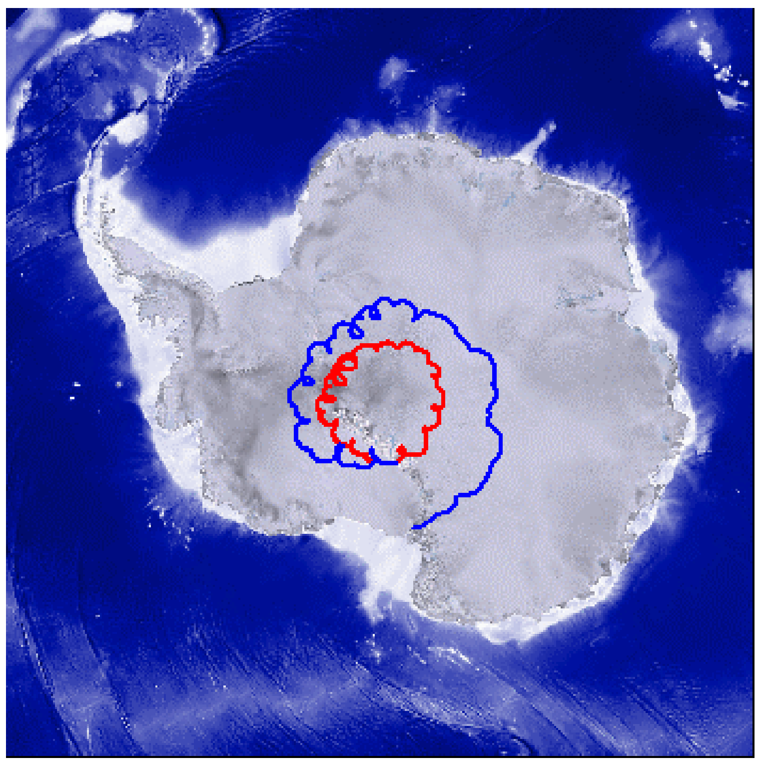
The submillimeter/terahertz (THz) portion of the electromagnetic spectrum (wavelengths 100 micron–1 mm, frequency 0.3–3THz) can be difficult to observe from ground or space. Detectors/receivers in this regime are less mature than at shorter (infrared) or longer (radio) wavelengths. However, this spectral range is important for probing the life cycle of the ISM (gas and dust), both in the Milky Way and in other galaxies. Terahertz radiation is absorbed by water vapor in the atmosphere, so it must be observed from space or near-space, or (in a few narrow wavelength bands) from dry, very high-altitude ground sites (e.g., Atacama Desert, Chile and the Antarctic plateau).

Principal Investigator (PI) Chris Walker (University of Arizona), leads the team for the Stratospheric Terahertz Observatory (STO). UA investigators work closely with teammates at APL/JHU, the SETI Institute, JPL, ASU, UMd, SRON, TU Delft, and Ball Aerospace. The STO team uses a balloon-borne, terahertz telescope with high spectral resolution heterodyne receives to explore the structures and spectral properties of gas in both star forming and non-star forming regions. The techniques are also applicable to studying star formation in active galaxies and are highly relevant to understanding more distant star-forming systems.

STO surveys the Galactic Plane in the luminous interstellar cooling lines of ionized Carbon (at 158 microns, or 1.90 THz), ionized Nitrogen (at 205 microns, or 1.46 THz), and neutral Oxygen (at 63 microns or 4.7 THz). STO receivers possess the sensitivity and spectral resolution needed to see molecular clouds forming, measure the rate of evaporation of molecular clouds, and separate the bulk motion of gas in the Galaxy from localize kinematic motions. By building a three dimensional picture of the ISM, STO studies the creation and disruption of star-forming clouds, determines what parameters govern the star-formation rate, and provide a template for stellar/interstellar feedback in other galaxies.

The STO instrumentation consists of an 80 cm telescope that feeds five cryogenic heterodyne receivers (two each for the Carbon and Nitrogen lines) and a Fast Fourier Transform Spectrometer system, along with control electronics. There is also a single receiver for the Oxygen beam. The receivers are inside a hybrid cryostat that provides 20+ days of cooling at ~4K. The telescope and cryostat are carried on a precision gondola. A calibration box is located between the telescope and cryostat, which can place a blackbody load at a known temperature in the detector paths. During flight, data is downlinked through both the NASA's Tracking and Data Relay Satellite System (TDRSS) and the Iridium Satellite System.

STO has flown three times. The engineering test flight on 15/10/2009, from Fort Sumner, NM, demonstrated successful operation of the tracking, pointing, and control of the telescope/gondola/instrument. A spectrum of the Orion molecular cloud validated end-to-end performance of the (warm) system.

Left: STO-2 undergoing pre-flight tests in Hangar #1 at the LDB facility on the Ross Ice Shelf. C. Groppi shown for scale. Center: STO-2 shortly after launch, 09/12/2016. Right: The subsequent flight lasted 21 days, and made 2 circles in the South Polar vortex, as indicated by the blue and red lines. (Image credits: C. Walker; CSBF)

The STO-1 flight took place 15–27/01/2012, from McMurdo base in Antarctica. A valve problem caused much of the liquid helium responsible for cooling the instruments to be lost. The few days of the mission with cold detectors were used for commissioning. During the warm part of the flight a Schottky diode receiver was used to further characterize flight systems.

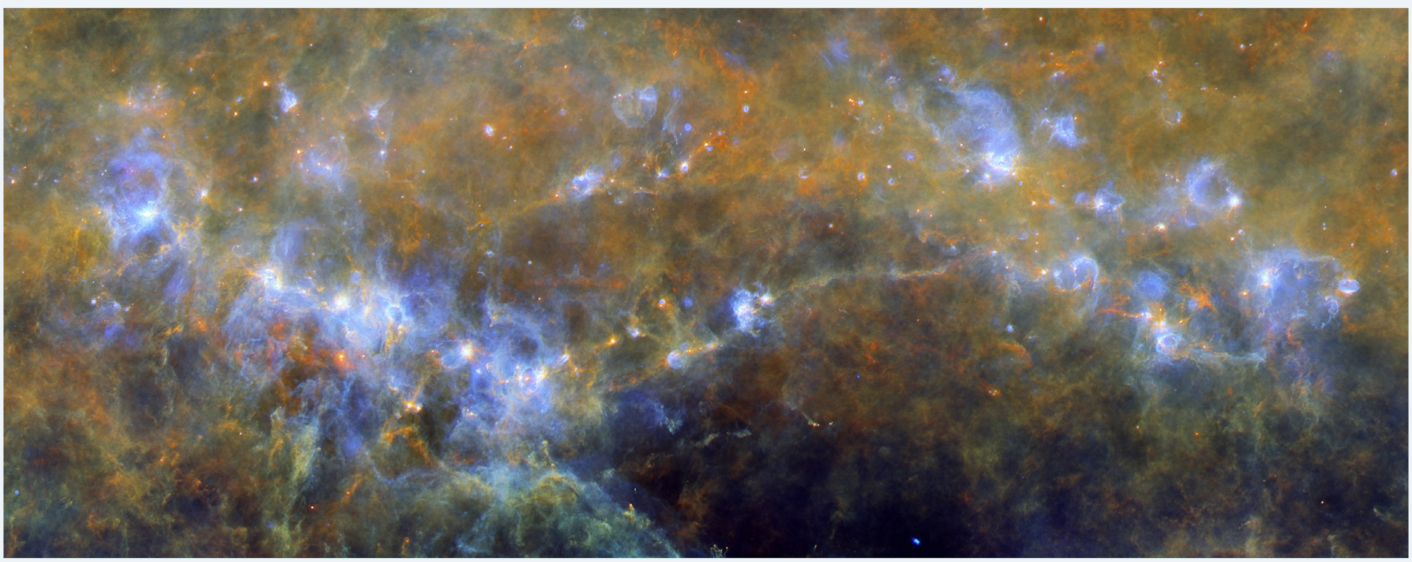
STO-2 flew from McMurdo 9–30/12/2016 (after being flight-ready in 2015–2016 Antarctic summer, but not getting a launch opportunity and wintering over in Antarctica). The team successfully observed ~8000 lines of sight in the galactic plane using its receivers. A problem with a control cable prevented observations of the Oxygen line. Data analysis from STO-2 is in progress by team members at UofA, SAO, JPL, and SRON (Netherlands). Initial results are expected later this year. To date, the effort has focused on Eta Carina.

PI Chris Walker notes that "Without student participation, neither STO-1 nor STO-2 would have gotten off the ground!" Graduate students working on the payload include: Mike Borden, David Lesser, Brandon Smith, Jenna Kloosterman (UA), Todd Veach, Kristina Davis (ASU), Michael Brasse (U. Cologne), and Ricard Farinha (Delft U. of Technology). Undergraduates also participated, including: Tiara Cottam, Casey Honniball, Allison Towner, and Marina Dunn. The development of STO instrumentation has and will be used in a number of theses and student projects.

As of March 2017, Walker and the STO team are moving to an even more ambitious mission: an enhanced version of STO has been selected to fly as an Explorer mission in 2021. The Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) will use an Ultra-long-duration-balloon to fly in near-space for 100–170 days. It will map a significant fraction of the

Star Formation: *Herschel* Maps Filaments in Giant Molecular Cloud RCW106

Stars are bursting into life all over this image from the *Herschel* space observatory. It depicts the giant molecular cloud RCW106, a massive billow of gas and dust almost 12 000 light-years away. Cosmic dust, a minor but crucial ingredient in the interstellar material that pervades our Milky Way galaxy, shines brightly at infrared wavelengths. By tracing the infrared glow of dust with the infrared sensors on *Herschel*, astronomers can explore stellar nurseries in great detail.



This three-colour image combines Herschel observations at 70 microns (blue), 160 microns (green) and 250 microns (red), and spans over 1º on the long side; north is up and east to the left. Image credit: ESA

Dense concentrations of the interstellar mixture of gas and dust where stars are being born are sprinkled across the image. The brightest locations (blue) are heated by newborn stars within, while the cooler regions are shown in red. The delicate shapes visible throughout the image are the result of radiation from the stars illuminating material disturbed by strong winds young stars. These winds carve bubbles and other cavities in the surrounding interstellar material.

The bright,blue region furthest to the left is known as G333.6-0.2; it is one of the most luminous locations in the infrared sky. It owes its brightness to a stellar cluster containing at least a dozen young, very bright stars that are heat the gas and dust around them.

Elongated thin structures, or filaments, stand out in the tangle of gas and dust and trace the densest portions of the star-forming cloud. It is largely along these filaments, dotted with many bright, compact cores, that new stars are taking forming.

Herschel observed the sky at far-infrared and submillimetre wavelengths for almost four years. By scanning the Milky Way with its infrared detectors, *Herschel* has identified an enormous number of filamentary structures, highlighting their universal presence throughout the Galaxy and their role as preferred locations for stellar birth.

The image was obtained as part of *Herschel*'s Hi-GAL key-project, which imaged the entire plane of the Milky Way in five different infrared bands. A spectacular video panorama compiling all Hi-GAL observations was published in April 2016. *Herschel* stopped science observations in 2013, when it ran out of cryogen for its instruments.

Full article at: **http://www.esa.int/spaceinimages/Images/2017/02/Star_formation_on_filaments_in_RCW106**

Milky Way's galactic plane, as well as mapping our neighbor galaxy, the Large Magellanic Cloud, in the emission lines of Carbon, Oxygen, and Nitrogen.

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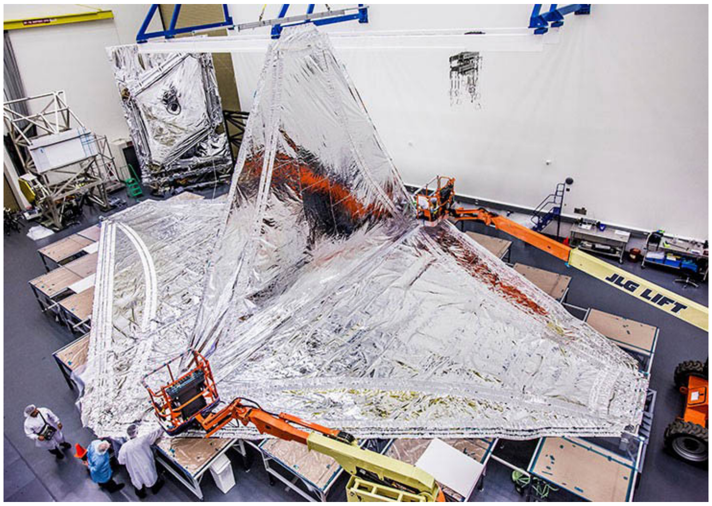
Webb Status and Progress

Susan Neff, COR *Program Chief Scientist*
Jonathan Gardner, NASA/GSFC, Webb *Deputy Project Scientist*

The *James Webb Space Telescope* (*Webb*) continues on schedule for launch in 2018. Observations made by *Webb* are expected to advance all aspects of astrophysics, particularly COR science.

The *Webb* Users Committee (JSTUC) members were announced in June. The composition consists of representatives of the General Observer (GO—10 members) community and members of the Instrument Definition teams (GTOs – 4 members). GTOs will remain on the committee through the end of guaranteed observations, 30 months after the end of commissioning. At least two members are from ESA nations, and one will be from Canada. The JSTUC will advise the observatory so that *Webb* can maximize its science performance. More information at: **https://jwst.stsci.edu/science-planning/user-committees/jwst-users-committee-jstuc**

The first community call for *Webb*, for Director's Discretionary Early Release Science (DD ERS) Observations, was announced at the January 2017 meeting of the American Astronomical Society. 106 proposals were submitted for DD ERS observations. Both raw and pipeline-processed data will become public immediately after processing and validation by STScI. Selected DD ERS proposals will be publicized prior to the Cycle 1 GO deadline. The call for Cycle 1 GO proposals is currently expected to be released in November

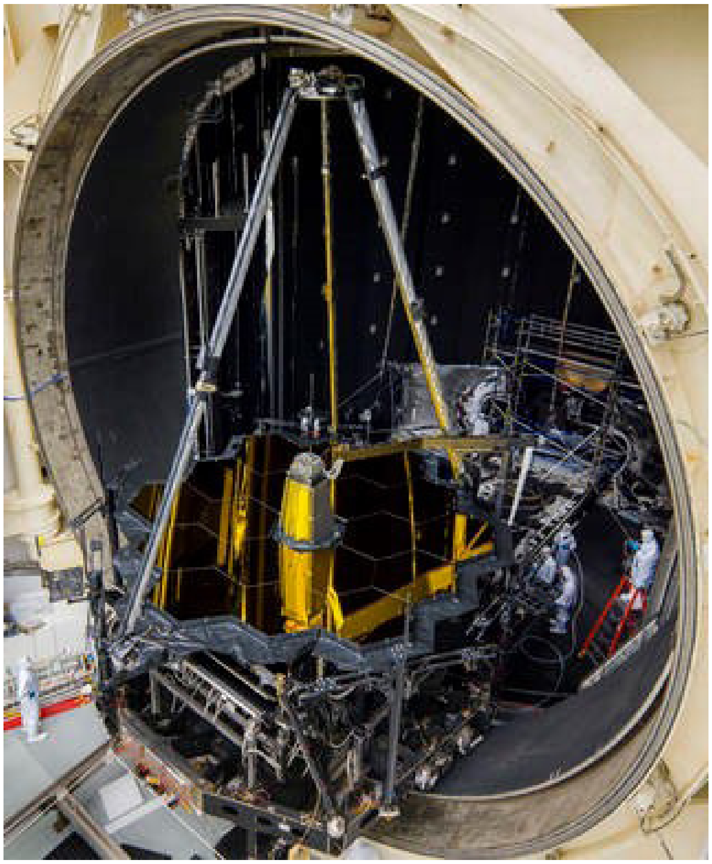


The first layer (of five) of the Webb telescope's sunshield, installed at Northrup Grumman's clean room in Redondo Beach, California. Credit: Northrup Grumman Corp

2017. Archival proposals based on DD ERS observations will be permitted beginning in Cycle 1.

In March and April, the Optical Telescope + ISIM (OTIS) completed final checking, to be sure that vibration and acoustic testing had not altered or damaged the telescope. *Webb* left Goddard Space Flight Center on 04/05/2017 in its special climate-controlled transport container, moving to Johnson Space Center (JSC) in Houston, Texas.

The vault-like 40 foot diameter, 40 ton entry door to Chamber A towers over engineers at Johnson Space Center in Houston. It was sealed shut on 11/07/2017, to start the 93 day final thermal vacuum test for the Webb Optical Telescope + ISIM (OTIS). Image credit: NASA/Chris Gunn



NASA's James Webb Space Telescope crossing the threshold into Chamber A at NASA's Johnson Space Center, Houston, on 21/06/2017. The telescope secondary mirror assembly (at top of the chamber entrance) cleared the door by 4.2 inches (10.7cm). Image Credit: NASA/Chris Gunn

After arrival at JSC, the OTIS was prepared for the next big cryogenic vacuum test, in Chamber A. The telescope is a close fit, but it slid into Chamber A on rails, with a clearance of 4.2 inches (10.7 cm), in late June. The telescope is suspended from the ceiling of Chamber A, to help isolate it from vibrations during testing. After checkout, the door was shut on 11/07/2017. A 93 day thermal-vacuum test follows; during much of this test the telescope will simulate space conditions at ~37K (-236 degrees Celsius, or -393 degrees Fahrenheit). It took about 10 days to pump out all the air, and nearly a month to lower the temperature in the chamber.

The spacecraft bus and the giant sunshield continue to make good progress at Northrup Grumman Aerospace Systems, in Redondo Beach, California, and are now fully assembled. In August, the five sunshield layers, responsible for protecting *Webb*'s optics and instruments, were fully installed. After careful folding and stowing of the layers, deployment testing began. Once the OTIS completes testing in Houston, it will move to California to be joined with the spacecraft.

For more information about *Webb*, visit **www.jwst.nasa.gov** or **www.nasa.gov/webb**

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NASA's Apollo-Era Test Chamber Now *Webb*-Ready

Robert Gutro, NASA/GSFC

NASA's "Chamber A," an enormous thermal vacuum testing chamber housed at NASA's Johnson Space Center in Houston, Texas, is now ready to conduct final optical testing on NASA's *James Webb Space Telescope* (*Webb* telescope), the largest space observatory ever. A National Historic Landmark, Chamber A is famous for being used to test Apollo moon mission hardware, including suited astronauts inside the chamber on occasion. In order to test *Webb* prior to launch, the chamber had to undergo major upgrades in the last several years.

Chamber A's upgrades were accomplished by engineers and technicians from NASA's Johnson Space Center in Houston, Texas, and NASA's Goddard Space Flight Center in Greenbelt, Maryland, including their contractor teammates, most notably from Jacobs Engineering and Harris Corporation. Some changes were made to the chamber and the surrounding facility and others were made to the design, construction, and installation of test equipment.

"In this partnership, Johnson will operate the chamber and Goddard will run the testing," said Paul Geithner, the *James Webb Space Telescope* project technical manager. "We've run multiple tests of everything, so we know it all works before using it this summer to test the flight hardware, which is the telescope plus integrated science instrument module."

Webb's telescope and the Integrated Science Instrument Module (ISIM) are two of the three major elements that comprise the *Webb* telescope Observatory flight system. The other is the Spacecraft Element (spacecraft bus and sunshield), which is currently under construction at Northrop Grumman Aerospace Systems (NGAS) in Redondo Beach, California.

This image, taken from inside the NASA Johnson Space Center Chamber A, captures the James Webb Space Telescope being lifted onto its test stand before sliding it into the chamber. Credits: NASA/Chris Gunn

With the upgrades necessary for testing the *Webb* telescope finally complete, Chamber A is now the largest high-vacuum, cryogenic-optical test chamber in the world. It is 55 feet (16.8 meters) in diameter by 90 feet (27.4 meters) tall. The main door alone is 40 feet in diameter (12.2 meters), weighs 40 tons, and is opened and closed hydraulically.

Out With the Old

Some Apollo-era legacy equipment was removed, such as a 'lunar platform' floor and solar simulation high-intensity lamps from inside the chamber. "Then, the 50-year-old facility's infrastructure, like the chilled water cooling system and air conditioning, backup power and the power feed, chamber clean airflow system, and building integrity (e.g., roof weatherproofing) were updated, refreshed, and improved," Geithner said.

In With the New

One of the things that was newly constructed and installed in Chamber A was a cold gaseous helium-cooled 'shroud' that enables the chamber to reach colder temperatures than it had ever reached before. This addition was necessary because *Webb*'s telescope and scientific 'instruments' (cameras and spectrometers) will operate at temperatures of around 37 Kelvin (K), which is around minus 393 Fahrenheit (F) / minus 236 Celsius (C). Chamber A previously had only a liquid nitrogen shroud inside, and because liquid nitrogen is 77K, you couldn't get test articles any colder than that. "We added a cold helium gas shroud that we've run down to about 11K, which is (minus 440 F/minus 262 C, thus enabling us to get the telescope to its operating regime and even to as low as around 20K to reach 'survival' temps," Geithner said.

Testing the *Webb* telescope requires a high vacuum and extremely low temperatures. The telescope also needs an arrangement that holds it and its test equipment in precise relative alignment inside the chamber while isolated from any sources

The James Webb Space Telescope has moved to NASA's Johnson Space Center in Houston, TX in May 2017 for the next big test - the cryogenic vacuum test in the Apollo-made-famous Chamber A. The telescope was placed into a climate-controlled container called STTARS and loaded into a C-5 cargo airplane. It was unpacked at NASA Johnson. Credits: NASA/ Sophia Roberts

of vibration, such as the flow of nitrogen and helium inside the shroud plumbing and the rhythmic pulsing of vacuum pumps. The engineers installed a massive steel platform suspended from six steel rods (vibration isolators) about 60 feet long (18.2 meters) each and about 1.5 inches (or 38.1 mm) in diameter, to hold the telescope and key pieces of test equipment. They installed sophisticated optical telescope test equipment including an interferometer, auto-collimating flat mirrors, and a system of photogrammetry 'precision surveying' cameras, and they already did tests with a surrogate 'pathfinder' telescope.

Webb is always kept in a clean environment to prevent dust and dirt from degrading its performance. The inside of Chamber A is clean, but unpacking, unfolding, re-folding and re-packing the *Webb* telescope requires a lot of space and therefore needed to be handled outside the chamber. So, engineers at NASA Johnson built a large cleanroom around the gaping entrance to Chamber A. The cleanroom provides room for the telescope to be hoisted from its shipping container and 'unwrapped' from protective bagging, deployed, rotated from horizontal to vertical, placed on its test platform, and finally slid into the chamber on rails and hung from the six long suspending rods, all in an ultra-clean environment. Even though the new cleanroom is big, it is barely large enough for these activities.

"The Goddard Space Flight Center and Johnson Space Center were responsible for the tremendously successful *Hubble Space Telescope* servicing missions," said Eric P. Smith, the director of the program, NASA Headquarters, Washington. "It's great to have the two centers team up again for this critical test of *Webb*, which is the scientific successor to *Hubble*."

Once telescope testing is complete, this sequence will run in reverse and the telescope will be shipped to Northrop Grumman Aerospace in California to meet up with the Spacecraft Element and finally become one complete *James Webb Space Telescope* observatory.

Testing, Testing, Testing

In the beginning, it will take a few weeks for everything inside the chamber to cool down and reach steady cryogenic temperatures, and similarly at the end it will take the final few weeks for everything to warm up to room temperature again, but every minute of the entire 93 days is jam-packed with specific tests to verify that the telescope performs as designed and will operate as it should in space.

To view a "Chamber A" image feature visit: **https://www.nasa.gov/image-feature/goddard/2017/nasas-james-webb-space-telescope-says-open-wide-to-chamber-a**

For more information about the *Webb* telescope, visit: **www.jwst.nasa.gov** or **www.nasa.gov/webb**

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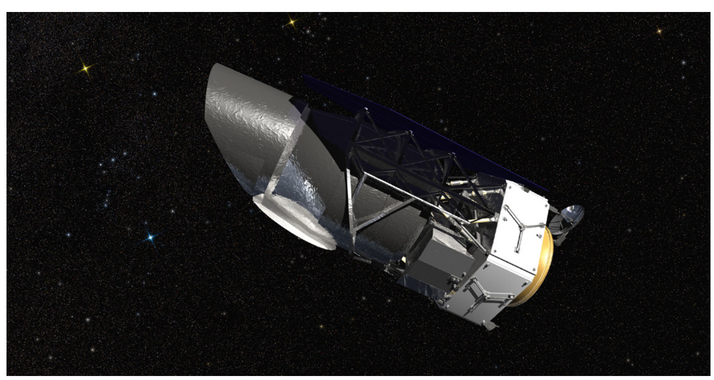
WFIRST Status and Plans

Susan Neff, COR *Chief Scientist*
Dominic Benford, NASA HQ, WFIRST *Program Scientist*

Although the *Wide Field Infrared Survey Telescope* (WFIRST) is not formally part of the COR portfolio, the science is great interest to the COR community. WFIRST was the top recommendation for large space missions in the 2010 Decadal Survey of Astronomy and Astrophysics. The mission will study the effects of dark energy and dark matter on the evolution of the Universe, as well as searching for exoplanets; it is also expected to have a significant General Observer and Guest Investigator program. Launch is currently baselined for the mid-2020s.

WFIRST formally began Phase A in February 2016, with a target of moving to Phase B in October 2017. Since then, the WFIRST team has been working to define science objectives, develop mission, instrument, and ground system performance requirements, and produce a notional plan for the eventual use and scientific productivity of the facility. The WFIRST project's ongoing Phase A effort has achieved its planned technology maturation goals, completed critical trade studies, and defined level 1–3 requirements and vetted them through the science community. The Optical Telescope Assembly (OTA) team has optically measured interferometric fringes using the Primary Mirror on the



WFIRST, shown here in an artist's rendering, will carry a Wide Field Instrument to provide astronomers with Hubble-quality images covering large swaths of the sky, enabling several studies of cosmic evolution. Its Coronagraph Instrument will directly image exoplanets similar to those in our own solar system and make detailed measurements of the chemical makeup of their atmospheres. Credit: NASA's Goddard Space Flight Center/ Conceptual Image Lab optical bench. This 'First Light' achievement was a first using actual WFIRST flight hardware (in testing).

A Midterm assessment of NASA's progress implementing the Decadal Survey recommendations, conducted by the National Academies of Science, was released on 16/08/2016. The report recognized the compelling science goals of WFIRST, but recommended that NASA conduct an independent assessment of the project before moving to the next phase.

In response to a National Academies' request, NASA's Science Mission Directorate has initiated the WFIRST Independent External Technical/Management/Cost Review (WIETR), with the goals of assuring greater stakeholder consensus, and defining a clear path forward. The System Requirements Review (SRR) / Mission Definition Review (MDR), which precede the transition to Phase B, have been delayed to allow NASA to incorporate the WIETR recommendations into the design and plans for WFIRST before proceeding.

Formal WIETR activities began with a detailed presentation by the project on 07–10/08/2017 to the entire board. After a caucus, the team will break up into subgroups. During the week of 14/08/2017, subteams reviewed the Wide Field Instrument and WFIRST starshade-readiness. The telescope was reviewed during the week of 21/08/2017, and the science centers and the coronagraph were reviewed during the week of 28/08/2017. The WIETR's final report is expected in October.

Announcement of the WIETR review: **https://www.nasa.gov/feature/nasa-taking-a-fresh-look-at-next-generation-space-telescope-plans**

Information on the Review team, including names of all membership: **https://www.nasa.gov/feature/goddard/2017/nasa-announces-independent-review-panel-members-for-wide-field-infrared-survey-telescope**

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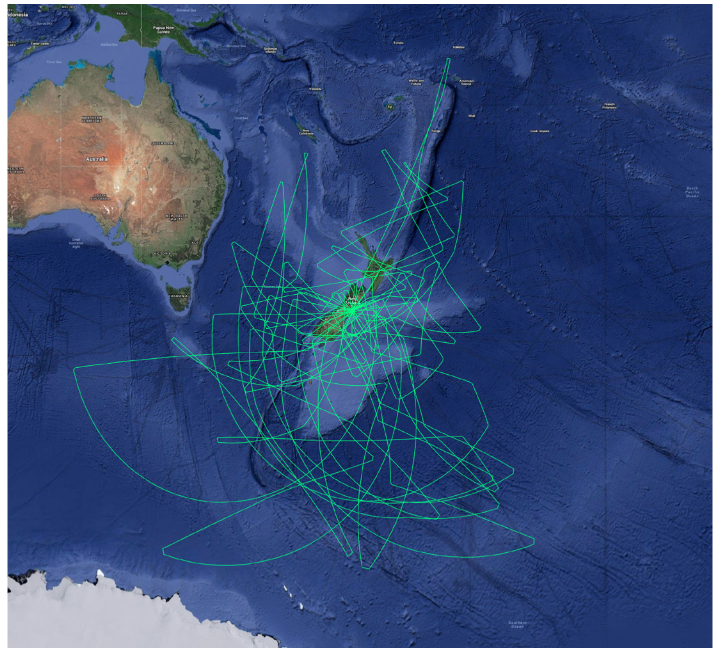
Summer 2017 News from SOFIA Today

Kimberly Ennico Smith, NASA/ARC, SOFIA *Project Scientist*

The *Stratospheric Observatory for Infrared Astronomy* (SOFIA) Observatory has returned to the Northern Hemisphere after a busy 4th deployment to New Zealand (see figure) during Cycle 5 of operations. In addition to providing access to the Galactic Center, southern hemisphere deployments provide at-altitude observation conditions at least 50% drier (on average) than those in the northern hemisphere, significantly enhancing data quality at far-IR wavelengths. Cycle 5 runs from 01/02/2017 through 31/01/2018; science investigation abstracts may be found at: **https://www.sofia.usra.edu/science/proposing-and-observing/sofia-cycle-5-results**.

During the southern campaign, 21/06/2017 through 13/08/2017, Guest Observer programs featuring the Galactic Center, the Central Molecular Zone of our Galaxy, and the Small and Large Magellanic Clouds (satellite galaxies of our Milky Way galaxy) dominated the observing time. Three science instruments (upGREAT, FIFI-LS, and FORCAST) provided high-spectral resolution and integral field spectroscopy in the far-IR, with imaging and moderate spectral resolution in the mid-IR. (For more information on SOFIA instruments, see: **https://www.sofia.usra.edu/science/instruments**)



A composite of all of the science flight plans conducted during the 2017 Southern Hemisphere deployment in Christchurch, New Zealand

A new observing mode for upGREAT was commissioned during the New Zealand campaign: 4GREAT, a simultaneous four color single-pixel-detector. Two channels, CH1 and CH2, are implemented using spare mixers of *Herschel*-Heterodyne Instrument for the far infrared: HIFI-channel 1 (492–635 GHz) and HIFI-channel 4 (892–1100 GHz). The third channel repurposes the current GREAT L1 detector (1.2–1.5 THz), while the fourth covers the frequency range of GREAT L2 (2.49–2.59 THz).

4GREAT is used in parallel with the HFA (High Frequency Array), a 1 x 7 array operating at 4.745 THz, made possible by the dual-cryocooler capability installed on SOFIA earlier this year. 4GREAT offers the possibility to observe several lines, including

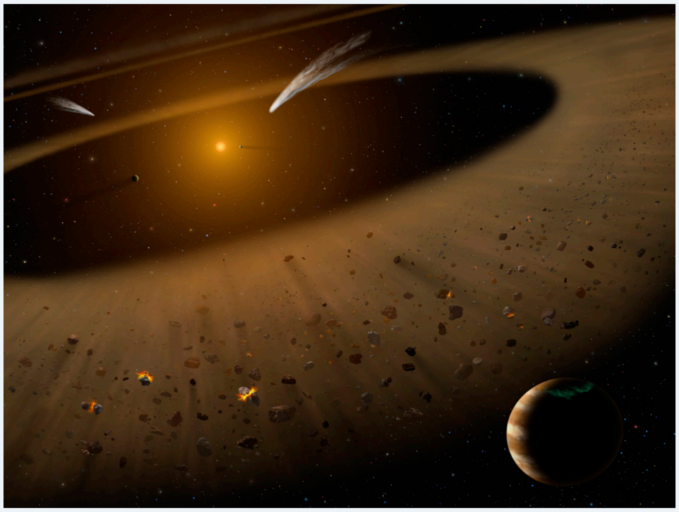
July 2017 commissioning flight with 4GREAT. PhD Candidate Carlos Duran, Max Planck Institute for Radio Astronomy, Bonn, Germany (standing). Credit: K. Ennico Smith

SOFIA Confirms Nearby Planetary System is Similar to Our Own

The *Stratospheric Observatory for Infrared Astronomy* (SOFIA) recently completed a detailed study of a nearby planetary system. The investigations confirmed that this nearby planetary system has an architecture remarkably similar to that of our solar system.

Located 10.5 light-years, the star Epsilon Eridani ("eps Eri") is the closest planetary system around a star similar to the early sun. It is therefore a prime location to research how planets form around stars like our sun.

Previous studies indicate that eps Eri has a debris disk, the material left over after planetary build-up. The debris can be gas and dust, as well as small rocky and icy bodies. Debris disks can be broad, continuous disks or may be concentrated into belts of debris, similar to our solar system's asteroid belt and the Kuiper Belt— the region beyond Neptune where hundreds of thousands of icy-rocky objects reside. Careful measurements of the motion of eps Eri indicate that a planet with nearly the same mass as Jupiter circles the star at a distance comparable to Jupiter's distance from the Sun.



Artist's illustration of the Epsilon Eridani system showing Epsilon Eridani b. In the right foreground, a Jupiter-mass planet is shown orbiting its parent star at the outside edge of an asteroid belt. In the background can be seen another narrow asteroid or comet belt plus an outermost belt similar in size to our solar system's Kuiper Belt. The similarity of the structure of the Epsilon Eridani system to our solar system is remarkable, although Epsilon Eridani is much younger than our sun. SOFIA observations confirmed the existence of the asteroid belt adjacent to the orbit of the Jovian planet. Credits: NASA/SOFIA/ Lynette Cook

With new SOFIA images, Kate Su of the University of Arizona and her research team were able to distinguish between two theoretical models of the location of warm debris in the eps Eri system. Su and her team ascertained that the warm material around eps Eri is arranged in at least one narrow belt rather than in a broad continuous disk.

"The high spatial resolution of SOFIA combined with the unique wavelength coverage and impressive dynamic range of the FORCAST camera allowed us to resolve the warm emission around eps Eri, confirming the model that located the warm material near the Jovian planet's orbit," said Su. "Furthermore, a planetary mass object is needed to stop the sheet of dust from the outer zone, similar to Neptune's role in our solar system. It really is impressive how eps Eri, a much younger version of our solar system, is put together like ours."

Full web feature: **https://www.nasa.gov/feature/sofia-confirms-nearby-planetary-system-is-similar-to-our-own**. This study was published in Astronomical Journal on 25/04/2017.

multiple transitions from the same molecule simultaneously, which constrains physical conditions. Potentially interesting transitions include Ammonia, (NH_3), Carbon monosulfide (CS), the Methylidyne radical (CH), Hydroxyl (OH), and Carbon Monoxide (CO and ^{13}CO).

On 10/07/2017, SOFIA chased the shadow of New Horizon's next fly by target, 2014MU69, a small (D < 40 km) Kuiper Belt Object located ~43 AU from the Sun. This was second in a series of three occultation events this summer. SOFIA's larger 2.5 m aperture and location over the Pacific Ocean were unique assets for the July 10th event. (See **http://pluto.jhuapl.edu/Mission/KBO-Chasers.php**)

Cycle 5 continues in September with a FORCAST series, a "suitcase deployment" to Florida in early October with HIPO and FLITECAM to measure a Triton occultation, followed by a long series with the SOFIA's highly demanded newest instrument HAWC+ (High-Resolution Airborne Wideband Camera).

Upcoming milestones for the flying observatory include: Cycle 6 proposal selections in October, Next Generation Instrument Proposal Call in late 2017, and the SOFIA Town Hall meeting on 11/01/2017, at the 231st AAS meeting near Washington, DC.

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COPAG Technology Interest Group (TIG) Activities

Paul Lightsey (Ball Aerospace), TIG co-Chair
Sarah Tuttle (University of Washington), TIG co-Chair

Each spring, the COR Program Office (PO) collects technology "gaps"—technologies that are needed to achieve future COR science goals, but that are not yet ready. The COR PO asks the COR community to submit gaps that are not already being addressed by the COR technology development program. The PO convenes a review board to recommend relative priorities of these gaps; recommendations are then available to HQ, for use in selecting technology development through the Strategic Astrophysics Technology (SAT) program. More information on this process may be found in the annual **Program Annual Technology Report** (PATR).

In the past, the COPAG Executive Committee (EC) has been asked to clean up the gaps list: combining gaps where possible, removing duplications, looking for and adding any missing gaps. This year, the COPAG formed a new **Technology Interest Group** (TIG), chaired by Paul Lightsey (Ball Aerospace) and Sarah Tuttle (University of Washington), which was asked to review and clean up the technology gaps list.

The TIG, like the COPAG's **Science Interest Groups** (SIGs), is formed of volunteers from the COR community; in the TIG's case, it is people interested in the interface between science and technology. Over the course of a month, the TIG reviewed the list of gaps provided by the COR office. The TIG was asked to: 1) combine similar or overlapping gaps, 2) refine gaps as needed to make them unique, 3) add any missing gap(s), and 4) recommend dropping any gap that did not require development, was not sufficiently well defined, or was not relevant to the COR program.

The TIG found that they needed to clarify the distinction between a technology **gap** and a **solution** for some gap descriptions. They also recommended some rewrites to consolidate gaps. Because the gap submission form limits input fields to 100–150 words, descriptions in some cases were somewhat cryptic, which the TIG found limited their insight into the current State of the Art. They also found that the cited references made it difficult to understand nuances in the interpretations of technology readiness level (TRL). In some cases, publicly accessible references may not contain sufficient information to justify a TRL (e.g., when organizations use internal IRAD funding and consider information proprietary). The TIG felt that this merited raising awareness in the community on how to provide TRL information in a defensible and visible public realm. The TIG also found that in some cases, Manufacturing Readiness Level (MRL) and/or Programmatic Readiness Level (PRL) was being conflated with TRL.

The TIG made several recommendations for improving the process in future cycles, including better clarity in the call on needed inputs, and more emphasis on publicly-available references.

Reminder: TIG membership is open to all interested parties. If you would like to be involved in future TIG activities, please contact us at **Plightse@ball.com** and **tuttlese@UW.edu**

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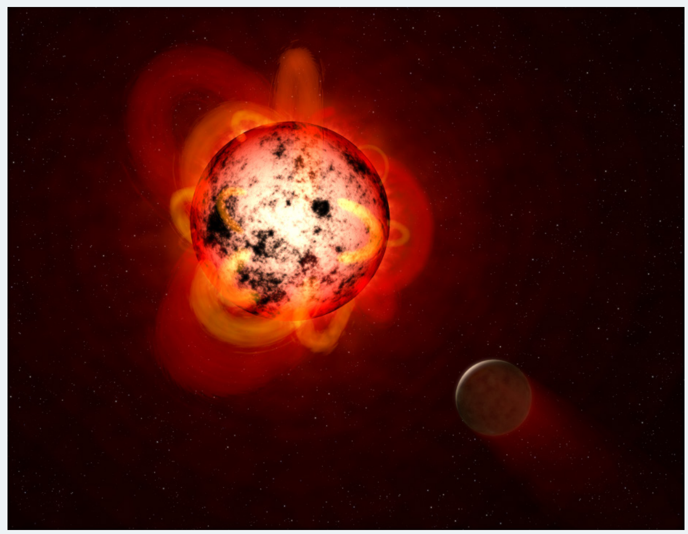
GALEX: Mini-flares may Jeopardize Habitability of Planets Circling Red Dwarf Stars

Recent discoveries of planets in the habitable zones of red dwarf stars suggest that Earth-sized worlds might circle billions of these stars, which are the most common type of star in our galaxy. However, many red dwarfs erupt with intense flares. Are red dwarfs really as friendly to life as they appear, or do these flares make the surfaces of any orbiting planets too inhospitable?

A team of scientists has combed through 10 years of ultraviolet observations by the GALEX mission, looking for rapid increases in the brightnesses of stars. Flares emit a significant fraction of their total energy in the ultraviolet bands, but red dwarf stars are dim in the ultraviolet. The high contrast between bright flares and dim stars, combined with the time resolution of the GALEX detectors, allowed the team to find and measure stellar flares from red dwarf stars.

First author Chase Million (Million Concepts, State College, PA), led a project to reprocess more than 100 terabytes of archival GALEX data. The GALEX data was sliced into very high time resolution bins. From images with exposure times of nearly half an hour, the team was able to identify flares lasting only seconds.

The team searched GALEX observations of several hundred red dwarf stars and detected dozens of flares. The flares detected are similar in strength to those produced by our own sun. However, because a red dwarf's planet would need to orbit much closer to the star to maintain a temperature friendly to life as we know it, such planets would be subjected to more of a flare's energy than Earth. Large flares can strip away a planet's atmosphere, and strong ultraviolet light from flares that penetrates to a planet's surface could damage organisms or prevent life from arising.



This illustration shows an artist's concept of a red dwarf star orbited by a hypothetical exoplanet. Red dwarfs tend to be magnetically active, displaying gigantic arcing prominences and a wealth of dark sunspots. Red dwarfs also erupt with intense flares that could strip a nearby planet's atmosphere over time, or make the surface inhospitable to life as we know it. By mining data from the GALEX archive, a team of astronomers identified dozens of flares at a range of durations and strengths. The team measured events with less total energy than many previously detected flares from red dwarfs. This is important because, although individually less energetic and therefore less hostile to life, smaller flares might be much more frequent and add up over time to produce a cumulative effect on an orbiting planet. NASA/ESA/G. Bacon (STScI)

Although individual flares on red dwarf stars may be less energetic than those on solar-type stars (and therefore less hostile to life), the smaller flares could be more frequent, adding up over time to produce an environment hostile to life. "What if planets are constantly bathed by these small, but still significant, flares?" asked Scott Fleming of the Space Telescope Science Institute (STScI) in Baltimore, Maryland. "There could be a cumulative effect."

Currently, team members Rachel Osten and Clara Brasseur (STScI) are examining stars observed by both the GALEX and *Kepler* missions to look for similar flares. The team expects eventually to find hundreds of thousands of flares hidden in the GALEX data.

"These results show the value of a survey mission like GALEX, which was instigated to study the evolution of galaxies across cosmic time and is now having an impact on the study of nearby habitable planets!" said Don Neill (Caltech). The GALEX mission ended in 2013 after more than a decade scanning the skies in ultraviolet light, but its archive is still yielding exciting discoveries.

More information at **http://hubblesite.org/news_release/news/2017-23**

Meet *Hubble* Fellow Anne Medling

Hubble Fellow Anne Medling investigates the fueling of, feedback from, and sometimes star formation associated with black holes at the centers of galaxies. She uses a combination of adaptive optics (which counteracts blurring from turbulence in the Earth's atmosphere) and integral field spectroscopy ("for astronomers who don't want to to choose between images and spectra"). The combined techniques allow her to map how gas and stars are distributed, and how they move in the centers of merging galaxies, where stars are forming now, and where the star formation used to be. Combining these data with upcoming high-resolution mid-infrared *Webb* obesrvations will provide an even deeper look into the life cycles of black holes. Observations of these nearby systems are important for the interpretation of distant, young galaxies, such as those observed with *Hubble* or expected to be imaged with *Webb*.

Her observations, mostly from the Keck telescopes on Maunakea, have found star-forming nuclear disks extending 50–500 pc from the galaxies' centers. (For comparison, the Sun is about 8 thousand parsecs from the center of our Milky Way galaxy). She has also found warm molecular gas flowing out of the galaxy centers, and identified unexpectedly massive black holes at many galaxies' centers. She is now working with the team that has built the FIRE simulations (led by P. Hopkins) to compare observed galaxy interactions, mergers, and resultant star formation/mass loss with high-quality hydrodynamic simulations of galaxy formation and evolution.

Anne did her undergraduate work at Caltech, where she obtained fast-response photometry from newly found supernovae and learned about precision differential photometry of stars in an open star cluster. She spent a year in Padova, Italy on a Fulbright Scholarship, creating radial velocity catalogs of stars in globular clusters from archival echelle spectra. Anne returned to the U.S. to do her PhD work at the University of California, Santa Cruz. Her thesis on the nucleii of merging galaxies laid the groundwork for her ongoing black hole research.

After she received her PhD, Anne spent three years at the Australian National University, where she began connecting small-scale nuclear outflows to larger-scale galactic winds. She joined the SAMI Galactic Survey Team, which is building a large database of integral field spectroscopy ideal for studying outflows in a wide range of host galaxies.

Anne says, "I've been interested in astronomy almost as long as I can remember. Every August, my family would visit my grandparents, who lived on a lake in Michigan—a much darker sky than I was used to at home. We'd always make a point of staying up to watch the Perseids meteor shower, and I was hooked. Of course, at that age, I had no idea what being an astronomer really meant: plenty of physics, math, and programming. Sometimes I think it's lucky that I ended up liking those things enough to keep pursuing my astronomy dreams, but it might be the other way around—that I liked them *because* they were the tools I needed for astronomy."

When she's not thinking about galaxy growth, Anne enjoys music, cooking, eating, and hiking with her family.

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Upcoming Events

11–15/09/2017	Stellar populations and the Distance Scale, Beijing, China
14–15/09/2017	OST Team Meeting, Baltimore, MD
18–22 /09/2017	Ages^2: Taking Stellar Ages to the Next Power, Elba, Italy
24–29/09/2017	Science Detector Workshop, Baltimore, MD
Early 10/2017	Draft call released for Next Generation SOFIA instrumentation
02–06/10/2017	Peering towards Cosmic Dawn, Dubrovnik, Croatia
04–06/10/2017	Mastering the Science Instrument and Observing Modes of *Webb*, Madrid, Spain
05–06/10/2017	LUVOIR Team Meeting, Boulder, CO
11/2017	Call for Cycle 1 *Webb* GO proposals
02/11/2017	*Hubble* Fellowship applications due
01/11/2017	NASA Postdoctoral Program applications due
08/01/2018	Joint PAG, COPAG, SIG and TIG meetings, Washington, D.C.
09–12/01/2018	AAS meeting, Washington, D.C.
15/03/2018	NASA SAT and APRA proposals due (NOI due 18/01/2018)