INFRARED SCIENCE INTEREST GROUP

No. 5 | Jan 2021

Contents

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From the IR SIG Leadership Council

2020 has been a year of significant challenges for all of us. As we reflect on how our professional community has reacted, we are continually impressed by your resilience, dedication, and perseverance. The JWST Cycle 1 proposals are now in the review process, a variety of flight programs like SOFIA, SPHEREx, and the *Roman* Telescope are proceeding on schedule, and most ground-based telescopes are back operating (roughly) as normal. We hope you take pride in all your accomplishments over the past year and take the time to take care of yourself and your loved ones, rest up when needed, and remain strong. The future remains as exciting and full of possibilities as ever.

The IR SIG's primary mission is to collect community input, foster consensus, and help shape the long-term goals of IR astrophysics. Our main priority is to engage the community spanning the entire IR wavelength range, including users of current facilities like SOFIA, ALMA, and the range of suborbital platforms, as well as upcoming observatories like JWST and the *Roman* Telescope. This semi-annual newsletter is a part of this effort, highlighting results, technological developments, and events from the IR community. We encourage contributions describing interesting, unique, and important science and technology breakthroughs from all our readers. Throughout the year, we will also continue to host a monthly webinar series (https://cor.gsfc.nasa.gov/sigs/irsig.php) and an annual splinter session at the winter AAS meeting. We encourage members of the community to get involved with the IR SIG and remain dedicated to ensuring our activities reflect the needs of our community, stakeholders, and early-career scientists of diverse backgrounds.

Sincerely,
IR SIG Leadership Council

SOFIA Detects Water on the Moon

Casey Honniball[1], Paul Lucey[2], Joan Schmelz[3]

[1] NASA Goddard Space Flight Center
[2] Hawaii Institute of Geophysics and Planetology, University of Hawaii
[3] Universities Space Research Association (USRA)

***Paper**:* Molecular water detected on the sunlit Moon by SOFIA,
Honniball, C.I., Lucey, P.G., Li, S. et al.
Nat Astron (2020), https://doi.org/10.1038/s41550-020-01222-x

Researchers using SOFIA have made the first-ever detection of the water molecule (H_2O) on the sunlit surface of the Moon. This discovery refines our understanding of the behavior of water and how volatile elements and compounds interact with airless bodies throughout the Solar System and beyond.

Water and other volatiles can influence the internal processes and surface expression of planets. Water suppresses the melting point of rock, promoting volcanism, and reduces the viscosity of planetary interiors, enabling more efficient internal circulation and heat transfer. Water and other volatiles tend to concentrate on planetary surfaces, creating atmospheres, hydrospheres, and cryospheres, and can even dominate the surface geology.

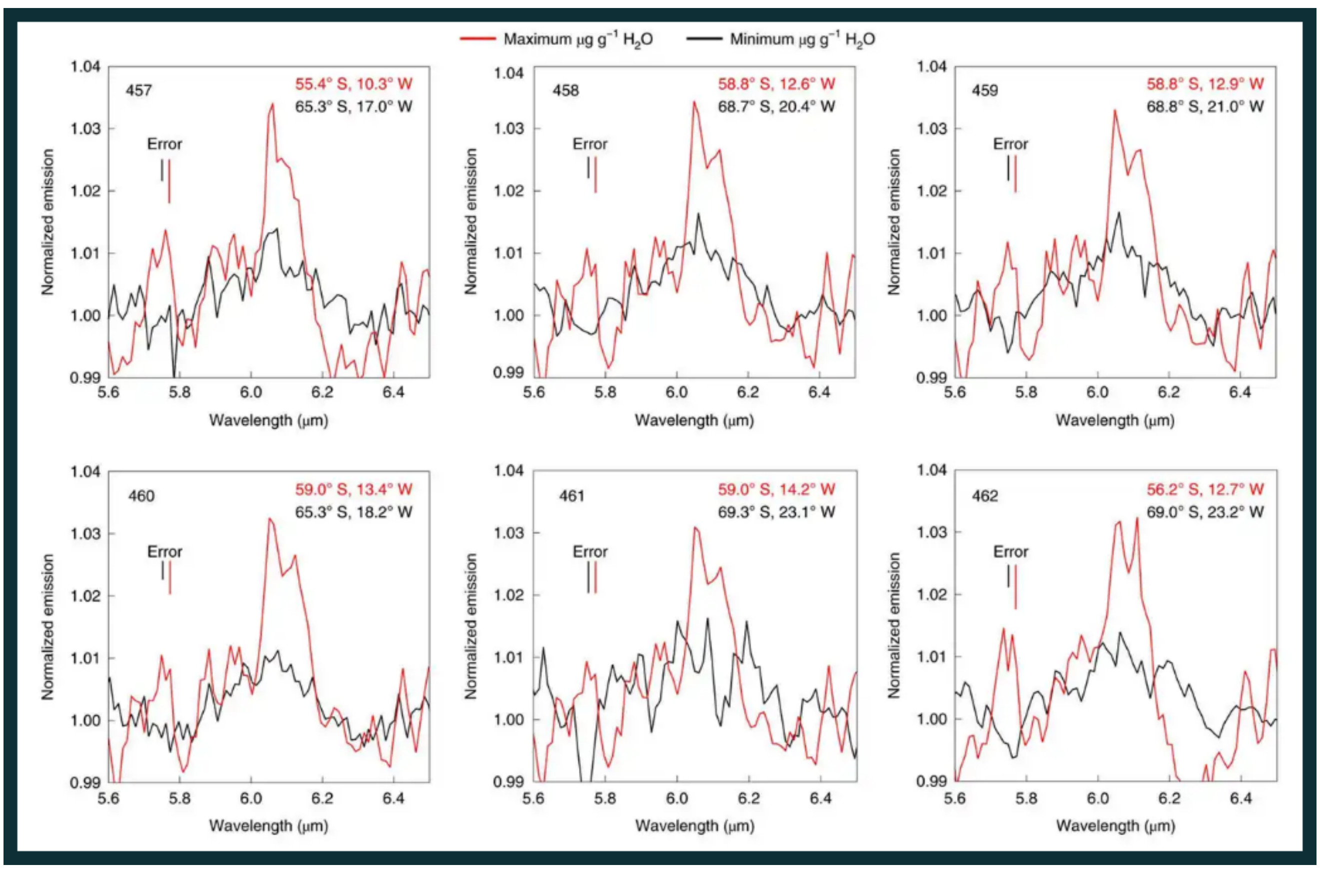
The Moon likely formed in a giant impact, stripping it of its initial volatile inventory and allowing it to begin as a "blank slate" for volatiles. This made the Moon a natural laboratory for the study of volatile elements and compounds added later in Solar System history. The hydrogen-rich solar wind and water-bearing meteorites are thought to be the principle conveyors of water to planetary surfaces, but their relative contributions as well as the space-surface chemistry interactions are poorly known.

Water has been detected previously in trace amounts in the lunar exosphere and in sparse occurrences as ice in permanent shadow at the lunar poles, but the possible pathways of water through the lunar environment are poorly understood. For decades, laboratory studies have shown that water's cousin, hydroxyl (OH-), can form from the hydrogen in the solar wind and oxygen in lunar minerals. Lunar hydroxyl has been detected remotely in reflectance spectra at 3 µm by spacecraft.

Recent laboratory experiments have shown that it is possible to form H_2O vapor from hydrogen irradiation by adding the energy simulating a meteorite impact. Studies have also shown that water from meteorites can be trapped in the glass formed during the impact. But H_2O has never been detected directly on the sunlit lunar surface. In fact, the H_2O and OH signals are blended at 3 µm, so these spacecraft observations cannot separate water from drain cleaner. Direct detection of water on the Moon had, therefore, eluded scientists, and new methods were needed to continue the search.

The unambiguous water detection was made possible by SOFIA's unique capabilities and the sensitivity of the FORCAST spectrometer. The fundamental bending vibration of the H-O-H molecular bond occurs at 6.1 µm in the infrared. This region of the spectrum is completely obscured from the ground by water in the Earth's atmosphere but is highly transparent from SOFIA's operational altitude in the stratosphere. In addition, the spectral feature at 6.1 µm is unique to H_2O and does not suffer from blending from other OH-related compounds.

SOFIA targeted high lunar latitudes near the South Pole, where the low temperatures could allow migrating water to transiently remain on the surface, and the high hydroxyl abundances could promote creation and trapping of water by impacts of small meteorites. Comparing the 6.1 µm emission band intensity to those of carefully calibrated water-bearing glasses, the team found water abundances of a



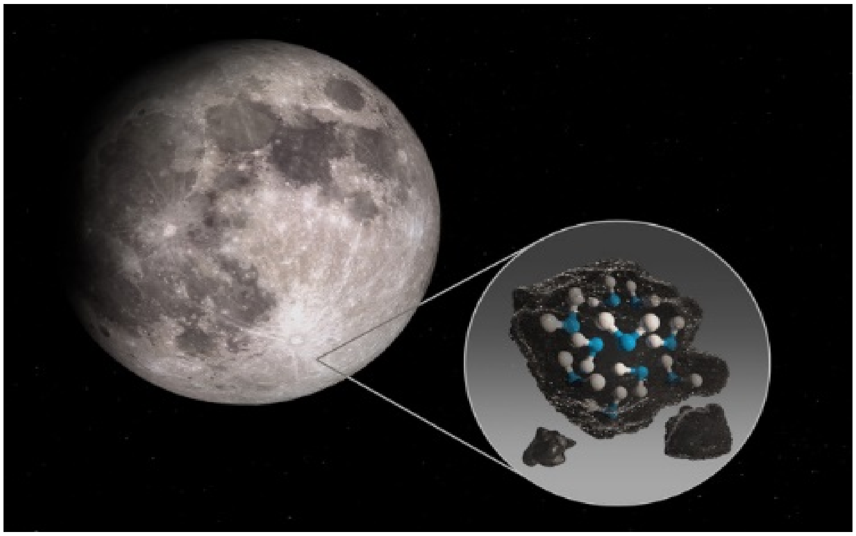
Spectra of the Clavius region show a strong 6 µm emission band, indicating the presence of H_2O at the locations noted in the top right corners (Clavius frame numbers are noted in the top left corners). Abundances derived from these spectra range from 100 to 400 µg g^{-1} H_2O. Abundance and location information can be found in Supplementary Tables 1 and 2 in the referenced paper. The error bars indicate 1σ uncertainty.

few hundred parts per million. It is the extreme sensitivity of SOFIA that allowed scientists to detect this miniscule amount of water, which is 100 times less than that in the Sahara Desert.

But even this amount of water is high by lunar standards, more in fact than can be adsorbed on lunar grains at the surface temperatures recorded by SOFIA. This result indicates that much of the water must be trapped in impact glasses or within/between grains sheltered from sunlight. These results indicate that the water has a meteoritic origin or is produced on the lunar surface itself from pre-existing hydroxyl. The team also found that the abundance of water varies with latitude, suggesting that meteorites may not the only source of water.

Further observations with SOFIA will create water maps of the nearside lunar surface and gather evidence supporting theories of the origin of lunar water. Observations covering large areas obtained at various times of the lunar day will enable scientists to learn about the storage, retention, and migration of water on the surface of the Moon. Studying lunar water remotely with SOFIA is critical for future NASA missions, including the VIPER lunar rover, a mobile robot that will explore the landscape near the moon's South Pole in 2022, and the Artemis program that will return humans to the moon by 2024.

SOFIA discovers water on sunlit surface of moon. Credit: NASA Ames



This illustration highlights the Moon's Clavius Crater in the southern hemisphere, where traces of water were detected by NASA's airborne observatory SOFIA. This is the first time water has been found on the sunlit surface of the Moon. The image depicts water molecules trapped inside tiny, glass bead-like structures within the lunar soil. These structures may prevent water from being lost to space, allowing it to remain on the harsh, nearly airless lunar surface. (Credit: NASA/Ames Research Center/Daniel Rutter)

Cold Quasars and the Evolution of Galaxies

Kevin Cooke[1], Allison Kirkpatrick[1], Joan Schmelz[2]

[1] University of Kansas
[2] Universities Space Research Association (USRA)

***Paper**: Dying of the Light: An X-Ray Fading Cold Quasar at z~ 0.405*
The Astrophysical Journal, *903*(2), p.106, 2020
Cooke, K.C., Kirkpatrick, A., Estrada, M., Messias, H., Peca, A., Cappelluti, N., Ananna, T.T., Brewster, J., Glikman, E., LaMassa, S. and Leung, T.D.

Galaxies evolve over cosmic time from brilliant blue star producers to dull red stellar graveyards – from the proverbial *Blue-and-New* to *Red-and-Dead*. Astronomers observe that the early universe is filled with galaxies with an average star formation rate hundreds of times that of today, but the population over time has become more dominated by galaxies where stars are no longer born. To understand how galaxies came to be, we must investigate how their star formation histories are affected by both stellar and non-stellar processes.

Star formation can be shut down through many routes, one of which relies on the supermassive black hole in the heart of massive galaxies. When a supermassive black hole actively accretes interstellar gas, the surrounding material becomes luminous across the electromagnetic spectrum. The energetic output from the resulting quasar has a tremendous effect on the host galaxy, heating and expelling the gas, and shutting down star formation. This feedback model is commonly cited as the method that causes a star-forming, gas-rich galaxy to transition to a non-star-forming, gas-poor galaxy. This crucial transition process is difficult to investigate, as the hot material surrounding the black hole outshines the host galaxy at nearly all wavelengths of interest. The one exception is the far infrared.

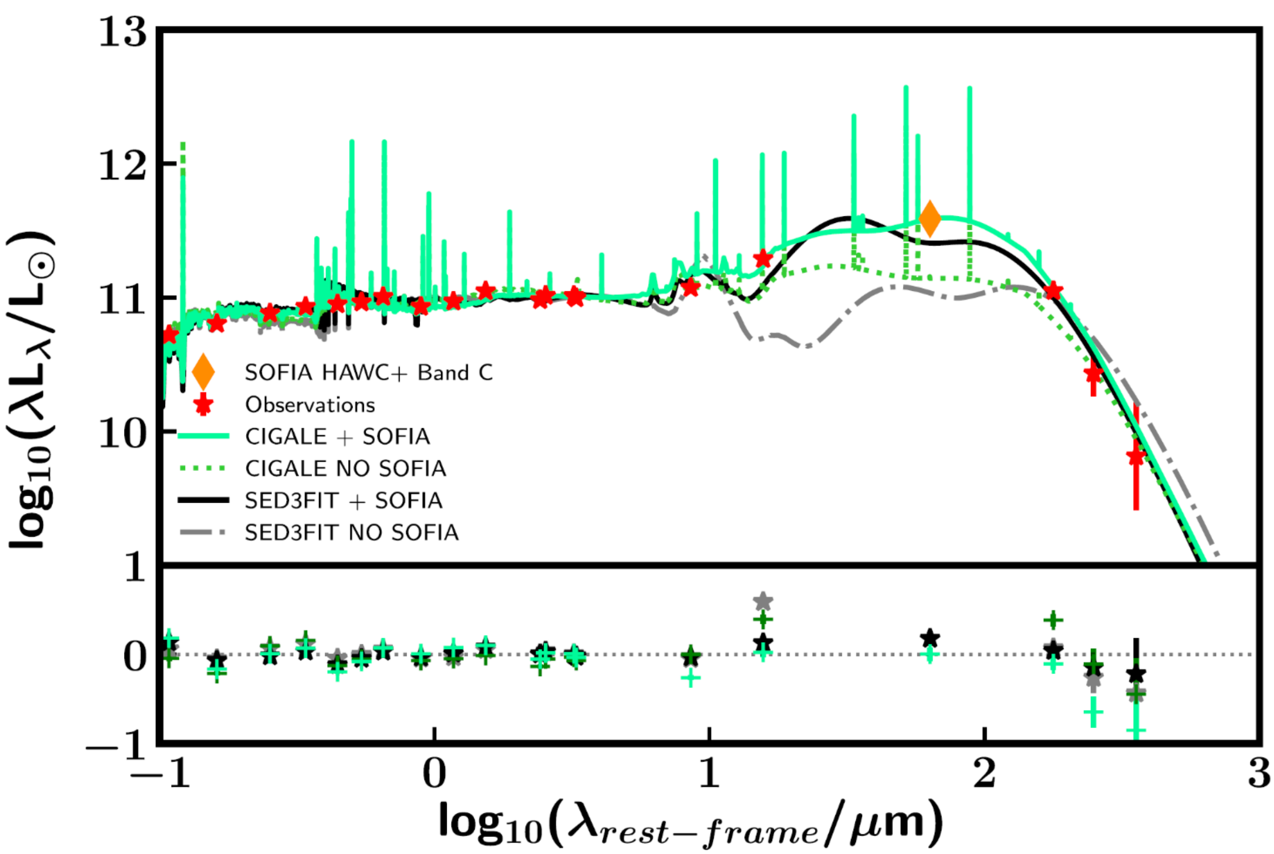
The HAWC+ instrument on SOFIA observes in this vital wavelength band. It can detect light from the star formation process without being overwhelmed by emission from the accreting black hole. The gas surrounding young stars is heated and reradiates its thermal energy in the far infrared. These observations are used to estimate the amount of star formation that has taken place over the past 100 million years.

SOFIA targeted a special *Cold Quasar*, a galaxy caught in that astronomically brief transition phase when the supermassive black hole is actively accreting but a significant amount of the infrared-luminous gas remains. Cold quasars continue to host star formation rates of ~100s of solar masses per year, hundreds of times more active than our own Milky Way Galaxy.

SCIENCE HIGHLIGHTS

HAWC+ observations at 89 μm of the cold quasar, CQ4479, were combined with optical observations from the Sloan Digital Sky Survey, infrared data from the Spitzer and Herschel space telescopes, and X-ray data from XMM-Newton to model the stellar component of the galaxy and the accretion behavior of the black hole.

The optical to far-infrared data were fit with a collection of stellar population, dust, and black hole models to determine the relative contribution of each to the total amount of light emitted by the galaxy. This process accounts for energy balance between the stars and dust, ensuring that the re-processed light observed in the far-infrared is consistent with the amount of energy absorbed by the gas. CQ4479 is best fit with a star-formation rate of 95 solar masses per year, nearly 50 times the rate in the Milky Way. Results indicated that the inclusion of just one extra data point from SOFIA, which traces the peak of far-infrared emission, can better constrain the star formation estimate by nearly a factor of two.



Top: the CIGALE (green) and SED3FIT (black) estimated SEDs of CQ 4479 both with (solid) and without (dashed) the SOFIA 89 μm detection in orange. The non-SOFIA photometric data are plotted as red star symbols. Bottom: the fractional residual $\frac{f_{obs}-f_{model}}{f_{obs}}$ *with errors as the vertical lines of each fitting package for each band. Color coding is identical in both panels.*

The black hole growth rate is constrained using archival X-ray and [O III] optical emission data from the XMM-Newton and the Sloan Digital Sky Survey, respectively. The X-ray emission indicates a slower growth rate than the [O III] estimate. One possible explanation for this discrepancy is that the X-rays trace the accretion rate on more instantaneous time scales than the [O III], so the black hole could have slowed down its accretion, at least at the epoch of observation.

Overall, the results indicate that the stellar population and black hole mass in CQ4479 are growing at the same rate, which is surprising since theory predicts that black hole growth succeeds stellar growth. CQ4479 is at the lower mass end of both stellar mass and black hole mass. The active black hole and stellar population could continue to grow for another 500 million years, tripling the mass of each before the black hole halts star birth.

Cold Quasars: The Death of Galaxies with Dr. Allison Kirkpatrick. Interview with John Michael Godier on the Event Horizon podcast, 2019.

Note the simulation of two colliding AGN's at the 14:00 mark.

Cold quasars represent an early stage of active galactic nucleus feedback and are a valuable laboratory for understanding how star formation and active supermassive black holes can co-exist. This brief window, where the galaxy has not yet succumbed to the devastating effects of the quasar, can help explain how massive galaxies formed in the early universe. As the only telescope capable of observing the majority of the host galaxy's emission, observations from SOFIA are crucial for understanding how these galaxies evolved over cosmic time into the universe we see today.

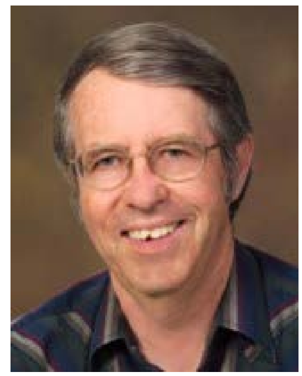
Artist's impression of a cold quasar, a galaxy with a newly emerging active galactic nucleus. The central supermassive black hole is rapidly accreting new material, generating energetic winds that sweep the gas and dust from the galactic center. This leaves the stars unobscured, glowing blue with little absorption, scattering, or reddening. New stars are actively forming in the galactic outskirts, still embedded in their cocoons of gas and dust (brown).

Credit: Michelle Vigeant.

JWST in 2020: Milestones Along a Rocky Road

Stacey Alberts, George Rieke

Steward Observatory, University of Arizona



As 2020 draws to a close (finally!), it's time to reflect on our setbacks and triumphs in what has been an extremely difficult year. For the James Webb Space Telescope (JWST), 2020 got off to an auspicious start: following technical complications in 2019 that consumed much of the schedule reserve, the work on the observatory had again found its rhythm.

Image credit: NASA/Desiree Stover

Then came the COVID-19 pandemic. Workarounds kept nearly to schedule for a few weeks, but the pace could not be sustained. Stringent safety precautions and reduced shifts were implemented.

"We are going to take care of our people. That's our first priority," said NASA Administrator Jim Bridenstine. "Technology allows us to do a lot of what we need to do remotely, but, where hands-on work is required…where we can't safely do that, we're going to have to suspend work and focus on the mission-critical activities." [1].

In January, a required annual review by the Government Accountability Office (GAO) had determined that the target March 2021 launch was going to be challenging; with the time lost in March and April, this had become more certain.

By May, a clearer picture of the impact of COVID-19 on the remaining JWST testing emerged. Work proceeded cautiously yet regained close to a pre-COVID pace. A new launch date of October 31, 2021 (Happy Halloween!) was announced, with the project expected to stay within the current budget.

> *"The perseverance and innovation of the entire Webb Telescope team has enabled us to work through challenging situations we could not have foreseen on our path to launch this unprecedented mission. Webb is the world's most complex space observatory, and our top science priority, and we've worked hard to keep progress moving during the pandemic." [2]*
>
> *-Thomas Zurbuchen, Associate Administrator, NASA's Science Mission Directorate.*

MISSION HIGHLIGHTS

JWST Solar Array Deployment. Credits: Northrop Grumman, edit by Sophia Roberts/NASA

The new schedule holds - including a robust margin of ~2 months schedule reserve - and several major markers have been reached under the restricted COVID-19 working conditions. In August, the Ground Segment Test was completed, demonstrating reliable end-to-end communication between JWST's flight hardware and ground systems [3]. Also, that month the Solar Array was attached to the full observatory and tested. The 20-foot (6-meter) array will provide the 1 kW JWST needs to operate at L2; its deployment and function are critical to JWST's operation [4].

Forging ahead, October saw the completion of the final "shake" and "vibe" tests, originally scheduled for the spring. This environmental testing of the fully assembled observatory mimics the acoustic and vibrational experience of lift-off, the last environment JWST will experience before space [5].

This was quickly following by Comprehensive Systems Testing, including two critical steps: Deployable Tower Assembly testing [6,7], which isolates the primary mirror and instruments from the heat and vibrations of the spacecraft bus.

JWST Deployable tower assembly, credit: NASA Goddard

JWST Telescope assembly and sunshield deployment. Credit: James Webb Space Telescope

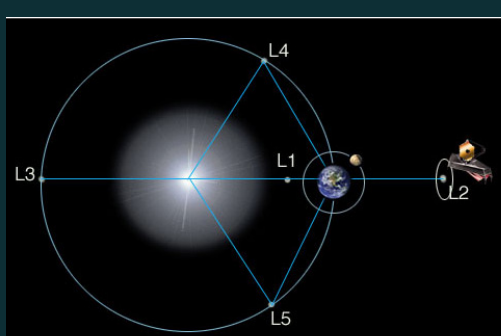
The second critical step was deployment and tensioning of the sunshield to ensure that its five delicate layers were intact after vibration testing [8]. Both tests were successfully completed with no significant issues discovered!

This amazing progress marks the beginning of the final check-out sequence which will ensure that JWST is ready for encapsulation into the fairing of the Ariane 5 rocket. After launch, the first six months will be dedicated to verifying that the observatory is operating as expected as well as obtaining preliminary calibrations for the spacecraft, telescope, and instruments. Science data will then start flowing to the astronomical community with the start of Cycle 1 in the summer of 2022.

MISSION HIGHLIGHTS

Final deployment and tensioning of the sunshield post vibe tests at the Northrup Grumman facility at Redondo Beach, CA. Photo credit: NASA/Chris Gunn [9]

After reaching these critical milestones, a final call for proposals for Cycle 1 was recently completed. A subsequent STScI report to the JWST User's Committee (JSTUC) revealed stunning results: 1173 proposals were received from 4332 unique PIs and co-Is from 44 countries, totaling 24,600 hours of prime observations. This is almost twice the number of proposals received for the first cycle of the Hubble Space Telescope (HST; 588). With 6,000 hours available, this puts the JWST Cycle 1 oversubscription rate at ~4.1! For comparison, HST's oversubscription is historically 4–8 (by orbits), with significant variation from year-to-year [10]. This, of course, includes the resubmission of GO proposals not accepted in the previous cycles, which will come into play for JWST in Cycle 2.



JWST's L2 Orbit

Normally, an object circling the Sun further out than the Earth would take more than one year to complete its orbit.

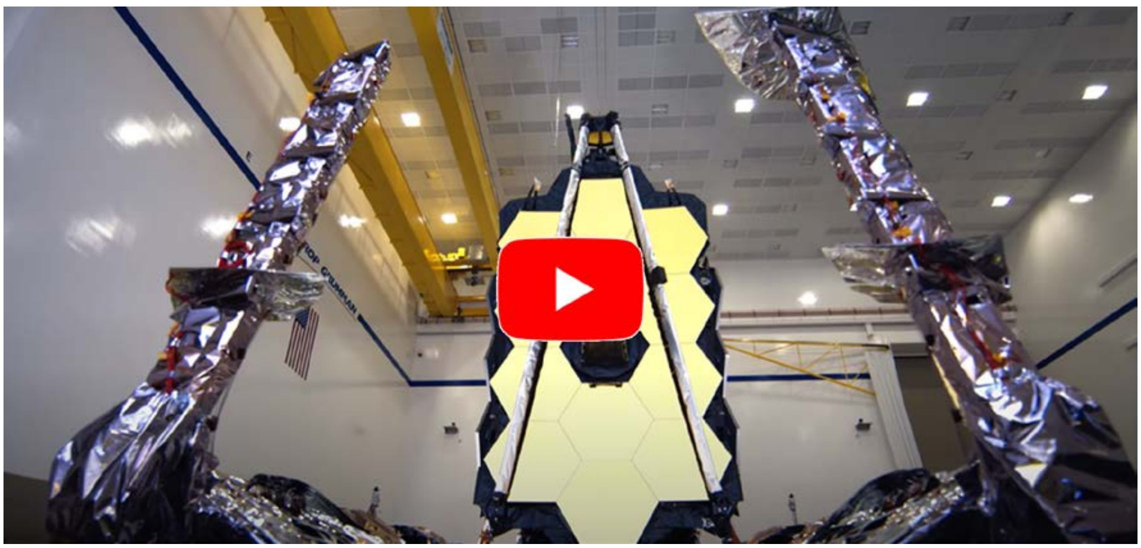
However, the balance of gravitational pull at the L2 point means that Webb will keep up with the Earth as it goes around the Sun. The gravitational forces of the Sun and the Earth can nearly hold a spacecraft at this point, so that it takes relatively little rocket thrust to keep the spacecraft in orbit around L2.

(jwst.nasa.gov/content/about/orbit.html)

MISSION HIGHLIGHTS

Until the TAC meetings in February and March, we can only speculate on what the Cycle 1 science program will look like. By (prime) hours requested, the community request breaks down into 41.7% NIRSpec, 31.1% MIRI, 22.5% NIRCam, and 4.7% NIRISS with NIRSpec IFU, NIRCam imaging, and MIRI MRS (IFU) the top three requested modes. The proposals span exoplanets and disks (25%), extragalactic and cosmology (44%), stars (25%), and the solar system (6%). This does not include coordinated or pure parallels, which expand the available science time (and science potential!) by running two instruments simultaneously.

Although 2020 is finally over, 2021 will be no less of a nail-biter. JWST must now undergo the final stow of the sunshield, a process that takes ~2 months of painstaking work which includes the careful off-loading of gravity to test something meant operate free of gravity in space. After final stow, the Observatory will complete its final check-out and then be packed up for the 2-week journey by ship to the Spaceport in Kourou, French Guiana. Next stop, L2!



NASA's Webb Telescope Comes Together: B-roll of an edited features howing techs & engineers successfully connecting the two halves of the JWST Observatory at Northrop Grumman. Credit: James Webb Space Telescope

[1] https://spacenews.com/coronavirus-pauses-work-on-jwst/
[2] https://www.nasa.gov/press-release/nasa-announces-new-james-webb-space-telescope-target-launch-date/
[3] https://www.nasa.gov/feature/goddard/2020/ground-segment-testing-a-success-for-nasa-s-james-webb-space-telescope
[4] https://www.nasa.gov/feature/goddard/2020/nasa-s-webb-powerhouse-solar-array-reconnects-to-the-telescope
[5] https://www.nasa.gov/feature/goddard/2020/nasa-s-james-webb-space-telescope-completes-environmental-testing
[6] https://www.nasa.gov/feature/goddard/2020/nasa-s-webb-completes-significant-testing-milestone-for-deployable-tower
[7] https://www.nasa.gov/feature/goddard/2020/tower-extension-test-a-success-for-nasa-s-james-webb-space-telescope
[8] https://www.nasa.gov/feature/goddard/2020/webb-sunshield-successfully-unfolds-and-tensions-in-final-tests
[9] https://news.northropgrumman.com/news/releases/northrop-grumman-and-nasa-complete-final-sunshield-deployment-test-on-the-james-webb-space-telescope
[10] https://arxiv.org/pdf/1908.03277.pdf

L3Harris Technologies Completes Primary and Secondary Mirrors for NASA's Nancy Grace Roman Space Telescope

Bonnie Patterson, Program Manager

Nancy Grace Roman Space Telescope, L3Harris Technologies

In September 2020, engineers and technicians at L3Harris Technologies finished figuring, polishing, and coating the primary mirror for NASA's Nancy Grace Roman Space Telescope, formerly known as the Wide Field Infrared Survey Telescope, bringing it one step closer to launch.

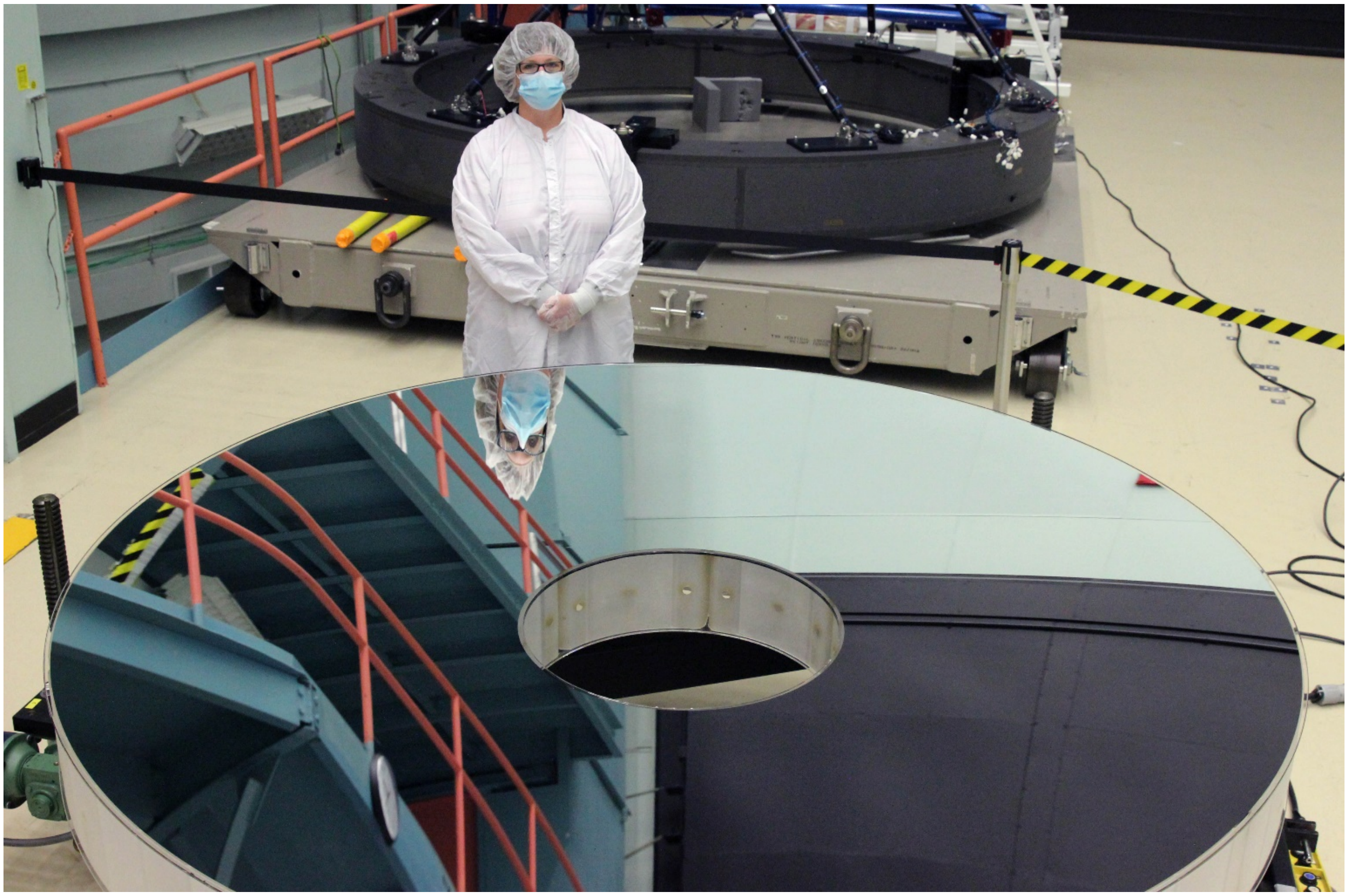
Roman's primary mirror will collect and focus light from exoplanets, stars, galaxies, and supernovae for the telescope, ultimately feeding scientific instruments. Roman will allow scientists to study the cosmos in a complementary way to the Hubble Space Telescope, using 100x larger field of view than Hubble, to study far more objects in the sky.

L3Harris employees applied advanced technology to create a lightweight primary mirror. The same diameter as Hubble's main mirror — nearly eight feet (2.4 meters) — Roman's primary mirror is one-fourth the weight of Hubble's which is a key benefit for all space missions.

> *"Scientific instruments require precision and accuracy, which is what our technicians and engineers brought to developing the Roman telescope's primary mirror," said "Fabricating space telescope mirrors is a craft, involving a painstaking process to remove molecules of glass that interfere with a mirror's precision. Ultimately, our work will help scientists discover parts of the universe previously unseen, like exoplanets and dark energy."*
>
> *Ed Zoiss, President, L3Harris Space and Airborne Systems.*

The primary mirror has undergone testing in L3Harris's thermal vacuum chambers designed to simulate the cold, harsh space environment, and an optical test verified the performance of the mirror. L3Harris engineers and technicians will simulate zero gravity by offloading the weight of the mirror through specialty support equipment specifically developed for this purpose.

The L3Harris team also completed the secondary mirror in November 2020, and by mid-December, the expert team successfully completed a Critical Design Review on the telescope. Through a pandemic, the program tasks were accomplished on schedule. Next up — the team will build the subassemblies with integration and test to follow. The important work the L3Harris team delivers on the Nancy Grace Roman Telescope continues the company's cadence of successful rigorous testing prior to integration with spacecraft.



L3Harris' Bonnie Patterson stands with the completed primary mirror for the Nancy Grace Roman Space Telescope. Image credit: L3Harris Technologies

Biography: Bonnie Patterson is a program manager at L3Harris, leading the Nancy Grace Roman Space Telescope program for the company. In this role, Bonnie is responsible for all aspects of the program, including financial and technical details. Her background includes mechanical and structural analysis with 20 years of experience in a product development environment. Bonnie holds a unique combination of detailed numerical analysis and testing experience with the ability to tie analysis results to design decisions and implementation. She holds a Bachelor of Science in Mechanical Engineering from Valparaiso University and a Master of Science in Mechanical Engineering from the University of Illinois. Bonnie is also a U.S. Patent holder.

A Single Photon Counting and Photon Number Resolving Detector for NASA Missions

Justin P. Gallagher, Donald F. Figer

Center for Detectors, Rochester Institute of Technology

Single photon counting large-format detectors will be a key technology for the future NASA Astrophysics missions such as the LUVIOR and HabEx mission concepts. The High Definition Imager instrument on LUVOIR has baselined a multi-gigapixel CMOS focal plane [1]. At the focal plane, tiling a 1 square degree field with ~10 micron-class pixels would lead to a 4.5 m x 4.5 m focal place, which is clearly prohibitive. With smaller pixels, the optics could be significantly more compact, and spectroscopy would be naturally accommodated with the photon counting performance. A next-decade mission to image exoplanet systems and perform spectroscopy of their atmospheres, such as that of HabEx, will require detectors with (i) ~10^{-10} contrast; (ii) optical and near-IR detection capabilities; (iii) a R>70 IFU able to measure the spectrum of a 30 mag exoplanet; and (iv) a 1" radius FOV [2]. The detectors necessary to meet these requirements would detect single photons, have high radiation hardness, low power draw, and high dynamic range. These requirements are not met by current optical-wavelength detectors, but are well matched to photon counting detectors.

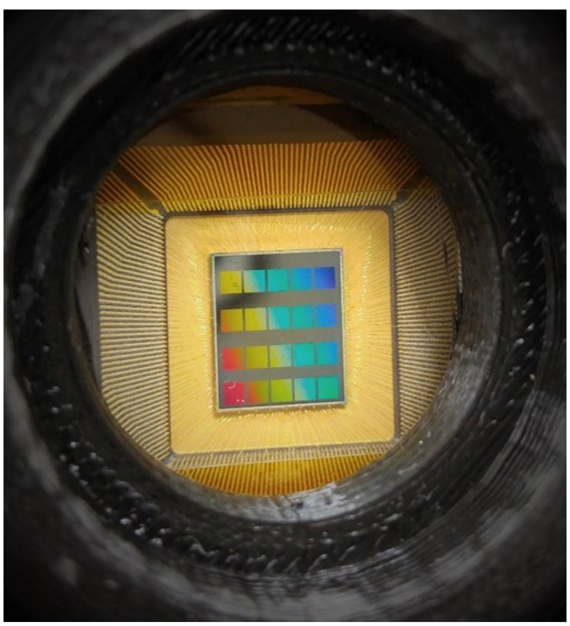


Fig. 1. Twenty 1-Mpix (300 – 1,000 nm) QIS detectors (colored squares) packaged on a chip carrier integrated in the QISPF camera system.

The NASA Cosmic Origins program office has selected this project to fund under the Strategic Astrophysics Technology program. The goal of the project is to mature a critical technology required to enable single photon counting large-format Complementary Metal-Oxide-Semiconductor (CMOS) detectors from Technology Readiness Level (TRL) 3 to 5. A new set of cryogenic-compatible electronics are in development to operate the devices for extensive laboratory characterization. After characterization, one device will be irradiated to replicate damage from high-energy radiation in space while another device will perform a telescope demonstration of the detector technology. In the final part of the project, the detector technology will be re-designed in collaboration with Dartmouth College for future NASA applications.

The Quanta Image Sensor (QIS), developed at Dartmouth [3], represents a new way to collect images in a camera. The device is fabricated using a 45/65 nm CMOS process and is designed to operate at wavelengths between 300 - 1100 nm [4]. The most fundamental design advance of the QIS is the invention of a new device structure and the use of very small geometries to reduce the capacitance of the readout sense node [5]. The small p-n junction sense node results in a significant voltage response to a single collected electron, typically a few hundred microvolts [6]. This high conversion gain yields a signal that is significantly greater than the naturally occurring voltage noise common in readout electronics.

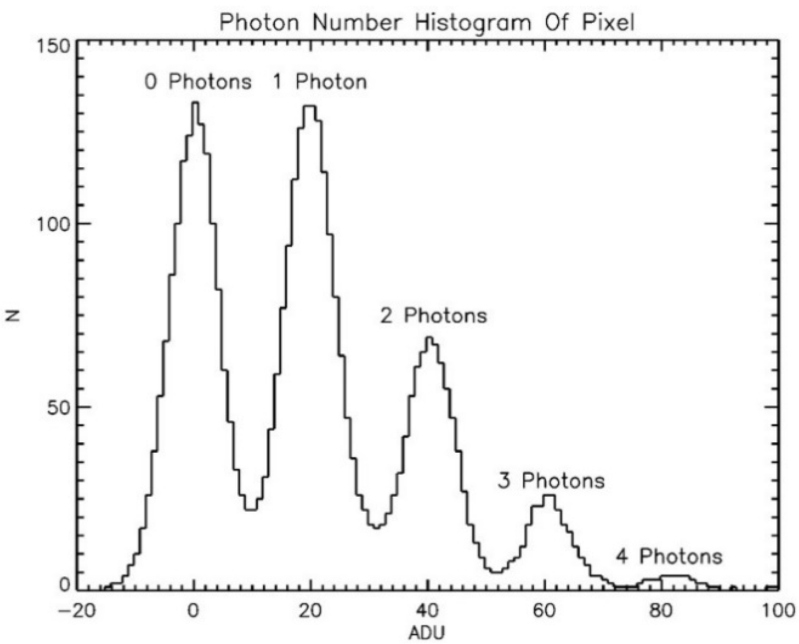


Fig. 2: Room temperature photon-number resolution validation of a single pixel.

Before the start of the project, the QIS Pathfinder (QISPF), a room temperature camera system, was purchased from Gigajot Technology, Inc. as a prototype test vehicle with the same detector technology (Fig. 1). The QISPF was utilized to generate the requirements for the cryogenic-compatible electronics and to provide an early start for the software design. In this process, we validated that the camera resolves photon number (Fig. 2). We developed our electronics and the mechanical mounting for mounting our detector PCB (Fig. 3) and cold electronics board.

We have assembled a team of graduate and undergraduate students to design the electronics system, perform the laboratory characterization, irradiate the devices, demonstrate the detector technology at a telescope, and redesign the detector. To date, this project has supported the research of two PhD graduate students, one prospective PhD graduate student, three MS students, two BS/MS students, and three undergraduate students. This project has also supported the transition of one MS student into a full-time staff position for the project

While the project detector technology is silicon-based for optical wavelengths, a graduate student at RIT is developing an infrared sensor that utilizes the same device structure and the use of very small geometries to reduce the capacitance of the readout sense node. Such a device potentially addresses top-priority technology gaps identified by NASA’s Astrophysics Program Offices, including large-format UV/Vis Focal Plane Arrays with sub-1.0-electron read noise at temperatures >150 K and visible detection sensitivity with sub-0.1-electron read noise, functioning in a space radiation environment. [7] [8] [9]

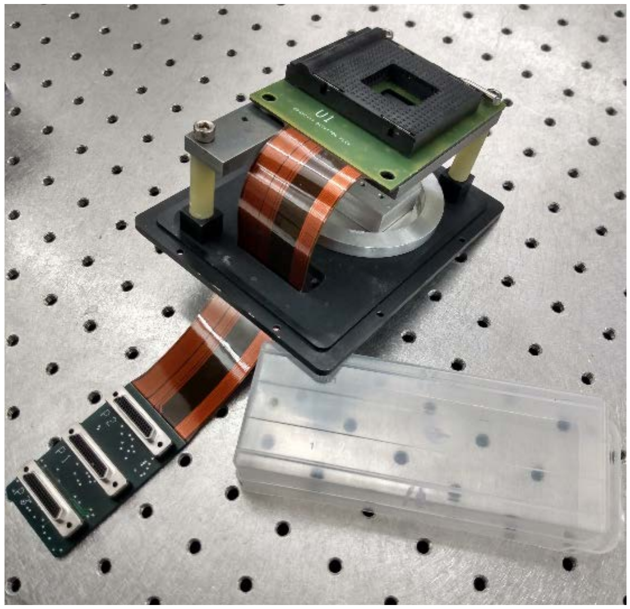


Fig. 3. Detector PCB and mechanical mount design for optical testing

[1] "LUVOIR Final Report," 26 August 2019. (119 MB) https://asd.gsfc.nasa.gov/luvoir/reports/LUVOIR_FinalReport_2019-08-26.pdf [Accessed 2020].

[2] B. S. Gaudi, E. Agol and D. Apai, "Exoplanet Exploration Program Analysis Group (ExoPAG) Report to Paul Hertz Regarding Large Mission Concepts to Study for the 2020 Decadal Survey," arXiv:1601.00008, 2015.

[3] E. Fossum, "The Quanta Image Sensor (QIS): Concepts and Challenges," Imaging and Applied Optics Technical Digest, 2011.

[4] J. Ma, Y. W. Chung, A. Gnanasambandam, S. H. Chan and S. Masoodian, Photon-Counting Imaging with Multi-Bit Quanta Image Sensor, Snowbird, Utah: International Image Sensor Workshop, 2019.

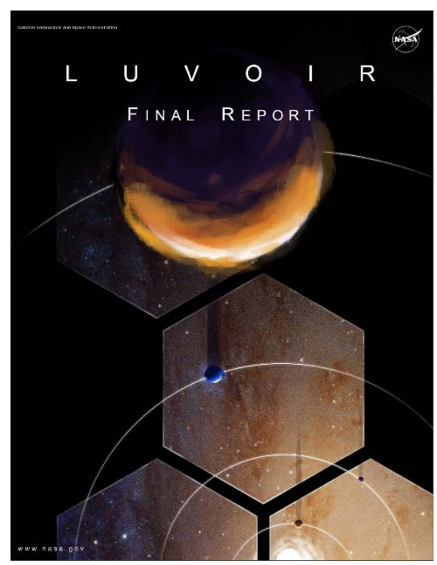
[5] W. Deng, S. Masoodian, J. Ma and E. R. Fossum, "Quanta image sensors: Photon-number-resolving megapixel image sensors at room temperature without avalanche gain," in SPIE, Orlando, 2018.

[6] J. Ma, S. Masoodian, D. A. Starkey and E. R. Fossum, "Photon-number-resolving megapixel image sensor at room temperature without avalanche gain," Optica, vol. 4, no. 12, p. 1474–1481, 2017.

[7] NASA, "Cosmic Origins Program Annual Technology Report," 2011.

[8] NASA, "Cosmic Origins Program Annual Technology Report," 2016.

[9] https://apd440.gsfc.nasa.gov/tech_gap-descriptions.html



Ref [1]. LUVOIR Final Report, Aug 2019, 426 pages

UPCOMING EVENTS

4 Jan – 5 Mar 2021 Fundamentals of Gaseous Halos – **ONLINE**
https://www.kitp.ucsb.edu/activities/halo21

11-15 Jan, 2021 237th American Astronomical Society Meeting – **ONLINE**
https://aas.org/meetings/aas237

25-28 Jan, 2021 Multiwavelength Probes of Galactic Atmospheres – **ONLINE**
https://www.kitp.ucsb.edu/activities/halo_c21

22-26 Feb 2021 Habitable Worlds 2021 – **ONLINE**
https://aas.org/meetings/aastcs8/habitable

23-25 Mar 2021 Rock, Dust and Ice: Interpreting planetary data workshop – **ONLINE**
hhttps://www.sofia.usra.edu/science/meetings-and-events/events/rock-dust-and-ice-interpreting-planetary-data

Mar 2021 –> Weekly Colloquia & Talks, SOFIA – **ONLINE**
https://www.sofia.usra.edu/science/meetings-and-events/events/colloquia

15-20 Mar 2021 Galactic & Extragalactic universe in the era of new generation radio/Optical/IR facilities
https://skamse2020.sciencesconf.org/ – **ONLINE**

24-28 May 2021 Workshop on Chemical Abundances in Gaseous Nebula: Milky Way to Early Universe
https://www.univap.br/universidade/instituto-de-pesquisa/agenda-e-eventos/chemical-abundances-in-gaseous-nebulae.html – **ONLINE**

19-23 July 2021 2021 Sagan Summer Workshop: Circumstellar Disks and Young Planets – **ONLINE**
https://nexsci.caltech.edu/workshop/2021/

CONTACT US

Keep in touch with the IR Science Interest Group.

IR SIG WEBSITE

https://cor.gsfc.nasa.gov/sigs/irsig.php

Our website is hosted on the NASA Cosmic Origins website.
It is a continual work in process; please contact us with any questions, comments, or suggestions for content.

@ir_sig

EMAIL LIST

https://cor.gsfc.nasa.gov/sigs/irsig/maillist/irsig_maillist.php

Sign up for announcements, information, and community discussion on our new email listserv! If you have been receiving email from us, no action is necessary, but if you have fallen out of touch or want to subscribe for the first time, please sign up.

IR SIG LEADERSHIP COUNCIL

The current members of the IR Science Interest Group (SIG) Leadership Council are:

Meredith MacGregor (Co-Chair)	University of Colorado Boulder
Mike Zemcov (Co-Chair)	Rochester Institute of Technology
Stacey Alberts	University of Arizona
Pete Barry	Argonne National Laboratory
Duncan Farrah	University of Hawaii
Jeyhan Kartaltepe	Rochester Institute of Technology
Jens Kauffmann	Massachusetts Institute of Technology
Lisa Locke	NASA Jet Propulsion Laboratory
Eric Murphy	National Radio Astronomy Observatory
Omid Noroozian	NASA Goddard Space Flight Center
Naseem Rangwala	NASA Ames Research Center
JD Smith	University of Toledo
Johannes Staguhn	Johns Hopkins University, NASA GSFC
Kevin Stevenson	Applied Physics Laboratory

Additional information about the IR SIG or to contact the IR SIG LC directly,

email: **irsiglc@gmail.com**.