

# Infrared Science and Technology Integration Group

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## From the IRSTIG Leadership Council

We are sure you'll agree that it has been a busy six months since our last newsletter. The Infrared community has been energetically applying the various recommendations of the 2021 Decadal Survey to our field, both in the formulation of new, vigorous science questions and in the development of the technologies that will propel our field into the next decade and beyond. Following its wildly successful launch, deployment, and commissioning, JWST released its first images in July. At the other end of the wavelength range, the FIR community has been industriously working to develop Probe-class mission concepts. A preliminary [Announcement of Opportunity](#) from NASA was issued on August 16, 2022. Travel in the astrophysical community has restarted in earnest, and many of us recently attended our first in-person meetings in 2 years. As part of this reawakening, the IRSTIG organized and hosted a meeting at the University of Colorado, Boulder in March that was attended by ~120 participants. We discussed a wide range of topics that touched on almost the entire range of science and technology relevant to Infrared Astrophysics. Subsequent meetings, including Summer AAS in Pasadena, have kept the conversation active and highlighted new opportunities and challenges for our community.

The STIG's primary mission is to collect community input, foster consensus, and help shape the long-term goals of IR astrophysical science and technology. Our main priority is to reach out to the community spanning the entire IR wavelength range, including users of current facilities like JWST, ALMA, and the range of suborbital platforms, as well as upcoming facilities like the Probe-class and Roman Missions. Building on the momentum from recent meetings and discussions, the IRSTIG is now planning to construct community surveys to understand our collective thoughts and feelings about the state of our field. In support of that effort, we are soliciting your input on the questions we should be asking the members of our community, the answers to which will be passed on to NASA, the NSF, and other stakeholders who formulate our

future opportunities. More details can be found towards the end thoughts. This semi-annual newsletter highlights recent results, technological developments, and events of relevance to the IR community. We encourage contributions describing interesting, unique, and important science and technology breakthroughs from all our readers. Throughout the year, we 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 STIG, and remain dedicated to ensuring that our activities reflect the needs of our community, stakeholders, and early-career scientists of diverse backgrounds.

Sincerely,  
The IR STIG Leadership Council

## IRSTIG Workshop Summary

### Summary of the 2022 IRSTIG Workshop: 'Astro2020 and IR Astrophysics: Planning for the Next Decade'

*Roberta Paladini- IPAC*

The IR STIG workshop 'Astro2020 and IR Astrophysics: Planning for the Next Decade' was held in Boulder, CO, from March 30 to April 1, 2022. The goal of the workshop was to help develop a community-driven vision for the next decade of IR astrophysics. The workshop was attended by 119 participants, including many students and early-career scientists with both US and international affiliations. Sessions included a mix of structured and unstructured time to give participants opportunities to talk in small groups and collaborate.



The workshop opened with an introductory talk by Dr. Dominic Benford, Program Scientist for the Nancy Grace Roman Space Telescope. Dr. Benford reviewed the programmatic landscape for IR Astrophysics in the next decade, in light of the constrained NASA budgetary situation and the recommendations of the Astro2020 decadal survey. In particular, he emphasized that the current NASA plan does not contemplate the start of a Flagship IR mission until at least 2030, while a Far-IR imaging or spectroscopy probe would be aligned with the Decadal Survey recommendations. To this end, NASA will release a draft for an Astrophysics Probe Announcement of Opportunity (AO) in Summer 2022 and a final version of the call in January 2023. This introduction was followed by several talks providing a summary of the status of Mid-

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and Far-IR technology, including detectors, readout electronics and telescopes, and emphasizing its relative level of maturity for a future Far-IR probe.

The second day of the workshop was dedicated to the presentation of four IR probe concepts that are being developed in preparation for the NASA AO call and their key science objectives. The four concepts are three single-aperture telescopes (FIRSST, PRIMA and SALTUS) and one interferometer (SPICE), with a mix of spectroscopic and imaging capabilities, and targeting a wide range of primary science, from studies of protoplanetary disks and the characterization of exoplanetary systems to the investigation of the origin and evolution of galaxies.

The third and final day of the workshop was focused on SOFIA, for which Astro2020 recommended the close-out of operations by 2023. The SOFIA Director, Dr. Margaret Meixner, and SOFIA Deputy Director, Dr. Bernhard Schulz, discussed the mission potential to address the Astro2020 recommendations while still in operation.

Unstructured discussion was spread out over all three of the days of the workshop. On each day, participants were assigned randomly to a discussion group and assigned a question to discuss. We adopted this strategy to ensure that all workshop participants, especially early-career scientists, had a chance to have their voice heard. During the small discussions, each group completed a slide with their main takeaway points. We then came back together and gave each group a chance to present their slide to the full workshop. The full list of questions discussed during the workshop are presented at the end of this article.

Closing remarks were delivered by the IR STIG Co-Chairs, Prof. Meredith MacGregor and Prof. Mike Zemcov. Overall, the workshop conclusions can be summarized as follows:

1. The IR domain: The IR is really three different wavelength regimes with three different types of enabling technologies. Combining all of these into one category is a misrepresentation and problematic when advocating for the IR community.
2. Community Engagement: The IR community needs to make a concerted effort to reach out to the broader astronomical community (especially early career researchers, although this also requires funding support) and the public.
3. Far-IR Probes: The range of probe concepts currently under development is a natural consequence of the cost cap. With this limitation, it is imperative that each probe demonstrates that the IR domain is the only one that allows a vast improvement in sensitivity and science discovery space. Broad community input and involvement throughout the entire process is essential in order to create strong support for the probe concept that will ultimately be selected in response to the AO call. Guest observer capabilities were considered an important part of

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any Probe mission, and the community expressed support for emphasizing broad capabilities that would enable the widest range of science cases.

4. SOFIA: We now know that SOFIA will stop operations by 2023. Given this, it is mandatory that new, intermediate opportunities for IR science and technology development are generated (balloons, SmallSats, Explorers, etc.) in order to fill the time gap between now and the potential launch of a Far-IR probe by the early 2030s. Our community should advocate for an increased cadence of selections of these kinds of missions over the next decade to maintain knowledge and capabilities, as well as training opportunities for students and early career researchers. This is vitally important to attract young people to ensure our community is vibrant over the long term.

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## Workshop Discussion Questions

### The Big Picture (Day 1)

1. Leaving aside their programmatic recommendations, what near/mid/far-IR observations are best motivated by the key science questions in the decadal survey?
2. Are there recommendations from the decadal survey that may cause long-term harm to the IR community? How might we remediate these?
3. What are some IR-focused science cases that could impact the architecture of the next NASA flagship mission? What science investigations do we need to do now to inform the design of a future flagship?
4. What technologies need urgent development to enable the science of the next decade? What is the ideal path forward to deploy these technologies short- and mid-term?
5. Are we missing opportunities to grow the IR community? How can we foster interdisciplinary work with other areas of astrophysics and science in general?

### Toward an FIR Probe Mission (Day 2)

1. Suppose that an X-ray probe gets selected in the current competition. How should the IR community move forward to be ready for a call in the 2030s? What science could be done from other platforms and how will we advance technology?
2. In order to maximize scientific return, how should the probe mission concepts balance survey vs. general observer (GO) science? What is the science trade space and how do we optimize return?

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3. Ultimately, at most one probe-class mission will be selected to fly. How do we foster unity as a community during the proposal process so that we are able to move forward cohesively once a selection is made?
4. How might a far-IR probe mission influence the science case and design of a future flagship mission? How would this fit into the broader mission landscape and complement sub-orbital platforms?
5. What science could be done by a probe-sized mission that would not be possible with smaller space, sub-orbital, or even ground-based programs?

## **Sub-Orbital Capabilities and Quandaries (Day 3)**

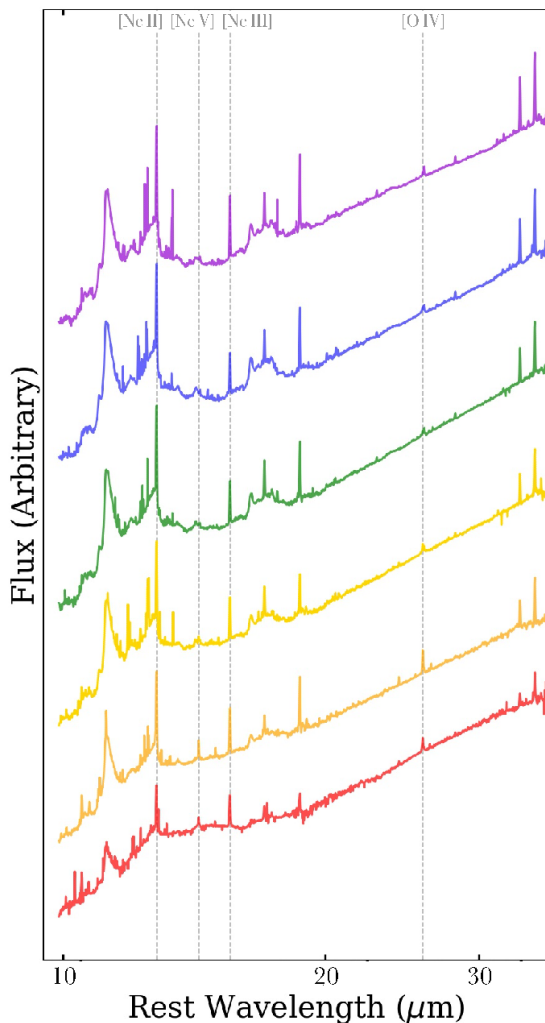
1. In the limit that SOFIA ends in 2023, how do we best position ourselves as a community to do excellent mid/far-IR science? What would be the impacts on the IR community's stability? What specific science areas would stall, if any?
2. In the limit that SOFIA does not end in 2023, what would be the scientific and technological impacts on the development of potential probe and flagship missions?
3. What are the scientific and technological justifications to keep SOFIA operating into the next decade? How would it fit into the future landscape of IR experiments?
4. What new sub-orbital capabilities would best enable the community to do new science and develop new technology?
5. What role should balloons play in the future landscape of IR experiments? How could balloons be better supported in order to promote our community's scientific interests and needs?



## Measuring Black Hole Accretion Rates in Low-Luminosity AGN with a New Empirical Decomposition of 25.9 $\mu\text{m}$ [O IV]

Meredith Stone – University of Arizona

Paper: Stone et al. 2022, ApJ, in press, [astro-ph 2206.05301](https://arxiv.org/abs/2206.05301)



The mid-infrared spectra of galaxies offer tracers of both star formation (SF) and supermassive black hole/active galactic nucleus (AGN) accretion. Two mid-infrared lines are most frequently used to trace AGN: [Ne V] at 14.3  $\mu\text{m}$  and [O IV] at 25.9  $\mu\text{m}$ . Each of these lines have their benefits and drawbacks: [Ne V] is a very pure AGN tracer with minimal contamination of its luminosity by SF but is intrinsically quite faint and difficult to detect in all but the most powerful AGN; [O IV] is brighter and easier to detect, but its ionization potential is such that it may be excited by high-mass stars as well as AGN. In weak AGN and SF-dominated galaxies, it is therefore difficult to trace AGN accretion in the mid-infrared even at low redshift, as [Ne V] may be too faint and [O IV] contaminated by star formation.

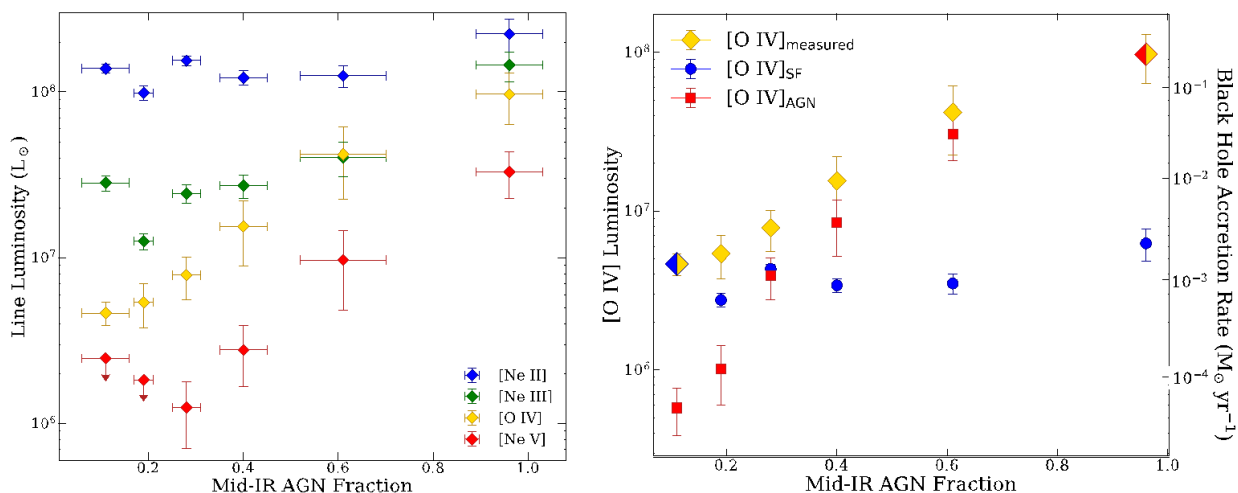
We set out to measure star formation and supermassive black hole accretion rates (BHARs) from the *Spitzer*/IRS spectra of the Great Observatories All-Sky LIRG Survey [1] of local infrared-luminous galaxies (GOALS;  $\$L_{\text{IR}, 8-1000 \mu\text{m}} \geq 10^{11} L_{\odot}$ ,  $z < 0.1$ ) using mid-infrared spectral lines ([Ne II] and [Ne III] for star formation, and [O IV] and [Ne V] for black hole

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accretion). In order to increase the SNR of the spectra and maximize detections, we stacked the spectra in six bins of AGN strength, quantified by the fraction of mid-IR emission produced by the AGN (the mid-IR AGN fraction) measured from the equivalent width of the 6.2  $\mu\text{m}$  PAH feature.

We detected [Ne II], [Ne III], and [O IV] in all six stacked spectra, and [Ne V] in all but the two lowest-AGN fraction stacks. In order to calculate the average black hole accretion rates of these two most SF-dominated stacks (where [Ne V] is not detected and [O IV] is maximally contaminated by star formation) we decompose the [O IV] luminosity into two components: one from the SF (proportional to the luminosity of SF line [Ne II]) and one from the AGN (depending on the mid-IR AGN fraction). The SF component can therefore be subtracted from any measurement of [O IV] to obtain the [O IV] luminosity arising from the AGN and therefore calculate the black hole accretion rate.

The BHARs derived [2] from uncorrected, SF-contaminated [O IV] agree at high AGN fractions but are more than an order of magnitude greater than the BHAR from corrected [O IV] in the two lowest-AGN fraction bins. When we correct the [O IV] luminosity for SF contamination and calculate BHARs, they agree well with those calculated from the [Ne V] luminosity.



*Left:* The measured luminosities of the four mid-infrared spectral lines studied: [Ne II] (blue), [Ne III] (green), [O IV] (yellow) and [Ne V] (red). The errors on the x-axis reflect the spread of AGN fractions in each bin. The star-forming lines [Ne II] and [Ne III] exhibit minimal evolution with AGN fraction, while the AGN-dominated lines [O IV] and [Ne V] both increase in luminosity by more than an order of magnitude with AGN fraction. Brighter, SF-contaminated [O IV] is detectable even in the two lowest-AGN fraction stacks, while [Ne V] is not. *Right:* The

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results of the empirical decomposition of the [O IV] luminosity into components from star formation and the AGN. The star-forming component (blue circles) is proportional to [Ne II] and relatively flat across the sample, while The AGN component (red squares) increases strongly with AGN fraction. At an AGN fraction of  $\sim 0.3$ , the two components contribute equally to the total [O IV] luminosity. The right axis reflects the black hole accretion rate calculated from the [O IV] luminosity.

Previously, [O IV] could only be robustly used as an AGN tracer in systems where the AGN emission was clearly dominant. With this empirical correction to [O IV], it can be pushed as a BHAR tracer to lower AGN luminosities or to understand the amount of contamination if a correction is not applied.

With *JWST*'s superior sensitivity and spatial resolution compared to *Spitzer*, [O IV] can be pushed as a BHAR tracer to galaxies hosting weaker AGN and used to understand the relationship between star formation and black hole accretion in galaxies of a much wider range of AGN luminosities. At higher redshift, [O IV] has great potential utility as a BHAR tracer in luminous systems with a future cold far-IR space telescope, such as PRIMA (PRobe far-Infrared Mission for Astrophysics, [3]).

### References

- [1] Armus et al. 2009, PASP, 121.880 (559).
- [2] Gruppioni et al. 2016, MNRAS, 458.4 (4297).
- [3] <https://workshop.ipac.caltech.edu/farirprobe/pag>



# Technology Highlights

## The Far-Infrared Spectroscopy Space Telescope – FIRSST

*Meredith MacGregor - Deputy PI, University of Colorado Boulder*

*Asantha Cooray - PI, University of California Irvine*

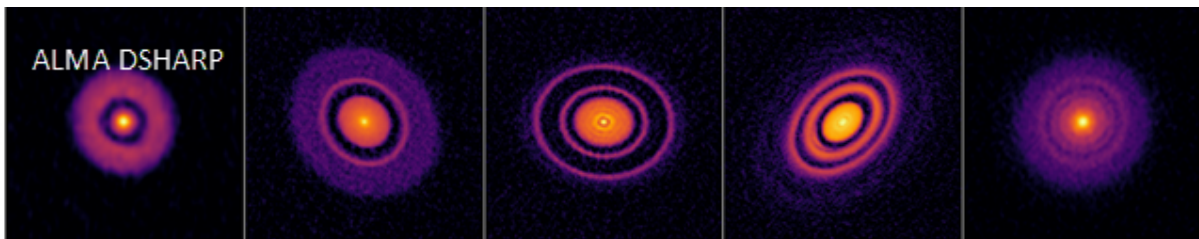
### Science Themes

The FIRSST science and instrument requirements are currently under study by a science steering committee made up of a diverse group of astronomers representing three core science areas. The technical development process is being overseen by an advisory board of senior scientists with a wide range of mission, operations, and management experience. Our core science questions are:



#### *(1) What is the diversity and evolution of planet-forming disks?*

The amount and evolution of gas in planet-forming disks sets the maximum mass of potential planets and the timescale for planet formation. FIRSST will precisely measure masses for the first statistical sample of protoplanetary disks using HD (56 and 122  $\mu\text{m}$ ) – the most robust known tracer of gas masses. We will also target atomic species such as [CII] (158  $\mu\text{m}$ ), [OI] (63  $\mu\text{m}$ ), and [NIII] (57  $\mu\text{m}$ ) to trace the dispersal of gas in planet-forming disks via photoevaporation and shed light on the origins of gas in more evolved debris disks.



#### *(2) What is the trail of water from molecular clouds to oceans?*

FIRSST will trace water (multiple lines between 32 – 538  $\mu\text{m}$ ) through all stages of star and planet formation – in star forming regions, protostellar cores, protoplanetary disks, and solar system bodies. By pairing the HDO line at 234  $\mu\text{m}$  with the 243  $\mu\text{m}$  water line, we will determine the D/H ratio in different environments and constrain the source of Earth's water.

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FIRSST will have unique capabilities to carry out this important precursor science, which will inform future flagship missions to study planetary habitability.

### *(3) How do galaxies assemble their material?*

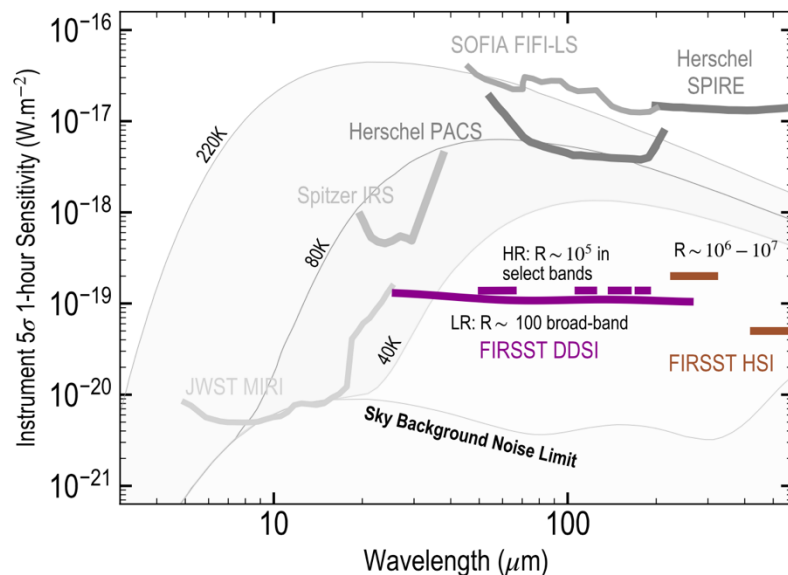
FIRSST will trace the production of metals, dust, and gas in galaxies along with their relation to star formation using broadband spectroscopy of fine structure lines and silicate PAH features. We will also look at the coevolution of black holes and galaxies, investigate the impact of AGN outflows, search for organic molecules in star forming regions, and map atomic and ionized gas in nearby galaxies.

Spanning all three of these science areas, we are looking into the instrument requirements to enable time-domain science including transient follow-up along with observations of stellar flares, protostellar accretion, and other targets of opportunity.

## Preliminary Instrument Design

FIRSST will be primarily a guest-observer facility (>90%) with GTO observations planned to demonstrate capabilities. The current baseline design is for a 2m-class, cryogenically cooled, single aperture telescope operating between 30 – 600  $\mu\text{m}$ . Instrument concepts under development include:

- (1) Broad-band  $R \sim 100$  multi-mode far-IR spectrometer from 30 – 300  $\mu\text{m}$  with up to  $R \sim 10^5$  capability on select spectral bands with 10% detection bandwidth
- (2) Heterodyne system with  $R \sim 10^6 - 10^7$  spectroscopy at longer wavelengths (200 – 600  $\mu\text{m}$ )

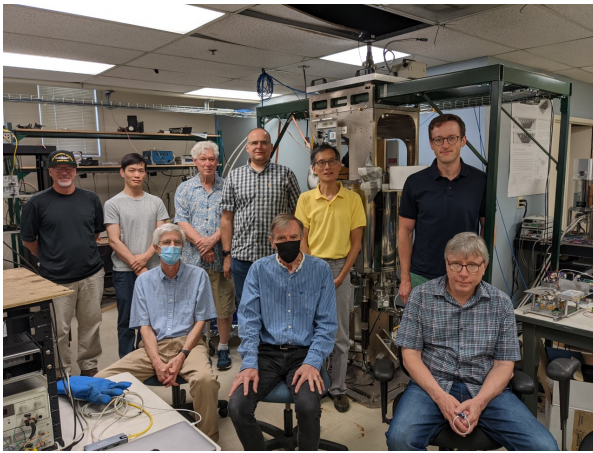


*The FIRSST team continues to want to hear community input in order to build a mission that will maximize science returns in all science areas. If you are interested in joining any of the science working groups or suggesting new science directions for FIRSST, please reach out!*

# Technology Highlights

## New wSMA Instrumentation for the Submillimeter Array

*Edward Tong for the wSMA Team*



The Submillimeter Array (SMA) was conceived three decades ago as the world's first submillimeter interferometer capable of sub-arcsecond imaging in the frequency range from 200 to 700 GHz. Since it began full science operations in 2004, it has introduced new receivers with wider intermediate frequency (IF) bandwidth, alongside with augmented polarimetric and dual frequency observing modes. The next step in the development of the SMA is called the wideband Submillimeter Array (wSMA). The wSMA upgrade will replace the original SMA

cryostats, receivers, and receiver selection optics with all new systems, and incorporate several major upgrades to the backend IF signal transport and correlator systems. This will enable the wSMA to operate with 32 GHz instantaneous bandwidth per receiver polarization and will form the basis of future development efforts.

Working with High Precision Devices (acquired by Form Factor in 2020), the wSMA team has developed a prototype cryostat for the wSMA upgrade. Each of the prototypes houses two receiver cartridges, one for the Low Band (LO coverage 210-270 GHz) and one for the High Band (LO coverage 280-360 GHz). One important feature of this cryostat is a cold selector wheel which allows either or both receiver cartridges to be used for simultaneous observation. Two such cryostats have been delivered in 2021. We have performed extensive testing of both prototypes, not only in terms of cooling capacity and cooldown times, but also of the optical alignment of critical elements within the cryostat. The prototype cryostat delivers a base temperature of 4.0 K, and fully meets our target alignment specifications.

An initial Low Band receiver cartridge has been assembled and fully tested, carrying the dual polarization front-end assembly and a pair of mixer blocks, one for each polarization. Work on assembling the first of the High Band receiver cartridges has begun and we expect to make cryogenic measurements of this alongside the Low Band cartridge in the coming months. We are developing plans to ship one prototype wSMA cryostat to the SMA site on Maunakea this fall to

check mechanical interfaces, to verify optical alignment, and to evaluate the on-sky performance of the receiver cartridges.

A number of wSMA production cryostats, featuring further performance enhancements, have been ordered. Once the prototype cryostat has been checked out at the SMA site, full scale deployment of the wSMA instrument is expected in the coming years.

## Community Surveys

### Input on Topics and Questions for Upcoming Community Surveys

In support of our mission to provide community feedback to NASA, the NSF, and other funding bodies, the IRSTIG is planning to deploy one or more surveys of the IR community over the next six months. We would like to understand your thoughts on matters including:

- Increasing access and opportunities to do science in the crucial 1-1000  $\mu\text{m}$  range.
- The desire for explicit access to Guest Observations in sub-orbital and Probe-class missions.
- The role of ground-based facilities for IR astrophysics.
- Development of technologies for the Flagship-class missions of the next decade.
- The maintenance of our vigorous and diverse community of scientists with activities and opportunities at all professional levels and roles.

We are now soliciting your input on the kinds of topics we should address and questions we should ask in these anonymous surveys. If you have input of any kind, please capture it in an email to [irsiglc@gmail.com](mailto:irsiglc@gmail.com) before September 15, 2022.

Over the next six months we will announce these surveys to the community and will collate and analyze the responses. Summative reports will be written and sent to stakeholders to help inform future decisions regarding funding, development opportunities, and strategic investments, in both the short and long term. We welcome and encourage your involvement in this crucial process!

## Upcoming Events

**7-9 Sep 2022 Precursors to Pathways: Science Enabling NASA Astrophysics Future Great Observatories – Online**

<https://exoplanets.nasa.gov/exep/astro2020-precursor-sci-workshop2/>

**14 Sep 2022 SPICE Community Workshop – Online**

<https://docs.google.com/forms/d/e/1FAIpQLSeE5MRNbpjxGx8nSLRw6mS3S3XFmkVW3oARKK7VbYTMXqyL0A/viewform>

**26-20 Sep 2022 Physics and Chemistry of Star Formation The Dynamical ISM Across Time and Spatial Scales – Puerto Varas, Chile**

<https://astro.uni-koeln.de/symposium-star-formation-2022>

**25-28 Oct 2022 Galaxy Evolution with the ESA Euclid mission and ESO telescopes – ESA, Madrid, Spain**

<https://www.cosmos.esa.int/web/euclid-galaxy-evolution>

**13-15 Dec 2022 Torus 2022 Workshop, Smoke and Mirrors – Leiden, Netherlands**

<https://www.torus2022.nl/>

## CONTACT US

Keep in touch with the IR Science and Technology Integration Group.

### IR STIG 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.

### EMAIL LIST

[https://cor.gsfc.nasa.gov/sigs/irsig/maillist/irsig\\_maillist.php](https://cor.gsfc.nasa.gov/sigs/irsig/maillist/irsig_maillist.php)

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