SOFIA's Instrumentation Future

Dr. Margaret Meixner, Director of SOFIA Science Missions Operations

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SOFIA
Stratospheric Observatory for Infrared Astronomy

NASA DLR USRA DSI

- A plan for future scientific instrumentation on SOFIA

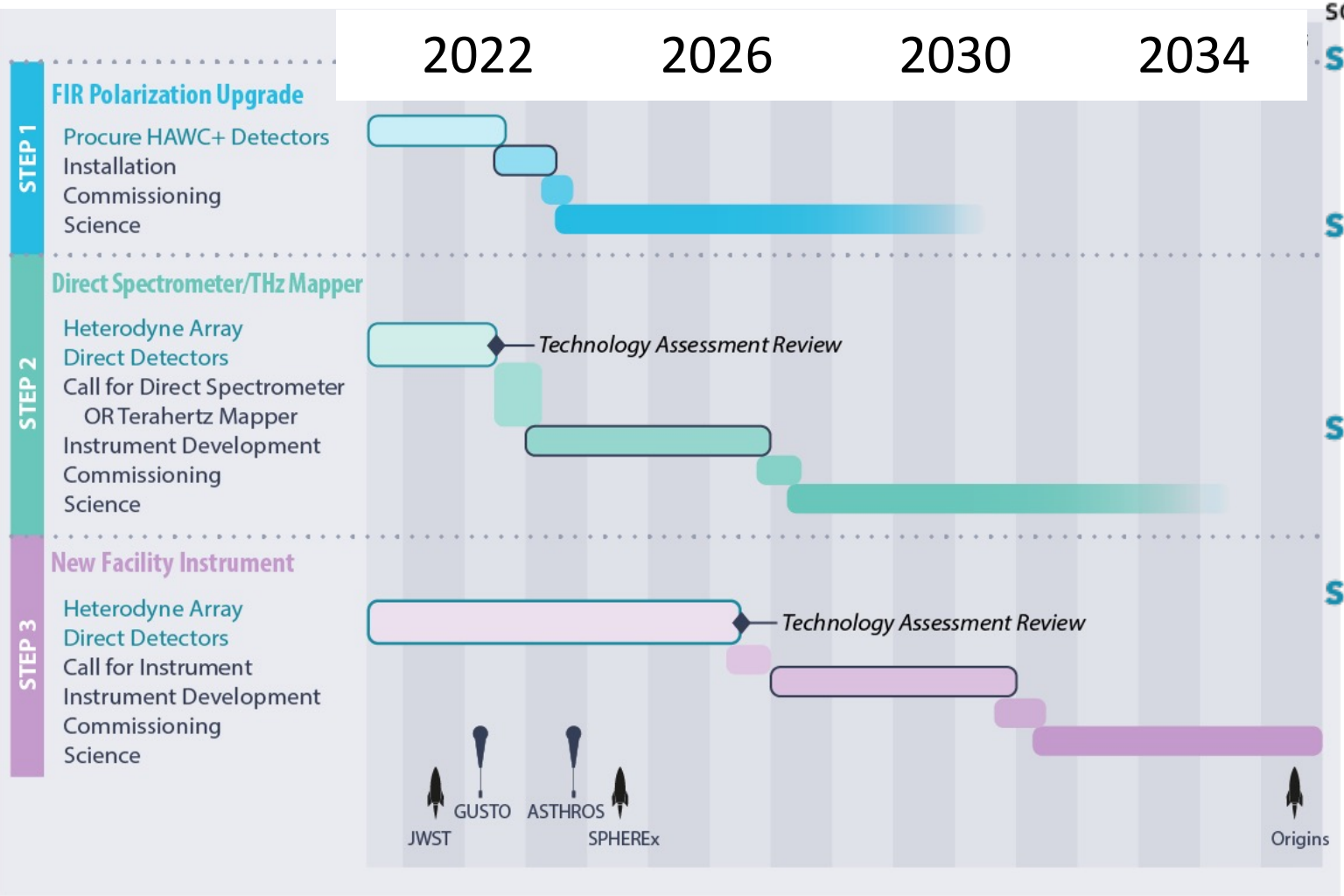
- Public report available for download:

https://www.sofia.usra.edu/sites/default/files/Other/Documents/instrument-roadmap-public.pdf

Instrument Roadmap: Science Cases

	Science Case	Required Measurement	New Instrument Capability
Star and Planet Formation	Protoplanetary disk gas masses	Velocity-resolved HD line at 112 μm	High-resolution direct-detection FIR spectrometer
	Star formation feedback	Entire star-forming-region (>deg^2), velocity resolved maps of FIR lines (C II, O I, O III, CO)	Wide-field FIR heterodyne mapper
	Role of magnetic fields in star formation	Polarization from entire molecular filaments (>deg^2)	FIR polarimeter with improved mapping speed
Path to Life	Astrochemistry and disk chemistry	Velocity-resolved spectroscopy (H_2 pure rotations, light hydrides, H_2O, O I)	High-resolution MIR & FIR spectrometer, improved wavelength coverage and sensitivity
	Comets, asteroid, protoplanetary disk minerals & ices	5-70 mm ice, mineral, PAH feature strengths	MIR moderate to low-res spectrometer with improved sensitivity
	Planets and cometary gas	Med-res and high-res spectroscopy	Improved sensitivity
Calibrating the Distant Universe	Role of magnetic fields in spiral arms	Map entire nearby galaxies in FIR polarimetry	FIR polarimeter with improved mapping speed
	Evolution of galaxies with metallicity and size	Wide-field spectroscopy of entire nearby galaxies in FIR lines (C II, O I, O III)	Moderate resolution FIR spectrometer with wide field of view, improved mapping speed
	Transient phenomena	Monitoring of stellar eruptions, mergers, novae, and supernovae	Sensitive, rapid-response MIR/FIR photometer

Notional Timeline



Two orthogonal inputs are combined to create this roadmap: science priorities and technology readiness.

Step 1: Upgrade HAWC+

- Enables 2 out of 9 science cases
- Upgrade can be made using current technology
- Enables large (legacy) programs efficiently

Step 2: Direct-detection 30-120 μm spectrometer

- Enables ~5 out of 9 science cases
- New science, expands SOFIA's discovery space, expands/broaden SOFIA's community
- Strong synergies with Webb and SPHEREx

Step 2: Terahertz Mapper

- Preserves and expands SOFIA's core capability
- In high demand by current SOFIA users
- Heterodyne arrays are further along technologically

Step 3: Instrument Call

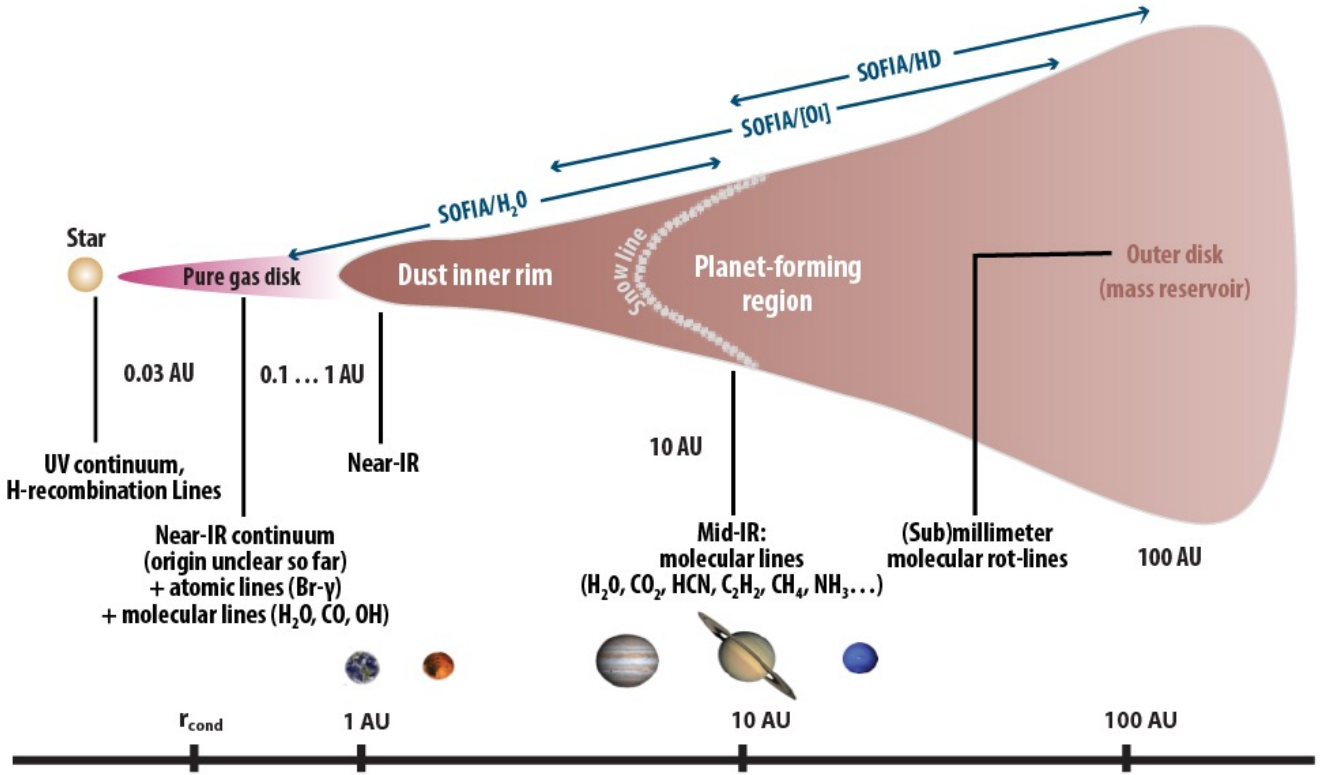
- Discoveries from SOFIA and other missions/observatories (e.g., Webb, GUSTO, ALMA, SPHEREx, VIPER) will change the scientific landscape/priorities of the community in the next 5 years
- Additional community input will be needed around 2024-25 to better define Step 3

Instrument Roadmap: Step 1 has started

- Replacing the HAWC+ detectors will increase the mapping speed for magnetic fields by a factor of up to 4
- NASA Goddard and NIST submitting a joint proposal to do this work.
- SMO will be part of implementation team

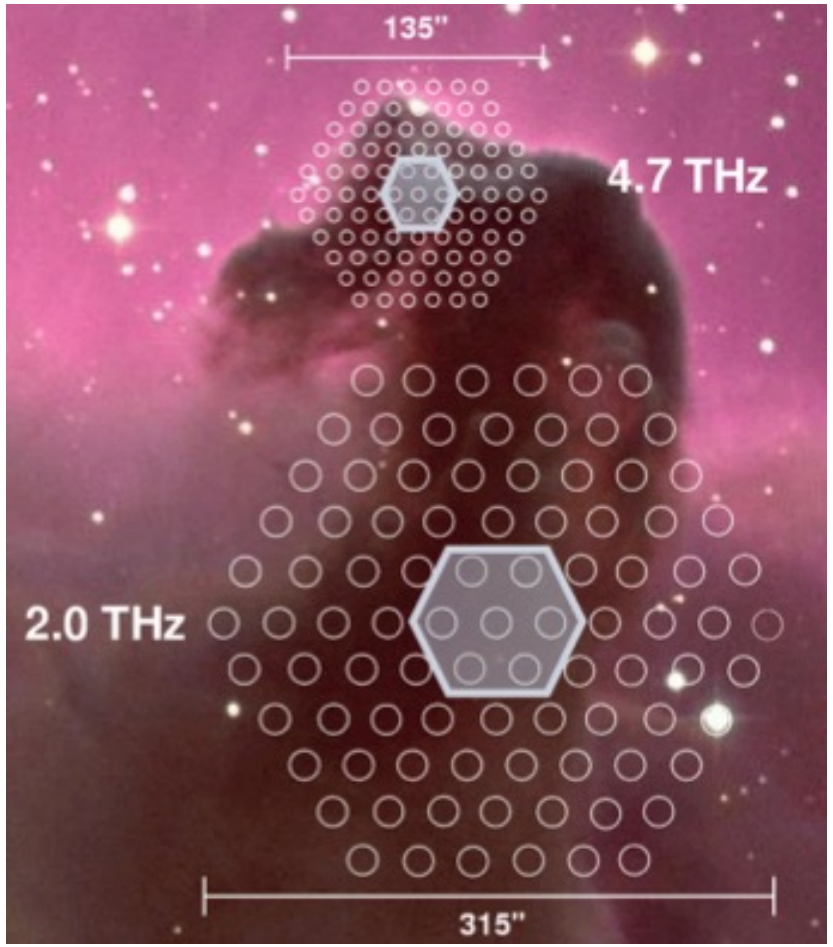
Step 2 Instrument: Concept 1

- Direct-detection 30-120 micron spectrometer
- Measure mass of protoplanetary disks using HD as a proxy for H_2



- Concepts at the workshops included:
  - Transition Edge Sensor (TES) detectors
  - Kinetic Inductance Detectors (KIDs).

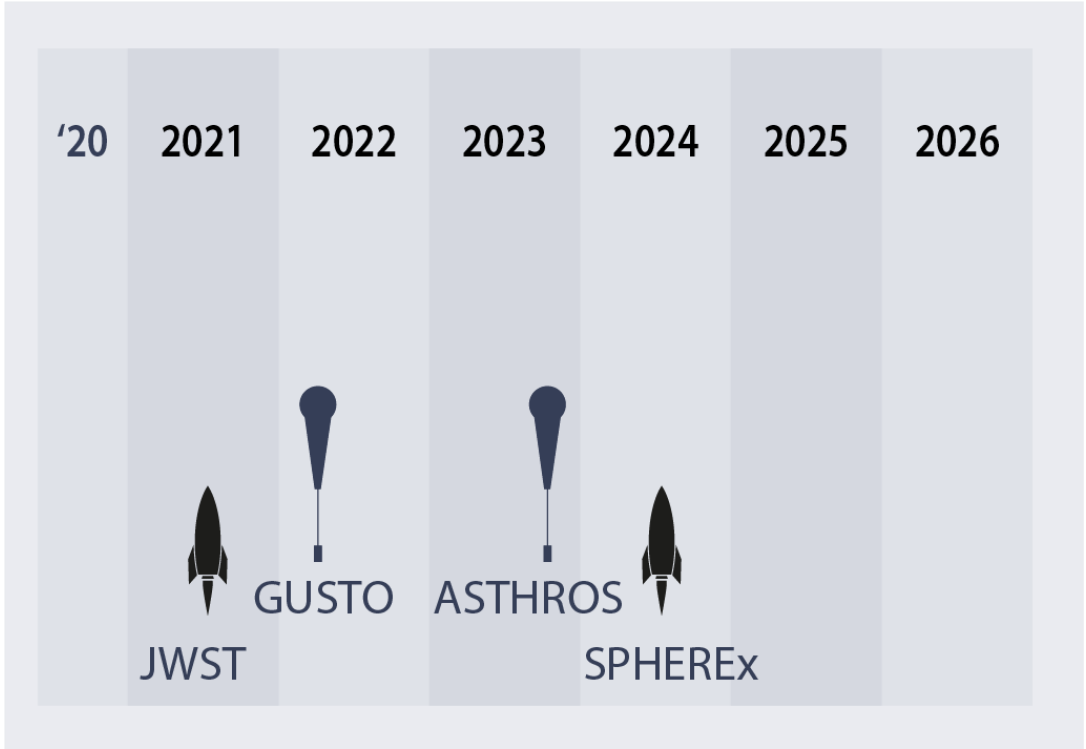
Step 2 Instrument: Concept 2

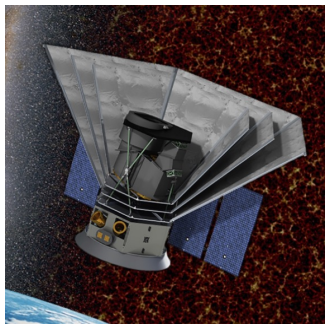


- Terahertz Mapper: 100-pixel Heterodyne Array
- Build on the success of the GREAT instrument
  - 14x faster mapping speed
- Utilize SOFIA's large focal plane
- Complementary to GUSTO
- Heterodyne technology development is farther along

Step 3: New Facility Instrument

- Discoveries from SOFIA and other observatories will change the scientific landscape and priorities
- Additional community input will be needed around 2024-25 to better define this step





German Instrumentation Initiative

The Future of Airborne Infrared/Submm Astronomy: Prospects and Opportunities

The Future of Airborne Infrared/Submm Astronomy: Instrument Solutions

Bernhard Schulz
Deputy SMO Director
DSI/Uni Stuttgart

Motivation & History

- SOFIA has no dedicated funding for instrumentation
- DLR funds SOFIA operations but no instrumentation
  - Original agreement between BMFT and BMWi
- FIFI-LS and GREAT were built with MPG and DFG funds
  - Especially DFG requires guarantees for science return
  - Obstacle: Senior Review 3 year cadence does not fit to typical 5 year instrument building period
- NASA Roadmap changes the landscape
  - NASA investing in SOFIA's future eases cancellation worries
  - Provides vision and opportunity to engage with German/European scientists, instrument builders and funding agencies

Plan for Germany/Europe

- Use the opportunity to change the SOFIA paradigm
  - NASA does senior reviews but that is a normal process
  - No serious alternatives for Infrared/Submm on the 10 year horizon
  - Long term NASA vision makes termination less likely!

- The German/European community can create a complementary 10 year vision for Infrared/Submm astronomy
  - SOFIA is a working observatory
  - Future lighter-than-air observatories are good additional options

- First determine science interests and requirements (July 26-28, 2021) ✓
- Second discuss instrumentation and funding (Nov 17-19, 2021)
- Write white paper summary (by end Jan 2022)

Workshop 26-28 Aug 2021 Report

The Future of Airborne Infrared/Submm Astronomy: Prospects and Opportunities

Preliminary
Biased
Incomplete

- 231 registered participants
- 3 days @ ~4.5h per day
- typical online attendance 80-90
- 56 Presenters
  - 10 invited speakers
  - 32 Contributed talks
  - 14 Poster presentations
- Summary presentation by Karl Menten
- Main Themes: ISM, PDRs, shocks, star formation, astrochemistry

- Top requested:
  - Heterodyne spectroscopy (~80%)
  - More sensitive lower R spectroscopy for extra galactic work and large scale line mapping
  - High res. MIR spectroscopy, evolved stars, plan. atmospheres...
  - magnetic field mapping and FIR SED mapping
- Specific requests:
  - Fine structure lines, deuterium, CO ladder, oxygen compounds
  - 350µm filter
  - large scale mapping of [NII] 122µm / 205µm
  - NIR capabilities for occultation obs.
- **Keep SOFIA Flying!**

Summary

- SOFIA has a bright future to make discoveries across astrophysics
- NASA Instrument Roadmap projects a 10-year future to enable discoveries
- This German/DSI hosted workshops are excellent next steps in the SOFIA partnership and its instrumentation future.