SOFIA Instrument Roadmap Workshop #1 Summary

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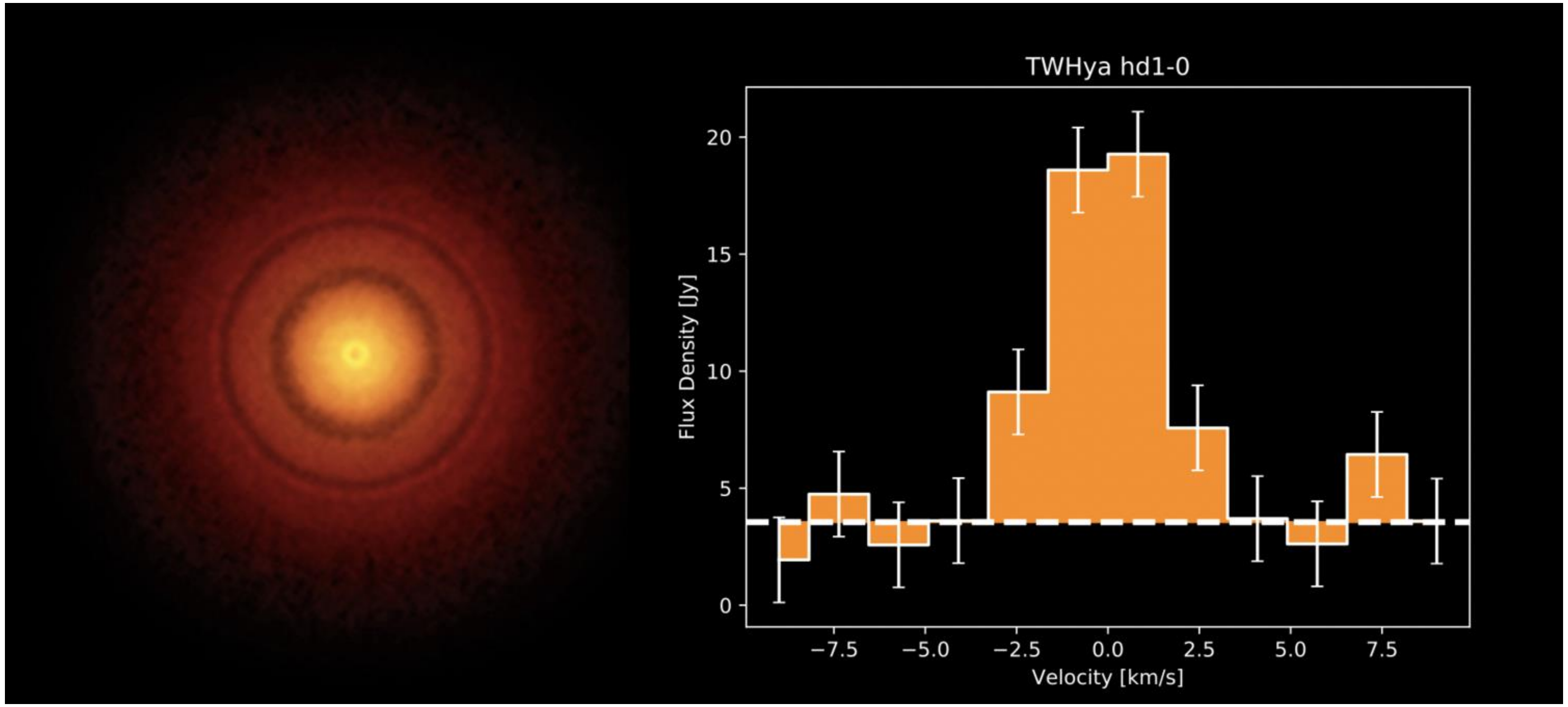
Worskhop #1 Summary

- Summary of SOFIA Science Cases Presented in Workshop 1
  https://www.sofia.usra.edu/science/instruments/instrument-development/workshop-building-2020-2025-instrument-roadmap
- Necessary Capability to Execute Key Science
- Gaps in SOFIA's Instrumental Capabilities
- Next Steps

Disk Masses

Mass determinations of protoplanetary disks from CO and dust continuum disagree by factors of >10

The **HD 1-0 line at 112 μm** is a more direct tracer of disk mass and is accessible to SOFIA

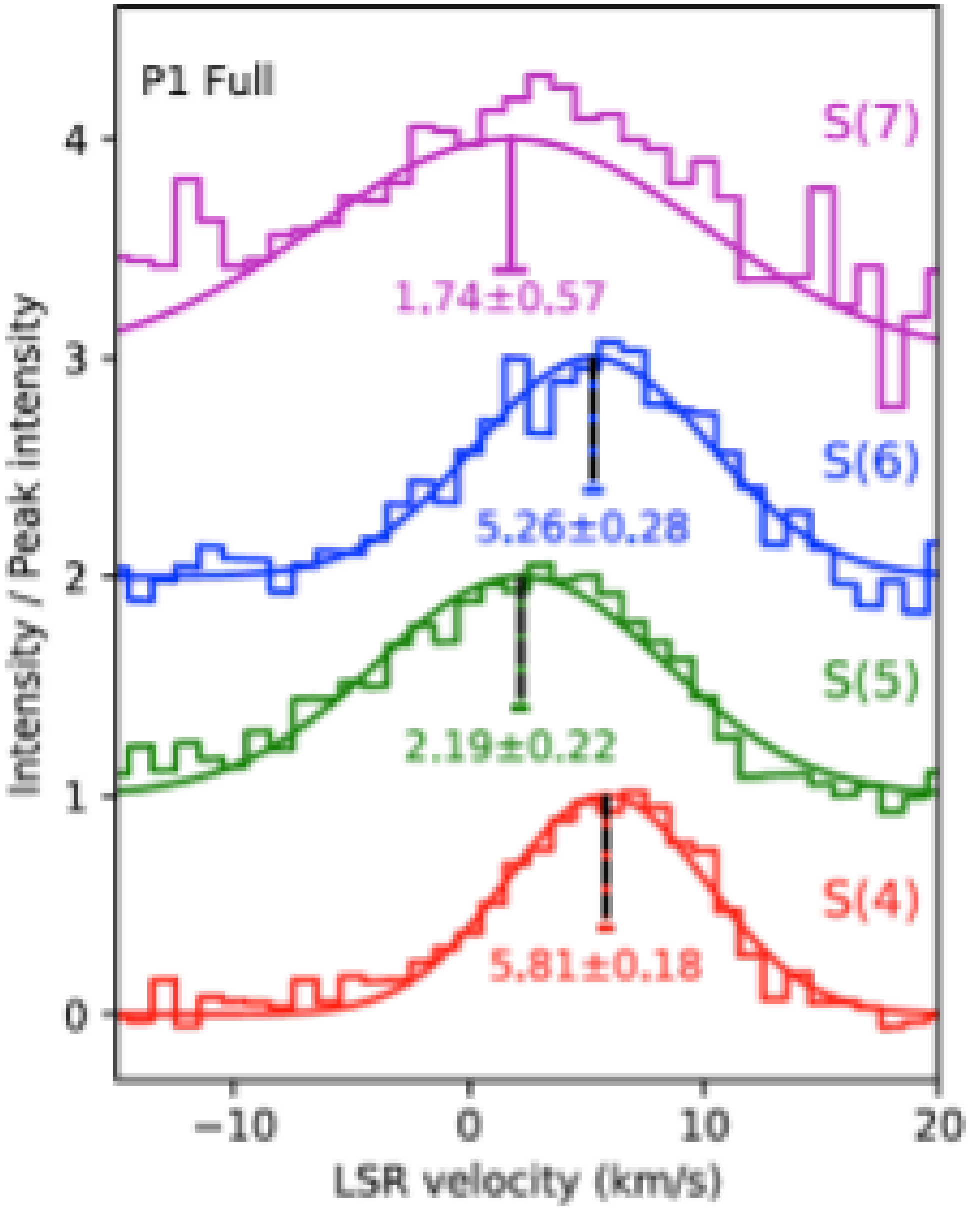


The ALMA dust continuum image of TW Hya is shown on the left (Andrews et al. 2016), while a simulated HIRMES high-resolution spectrum of the HD 1-0 ground-state line at 112 μm is shown on the right.

Source: www.hirmes.org/science

ISM Diagnostics

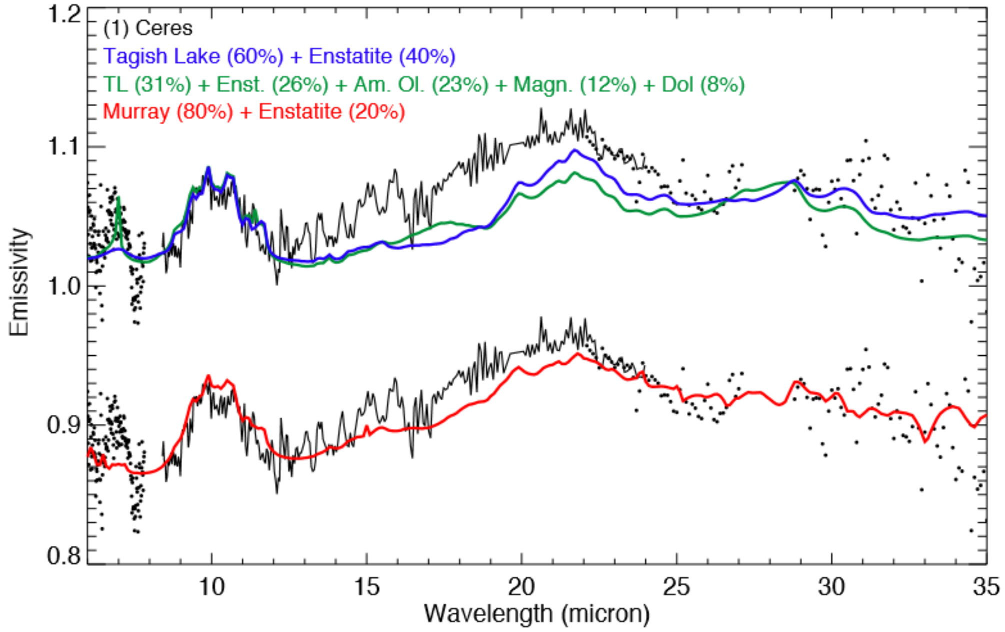
- A number of important **diagnostic spectral lines** are found only in the mid- and far-IR,
  - H_2 ortho and para rotational lines
  - Simple hydride molecules (HD, SH, HeH^+, etc.)
  - FIR fines structure lines ([C II], [O I], [O III], [Si II], etc.)



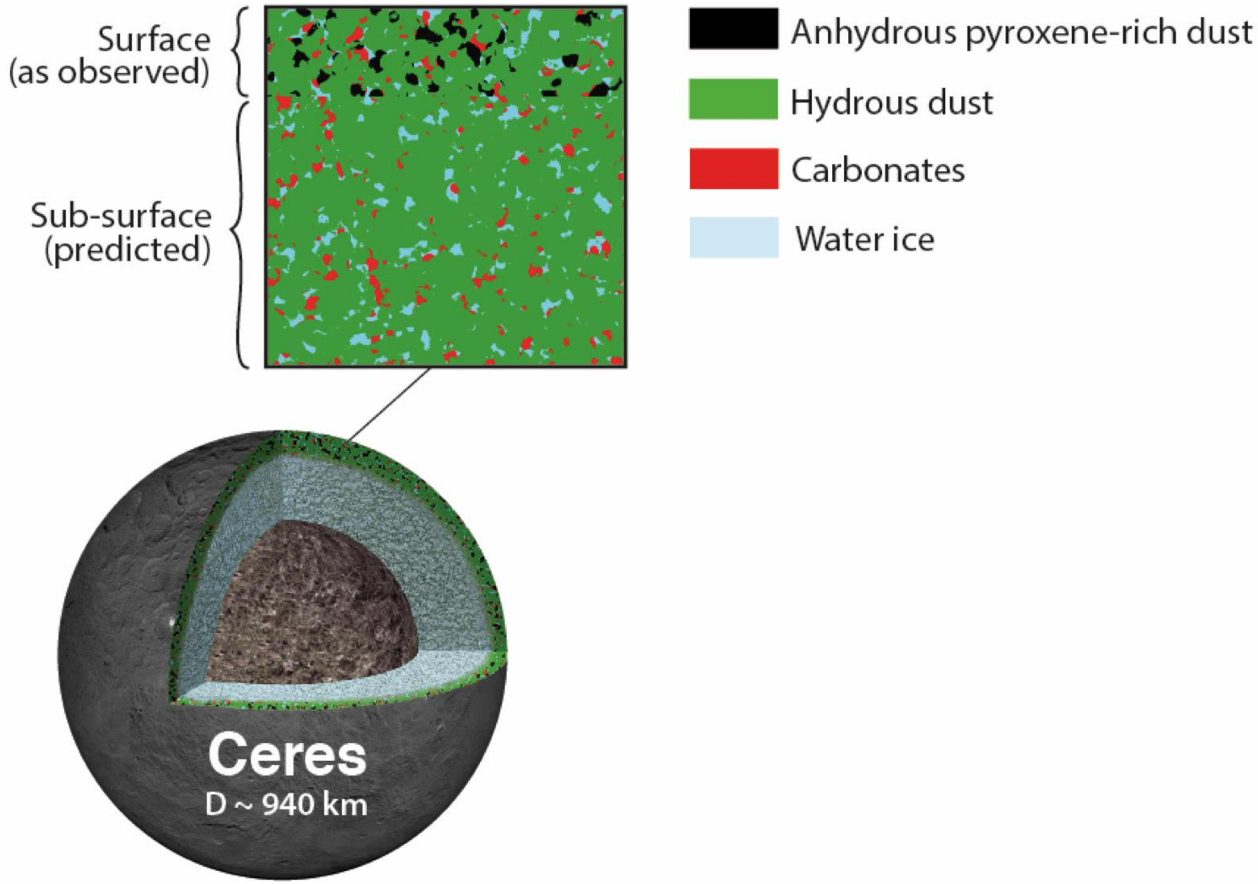
SOFIA finds a velocity difference between ortho- and para-molecular hydrogen lines, as predicted for a slow shock. Neufeld et al. 2019

Solid Bodies, Ices and Minerals

- **Broad solid-state ice and mineral features** appear in the mid- and far-IR

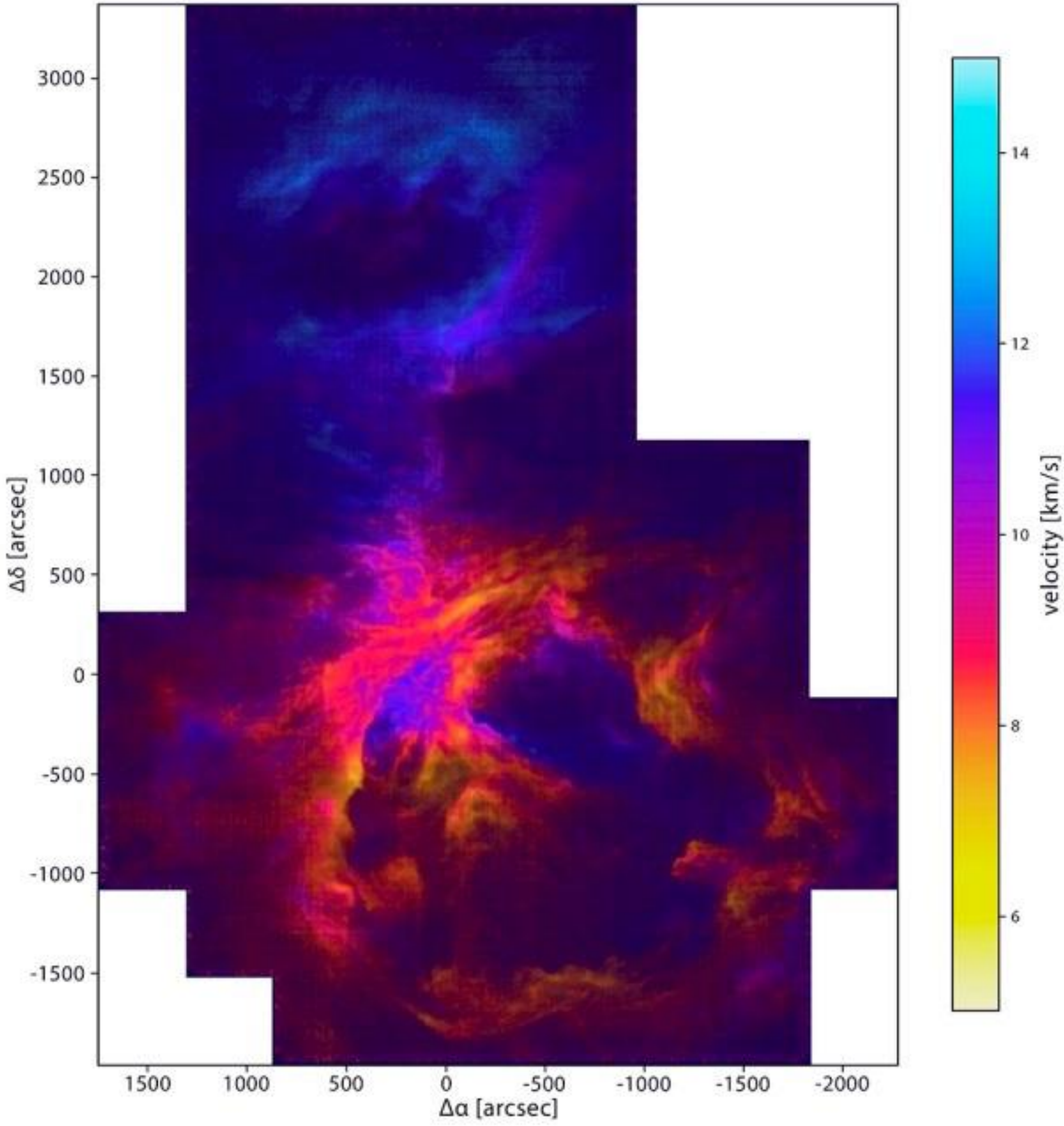


Vernazza et al. 2017



Star Formation

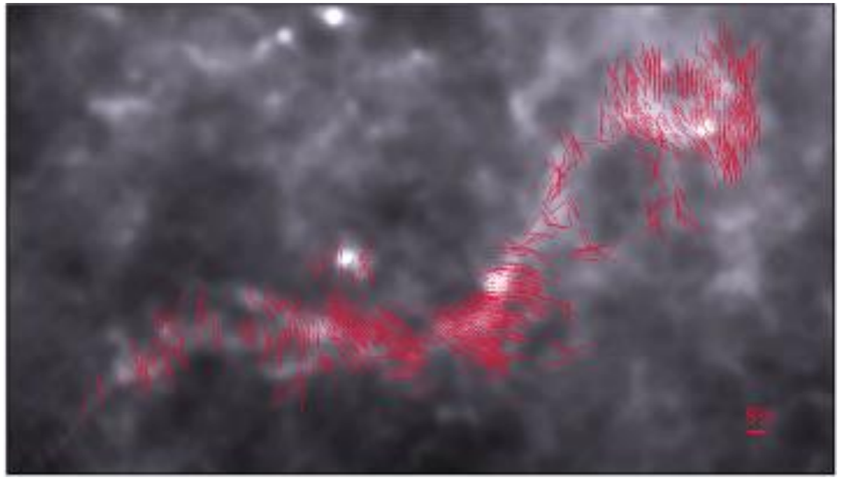
- A number of important **diagnostic spectral lines** of photodissociation regions are found in the far-IR,
  - FIR fines structure lines ([C II], [O I], [O III], [Si II], etc.)
  - High-J CO lines
  - For large maps, SOFIA outperforms *Herschel* by large factors



SOFIA [CII] image of a square-degree in Orion, color-coded by the velocity centroid of each of the >2 million line profiles [Pabst et al. 2019]. This new view of Orion reveals a rich structure, including two large expanding bubbles, filaments, colliding flows, and a completely distinct view of the molecular gas distribution compared to that previously observed in CO.

Magnetic Fields in Dusty Regions

HAWC+ **far-IR polarimetry** offers a direct probe of magnetic field at the peak wavelength of the thermal emission.

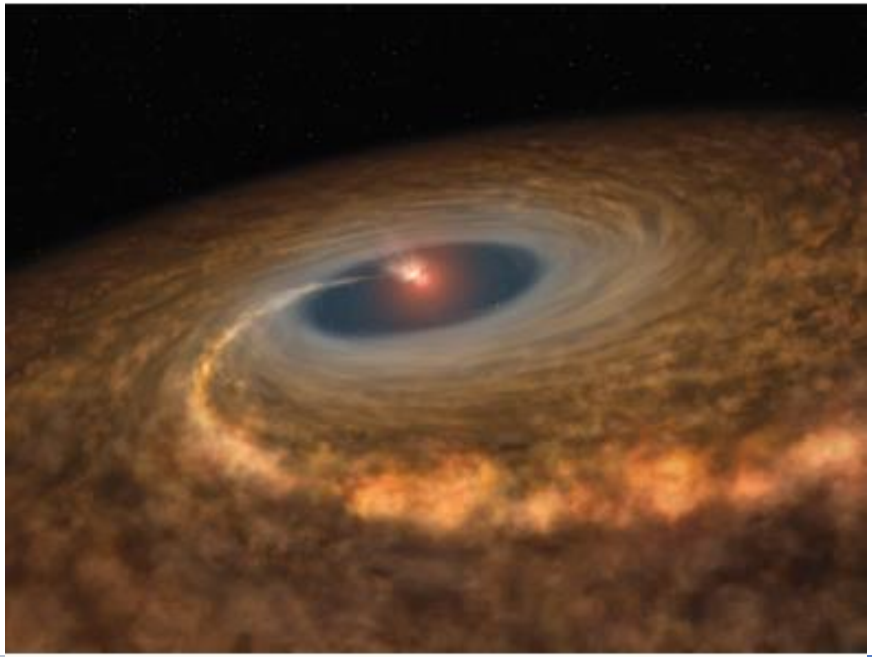


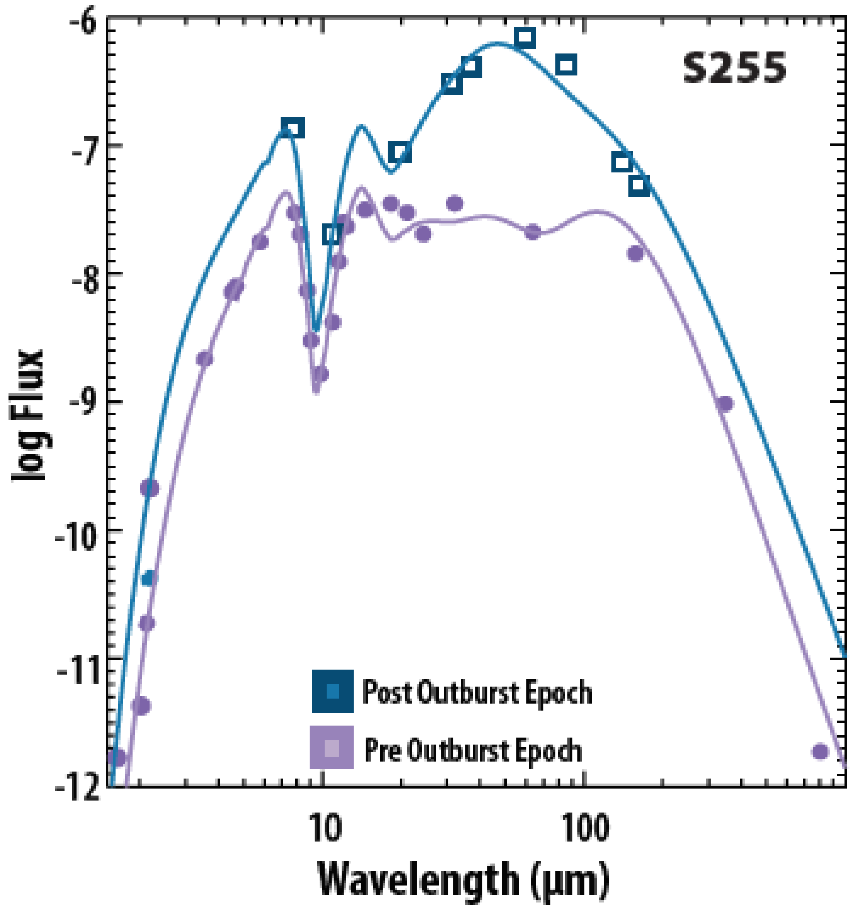
Top magnetic field (striations) in the starburst galaxy M82 (Jones et al. 2019)

Bottom magnetic field vectors in the Infrared Dark Cloud "the Snake (Stephens et al., 2020)

Stars, Novae, and Supernovae

SOFIA can provide crucial **mid- and far-IR monitoring** data to track luminosity evolution in time-variable sources.



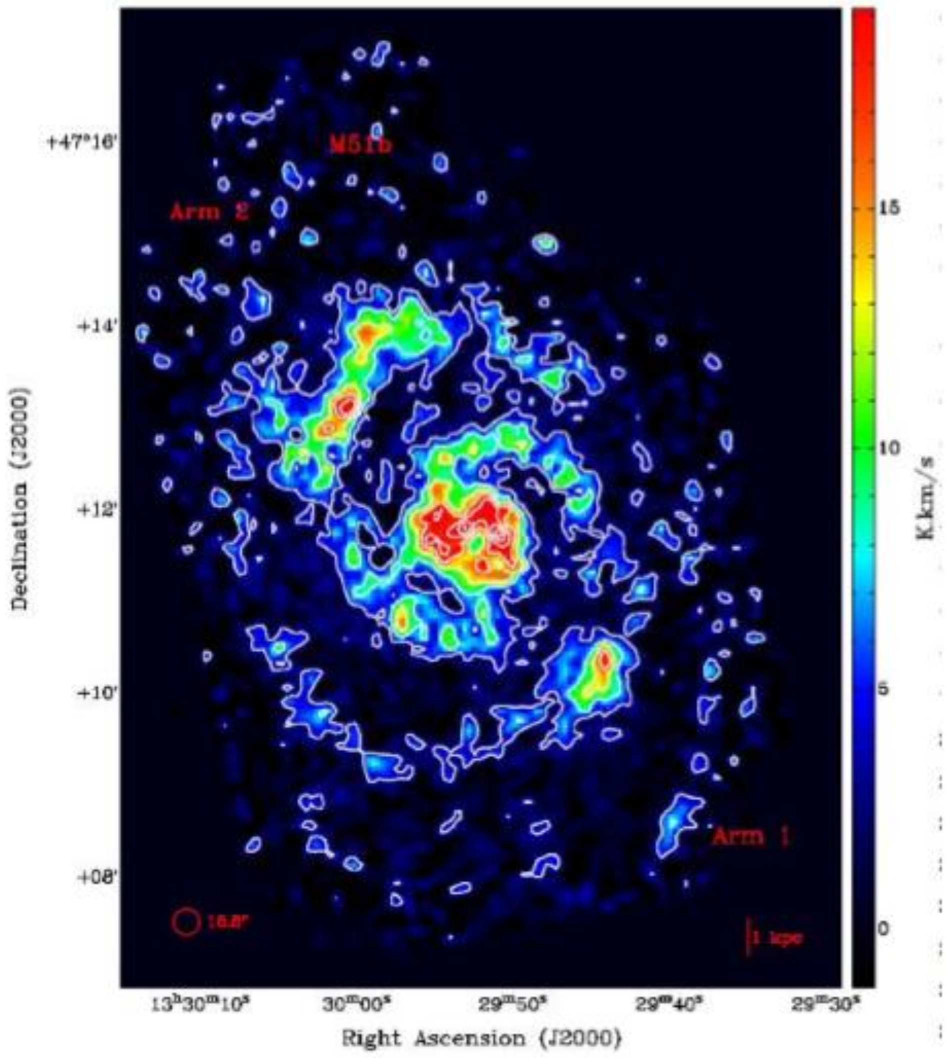


A stochastic accretion event of 2 Jovian masses in S255
Carrati o Garatti et al. 2016

Galaxies

Mid-IR and far-IR medium- and high-resolution spectroscopic imaging of important coolants of ISM ([C II], [O I], [O III], [Si II], etc.)

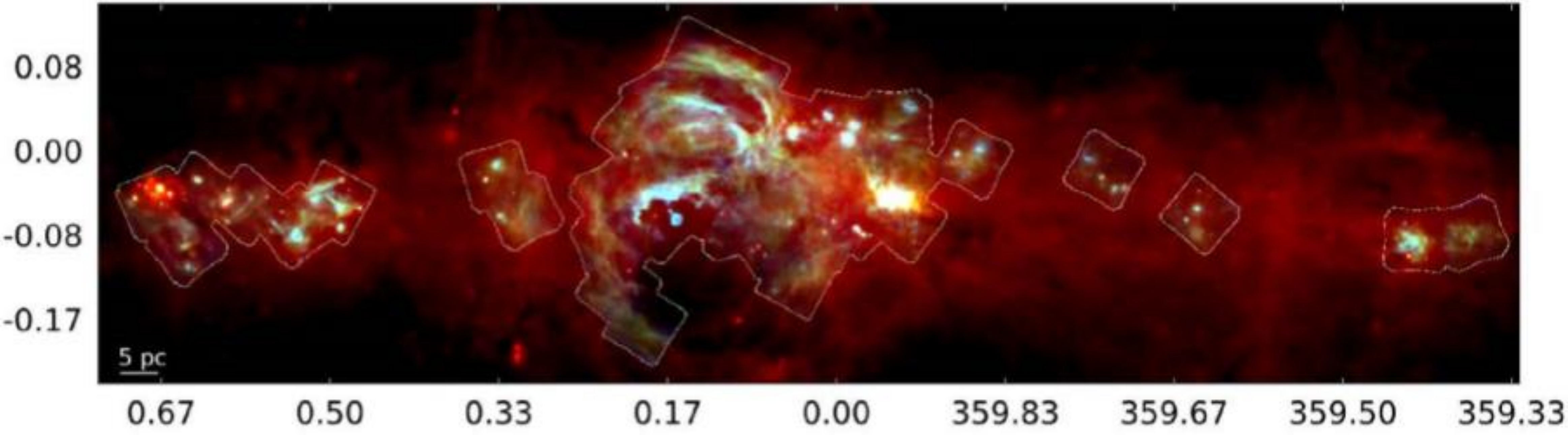
SOFIA upGREAT [CII] M51 map



Pineda et al. 2018, Pineda et al. 2020 submitted

Galactic Center

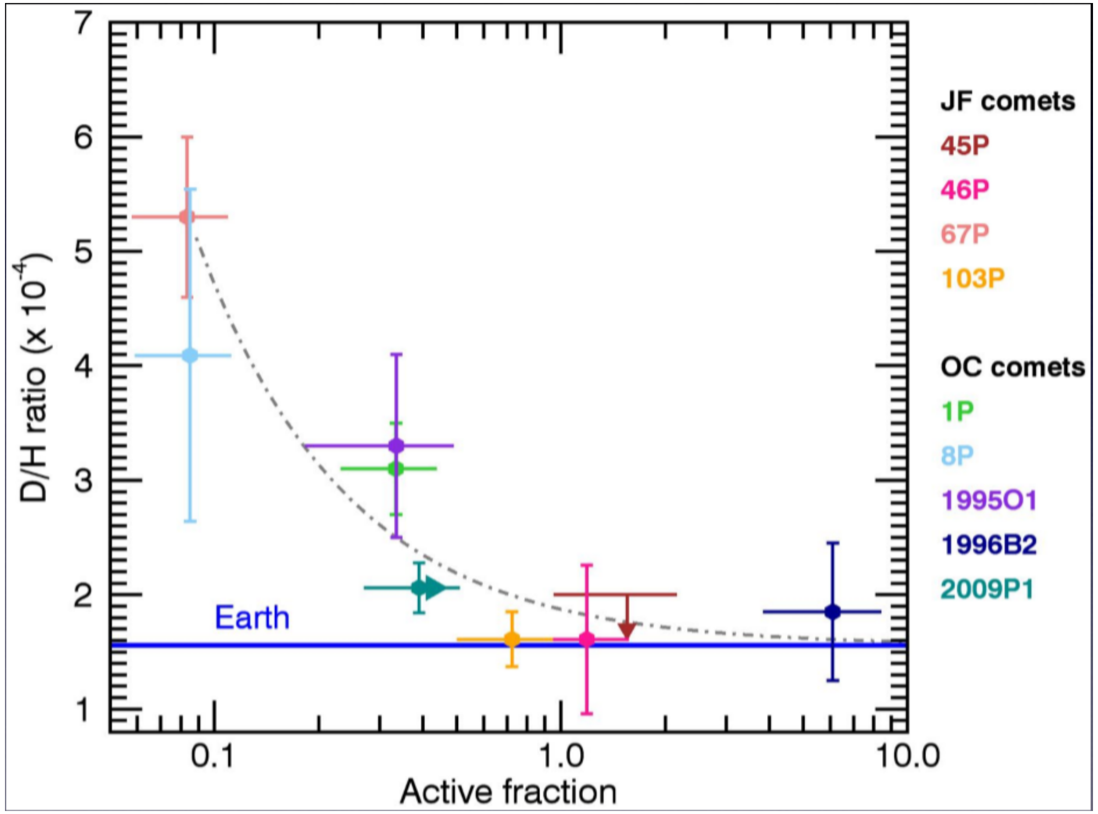
SOFIA can probe the nearest galactic nucleus at excellent spatial resolution with all of its instruments.



Galctic Center Legacy Project: 8 μm 25 μm 37 μm Hankins et al. 2020

Solar System Gas Atmospheres and Comets

SOFIA probes planetary atmospheres and outgassing of comets, especially **mid-IR water lines, hyrdrides, and D-bearing lines** that are difficult or impossible to do from the ground (HDO, H_2O, $H_2{}^{18}O$…)



Lis et al. 2020

Workshop 1 Themes

Science Case	Capability
Disk Masses	HD line at 112 μm
ISM/disk diagnostics	High-res MIR/FIR spectroscopy (hydrides, Si II, H_2O)
Disk/Solar System Ices + solids	Med-res MIR spectroscopy (ice features)
Star Formation/ISM	High-res FIR spectral imaging (C II, O I, O III…)
Galaxies/Star Formation B-field	MIR and FIR polarimetry
Stars/Novae/Supernovae	Monitoring/Photometry/Imaging
Galaxies ISM	Med-res spectroscopy (C II, O I, O III…)
Galactic Center	Imaging, spectroscopy, polarimetry
Solar System/Comets gas	Med-res and High-res spectroscopy, imaging

Identified Gaps

- 30 to 120 μm medium- to high-resolution spectroscopy/imaging
- Mapping speed for existing instruments
- Wavelength coverage for existing instruments
- Sensitivity at some key wavelengths
- Line Polarimetry

Synergies

- SOFIA's access to the mid-IR and far-IR sky can support science at other wavelengths
- JWST and ALMA at neighboring wavelengths
- Other observatories with large FOV and mapping capability:
  - Green Bank (Joint Call Cycle 9)
  - SMA
  - JCMT
  - ALMA 7m
  - APEX

Where do we go from here?

SMO will evaluate the contributions and from the workshops to assess the best science SOFIA can do, to identify gaps in instrumental capabilities, and to gather feedback from the community on SOFIA's future role in astrophysics.

Based on this community input and external Red Team review, SMO will develop an instrument roadmap document and submit to NASA.

We want your help…please provide us advice and give us your feedback! Googledoc, SOFIA website, jjackson@sofia.usra.edu