SOFIA Instrument Roadmap Workshop #1

Summary

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Worshkop #1 Summary

• Summary of SOFIA Science Cases Presented in Workshop 1

• 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 $\mu$m** 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 $\mu$m 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.)**

*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.

Galactic 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$_2$O, H$_2^{18}$O...)

Lis et al. 2020
## Workshop 1 Themes

### Science Case

- Disk Masses
- ISM/disk diagnostics
- Disk/Solar System Ices + solids
- Star Formation/ISM
- Galaxies/Star Formation B-field
- Stars/Novae/Supernovae
- Galaxies ISM
- Galactic Center
- Solar System/Comets gas

### Capability

- HD line at 112 \( \mu \text{m} \)
- High-res MIR/FIR spectroscopy (hydrides, Si II, H\(_2\)O)
- Med-res MIR spectroscopy (ice features)
- High-res FIR spectral imaging (C II, O I, O III…)
- MIR and FIR polarimetry
- Monitoring/Photometry/Imaging
- Med-res spectroscopy (C II, O I, O III…)
- Imaging, spectroscopy, polarimetry
- 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