Time-Domain Astronomy with SOFIA: Results from Current Observations with FORCAST & Prospects with the Proposed New Instrument S3

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The most recent Decadal Review identified “time-domain astronomy” as an important frontier for astrophysical investigations. A key advantage to SOFIA in this realm is its 20+ year lifetime which allows long-term scientific studies that are not possible with space-based infrared missions alone. Here, we present two time-domain projects enabled by SOFIA’s unique capabilities, one with current instrumentation - FORCAST, and the second with a proposed new instrument - S3.

‘Real-Time’ Evolution of Carbon-Rich Post-Asymptotic Giant Branch Stars

30+ Years: IRAS → ISO → Spitzer → SOFIA

Project 1: Obtain 5–37 µm spectra with SOFIA’s FORCAST of carbon-rich post-Asymptotic Giant Branch (post-AGB), one of the most fleeting stages in a star’s life.

• Most phases of stellar evolution occur on timescales of millions or billions of years, but the post-AGB phase, when a star rapidly transitions from a cool, dust-enshrouded object to a bare white dwarf illuminating a planetary nebula, lasts only ~1,000-10,000 years.

➢ We will compare the new FORCAST spectra to mid-IR spectra obtained at ~10–15 year intervals over the past 35 years with Spitzer, ISO, and IRAS.

Example 1: HR 4049

- Good agreement in shape & flux - even small bumps & wiggles for ISO & Spitzer
- Is the IRAS/ISO difference at ~7-8 µm real?

Example 2: HD 56126

- Intriguing differences in the 11-19 µm Spitzer data
- Are the changes in the enigmatic 21 µm feature real?

➢ What will the FORCAST data show?

Post-AGB Targets & Data

<table>
<thead>
<tr>
<th>Star</th>
<th>Prior Datasets</th>
<th>SOFIA FORCAST Observations</th>
<th>Data Delivery</th>
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<tr>
<td>RAFGL 618</td>
<td>IRAS LRS, ISO SWS</td>
<td>Aug. 22, 2018</td>
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<td>HD 56126</td>
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<td>Pending TBD</td>
<td>TBD</td>
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Kinematic Imaging of Biogenic Molecules in Protoplanetary Disks with S3: The Submillimeter Spectrometer for SOFIA

Project 2: Observe protoplanetary disks with a proposed new instrument: the high sensitivity, high spectral-resolution, heterodyne Submillimeter Spectrometer for SOFIA, S3

- Enabled by improved digital backend spectrometers, low noise amplifiers, local oscillators, and closed cycle refrigerators
- Repeatedly observe the line profiles of NH₃ and isotopic H₂O in protoplanetary disks with S3 and their changes over the course of 3 years.
- Trace the structure and composition of the disk, constraining disk dynamics and planet formation models for each system.

➢ These observations by S3, 8-10x more sensitive than 4GREAT, would allow Doppler tomography and similar techniques to kinematically image, for the first time, the inner regions of the planet-forming systems.

S3: 2 unique new bands and a 3rd band an order of magnitude more sensitive than 4GREAT

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