Spectral Mapping in the Mid-Infrared
and assorted recollections

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What is Spectral Mapping?

- Image Slicer with Virtual Slit?
- Fiber Bundle Maps?
- Fabry-Perot Tuned Etalon?
- Long Slit Scan Maps with Continuous Readout?
- "Step and Stare" with a Traditional Slit?

Yes
Which flavor is better?

✓ Constrained Pixel Count?
✓ Space Environment — no “sky” variability?
✓ Low/no instrument variability?
✓ Low/no stepping overhead?
✓ No source variability over mapping duration?

~Identical
Spectral Mapping Now Everywhere

MUSE observations of NGC 628

[OIII]  
Ha  
[SII]

Kreckel+ 2017
SOFIA/FIFI-LS

Orion Nebula

Becklin-Neugebauer object

Trapezium stars

Orion Bar

SOFIA / FIFI-LS
FIFI-LS Team

[O I] 63 μm

[O I] 145 μm

[C II] 157 μm

NASA/Spitzer/Harvard-Smithsonian CfA, Thomas Megeath
Early NIR Spectral Mapping

Murphy, Matthews, & Soifer, 1999
## Putting IRS Mapping in Context

<table>
<thead>
<tr>
<th>IRS Component</th>
<th>Hours</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>irs</td>
<td>17769.8</td>
<td>41.9%</td>
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<tr>
<td>irsstare</td>
<td>11396.3</td>
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<tr>
<td>irsmap</td>
<td>5047.5</td>
<td>28.4%</td>
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<tr>
<td>irs</td>
<td>726.7</td>
<td>4.1%</td>
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<td>irspeakup</td>
<td>599.3</td>
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<th>MIPS Component</th>
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<tbody>
<tr>
<td>mips</td>
<td>13232.4</td>
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<td>mipsphot</td>
<td>6017.0</td>
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<td>mipsscan</td>
<td>5936.2</td>
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<td>mips</td>
<td>751.7</td>
<td>5.7%</td>
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<tr>
<td>mipssed</td>
<td>459.8</td>
<td>3.5%</td>
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<tr>
<td>mipstp</td>
<td>67.7</td>
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<table>
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<th>Percentage</th>
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<td>iracmap</td>
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<td>irac</td>
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<tr>
<td>iracpc</td>
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<td>0.0%</td>
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</table>

(Cold Mission)
Putting IRS Mapping in Context

- Staring
- Mapping
- Peakup
- Other
IRS Spectral Mapping
History

- 1996: Joined Jim’s group

- 1997 **SCORE** deployed at Palomar

- 2000: Renewed discussions of IRS “Scan Mapping” ⇒ “Step & Stare”

- 2002: Joined SINGS team at Arizona, developed **CUBISM**

- 2003, December: **First IRS Spectral Cube**

- 2003, Christmas Day: **First “Real”** IRS Cube produced: Galaxy NGC7331

- 2004: **First IRS Cubes published**
<table>
<thead>
<tr>
<th>OBJECTS TO BE SEEN BY SIRTF</th>
<th>VELOCITY (RELATIVE TO THE SPEED OF LIGHT)</th>
<th>DISTANCE (LIGHT YEARS) OR TIME (YEARS AGO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge of Universe</td>
<td>99.99%</td>
<td>17 Billion</td>
</tr>
<tr>
<td>Forming Galaxies</td>
<td>99%</td>
<td>15 Billion</td>
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<tr>
<td>Quasars</td>
<td>60%</td>
<td>10 Billion</td>
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<td>Distant Galaxies</td>
<td>1%</td>
<td>1 Billion</td>
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<tr>
<td>Life Cycles of Stars</td>
<td>0.000001%</td>
<td>$10^5$</td>
</tr>
<tr>
<td>Comets and Planets</td>
<td>-</td>
<td>-</td>
</tr>
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</table>
CUBISM

- Custom reduction and analysis tool for IRS Spectral Maps

Smith+ 2007
The guts of CUBISM

Step 1
Step 2
Step 3

Smith+ 2007
JD Smith <jdsmith@as.arizona.edu>  
12/5/03  

to Lee, George, Danny, Helene, Tom, Rob  


Announcing the first IRS Step & Stare Spectral Cube ever assembled on the face of the planet! Pictures available:
First real cube, and a new PAH

Smith+ 2004
A new PAH

Smith+ 2004, 2007
H$_2$ cooling in Stefan’s Quintet

Cluver+ 2010
H₂ cooling in Stefan’s Quintet

![Diagram](image)

Appleton+ 2017
Cassiopeia A
Compression in Reverse Shock

\[ \Delta \alpha (\text{arcsec}) \]

\[ \Delta \delta (\text{arcsec}) \]

\[ n_e (\text{cm}^{-3}) \]

\[ [\text{SIII}] 18\mu m/33\mu m \]

Smith+ 2009
A Symmetric Supernova Asymmetry?

- Pure Ne/O lobes along NS kick direction.
10,000 Earths' Worth of Fresh Dust Found Near Star Explosion

Rho+ 2007
Interstellar C60 discovered

Sellgren+ 2010
Blind Surveys

- Blind LL spectral mapping survey in the GOOD field.
- 45 sources, $z=0.2–2.2$
- A few very high line-to-continuum sources without GOODS counterparts.
IRS mapping inspirations

NGC4559

[CII]
The Future of MIR Spectral Mapping

- MIRI on JWST

The Mid-Infrared Instrument (MIRI) provides:

- Imaging in nine (9) photometric bands from 5 to 28 µm, \( \lambda/\Delta \lambda \approx 5 \), with a field of view (FOV) 74'' x 113''

- Sub-array imaging (with shorter exposure times) for bright targets and high sky backgrounds:
  - SUB64 – 7.0'' x 7.0''
  - SUB128 – 14.1'' x 14.1''
  - SUB256 – 28.2'' x 28.2''
  - BRIGHTSKY – 56.3'' x 56.3''

- Coronagraphic imaging facilitated by three (3) four-quadrant phase masks (4QPMs) at 10.65, 11.4, & 15.5 µm (24'' x 24''), and a Lyot coronagraph at 23 µm (30'' x 30'')

- Low Resolution Spectrometer (LRS: \( \lambda/\Delta \lambda \approx 100 \) at 7.5 µm), which covers wavelengths from 5 to ~ 12 µm using a 0.51'' x 4.7'' slit, or in SLITLESS configuration

- Medium Resolution Spectrometer (MRS: \( \lambda/\Delta \lambda \approx 1550–3250 \)), which covers wavelengths from 4.9 to 28.8 µm, enabled by four Integral Field Units (IFUs) with FOVs of 3.9'' to 7.7''