SPIRE Fourier Transform Spectrometer Observing Modes

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The SPIRE Imaging FTS

- Fourier Transform Spectrometer → entire spectral coverage is observed in one go
- 2 Bolometer detector arrays for short and long wavelength bands

2.6’ unvignetted beam footprint

194 – 324 µm
(1545 – 925 GHz)

316 – 672 µm
(949 – 446 GHz)

Pixel spacing ~ 2 beam widths

SSW
SLW

Beam FWHM ~ 16”
Beam FWHM ~ 34”
Spectral Coverage

SPIRE

HIFI

PACS

SLW

SSW

194 – 672 µm

(1545 – 446 GHz)

(51.5 – 14.9 cm⁻¹)

Good overlap with PACS (194 – 210 µm)
Observing Choices

Source size
- Single point (1 FOV with diameter of 2’)
- Raster (many FOVs)

Spatial sampling
- Sparse
  - 2 beam spacing
- Intermediate
  - 1 beam spacing
- Full
  - ½ beam spacing (Nyquist)

Spectral resolution (unapodised)
- High 0.04 cm\(^{-1}\) (1.2 GHz)
- Medium 0.25 cm\(^{-1}\) (7.5 GHz)
- Low 1.0 cm\(^{-1}\) (30 GHz)

(constant in frequency)
Point Source Spectrum

→ SINGLE POINT: SPARSE

- Always get data from whole array
- HSpot shows location of array pixels for sparse mode
Point Source Spectrum 2

- Instrumental profile is a Sinc function

\[
\text{with a FWHM} \quad 1.2 \times \text{resolution}
\]

\[
\text{FWHM} = 0.048 \text{ cm}^{-1} = 1.4 \text{ GHz}
\]

- Apodisation reduces ringing in the side lobes

...but increases the line width by 20-30%
Point Source Spectrum 3

LOW $\Delta \sigma = 1.0 \text{ cm}^{-1}$ (30 GHz); \hspace{1cm} R = 52 – 15

- Continuum measurements
- 36 resolution elements across the whole range
  (sampled at $\frac{1}{4}$ res. element)
Point Source Spectrum 4

INTERMEDIATE  \( \Delta \sigma = 0.25 \text{ cm}^{-1} \) (7.5 GHz); \( R=200 – 60 \)

HIGH  \( \Delta \sigma = 0.04 \text{ cm}^{-1} \) (1.2 GHz); \( R=1290 – 370 \)

- Line spectroscopy
- Measurement of total integrated line fluxes
  (line widths 280 – 840 km/s in HIGH resolution mode)

HIGH + LOW

- Line spectroscopy with high S/N continuum measurement
  (number of HIGH and LOW resolution scans are set independently)
Spectral resolution in HIGH & INTERMEDIATE modes

- **200 µm**
  - INTERMEDIATE res x 50
  - HIGH res x 10
  - 20 km/s line

- **609 µm**
  - INTERMEDIATE res x 150
  - HIGH res x 30

- **200 µm**
  - (1499 GHz)
  - 280 km/s (HIGH)
  - 1810 km/s (INT)

- **609 µm**
  - (492 GHz)
  - 850 km/s (HIGH)
  - 5510 km/s (INT)
Extended Source

→ SINGLE POINT: SPARSE, INTERMEDIATE or FULL

SPARSE
2 beam spacing
SSW: 33"
SLW: 51"

FULL
½ beam spacing
SSW: 8"
SLW: 12"

INTERMEDIATE
1 beam spacing
SSW: 16"
SLW: 25”
Extended Source 2: Raster Map

→ RASTER: SPARSE, INTERMEDIATE or FULL

- Raster map is made up from a combination of individual fields of view
- Raster direction is fixed to spacecraft axes not to sky coordinates → check visualisation!
- Coverage is a parallelogram on sky
- Split into separate observations to make more complicated shapes
Raster is performed in spacecraft coordinates.

Therefore orientation on the sky changes depending on source position & visibility constraints.
• Raster is performed in spacecraft coordinates
• Therefore orientation on the sky changes depending on source position & visibility constraints
Sensitivity

- Mechanism makes scans in pairs (forward & reverse)
- Integration time depends on repeats of scan pairs (at least 2 repeats so glitches can be removed)
- Average point source sensitivity (Low Res):
  \[ \sim 1.2 \text{ Jy (1}\sigma\text{ in 1 sec)} \quad \ldots \quad \sim 100 \text{ mJy } 5\sigma \text{ in 1 hour} \]

For variation of sensitivity with wavelength, see the SPIRE Observer’s Manual

Note that all sensitivities are quoted for a point source on axis

Minimum times for each spectral resolution are:

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Time</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW (30 GHz)</td>
<td>26 sec</td>
<td>0.24 Jy RMS</td>
</tr>
<tr>
<td>MEDIUM (7.5 GHz)</td>
<td>98 sec</td>
<td>0.5 Jy RMS → 3.6 \times 10^{-17} \text{ W/m}^2</td>
</tr>
<tr>
<td>HIGH (1.2 GHz)</td>
<td>269 sec</td>
<td>1.8 Jy RMS → 2.2 \times 10^{-17} \text{ W/m}^2</td>
</tr>
</tbody>
</table>
Why use SPIRE for line spectroscopy?

- In HIGH resolution mode (min length 269 sec), \( RMS \) in line flux is \( 2.2 \times 10^{-17} \text{ W/m}^2 \)
- What does this integrated flux mean in terms of temperature units?
  - *Depends on intrinsic line width*

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>535 µm</th>
<th>200 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>560 GHz</td>
<td>1499 GHz</td>
</tr>
<tr>
<td>( T_{\text{rms}} ) (20 km/s line)</td>
<td>0.13 K</td>
<td>0.03 K</td>
</tr>
<tr>
<td>( T_{\text{rms}} ) (5 km/s line)</td>
<td>0.51 K</td>
<td>0.14 K</td>
</tr>
</tbody>
</table>

**CONCLUSION**

SPIRE is useful for *integrated flux* measurements of *BROAD lines*, particularly at high frequencies.

**Additional advantages:**
- always observes full spectral range simultaneously
- always get a sparse map of the source
HSpot

Source size
1 FOV
Raster

Spatial sampling
2 beam
1 beam
½ beam

Spectral resolution
High
Medium
Low

Number of repeated Spectrometer mechanism scan pairs (minimum 2)

*ie. this sets the integration time per point*
More Details

Refer to the AO for more details, including HSpot examples:

http://herschel.esac.esa.int/Docs/SPIRE/html/spire_om.html

Specifically:

• **Chapter 2**, Section 2.3 ("Spectrometer")
• **Chapter 3**, Section 3.1 ("Sensitivity")
• **Chapter 4**, Section 4.2 ("Spectrometer AOT Modes")
• **Chapter 6**, Section 6.4
  ("HSpot Components for Setting up a SPIRE Spectrometer Observation")