Day 4: SPIRE
Analysing SPIRE FTS spectra

Rosalind Hopwood
The SPIRE Fourier Transform Spectrometer

**THE FTS**
- Bolometer arrays
- Beamsplitters
- SPIRE optical bench

**FTS mechanism**
- Input 1 Telescope
- Input 2 Calibrator

**WAVELENGTH COVERAGE**
- **SLW**: 447-1018 GHz, 970-440 km/s, 1.2 GHz
- **SSW**: 671-294 μm, 450-280 km/s, 1.2 GHz

**INSTRUMENTAL LINE WIDTH HR**
- **SLW**: 970-440 km/s, 1.2 GHz
- **SSW**: 450-280 km/s, 1.2 GHz

**SPECTRAL RESOLUTION**
- **HIGH (HR)**: 1.2 GHz
- **LOW (LR)**: 25 GHz

**MAPPING MODES**
- **2.6’ FoV**
  - Sparse: single pointing
  - Intermediate: 4 point jiggle
  - Full: 16 point jiggle

**CALIBRATION ACCURACY**
- **Point-source**: 6%
- **Extended-source**: 1% sparse mode & 7% mapping mode

**CONTINUUM OFFSET (additive):**
- **SLW**: 0.4 Jy
- **SSW**: 0.3 Jy
- **Extended calibration**: 3.4x10^{-20} Wm^{-2}Hz^{-1}sr^{-1}, 1.1x10^{-19} Wm^{-2}Hz^{-1}sr^{-1}

**SPECTRAL PROFILES**
- **SLW**
- **SSW**

**SPARSE OR MAPPING RASTER PATTERN**
- User defined FoV

**SYSTEMATIC ERRORS**
- **Point-source**
  - **Extended-source**
  - **Sparse mode**: 7% mapping mode
  - **Continuum offset**:
    - **Point-source**
      - **Extended**
    - **SLW**: 0.4 Jy, 3.4x10^{-20} Wm^{-2}Hz^{-1}sr^{-1}
    - **SSW**: 0.3 Jy, 1.1x10^{-19} Wm^{-2}Hz^{-1}sr^{-1}

**Herschel Science Archive Level-2**
- SPARSE example for HR
- **Point-source calibrated Spectra**: “HR_spectrum_point”
- Extended calibrated: “HR_spectrum_ext”
- **MAPPING example for HR SLW**
- Spectral cubes: “HR_SLW_cube”
- Unaveraged spectra: “HR_SLW_spectrum2d”

**Herschel**

**The FTS flyer**
Analysing SPIRE FTS spectra

Reference material

- **SPIRE DRG**: Chapter 7 for the Spectrometer
- **FTS calibration**: Swinyard et al. 2014 (*arXiv:1403.1107*)
- **FTS calibration program**: Hopwood et al. 2015 (*arXiv:1502.05717*)
- Experimental Astronomer, Volume 37, Issue 2, July 2014
  - Five FTS papers (*including the mapping paper above*)
    - Fulton et al. FTS RSRFs *arXiv:1401.2049*
    - Hopwood et al. Telescope model correction *arXiv:1401.2047*
    - Lu et al. Bright source mode *arXiv:1401.2045*
    - Valtchanov et al. Relative pointing offsets *arXiv:1401.2043*
- **SECT**: Wu et al. 2013 (*arXiv:1306.5780*)
- **Pipeline**: Fulton et al. 2010 (to be updated soon) (*SPIE Conference Series, 2010*)
Analysing SPIRE FTS spectra

Documentation is your first port of call

All you need to know about FTS data reduction and identifying potential issues:

SPIRE Data Reduction Guide (SDRG):
Chapter 7 for the Spectrometer
Relevant sections for this session are:
• 7.4 Pointing considerations
• 7.5 Recipes for faint & medium strength sources
• 7.6 Recipes for semi-extended sources
• 7.11 Spectral Analysis

For more technical stuff:

SPIRE Handbook (formerly the observer’s manual)
• Overview of the instrument and flux calibration

Up-to-date FTS uncertainties:

Calibration of the SPIRE FTS (Swinyard et al. 2014)
Characterisation of the SPIRE FTS (Hopwood et al. 2015)

Data Analysis Guide (DAG):
• Chapter 3 Plotting
  worked examples are helpful for scripting

All the HIPE help you should need
Analysing SPIRE FTS spectra

Aim for today: identifying, understanding and correcting problem spectra

- Examining FTS data for potential problems
- Understanding where problems may originate
- Correcting your data
  - Background subtraction
  - Pointing offset: SECT
  - Partially extended: SECT
  - (Droopy SLWC3)
- SECT: a closer look
- Spectral line fitting
- Noise estimate
- Comparison with the photometer
Aim for today: identifying, understanding and correcting problem spectra

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- Noise estimate
- Comparison with the photometer
A note on the Spectrometer useful scripts

Designed to:
• help facilitate FTS data processing/analysis
• be easily understood -> if not, let us know
• be easy to edit
• to compliment each other e.g.

- Spectrometer Array Footprint Plot
- Spectrometer Background Subtraction
- Spectrometer Line Fitting
- Spectrometer Cube Fitting
- Spectrometer Thumbnail Mosaic Plot
- Spectrometer Convolve Spectrum
- Spectrometer Noise Estimate
- Combine PACS and SPIRE spectra
HSA L2 data is now **HIPE 13** processed, no need to rerun the pipeline unless:

- You want a closer look at intermediate steps
- Get the unaveraged scans
- Exclude the vignetted detectors from your maps: just the last bit of the script

‘SPIRE Calibration’ view: See what’s new in the SPIRE calibration

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**Analysing SPIRE FTS spectra: a note on HSA data**

The SPIRE calibration tree "spire_cal_13_1" was released in December 2014 to be compatible with HIPE v13.0.

Note that this calibration tree corrects problems found in the "pre-release" tree, 13.0.

**Impact of the changes compared to the previous release (12.4)**

**Photometer:**

- The beam profile maps are improved using the shadow observations of Neptune (i.e. better characterising and removing the background).
- The corresponding beam areas given in the metadata of the beam products are updated accordingly.
- The radial beam calibration product has been updated to match the new beams.
- All the colour correction products have been updated following the beam updates.
- In order to improve the operation of the source extractors, the beam profiles are adjusted to be relevant for a 1 Jy source - previously the peak of the profile was fixed to 1 Jy, but the new profiles integrate to 1 Jy. In addition, the map consists of an odd number of pixels so that the beam centre is precisely at the centre of the central pixel.
- A new "fine" beam map is provided for each band with 1" pixels. The "nominal" maps are available with pixel sizes of 6", 10" and 14" for PSW, PMW and PLW.
- The K4 parameters in the Flux Conversion product metadata are updated (very small change to K4E).
- The Planck HFI colour correction table has been updated following the beam updates (very small change).
- The parameters in the temperature drift calibration product that are used to perform cooler burp correction have been updated to improve the correction.
HSA L2 data is now **HIPE 13** processed
no need to rerun the pipeline unless:

- You want a closer look at intermediate steps
- Get the unaveraged scans
- Exclude the vignetted detectors from your maps: just the last bit of

---

**Spectrometer:**

- The non-linearity product has been updated to better fit observations made with low subktemp at the beginning of each pair of FTS observing days (i.e. the observations following the cooler recycle). This results in a much improved SLWC3 spectral shape.
- The other RSRF, telescope model and flux conversion products were updated following the non-linearity update.
- The PhaseCorrLim product was updated to correct the metadata - no effect on the data.
- The TempDriftCorr product has been removed as it is not used by the pipeline.
HSA L2 data is now **HIPE 13** processed no need to rerun the pipeline unless:

- You want a closer look at intermediate steps
- Get the unaveraged scans
- Exclude the vignAed detectors from your maps

**If your data is pre-HIPE 13 processed, download it again now!**

**Spectrometer:**

- The non-linearity in the subktemp at the end of the observations following the cooler recycle). This results in a much improved SLWC3 spectral shape.
- The other RSRF, telescope model and flux conversion products were updated following the non-linearity update.
- The PhaseCorrLim product was updated to correct the metadata - no effect on the data.
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**Analysing SPIRE FTS spectra: a note on HSA data**
Examining FTS data

Downloading an observation straight from the HSA into HIPE:

e.g. observation = getObservation(1342197486, useHsa=True)

ObservationContext for SPIRE data of observation 1342197486

<table>
<thead>
<tr>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOR label: Calibration_cycle14_1-SpireSpectroPointGen-CR-Rep5-NGC7027</td>
</tr>
<tr>
<td>Instrument: SPIRE</td>
</tr>
<tr>
<td>Object: NGC 7027</td>
</tr>
<tr>
<td>AOT: Spectrometer</td>
</tr>
<tr>
<td>RA Nominal: 21h 7m 1.59s</td>
</tr>
<tr>
<td>SPG Version: SPG v13.0.0</td>
</tr>
<tr>
<td>Resolution: CR</td>
</tr>
<tr>
<td>Bias Mode: nominal</td>
</tr>
<tr>
<td>LR Repetitions: 0</td>
</tr>
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</table>

Check out the Summary information
Examining FTS data

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- **Resolution:** CR
- **Bias Mode:** nominal
- **SPG Version:** SPG v13.0.0
- **LR Repetitions:** 0
- **Obs. ID:** 1342197486
- **Obs. Date:** 2010-06-01T16:57:05Z
- **Obs. Mode:** Single Pointing
- **Dec. Nominal:** 42° 14' 10.2"
- **Operational Day:** 383
- **Map Sampling:** sparse
- **Total Repetitions:** 5
- **HR Repetitions:** 5

Check out the *Browse Product* image

Spectra from the centre detectors
Analysing SPIRE FTS spectra

Examining FTS data

Downloading an observation straight from the HSA into HIPE:
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</tr>
<tr>
<td><strong>Instrument:</strong> SPIRE</td>
</tr>
<tr>
<td><strong>Object:</strong> NGC 7027</td>
</tr>
<tr>
<td><strong>AOT:</strong> Spectrometer</td>
</tr>
<tr>
<td><strong>RA Nominal:</strong> 21h 7m 1.59s</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td><strong>Bias Mode:</strong> nominal</td>
</tr>
<tr>
<td><strong>LR Repetitions:</strong> 0</td>
</tr>
</tbody>
</table>

Check out the **Browse Product** image

ANY PROBLEMS?

Not for this one!

OD 383, NGC 7027, HR, 5 reps

Spectra from the centre detectors
Analysing SPIRE FTS spectra

See a problem -> documentation is your first port of call

SPIRE Data Reduction Guide (SDRG):
Chapter 7 for the Spectrometer
Relevant sections for this session are:
• 7.4 Pointing considerations
• 7.5 Recipes for faint and medium strength sources
• **7.6 Recipes for semi-extended sources**
• 7.11 Spectral Analysis

7.6.2 Does my spectrum need correcting?
Analysing SPIRE FTS spectra

7.6.2 Does my spectrum need correcting?

1. Point-source embedded in extended emission
2. Point-source observed with a significant pointing offset
3. A source with partially extended morphology

All three issues lead to a jump between SLW and SSW: Separating the cause of the jump is necessary

This may be difficult and sometimes not possible
Analysing SPIRE FTS spectra

7.6.2 Does my spectrum need correcting?

A fourth issue: now corrected in HIPE 13... for the most part

The nonlinearity correction has been updated for HIPE 13

It corrects an issue for observations taken at the beginning of each pair of FTS operational days

There are a few rare exceptions

This issue was only significant for faint sources

If you see your HIPE 13 reduced SLWC3 spectrum “drooping” contact the helpdesk
Analysing SPIRE FTS spectra

7.6.2 Does my spectrum need correcting?

A fourth issue: now corrected in HIPE 13... for the most part

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There are a few rare exceptions

If you see your HIPE 13 reduced SLWC3 spectrum “drooping” contact the helpdesk
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

AFGL4106: post-red supergiant binary; medium source (> 10Jy)

observation_1 = getObservation(1342246991, useHsa=True)

Check out the browse product image

ANY PROBLEMS?
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

AFGL4106: post-red supergiant binary; medium source (> 10Jy)

\[ \text{observation}_1 = \text{getObservation}(1342246991, \text{useHsa}=\text{True}) \]

ANY PROBLEMS?

- The extended background is point-source calibrated, which leads to a poor continuum shape and extra fringing
- SLW is more strongly affected due to larger beam size (~2 ×SSW)
- Large-scale continuum shape can be corrected

![Graph showing spectral lines and fringing](image-url)
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

Useful script: *Spectrometer array footprint plot*

Plots the FTS footprint over a photometer map

- If no photometer map inputted then *photObsids* used (if there are any)
- Photometer map should be FIR/submm
- Use to identify a background/foreground
- Use to check for contaminating neighbours

*Hopwood et al. 2015. Script edited for plotting colours.*
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

Useful script: *Spectrometer array footprint plot*

Hopwood et al. 2015 figure 2. Script edited for plotting colours.

Point-like

Point-like sitting in Galactic Cirrus (IRAS 100 µm)

Partially extended morphology
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

Useful script: *Spectrometer background subtraction*

**SLW 1st ring**

**SSW 2nd ring**
Analysing SPIRE FTS spectra

1 Point-source embedded in extended emission

Useful script: Spectrometer background subtraction

Shape improved < 750 GHz
Fringing > 850 GHz for SLW still there
Jump between the bands is corrected

SLW 1st ring

SSW 2nd ring
Analysing SPIRE FTS spectra

① Point-source embedded in extended emission

Useful script: *Spectrometer background subtraction*

A word of caution

- There is real flux in the detector rings
- See Hopwood et al. 2015 for more details
- For a point source (Uranus/Neptune) bang on the centre there is around
  - 1.9% in SLW 1st ring
  - Only 0.1% in SSW 2nd ring
  - (1.4% SSW 1st ring: not used)
- Point source calibration accounts for this “missing” bit
- Lots more flux in for semi-extended sources
- For AFGL4106 the results are worth the loss: fitting is easier

Hopwood et al. 2015

BGS script results

AFGL4106

SLW 1st ring
SSW 1st ring
SSW 2nd ring

% of centre detector
### Analysing SPIRE FTS spectra

2. **Point-source observed with a significant pointing offset**

AFGL2688: point-like source with FWHM 6.6"

\[ \text{afgl2688Obs} = \text{getObservation}(1342198270, \text{useHsa}=\text{True}) \]

<table>
<thead>
<tr>
<th>ObservationContext for SPIRE data of observation 1342198270</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary</strong></td>
</tr>
<tr>
<td>AOR label: Calibration_cycle15_1--SpireSpectroPointGen--CR--Rep5--AFGL2688</td>
</tr>
<tr>
<td>Instrument: SPIRE</td>
</tr>
<tr>
<td>Object: AFGL2688</td>
</tr>
<tr>
<td>AOT: Spectrometer</td>
</tr>
<tr>
<td>RA Nominal: 21h 2m 18.78s</td>
</tr>
<tr>
<td>Dec. Nominal: 36° 41' 41.2&quot;</td>
</tr>
<tr>
<td>Resolution: CR</td>
</tr>
<tr>
<td>Bias Mode: nominal</td>
</tr>
<tr>
<td>LR Repetitions: 0</td>
</tr>
<tr>
<td>Obs. ID: 1342198270</td>
</tr>
<tr>
<td>Obs. Date: 2010-06-13T11:20:55Z</td>
</tr>
<tr>
<td>Obs. Mode: Single Pointing</td>
</tr>
<tr>
<td>Operational Day: 395</td>
</tr>
<tr>
<td>Map Sampling: sparse</td>
</tr>
<tr>
<td>Total Repetitions: 5</td>
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<tr>
<td>HR Repetitions: 5</td>
</tr>
<tr>
<td><strong>Meta Data</strong></td>
</tr>
<tr>
<td>name</td>
</tr>
<tr>
<td>posAngle</td>
</tr>
<tr>
<td>pmRA</td>
</tr>
<tr>
<td>pmDEC</td>
</tr>
<tr>
<td>raDecOffset</td>
</tr>
<tr>
<td>bsmOffset</td>
</tr>
<tr>
<td>radialVelocity</td>
</tr>
<tr>
<td>velocityDef...</td>
</tr>
<tr>
<td>origin</td>
</tr>
</tbody>
</table>

See the DRG 7.4. Pointing Considerations
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

In this case the jump must be due to a pointing offset

Jump between the bands

See the DRG 7.4. Pointing Considerations
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

AFGL2688: point-like source with FWHM 6.6”

`afgl2688Obs = getObservation(1342198270, useHsa=True)`

See the DRG 7.4. Pointing Considerations
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

AFGL2688: point-like source with FWHM 6.6"

afgl2688Obs = getObservation(1342198270, useHsa=True)

<table>
<thead>
<tr>
<th>Meta Data</th>
<th>value</th>
<th>unit</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>posAngle</td>
<td>49.54662054853345</td>
<td>deg</td>
<td>Spacecraft pointing Position angle</td>
</tr>
<tr>
<td>pmRA</td>
<td>0.0</td>
<td>arc...</td>
<td>Target's proper motion RA (arcsec/yr) as given by the...</td>
</tr>
<tr>
<td>pmDEC</td>
<td>0.0</td>
<td>arc...</td>
<td>Target's proper motion Dec (arcsec/yr) as given by the...</td>
</tr>
<tr>
<td>raDecOffset</td>
<td>3.370912089616513</td>
<td>arc...</td>
<td>The offset between the commanded position and the actual reconstructed position, which includes any systematic BSM offset (bsmOffset), but not the APE.</td>
</tr>
<tr>
<td>bsmOffset</td>
<td>1.72</td>
<td>arc...</td>
<td>BSM offset position (0.0 or 1.72 arcsec), which is corrected for by the point-source calibration. This systematic offset is included in the raDecOffset value.</td>
</tr>
<tr>
<td>radialVelocity</td>
<td>33.623232777015694</td>
<td>km/s</td>
<td>Spacecraft velocity along the l-of-s of the source.</td>
</tr>
<tr>
<td>velocityDef</td>
<td>RADI-LSR</td>
<td></td>
<td>The velocity definition and frame.</td>
</tr>
<tr>
<td>origin</td>
<td>Herschel Science Centre</td>
<td></td>
<td>Site that created the product.</td>
</tr>
</tbody>
</table>

See the DRG 7.4. Pointing Considerations

raDecOffset and bsmOffset give info on KNOWN pointing offset. The APE is still associated to the pointing:

raDecOffset “The offset between the commanded position and the actual reconstructed pointing, which includes any systematic BSM offset (bsmOffset), but not the APE.”

bsmOffset “BSM offset position (0.0 or 1.72 arcsec), which is corrected for by the point-source calibration. This systematic offset is included in the raDecOffset value.”
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

SECT: correcting for pointing offset

A. Using HIPE to get the pointing info:

```python
obsid = 1342198270
afgl26880bs = getObservation(obsid, useHsa=True)
print afgl26880bs.meta['creator'].value
#SPG v13.0.0
print afgl26880bs.meta['raDecOffset'].value,
afgl26880bs.meta['bsmOffset'].value,
afgl26880bs.meta['raDecOffset'].value -
afgl26880bs.meta['bsmOffset'].value
#3.37091208962 1.72 1.65091208962
```

B. Using the relative pointing method of Valtchanov et al. 2014: $6.21'' \pm 0.32''$

- Needs repeated observations
- A reference observation is used to correct the others
- BSM offset should not be subtracting for input into SECT:
  - SECT automatically de-corrects this offset, if necessary

Which gives us:

A) 3.37'' the "Herschel" offset

B) 6.21'' the relative offset

See the DRG 7.4. Pointing

Considerations

See the DRG 7.6. Recipes for
semi-extended sources
② Point-source observed with a significant pointing offset

Semi Extended Correction Tool SECT: the GUI

The semiExtendedCorrector task:

Input variables:
- Point source calibrated spectrum object (SPSS)
- SPIRE calibration context

Options:
- For plots: doPlots
- To optimise source model diameter: optimiseDiameter
- Untick applyCorrection to get the correction itself back

- gaussRefBeamDiam
- couplingThreshold

Used to set the reference beam
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

**SECT: the reference beam**

The `semiExtendedCorrector` task

The reference beam:
- Used to **normalise** the spectrum so the output is equivalent to a spectrum observed with a **frequency independent Gaussian beam**
- Default FWHM is 40"
- FWHM can be set to match another telescope
- Set FWHM large to remove effect of reference beam (the whole source distribution is within the beam)

**Figure 7.52. The reference beam.**
- The final spectrum is normalised to include the emission inside the reference beam.
- The source distribution is assumed to be independent of frequency.

See the DRG 7.6. Recipes for semi-extended sources
Analysing SPIRE FTS spectra

② Point-source observed with a significant pointing offset

SECT: *the source distribution model*

The *semiExtendedCorrector* task:

- *sourceModel*
  - Gaussian/top hat/Sersic
  - x and y offsets can be set
  - The profile is shown under the FTS array footprint in the bottom panel
  - Errors increase for source models larger than the SSW beam size
  - A point-source can be inputted as a Gaussian with diameter 0.01"
  - Greater control of SECT can be achieved with a script

SECT takes into consideration:
- SLWC3 is offset to SSWD4 by 2.2”
- Observations before OD 1011 were taken with the BSM set to 1.72”
- These issues are corrected for by the point source calibration so SECT de-corrects for internally

See the DRG 7.6. Recipes for semi-extended sources
Analysing SPIRE FTS spectra

2 Point-source observed with a significant pointing offset

SECT: correcting for pointing offset

Running SECT in a script for the miss-pointed AFGL2688 observation:

```bash
# Get the SPIRE calibration
cal = spireCal(pool="spire_cal_13_1")

# Get the Level-2 point-source calibrated product (spss)
spss = afgl2688Obs.level2.getProduct("HR_spectrum_point")

# Creating the model image (for a point source):
# (SourceModel, diameter, x offset, y offset, eccentricity, rotation angle)
shape = SemiExtendedSourceModelShape("gaussian", 6.6, offset, 0.0, 0.0, 0.0)

# Run the tool - the output is the corrected spectrum
correctedSpectrum = semiExtendedCorrector(spectrum=spss, calibration=cal, doPlots=1, sourceModel=shape)
```

For more SECT examples and an example script go to the 2014 spectroscopy workshop page: [http://herschel.esac.esa.int/twiki/bin/view/Public/OnlineSpectroscopyWorkshop2014](http://herschel.esac.esa.int/twiki/bin/view/Public/OnlineSpectroscopyWorkshop2014)
② Point-source observed with a significant pointing offset

SECT: correcting for pointing offset

Running SECT in a script for the miss-pointed AGL2688 observation:

A) metaData offset = 3.37"

B) relative offset = 6.21"

Corrected AGL2688 spectrum

Correction for 6.6arcsec gaussian source; offset 3.37arcsec, 0.0arcsec

Step between the bands is reduced

Corrected AGL2688 spectrum

Correction for 6.6arcsec gaussian source; offset 6.21arcsec, 0.0arcsec

Step between the bands is removed

See the DRG 7.6. Recipes for semi-extended sources

RA and Dec requested might not be at the submm peak

Relative offset method gives the better result: but only possible if there are lots of observations of the same source
Analysing SPIRE FTS spectra

③ A source with partially extended morphology

NGC6302: the Butterfly nebula with FWHM 18”

ngc6302Obs = getObservation(1342265809, useHsa=True)

- raDecOffset is minimal (0.25”)
- OD is > 1011 so bsmOffset is 0
Analysing SPIRE FTS spectra

③ A source with partially extended morphology

Large jump between the bands!

See the DRG 7.6. Recipes for semi-extended sources
Analysing SPIRE FTS spectra

③ A source with partially extended morphology

FTS calibration

Extended calibrated

Point-like

Semi-extended

Extended

Point-source calibrated

Point-like

Semi-extended

Extended

See the DRG 7.6. Recipes for semi-extended sources
Analysing SPIRE FTS spectra

③ A source with partially extended morphology

FTS calibration

Point-source calibrated spectra for a semi-extended source

See the DRG 7.6. Recipes for semi-extended sources
A source with partially extended morphology

SECT: correcting the data for extent

The SECT algorithm is based on the forward coupling efficiency to the source distribution: so a good knowledge of the source distribution is key.

Here we use the default SECT settings with:
- a basic elliptical Gaussian
- FWHM of 18"
- Eccentricity of 0.2
- No x- or y-offset

And setting the source model diameter to be optimised (optimiseDiameter=True).
Analysing SPIRE FTS spectra

③ A source with partially extended morphology

**SECT: the plots**

Correction (central detectors)

Correction for 18.0 arcsec gaussian source; offset 0.2 arcsec, 0.0 arcsec

SECT plots the correction applied

if $applyCorrection = 0$ the correction is outputted (instead of the corrected data)

see Wu et al. 2013 & DRG Section 7.6
Analysing SPIRE FTS spectra

A source with partially extended morphology

SECT: the plots

SECT plots the diameters tried when it searches for the optimum -> in this case 18.5"

see Wu et al. 2013 & DRG Section 7.6
Analysing SPIRE FTS spectra

3. A source with partially extended morphology

SECT: the plots

**Corrected NGC6302 spectrum**

Correction for 18.5arcsec gaussian source; offset 0.0arcsec, 0.0arcsec

SECT plots the uncorrected and corrected spectra

No more jump

The corrected spectra look good, but room for improvement:

*Needs better knowledge of the source model!*

---

see Wu et al. 2013 & DRG Section 7.6
Fits sinc profiles to each line + polynomial for the continuum

fit is performed simultaneously for each detector
Analysing SPIRE FTS spectra

Line fitting to SECT corrected NGC6302

Useful script: *Spectrometer Line Fitting*

See the DRG 7.11 and the script itself for full details, but here’s a summary:

- The continuum is usually well approximated by a polynomial:
  
  *The script uses a 3rd order polynomial*

- The $^{12}$CO lines are included as default
  
  *Either add more to the list or follow the script to add a new list or read lines in from a text file*

- The unresolved instrumental line shape is approximately a sinc
  
  *The script fixes the width using ‘actualResolution’ from the metadata*

- If lines are partially resolved a *sincGauss* profile can be used
  
  *Only necessary for lines with a width > 200 km/s*

- The script can be run with point-source or extended source calibrated spectra

- Redshift can be input where necessary
  
  The output will need adjusting to give redshift, but the script tells you how!

See the DRG 7.11. Spectral analysis
Analysing SPIRE FTS spectra

Line fitting to SECT corrected NGC6302

Useful script: *Spectrometer Line Fitting*

SLWC3: NGC6302
OBSID: 1342265809 (0x500159D1)

SSWD4: NGC6302
OBSID: 1342265809 (0x500159D1)

Polynomial fits the continuum well

Fringing left from point-source calibrating semi-extended emission

13CO lines

Missed line might be affecting fit to the nearby CO line

A good start, but more lines needed to improve the results

See the DRG 7.11. Spectral analysis
Analysing SPIRE FTS spectra

Line fitting to SECT corrected NGC6302

Useful script: *Spectrometer Line Fitting*

**SLWC3: NGC6302**

OBSID: 1342265809 (0x500159D1)

**SSWD4: NGC6302**

OBSID: 1342265809 (0x500159D1)

See the DRG 7.11. Spectral analysis
Analysing SPIRE FTS spectra

Apodized data

Good for checking lines

**BUT** line measurements should be performed on the standard data

See the DRG 7.11. Spectral analysis
Analysing SPIRE FTS spectra

Spectral noise

See the DRG 7.5.3/SPIRE Handbook/public twiki (see link below) for info on FTS noise, but here’s a summary:

- There are three main sources of uncertainty
  1. Random noise – beats down with integration time
  2. Large-to-mid scale systematic noise associated with the instrument
  3. Small-scale systematic noise, i.e. fringing and line wings

- Measure the spectral noise to check of your data’s processing. The “error” column only represents the random noise
  Useful script: Estimate Spectral Noise

- Noise should be measured after subtracting the lines
  Useful script: Line Fitting script

- For faint sources and line subtracted data the noise should be at least as good as HSpot
  The Noise Estimate script plots a comparison with HSpot

- See the public twiki for the Spectrometer uncertainties

http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb
Analysing SPIRE FTS spectra

Estimating the noise

Useful script: *Spectrometer Noise Estimate*

③ A source with partially extended morphology

NGC6302 1342265809

OD 1389, HR, 4 reps

1σ noise [Jy]

Frequency [GHz]

Error column  HSpot (HR)  Uncorrected

Plot adapted from the script
Green dashed is noise estimate for the data straight from the archive
Lines dominate the noise

See the DRG 7.5.3 Check Spectral Noise
Analysing SPIRE FTS spectra

Estimating the noise

Useful script: *Spectrometer Noise Estimate*

③ A source with partially extended morphology

NGC6302 1342265809

OD 1389, HR, 4 reps

1σ noise [Jy]

Frequency [GHz]

Plot adapted from the script

Blue is noise estimate for SECT corrected. Noise goes up as data is corrected up

Lines dominate the noise

See the DRG 7.5.3 Check Spectral Noise
Analysing SPIRE FTS spectra

Estimating the noise

Useful script: *Spectrometer Noise Estimate*

③ A source with partially extended morphology

NGC6302 1342265809
OD 1389, HR, 4 reps

 Plot adapted from the script
Orange is noise estimate for the SECT corrected and 12CO line fitted and subtracted data
Still lines in there
Analysing SPIRE FTS spectra

Estimating the noise

Useful script: *Spectrometer Noise Estimate*

③ A source with partially extended morphology

NGC6302 1342265809
OD 1389, HR, 4 reps

The noise is above HSpot due to SECT!

Plot adapted from the script
Red is noise estimate for the SECT corrected and line subtracted data
Most significant lines are removed

NGC6302
Analysing SPIRE FTS sparse observations
Comparing with the photometer: AFGL4106

HIPE task `spireSynthPhotometry` (used to be `specMatchPhot`)

**Synthetic Photometry**

Background subtracted

**Synthetic Photometry**

Pre-background subtraction

**Table dataset output**
- Detectors
- Synthetic phot
- Synthetic phot errors
- Photometer phot

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**Analytical photometry results**

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Herschel On-Line Spectroscopy Data Processing Workshop 24 April 2014
Analysing SPIRE FTS spectra

Summary

• If you don’t have HIPE 13 data: update from the HSA
• The SDRG is the first port of call to look for help + info
• Background/pointing/extent can all cause a jump between the bands
• Off-axis subtraction of backgrounds can be effective for point-like source
• Pointing offsets can be corrected with SECT
  
  (new dedicated pointing correction task for HIPE14)
• Source extent leads to poorly calibrated data:
  • Semi-extended data must be corrected with SECT
  • You need a good understanding of the source
• Fit all lines (sinc) and continuum simultaneously
• Useful scripts provide a handy workflow within HIPE
• The best place to inspect, diagnose, correct and analyse your FTS data is in HIPE!
Analysing SPIRE FTS spectra

Estimating the noise

Useful script: *Spectrometer Noise Estimate*

① Point-source embedded in extended emission
- Background subtraction affects large-scale noise only

AFGL4106 1342246991
OD 1126, HR, 4 reps

Plot produced by the script
Green dashed is noise estimate for the background corrected data
Lines dominate the noise

BGS script results
figure 7.37: Comparison of the $2\sigma$ APE distribution, shown as a blue cloud, before (left) and after (right) OD 1011.