**Release Note for the**
**Spectrometer Mapping AOT**

**Prepared by the SPIRE ICC**

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## Introduction

The mapping modes for the spectrometer can be used to schedule observations to create spectral maps of extended sources. This includes jiggle maps (2 arcmin coverage) and raster maps (>2 arcmin coverage) and combinations thereof.


Instrument Settings for
Jiggle Maps:

| | |
|---|---|
| Pointing Mode: | Single Pointing |
| Image Sampling: | Intermediate or Full |

Raster Maps:

| | |
|---|---|
| Pointing Mode: | Raster |
| Image Sampling: | Sparse |

Jiggle & Raster Maps:

| | |
|---|---|
| Pointing Mode: | Raster |
| Image Sampling: | Intermediate or Full |

In all cases, Spectral Resolution can be set to High, Medium, Low, or High and Low.

The mapping AOTs have been released for nominal detector bias settings which are optimized for faint to moderately bright astronomical sources. It is not yet possible to make spectral maps of bright sources.

More detailed notes on using the spectral mapping AOTs:

- The short wavelength detector array SSW, which covers the spectral range between 193 and 321 μm, contains two unusable detectors which can lead to holes in the jiggle maps.
- The effective dynamic range of a detector can vary between observations and is set at the beginning of each observation. This can lead to clipped signals for sources with significant brightness gradients on the scale of the jiggle pattern (28" step for intermediate; 14" step for full sampling). Signal clipping can occur either at the maximum or the minimum of the interferogram and can be successfully corrected as long as only a small number (<5) of consecutive samples are clipped. In cases where more severe clipping occurs, individual detector timelines may remain unusable at one or more jiggle positions and this may affect map coverage. Our recommendation is to set the map coordinates to the scientifically most interesting part of the source so that this is used to set the dynamic range.
- The released AOTs have been used successfully to create spectral maps of the Orion bar. These observations were used to estimate the maximum source brightness that can be observed with the nominal detector settings: 55 Jy on average for the SLW band and 175 Jy

on average for the SSW band. Observers planning to observe brighter sources should consult the HSC/ICC for further advice.

- Full spatial sampling refers to independent data points at intervals of approximately half a beam-width. The distance between data points increases to approximately one and two full beam-widths for intermediate and sparse spatial sampling. The grid size of the standard spectral cubes is set to match these distances (see below).

**Data processing**

The Herschel Science Centre uses a Standard Product Generation pipeline to process all spectral maps. This pipeline performs the same data processing steps as the pipeline for point source observations. Both pipelines will populate the data pools with identical intermediate data products. All the comments made on noise and sensitivity for point source observations apply also to spectral mapping. Data processing for spectral mapping differs from processing a point source observation by adding a projection of the point spectra onto a level-2 data product, a regularly gridded, spectral cube. The current projection algorithm employs a brute-force nearest neighbour interpolation for that purpose. This algorithm does not average the spectra within one map pixel (but assigns the single spectrum closest to pixel centre). It also does not flag those map pixels where no single spectrum was observed within its footprint, but assigns the nearest neighbour (even if it is outside the pixel boundary). Alternative gridding algorithms may be available for interactive processing in the future.

The standard grid size set in the pipeline for the different modes is as follows:

| Mode | SSW grid size [arcsec] | SLW grid size [arcsec] |
|---|---|---|
| Raster Map - Sparse Sampling | 38 | 70 |
| Jiggle or Jiggle & Raster Map - Intermediate Sampling | 19 | 35 |
| Jiggle or Jiggle & Raster Map - Full Sampling | 9.5 | 17.5 |

In order to calibrate the spectral mapping AOT, the point source calibration scheme must be extended beyond the current capabilities of the data processing software. Until the full implementation of these calibration procedures and their deployment at the Herschel Science Centre, the resulting spectra will not contain scientifically meaningful data. It is recommended to consult with the Herschel Science Centre to clarify the data processing status before starting data analysis.

**Spectral range, line shape, and resolution**

The spectral range for the centre detectors also applies to the detectors used for spectral mapping, quoted below for reference. The signal-to-noise ratio will vary across detectors towards the edges and the signal quality may degrade towards the band edges.

| Band | Cut-On | Cut-Off |
|---|---|---|
| SSW | 193 μm | 321 μm |
| SLW | 300 μm | 685 μm |

The Instrumental Line Shape for all detectors of the SPIRE spectrometer is well modelled by the Sinc/Gauss function for the unapodized/apodized data. All detectors achieve the target spectral resolution:

| Mode | Unapodized Spectral Resolution Element | FWHM of an Unresolved Unapodized Line |
|---|---|---|
| High | 0.0398 ± 0.0002 $cm^{-1}$ | 0.0480 ± 0.0002 $cm^{-1}$ |
| Medium | 0.240 ± 0.010 $cm^{-1}$ | 0.290 ± 0.012 $cm^{-1}$ |
| Low | 0.83 ± 0.04 $cm^{-1}$ | 1.00 ± 0.05 $cm^{-1}$ |

**Beam sizes**

The average width of the beams has been measured only photometrically for all detectors in the two arrays and the FWHMs of equivalent Gaussian beam shapes are given below. The standard variation of the beam widths within each array is 0.5 arcsec. Note that the assumption of Gaussian beam shapes is quite poor, so that the quoted FWHM cannot be used to determine an accurate beam area in steradians (see point source release note).

| Band | Equivalent FWHM of a Gaussian beam |
|---|---|
| SSW | 19 arcsec |
| SLW | 35 arcsec |

The width of a point source in a spectral cube is in agreement with these values. At the present time, the variation of beam size as a function of frequency has only been carried out for the central detectors (see point source release note). Currently, the assumption that all detectors share a similar beam profile as a function of frequency appears reasonable but has not yet been confirmed.

**Pointing**

The pointing accuracy within fully sampled spectral maps is within the uncertainty set by the satellite Absolute Pointing Error of approximately 2.0 arcsec. For raster maps, the Relative Pointing Error of 1.0 arcsec adds to the pointing uncertainty. When mapping a point source with full spatial sampling (without performing a raster pattern), the distance between the point source according to an astronomical catalogue and the derived source location has been shown to be less than the edge of one pixel (9.5/17.5 arcsec for SSW/SLW). Also, the spectral map was in good agreement with a scan map from the SPIRE photometer.

**Wavelength scale accuracy**

The wavelength scale for each detector is corrected by a calibration factor specific to each detector in the pipeline. This correction ensures a high level of consistency for the location of line centres between detectors with a standard deviation of ±5 km/s and an overall residual velocity of 11 km/s on average. The residual velocity is consistently below 5% of the quoted high spectral resolution element. Further improvements of the wavescale calibration may be possible.

**Flux calibration accuracy**

The considerations concerning the accuracy of the flux calibration for the SPIRE Spectrometer Point Source AOT also apply to spectral mapping. There is currently an additional uncertainty in mapping observations due to imperfect detector flat fielding across the array. This leads to an additional uncertainty of 10-15% in the absolute continuum levels in the final gridded spectral cube. This is expected to improve with better characterization of the array.

**Noise and sensitivity**

The considerations concerning sensitivity and noise for the SPIRE Spectrometer Point Source AOT also apply to the SPIRE Spectral Mapping AOT. Also consider the following:

- The spectral noise in a given spectrum decreases as expected with number of iterations for all detectors across the arrays.
- Line flux sensitivity (in terms of W $m^{-2}$ in beam) is essentially the same for a point source as for a given map point.
- For a fully sampled map, spatial pixels in the spectral cube can be coadded/resized to enhance sensitivity somewhat (as in the photometer) – but it is best to assume no enhancement in sensitivity as calibration errors or other imperfections may counteract the gain available in principle.
- Absolute continuum calibration should be cross-checked by including a map with the photometer in the programme (will generally occupy only a small fraction of the time for the FTS observations).

The detectors perform as designed and the ICC is currently working on refining calibration procedures (reference interferogram, relative spectral response, flat-fielding) to take full advantage of the performance of the detector arrays.