SPECTRAL PROCESSING REQUIREMENTS FOR THE HERSCHEL SPIRE IMAGING FOURIER TRANSFORM SPECTROMETER

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ABSTRACT

The SPIRE instrument on board the Herschel satellite contains an imaging Fourier Transform Spectrometer. This instrument simultaneously covers the 194–672 μm wavelength range, with an unvignetted field of view of 2.6', and pixel FWHM of $\sim$16" (short wavelengths) and $\sim$35" (long wavelengths). It will be possible to operate in a raster mode, and so cover large areas of sky. The data produced will be either low spectral resolution continuum measurements or have higher spectral resolution to observe lines. We describe the instrument characteristics and the software requirements for scientific analysis of the resulting 3D spectral data cubes.

Key words: Fourier Transform Spectroscopy; data processing; spectral datacubes; sub-mm.

1. INTRODUCTION

SPIRE, the Spectral and Photometric Imaging Receiver, is an imaging photometer and spectrometer for ESAs Herschel Space Observatory, due for launch in 2008. It contains an imaging Fourier Transform Spectrometer (iFTS), which provides medium spectral resolution over a broad range.

The compact optical layout with dual input and output ports follows a Mach-Zehnder configuration using two high-efficiency intensity beamsplitters. The servo-controlled scanning mirror mechanism is based on a double-pendulum design. A mechanical displacement leads to a four-fold change in the optical path difference. A thermal calibration source is placed at the entrance of the second input port of the FTS to compensate for the emission from the warm telescope.

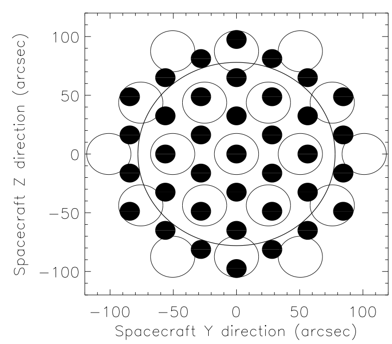

Figure 1. The layout of the SPIRE iFTS detector arrays. SSW pixels are shown as filled circles and SLW as empty circles. The 2.6' unvignetted field of view is also shown.

2. INSTRUMENT CHARACTERISTICS

The full spectral range is covered by 2 spider-web bolometer detector arrays operating at $\sim$300 mK: the spectrometer short wavelength array (SSW) covering 194–324 μm and the spectrometer long wavelength array (SLW) covering 316–672 μm. Measured pixel full width at half maxima (FWHM) are 16"–18" for SSW and 31"–40" for SLW.

The footprint of the unvignetted field of view on the detector array has a diameter of 2.6' and contains 19 & 6 fully functional pixels for SSW and SLW. The detectors are hexagonally packed with a spacing of $\sim$2 beam widths (32.5" for SSW and 50.5" for SLW). The layout of the arrays is shown in Fig. 1. An internal Beam Steering Mirror (BSM) can be used to 'jiggle' the field of view to increase the spatial sampling.

Each pixel of the SPIRE iFTS will simultaneously observe the entire spectral range 51.5–14.9 cm^{-1} (194–672 μm). The spectral resolution is constant in wavenumber (and frequency), while the resolving power changes

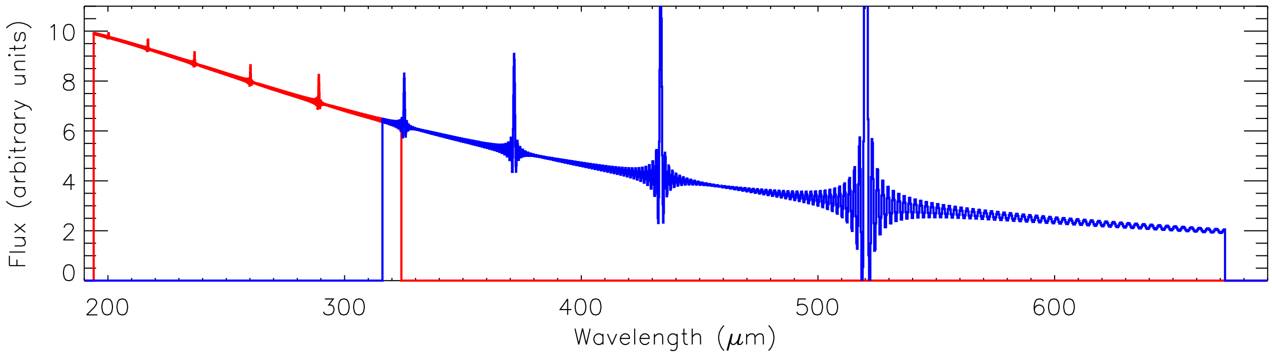

Figure 2. A simulation of a line spectrum for the SPIRE iFTS using high spectral resolution mode. The data from SSW are shown in red and from SLW are shown in blue. The instrumental line shape of a sinc function can clearly be seen.

linearly as $R = \sigma/\Delta\sigma$ up to 1300,

- HIGH Resolution: $\Delta\sigma$ = 0.04 cm^{-1} (1.2 GHz)
- MEDIUM Resolution: $\Delta\sigma$ = 0.25 cm^{-1} (7.5 GHz)
- LOW Resolution: $\Delta\sigma$ = 1.0 cm-^{1} (30 GHz)

The spectral range complements the other instruments on board Herschel, overlapping with the Photodetector Array Camera and Spectrometer (PACS; 55–210 μm) at the short wavelength end, with very similar spectral resolution. The range covered by the Heterodyne Instrument for the Far Infrared (HIFI) overlaps much of the SPIRE range but with much higher spectral resolution.

The spectral response function of a FTS is a sinc function and will present itself in the data when observing spectrally unresolved features (e.g. Fig. 2). This well defined function has to be taken into account during extraction of spectral line information in order to achieve the best spectral resolution. Apodisation functions can be applied during data processing to suppress the side-lobes of the line shape. However, this will result in an increase of the line width between 10–100%, depending on the selected apodisation function.

3. ANALYSIS OF SPECTRA AND SPECTRAL IMAGES

To extend the area covered, multiple fields of view can be observed using a raster mode. This will produce large spectral cubes for analysis. The spatial sampling of each field of view in the raster is determined by the number of ‘jiggles’ of the BSM. The final spatial sampling can be sparse (2 beam spacing), intermediate (1 beam spacing) or full Nyquist (1/2 beam spacing).

The data from the SPIRE iFTS will be in the format of Herschel spectral cube products. Compatibility with Virtual Observatory products is under investigation.

Individual spectra measured by the SPIRE iFTS will require specialised spectral analysis tools including,

- Combine data from all three Herschel instruments (esp. SPIRE and PACS)
- Combine repeated data from identical/different pixels with different signal-to-noise ratios
- Convert the inherently linear SPIRE wavenumber scale into wavelength, frequency, velocity
- Allow for simultaneous processing for the entire spectral range with varying beam sizes
- Allow for blended line profiles

The data produced will always be in the form of 3D spectral data cubes, with axes RA, Dec and wavenumber. Spectral analysis tools for the SPIRE iFTS will be implemented within the Herschel Common Science System (HCSS) software. They will allow for,

- Resampling of spectral cubes to a regular grid of spatial positions
- Line extraction for a spectral cube (position, amplitude, flux)
- Continuum fitting (e.g. polynomial, multiple black body function) after masking out lines
- Model fitting both for continuum and line emission
- Convolution of cubes to different beam sizes (e.g. to compare SSW, SLW and with PACS and other instruments)
- Convolution of higher resolution spectra (e.g. HIFI, or model spectra) to the SPIRE iFTS resolution
- Interactive or automated data analysis