SPIRE Spectrometer pipeline products

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Exploiting the Herschel Science Archive
SPIRE Spectrometer SPG products

Outline

• Standard Product Generation (SPG) products in the HSA
  • Why you should be using HIPE 14 processed data
  • What different pipeline products are available
  • Standalone Browse Products (SPBs)
• Artefacts and issues: are the products science ready?
• Calibration accuracy
SPIRE Spectrometer SPG products

Pipeline products in the HSA

- All SPIRE pipeline products are processed with the final calibration files (spire_cal_14_3) as of HIPE 14.1
- All final SPIRE pipeline products are available via the HSA
SPIRE Spectrometer SPG products
Pipeline products in the HSA

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- Notable improvements for HIPE 14:
• All SPIRE pipeline products are processed with the final calibration files (spire_cal_14_3) as of HIPE 14.1
• All final SPIRE pipeline products are available via the HSA
• **Notable improvements for HIPE 14:**
  • Correction for low resolution data affected by bumps (*Marchili et al. 2016, arXiv:1610.02862*)
SPIRE Spectrometer SPG products
Pipeline products in the HSA

- All SPIRE pipeline products are processed with the final calibration files (spire_cal_14_3) as of HIPE 14.1
- All final SPIRE pipeline products are available via the HSA
- Notable improvements for HIPE 14:
  - Correction for low resolution data affected by bumps (Marchili et al. 2016, arXiv:1610.02862)
  - Extended-source calibration correction
    - Corrects for the far-field coupling efficiency of the FTS feedhorns
    - We use the far-field coupling efficiency derived by Wu et al. (2013)
    - The correction for SSW is adjusted by 10%
    - Full details of this correction will be available in Valtchanov et al. (in preparation)
  - Only Spectrometer extended-source data processed with HIPE 14 should be used for scientific analysis
All SPIRE pipeline products are processed with the final calibration files (spire_cal_14_3) as of HIPE 14.1

All final SPIRE pipeline products are available via the HSA

Notable improvements for HIPE 14.1:

- Bright source mode was fixed with re-derived bright gains
• Products are saved after several key stages of processing
• You can grab the full Observation Context
• Or just the Standalone Browse Products (SBP)
  • i.e. the fully processed pipeline products
• Products are saved after several key stages of processing
• And organised in Observation Contexts

<table>
<thead>
<tr>
<th>SPG Level</th>
<th>Description</th>
<th>Science Ready</th>
<th>Served as..</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level-0</td>
<td>Raw data comprising of all the data from a single building block</td>
<td>✗</td>
<td>Obs Context</td>
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<tr>
<td>Level-0.5</td>
<td>Uncalibrated, uncorrected timelines in Volts</td>
<td>✗</td>
<td>Obs Context</td>
</tr>
<tr>
<td>Level-1</td>
<td>Interferograms for each pointing and Jiggle position</td>
<td>✓</td>
<td>Obs Context</td>
</tr>
<tr>
<td>Level-2</td>
<td>Includes fully processed products + QC</td>
<td>✓</td>
<td>Obs Context SBP</td>
</tr>
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</table>
Products are saved after several key stages of processing and organised in Observation Contexts.

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<td>Includes fully processed products.</td>
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**SBP**

SPIRE Spectrometer SPG products
Pipeline products in the HSA
Level 2 Product!

- Spectral Cube
- PreCube (Spectrum 2d)
- Extended Spectrum
- Point Source Spectrum

**Level 1 Product**

- Spectrometer Detector Interferogram
- Make Same OPD
- Baseline Correction
- Second Level Deglitching
- Phase Correction
- Fourier Transform
- Spectrometer Detector Spectrum

**Level 0.5 Products**

- Detector response
- Non-Linearity Correction
- Clipping Correction
- Correct Time Domain Phase
- Create Interferogram
- Spectrometer Detector Interferogram
- OPD limits

**Auxiliary Products**

- Spacecraft Pointing Product
- Spacecraft Apertures Product
- Spacecraft Housekeeping Product

**Level 0.5 Products**

- Calculate BSM Angles
- BSM positions
- BSM Angles Timeline
- Create SPP
- Detector angle offsets

**Level 1**

- Time offset
- SMEC ZPD Step factor
- Phase corr limit
- Therm time con
- Instrument Correction
- Bright Gain
- (Bright Gain)

**Level 2**

- Telescope RSRF
- Instrument RSRF
- Extended Flux Conversion
- Telescope Correction
- Average Spectra

- Point-source Flux Conversion
- Average Spectra
- Apodize
- Apodize

- Radial Velocity correction
- Sort Meta Data
- Create WCS
- ExtCorr
- spatial gridding

- Bright Gain
- (Bright Gain)

- Telescope Correction
- Average Spectra
- Apodize
- Apodize

- Radial Velocity correction
- Sort Meta Data
- Create WCS
- ExtCorr
- spatial gridding

- Bright Gain
- (Bright Gain)
SPIRE Spectrometer SPG products

*Fully calibrated pipeline products: Level-2*

- Two types of fully processed products are available depending on the observation mode
- For all Level-2 products there is an apodized version too

<table>
<thead>
<tr>
<th>Mode</th>
<th>Product</th>
<th>Science Ready</th>
<th>SBP</th>
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<tbody>
<tr>
<td><strong>Single pointed sparse</strong></td>
<td>Extended-source calibrated spectra (W/m²/Hz/sr)</td>
<td>✔</td>
<td>✘</td>
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<tr>
<td></td>
<td>Point-source-calibrated spectra (Jy)</td>
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<td>✔</td>
</tr>
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</table>
SPIRE Spectrometer SPG products

Fully calibrated pipeline products: Level-2

Archive tar file folder structure for Level-2

For H+LR mode there is one HR and one LR set of products
SPIRE Spectrometer SPG products

Fully calibrated pipeline products: Level-2

Level-2 FITS file structure for sparse single pointing spectral product using fv

FITS extension names

<table>
<thead>
<tr>
<th>Index</th>
<th>Extension</th>
<th>Type</th>
<th>Dimension</th>
<th>View</th>
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<td>13</td>
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SPIRE Spectrometer SPG products

Fully calibrated pipeline products: Level-2

Level-2 FITS file structure for sparse single pointing spectral product using fv

FITS extension names
Right click to access the SBPs: point-source calibrated spectra

Click on the postcard to open it

Single pointed sparse mode
SPIRE Spectrometer SPG products

- Postcard shows the CP cubes
- SBPs are the CP, but we recommend downloading the Naïve cubes as well

<table>
<thead>
<tr>
<th>Observation ID</th>
<th>Postcards</th>
<th>Target</th>
<th>RA/DEC</th>
<th>Instr.</th>
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<td>05h 35m 22.92s -05d 24' 56.48&quot;</td>
<td>SPIRE</td>
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</table>

**Mapping mode**

HD37041, full, HR, OBSID=1342228734

(RA,Dec) = (5h35m22.9s, -5°24'56'') (J2000), OD=857

![Graph Image](image.png)
SPIRE Spectrometer SPG products
Remaining artefacts

• Instrument residual below 600 GHz can lead to a distorted spectral shape

• Prior to OD 400 the non-linearity correction may not perfect for some observations taken the beginning of an FTS observing pair of days

• SSWB4 spectra suffer high noise after OD 710

• These issues are only significant for faint sources
Many observations have science-ready SPG products
But there are a number of issues that requires further processing
The main issues for FTS spectra are
1. Point source in high background/foreground emission (HPDPs coming soon)
2. Pointing offset
3. Partially extended sources
See the SPIRE Spectrometer data analysis presentation for specific examples on each of these points
Other problem that can be seen for some observations are
- failed processing due to some on-board anomaly
- a few with bad scans or detectors
- spectra with poor spectral resolution
For these there will be Highly Processed Data Products (HPDPs) in the near future and these are discussed further in the next presentation “SPIRE Spectrometer expert provided data products”
• The intrinsic FTS line shape is not a perfect sinc
• There is a 2.6% shortfall in line flux measured using a sinc profile
• Flux is not lost but redistributed
• See Hopwood et al. 2015 for more details
1σ additive uncertainty on the continuum

Telescope and instrument residual (<600 GHz for the latter)

Highly frequency dependent
1σ noise in a 1 hour observation

Derived using observations of dark sky and featureless sources

Frequency dependent
How the calibration improvements translate to real data

![Plot showing the flux density vs. frequency for different sources and models.](image-url)
SPIRE Spectrometer SPG products
Point-source calibration accuracy

- Average continuum offset (Jy): SLWC3 0.4, SSWD4 0.3
- Average sensitivity (Jy): SLWC3 0.2, SSWD4 0.2

- Repeatability is 6 % with the following contributions:
  - Absolute systematic uncertainty in the models from comparison to Uranus and Neptune: ± 3%
  - Statistical repeatability determined from observations of Uranus and Neptune (after correcting for pointing offset): ± 1%
  - Continuum offset
  - the effect of the Herschel APE

- Integrated line flux repeatability:
  - < 6% for standard point-source calibrated spectra
  - < 3% after correction for pointing offset

- < 7 kms\(^{-1}\) line velocity repeatability before and after pointing correction
☆ 1σ additive uncertainty on the continuum
☆ Telescope and instrument residual (< 600 GHz for the latter)
☆ Increased for HIPE 14 due to extended-source calibration correction
1σ noise in a 1 hour observation
- Derived using observations of dark sky and featureless sources
- Frequency dependent

![Graph showing 1σ noise in 1 hour observation over frequency range from 500 to 1500 GHz.]

**Graph**
- **Y-axis:** 1σ in 1 hr [10^-19 W m^-2 Hz^-1 sr^-1]
- **X-axis:** Frequency [GHz]
- **Legend:**
  - HIPE 13 (black line)
  - HIPE 14 (pink line)
SPIRE Spectrometer SPG products

Extended-source calibration accuracy

- Average continuum offset (W/m$^2$/Hz/Sr): SLWC3 9.4e-20 SSWD4 2.3e-19
- Average sensitivity (W/m$^2$/Hz/Sr): SLWC3 4.6e-20 SSWD4 1.8e-19

- Extended-source calibrated observations in sparse mode:
  - repeatability ± 7%
  - This is for fully extended source
  - The uncertainties are greater for sources that are not fully extended

- Mapping repeatability ± 7% (Benielli et al. 2014 based on Naïve projection of all the Orion Bar observations)

- The repeatability for cubes obtained from the HSA is similar to that found by Benielli et al., 2014:
  - 6-10% for Naive projected cubes
  - 4-10% for CP cubes
  - The uncertainties sharply increase below 700 GHz in the SLW band, although this increased is less dramatic for CP cubes.
SPIRE Spectrometer SPG products

Calibration accuracy: the literature

• Calibration accuracy published in
  • **FTS calibration**: Swinyard et al. 2014 (arXiv:1403.1107)
  • **FTS calibration program**: Hopwood et al. 2015 (arXiv:1502.05717)
  • **LR calibration**: Marchili et al. 2016 (arXiv:1610.02862)
  • **FTS Mapping**: Benielli et al. 2014 (arXiv:1401.2040)
    • *Part of five papers in the Experimental Astronomy special edition*
    • *(other four are: Bright mode, telescope correction, relative pointing offset, RSRFs)*

• Also see the
  • SPIRE Handbook
  • SPIRE DRG
  • FTS flyer
  • Twiki SPIRE calibration page
    [http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb](http://herschel.esac.esa.int/twiki/bin/view/Public/SpireCalibrationWeb)

• Outstanding
  • Mapping uncertainties are presented in Benielli et al. 2014 based on Naïve spectral cubes. A report on CP cube uncertainties is in preparation.