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**DOCUMENT**



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# Herschel/HIFI Spectral Map Highly Processed Data Products

## Release Notes

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# APPROVAL

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# CHANGE LOG

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Added description for Bands 1a, 2a and 4b HPDPs		1.2	18 July 2018



## Table of Contents

<b>1</b>	<b>INTRODUCTION.....</b>	<b>2</b>
<b>2</b>	<b>DESCRIPTION OF THE HPDPs .....</b>	<b>2</b>
<b>2.1</b>	<b>Motivation and Scope of the Spectral Map HPDPs.....</b>	<b>2</b>
<b>2.2</b>	<b>Method of the Spectral Map HPDP generation .....</b>	<b>3</b>
2.2.1	Summary of the interactive processing .....	3
2.2.2	Data processing flow .....	8
<b>2.3</b>	<b>Content of the HPDPs.....</b>	<b>12</b>
2.3.1	Delivered contents, format and structure .....	12
2.3.2	File naming .....	14
2.3.3	HPDP queries in the HSA and IRSA.....	16
<b>3</b>	<b>Acknowledgements and Referencing.....</b>	<b>16</b>
	<b>Appendices .....</b>	<b>18</b>

## **1 INTRODUCTION**

This document describes the “Highly Processed Data Products” (HPDPs) created interactively in HIPE from HIFI observations obtained with all Observing Modes of the Spectral Mapping AOT. The motivation behind these particular products and processing details are summarized, providing a reference for Users of these data available in the Herschel Science Archive (HSA; <http://www.cosmos.esa.int/web/herschel/science-archive>) and the NASA InfraRed Science Archive (IRSA<sup>1</sup>) at IPAC.

Some of the mandatory information which is used to fill in the essential fields in the HSA User Interface (HUI) is also described.

## **2 DESCRIPTION OF THE HPDPs**

### **2.1 Motivation and Scope of the Spectral Map HPDPs**

A number of data processing steps for HIFI spectral mapping observations can be carried out interactively in HIPE that will maximize data quality around the scientific goals, but which could not be incorporated in the HIFI Standard Product Generation (SPG) for practical reasons. These operations have been taught at data processing workshops held over the course of the mission at HSC and NHSC. While some of these steps could, over time, be integrated into the pipeline, their complexity to account for a wide range of data reduction parameter space would require substantial effort to implement, then verify that the majority of all mapping observations have been processed as expected. There are nonetheless certain operations that would require User interactions.

In the interest of ensuring the broadest access to HIFI’s scientific returns, the substantial amount of HIFI science which remains to be exploited in the HSA, and the general dependency on the *Herschel* data processing system for the most effective processing methods, HIFI ICC scientists have interactively processed a selection of mapping observations starting with Level 2 products from the final (SPG 14.1.0) pipeline and applied interactive tools and scripts in HIPE 14.1 to 15.0, minimizing data artifacts and maximizing

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<sup>1</sup> <http://irsa.ipac.caltech.edu/Missions/herschel.html>



signal-to-noise ratios. This alleviates a concern for engagement by the future User community with HIPE, such that these HPDPs are as close to science-ready as possible and can be loaded into almost any environment for further high-level analysis.

## 2.2 Method of the Spectral Map HPDP generation

### 2.2.1 Summary of the interactive processing

The main interactive processing steps involve:

- 1) Corrections for strong standing waves or drift in the spectral dataset baselines.
- 2) Product merging: H and V polarization signal output products from a single observation, and across multiple observations.
- 3) Spatial resampling of the mapping grid.
- 4) Inspection for sky reference (off-source) line contamination.
- 5) Production of optimal browse-quality spectra and integrated line or channel maps.

1. **Baseline corrections.** One of the most important interactive steps needing human eyes concerns corrections to the baselines for residual standing waves and/or uncalibrated drift, in the presence of spectral features spanning wide ranges of intensities and profile complexity. The HIFI pipeline applies an algorithm which attempts to mask spectral features for the purpose of measuring the noise performances in the calibrated spectra (the `mkRms` task). An incorrect (usually higher) noise measurement due to problematic line masking sometimes occurs but does not affect the data. The masks needed for best baseline corrections, on the other hand, clearly impact the signal after applying one of the HIPE tools for ripple or drift correction (`fitHifiFringe` or `fitBaseline`). The relative strengths of the spectral features of interest in an observation can also influence decision-making on the extent of baseline corrections that are needed. Interactive corrections can usually be foregone for observations containing a single line, placed away from a band edge, typically less than  $\sim 100 \text{ km s}^{-1}$  FWHM, and stronger than  $\sim 5 \text{ K}$  (both numbers depending on LO band), as long as the detailed shape of the profile near the baseline is not important. Many mapping observations deviate significantly from such simplicity.

During baseline cleaning every effort is made to preserve source continuum levels at each map point. However, 1) it was not possible to preserve the source continuum in the presence of platforming (the presence of important offsets between subbands), and



2) in the HEB bands 6 and 7, residual instrument drift often dominates over weak continuum emission from the source, and in such cases continuum and drift may not be possible to distinguish in all datasets. Thus when drift is evident and continuum emission is very weak compared to the baseline distortions and RMS noise, the continuum may be subtracted along with the errant baseline shapes in order to improve spectral line S/N, or else to simply demonstrate absence of line detection to within the final baseline RMS noise.

In some instances, potential spectral features could be weak and very broad, spanning more than one spectrometer sub-band. In these cases baseline cleaning is risky and has been skipped, and improvements to data quality are limited mainly to the merging of the spectrum datasets from the two polarizations.

**2. Product merging.** Data from the H (horizontal) and V (vertical) polarized signal chains are independently processed in the pipeline. However, the radiometric noise levels expected for an observation were calculated in the HSpot planning tool under the assumption that science data from both H and V chains are merged. Merging in the pipeline is carried out as an intermediate step for the purpose of measuring baseline noise performances, however these merged products are not saved in part because of the interactive baseline cleaning steps that may be needed on the input HTPs (as potentially revealed by high and disparate noise levels). Several other conditions that make automated merging undesirable occur frequently enough to avoid this as step in the SPG.

The main scientific reason to avoid product merging is for observations of intrinsically polarized sources (which cannot be judged/assumed in the pipeline). In data quality terms, the most common situation that discourages H and V product-merging occurs at certain frequencies where LO power has been low, and one or the other mixer has been under-pumped, leading to inadequate response corrections and higher drift artefacts (larger baseline offsets and standing waves). More infrequently, compact line-emitting source observations with telescope pointing errors of more than roughly  $1/3$  the frequency-dependent beam size may show H vs. V signal imbalance. This is a consequence of the optical non-coalignment of the H and V mixer beams, depending on LO band. Both internal and external types of imbalances have metrics that are measured and reported in the HIFI pipeline, and these aid in the interactive judgement on the extent of baseline clean-up that may be necessary, and then on subsequent merging of the H and V data.

Product merging can also include combing multiple observations taken at different times, with overlaps in (a) the same source or region, and/or (b) sky frequency



coverage. A limited number of these types of products have been included in the initial release of the HIFI Map HPDPs (see the Appendix).

- 3. Spectral cube re-gridding.** The spatial dimensions of spectral cubes produced in the HIFI pipeline follow the commanded spacing of each map readout point along the scan legs, and between scan legs, as closely as possible. This sets the projected pixel sizes. Early observations lack the information on how the precise spacing was set in the observation request, and for these cases the `doGridding` task in the pipeline estimates the dimensions from the attitude assignments to each spectrum dataset in the observation. This generally works well to recover the commanded dimensions, but corrections are sometimes needed following visual inspection of the reconstructed pointing patterns.

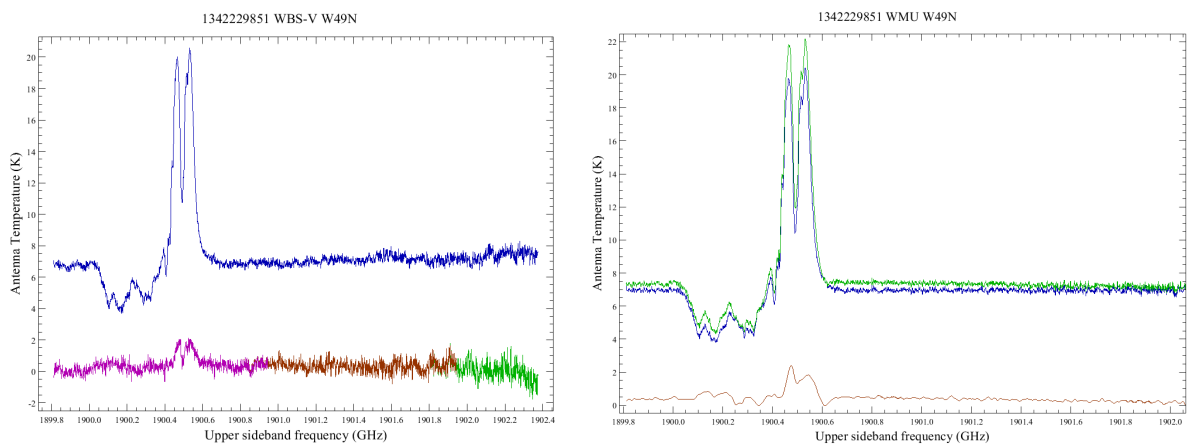
The spatial sampling can also be optimized to some level of oversampling, according to the observed signal-to-noise ratios (SNRs), bearing in mind that source structures at high SNRs can be measured to a fraction of the beam size. For HIFI this is in the range of  $\approx 1''$  (Band 7b) to  $4''$  (Band 1a), and depends on the initial requested sampling (Nyquist or lower) and observing mode.

- 4. Inspection for spectral line contamination.** Most HIFI mapping observations have employed measurements at a reference (OFF) sky position for correction of the optical standing waves. The position was set in HSpot by the observer, ideally chosen where no spectral features occur within the IF, but this has not always been the case. When a spectral line is present in the OFF spectra, the effect is to create a false absorption feature in the final products, when an emission line is picked up at the OFF position and is chopped into the ON science data by subtraction in the standard Level 1 pipeline. It will be a relatively constant effect in the ON science data (attenuated by possible drift of the instrument over the course of observing between periodic visits to the OFF position, or by spatial variations due to telescope pointing scatter or in the DBS raster throw positions at  $3'$  on either side of the ON map), and is usually weak.

A list of obsids identifying observations that have a spectral feature in the reference spectra is given in the Appendix. Users are encouraged to inspect the isolated OFF spectra made available by the Herschel Science Centre as Highly-Processed Data Products. Those spectra are planned to be served through the HSA user interface, but in the meantime they can be retrieved as standalone FITS files at <http://www.cosmos.esa.int/web/herschel/highly-processed-data-products>. Note that a few spectral maps were executed without sky OFF measurements at the Observer's request (the so-called "NoRef" modes). Secondly, it is often helpful to treat the OFF spectra with a defringing or standing wave removal tool such as `fitHifiFringe` in

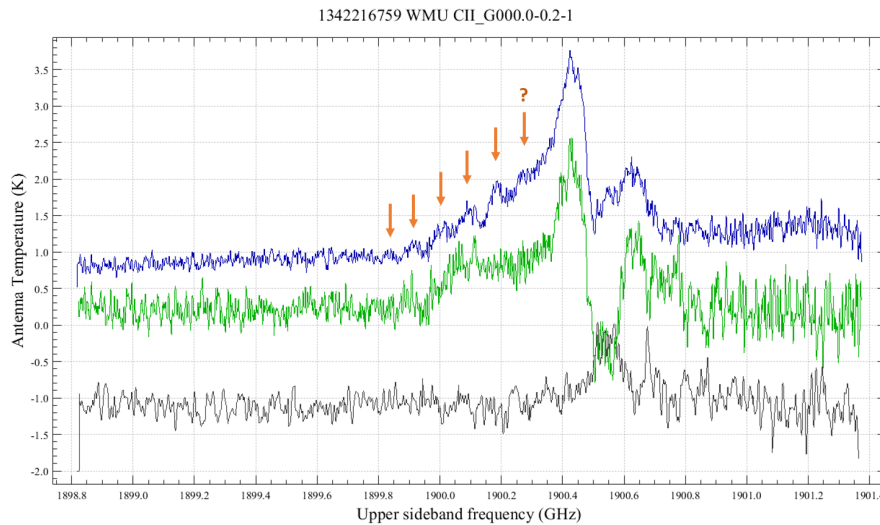
HIPE, to best reveal potential line contamination.

**Treatment:** Observations in Band 7b which have employed OTF mapping with the Load Chop mode have been processed by an alternative method to avoid the line contaminations. This involves skipping the reference subtraction in the HIFI Level 1 pipeline --- avoiding that spectral features at the OFF position are chopped into the science target map --- then re-deriving and applying a new ESW solution, and treating the OSWs with fitted sine waves, then carrying on with HTP merging and regridding. This method can sometimes improve baseline quality as well, by using noiseless sine curves to remove the OSWs. An example is shown below in Figure 1. However, the method does not always result in the best possible ESW corrections (usually a consequence of line masking effects) and some residuals may persist. An example is shown in Figure 2. The HPDPs processed with the alternative method are still regarded as the best products, but the Astronomer may wish to compare the cubes from the SPG, which used standard off subtraction in case of uncertainty about specific features in the line profile which may be related to the ESWs. Making a cube average spectrum from the observation in question and comparing this to the HPDP average spectrum is usually sufficient.



*Figure 1.* Example of a spectral map of W49N with line contamination at the reference OFF position, and corrections. On the left is shown the average spectrum (blue) from the WBS-V spectral cube as processed in the standard HIFI pipeline (v14.1.0), showing a complex  $C^+$  profile with both self-absorption and emission from the background source (Gerin et al. 2015 A&A, 573, A30). The lower spectrum on the left is the WBS-V average of sky reference OFF position measurements, showing at least 3 components of  $C^+$  emission + absorption as well as a weak continuum. On the right is shown the average spectrum from the HPDP cube (merged WBS-H and -V) without correction for OFF contamination (blue), and from the cube using the alternative processing to avoid the contamination (green), described above in Sec. 2.2.1 point 4. The difference spectrum is plotted at the bottom (brown). None of the spectra are offset and all are plotted at native channel spacing of the WBS.





*Figure 2.* Example of a spectral map data processed with standard OFF subtraction (green) using sky reference spectra from the designated OFF position (grey), and the same data processed as described in Sec. 2.2.1 point 4 (blue). The features indicated by red arrow are suspected ESW residuals, resulting from line masking across the range 1899.85 – 1900.81 GHz. The reference spectrum is the average of both H and V measurements at the OFF and has been smoothed to 2 MHz resolution, and offset by  $-2.0$  K for clarity. The blue and green spectra are at native resolution and have not been offset.

The alternate processing method to skip OFF subtraction and treat the OSWs with sine waves works best for the OTF Load Chop mode, relying on the additional measurements of the internal cold thermal load to compensate for short term instrumental drift. Other mapping modes including DBS Raster are not suited to this method. Moreover, the method works best in Band 7b and especially at LO frequencies covering the C<sup>+</sup> line (at low redshift), where the catalog of spline curves used to correct the ESWs is most extensive. Very poor results were found in Band 6a at frequencies covering the [N II] line, thus no HDPDs using this method are produced there.

5. **Optimized preview products.** While not specifically intended as the main product outputs, it has been recognized that the auto-generated browse products and images seen in the postcard previews for each observation in the HSA often give an inadequate if not occasionally misleading impression of the map's spectral and spatial information, thus affecting impressions of the potential scientific content. Interactively optimized browse products from the processed spectral cubes have been created for each map, giving best impressions of the data content, offering high level science-ready products (depending on the User's need) as well.

The preview products include an average spectrum for each cube, and an integrated spectral line intensity map or a frequency channel map. A line intensity map is



produced only when a spectral line is reasonably detected in a WBS cube, and is given in units of K km/s. Otherwise, a frequency channel map is produced, showing either the distribution of continuum emission across the mapped region, or else simply baseline noise. The channel map is an average of 6 frequencies spaced across the observed IF, avoiding the sub-band edges, and is given in units of K (on a  $T_A^*$  scale). *The user must remember that all HIFI observations at a fixed LO setting (so all maps and Point observations) are double-sideband, thus the indicated continuum levels must be scaled accordingly, i.e.,  $I_{cont}(v)/2.0$  assuming a sideband gain ratio of unity at all points in the IF.*

Integrated line maps are not produced from the HRS cubes, since sub-band coverage is often offset in frequency from the spectral features and/or lacks adequate baseline coverage to set the full line integration range (thus could be misleading), particularly for broad lines when the HRS has been used in resolution configurations that give less than the full coverage of the IF (i.e., the wide-band configuration).

### **2.2.2 Data processing flow**

The main data reduction flow generally applicable to all spectral map HDPD generation is described as follows:

#### **1. Visual inspections.**

Observations processed with SPG v14.1 are downloaded directly from the HSA, loaded into HIPE (using a v14 or 15 build), and the Level 2.5 HTPs and spectral cubes are inspected using SpectrumExplorer (SE). Inspection points are for:

- Residual Electrical Standing Waves (ESWs, Bands 6 and 7 only)
- Residual Optical Standing Waves (OSWs)
- Non-periodic drift or artifacts in the baselines
- Regions of the spectrum flagged for artefacts and which may interfere with spectral features.
- Line contamination in the sky reference OFF position.
- The pointing pattern of the datasets, and spatial sampling of the cubes.

#### **2. Electrical Standing Wave corrections.**

Corrections for ESWs for all HIFI observations in Bands 6 and 7 have been applied in SPG 13.0, with some updates in SPG 14.0. Occasionally the fits are affected by inadequate line masking, particularly for very broad, low-intensity lines, or complex profiles with multiple components that may include both emission and absorption. Such cases require setting the mask ranges manually.



### 3. Optical Standing Wave corrections.

No OSW corrections separate from those designed by the standard calibration scheme using the sky reference with each observation (where it has not been skipped in the AOR by the Observer) are applied in the SPG, thus any residuals are taken care of outside of the pipeline. Residuals are more common in Bands 6 and 7 observations.

OSW residuals are treated on a polarization basis with `fitHifiFringe` where necessary, generally with the following parameter settings (but may be varied on a case-by-case basis):

- Defaults for the number of fringes, and the upper, lower and typical periods which are band-dependent.
- Mask ranges (for spectral features and/or potential unflagged spurs) are set manually, using the map average spectrum.
- Sub-bands are stitched, unless platforming in a sub-band is detected.
- Baselines at each map point are fit and subtracted when no continuum emission can be discerned (e.g., when the baseline in the map average has zero or negative intensity and drift is clearly present and can be represented by a low-order polynomial).
- The median baseline levels at each map point can be re-injected, for cases where low-order drift in the line-free regions of the baseline can be removed first.

The `fitHifiFringe` applications are usually done with the task GUI.

### 4. Polynomial fitting/removal of baseline drift.

The `fitBaseline` task provides another option for removing non-sinusoidal baseline distortions, with functionalities for line masking, polynomial order, and re-injection of the median levels. There are no specific defaults for this task, also applied from the GUI.

### 5. Cube construction.

The spectral cubes are generated with the following main operations:

- 5.1. Check for sky reference (OFF) contamination in the reference spectra under the calibration tree (Step 1 above).
- 5.2. Re-fit the ESW solution for Band 6 or 7 maps.
- 5.3. Apply OSW corrections.
- 5.4. Apply polynomial baseline drift corrections.
- 5.5. Re-derive and/or apply new or alternate telescope pointing reconstruction.
  - This step is no longer needed for input data processed in SPG 14.0.1 or 14.1.0. All observations use either improved gyro-based pointing reconstruction or a



simpler version, according to quality flags in the observation's PointingProduct.

- 5.6. Set the Boolean option to process only WBS data.
  - Applicable when, e.g., no HRS science data are present.
- 5.7. Set the Boolean option to measure new noise statistics with `mkRms`.
  - This option is useful for gauging differences in noise performances following baseline cleaning of the input HTPs. The default is set to false since the task is highly resource-intensive.
- 5.8. Confirm data quality H and V polarization data prior to merging and gridding.
  - The requirement ensures that the noise measured in the separate H and V data differs by no more than 20%, as indicated by the `rmsNoiseHV` flag raised in the pipeline. As a relative difference, it is usually insensitive to line masking details.
- 5.9. Merge H and V HTPs, using the `mergeHtps` task, subject to settings of Step 5.8.
  - Some observations obtained over similar spatial regions and LO settings have also been merged. This entails combining compatible and similarly-processed H and V HTPs from multiple observations into the same container, which is fed to the spectral cube gridding task. The metadata for such stacked observations require special treatment (see item 7 below).
- 5.10. Regrid the cubes using the `doGridding` task.
  - This is done on merged HTPs unless merging has been skipped (according to Step 5.8), then on the unmerged HTPs. The parameters to be set are:
    - Sampling, specified by one of: an oversample factor, x and y dimensions of the pixels, or the map dimensions in number of pixels along the x and y axes, where x and y represent the cross-scan and scan directions, respectively.
    - The option to interpolate the signal between points, intended primarily for OTF maps using the Load Chop and Frequency Switch modes.
    - Additional parameters, e.g. on the filter functions for spatial weighting of map points, are done by directly editing the call to the task if needed.
- 5.11. Save the processed cubes in FITS files, for each spectrometer and each sideband.

## 6. Preview products.

Two types of products are created from the processed cubes with spectral cube toolbox tasks that are adjusted for each observation:

- **Average spectra** of the entire mapped region, on both sideband frequency scales, WBS and HRS (when utilized in the observation).
- **An integrated line intensity map, or a channel map**, WBS only.



Like the spectra at each map point in the cube, the intensity units for the average spectra are on a  $T_A^*$  [K] scale.

The integrated line intensity map is produced by first converting the frequency scale in one of the WBS cubes (sideband is not important) to velocity, setting the reference frequency at the peak of the strongest detected line. The cube is then integrated over the apparent velocities of all emission features, yielding a 2D map on a  $K \times \text{km s}^{-1}$  scale.

- The intensity map is intended for quickly assessing maximum integrated emission characteristics in the mapped region. For science, the User may desire to integrate the cubes over specific velocity channels for individual features separately, on an LSR velocity scale that is appropriate for the transitions of interests.
- When no spectral feature is detected, a simple channel map is produced as an average of 6 frequencies across the observed IF. The channel map indicates either source continuum emission (remembering that  $T_A^*$  values reflect the folded sidebands of data), or the baseline noise of the processed observation. The User can assess lack of line or continuum detection from a quick glance at the provided average spectrum, or else by inspection of the spectral cube.

## 7. Metadata modifications.

The original metadata produced with the cubes from the standard pipeline are preserved in FITS keywords; however certain keywords are also added and others filtered to reflect the merging process. The processing history is also propagated; however, it contains the history only for tasks which are also used in the pipeline. The `fitHifiFringe` and `fitBaseline` interactive tasks, for example, do not have functionality to write the history into the processed HTPs in a manner consistent with pipeline modules, and thus they are absent from the cubes.

Cubes created from more than one observation also contain the individual obsids in the header, as `obsid001`, `obsid002`, etc. Many other keywords (e.g, pertaining to observing mode, specific proposal information, AOR labels, etc.) have been filtered out, since they are judged too unwieldy to propagate for each observation as a set of new keywords. This information can be read from the headers of the input observations specified by the `obsidXXXX` keywords. Similarly, positional keywords `RA_NOM`, `DEC_NOM` refer to an average of requested pointings for the input observations, while `RA` and `DEC` are the average of reconstructed positions. These are principally useful for archive queries on position. The actual WCS of the constructed cubes will be convolved from the pointing accuracies of the individual input observations.



## 2.3 Content of the HPDPs

### 2.3.1 Delivered contents, format and structure

The output products for every processed spectral map include:

- 3-D **spectral cubes** in FITS format.
- 1-D spectral cube average **spectra** in FITS format.
- 2-D integrated line intensity or frequency channel **images** FITS format.
- Browse (preview) plots of the 1-D spectra in JPG format.
- Browse (preview) plots of the 2-D images in JPG format.

For each observation up to 9 HPDPs written to FITS are available:

- Spectral cubes: 2 spectrometers  $\times$  2 sidebands = 4 spectral cubes.
- Spectral averages: 2 spectrometers  $\times$  2 sidebands = 4 spectra.
- Integrated line intensity *or* channel map: 1 spectrometer (WBS) = 1 map.

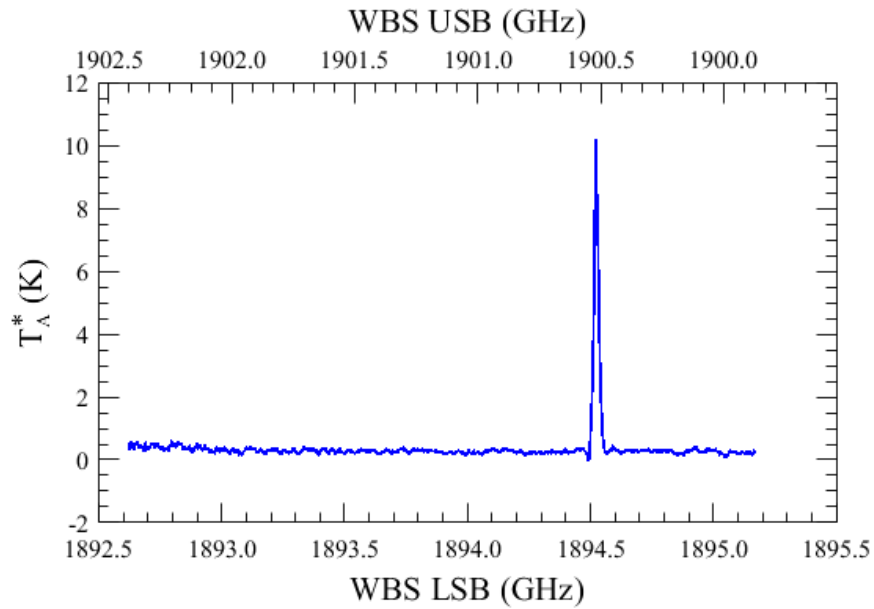
When HRS data are not available, the number of WBS-only products is 5 (2 cubes + 2 spectra + 1 map).

Preview plots are provided as jpeg's for the cube average spectra and for the integrated intensity or channel map.

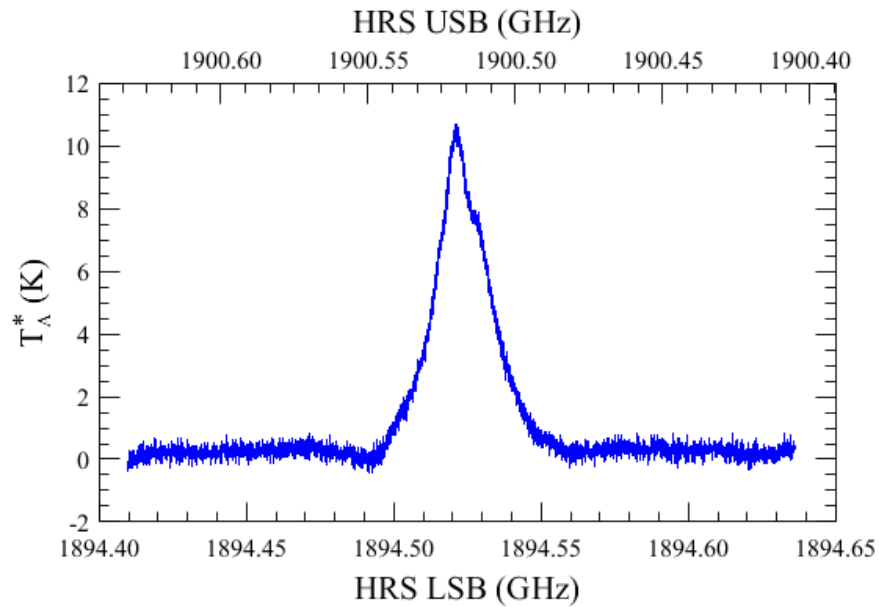
- The average spectra have the USB and LSB frequencies on the same plot. For example:



### 1342213713 NGC7023-3

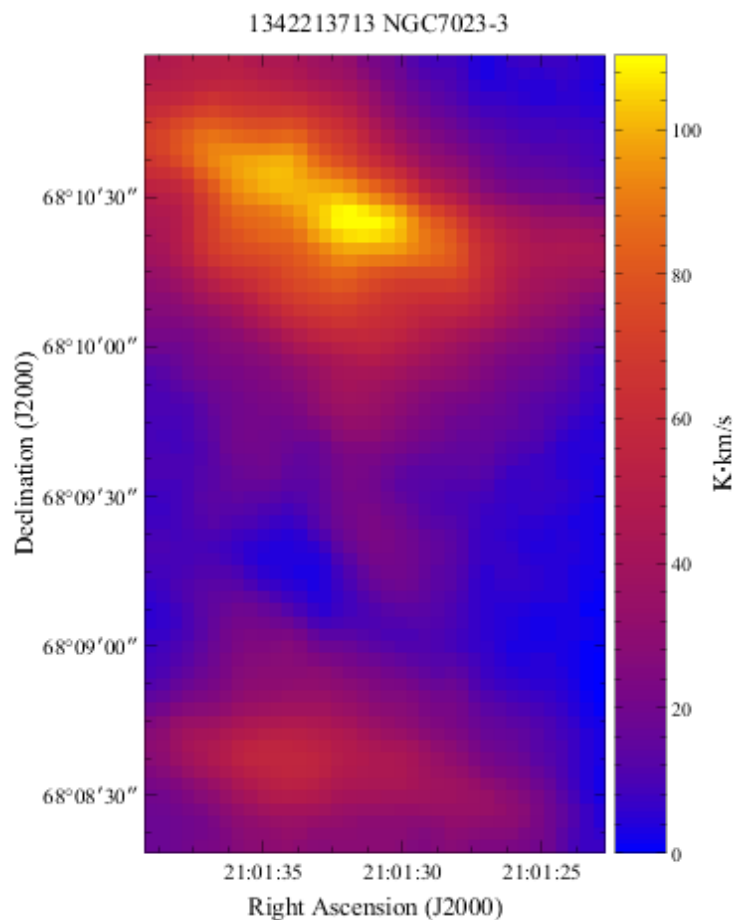


### 1342213713 NGC7023-3



Please note that for Band 1a and 4b, additional information was added to the plot, which identifies regions of the spectrum that may have been affected by spurs (red lines on the plot).

- 1 image plot for the integrated line intensity map from the WBS, if it is also present as a FITS file. Plots use the “pastel” color table in HIPE, with a 99.5% intensity cut level, and a color bar. *The plotting area is set so that proportions are as on the sky.* This means that the HPDP image plots will be of variable size (compared to SPG browse product intensity map plots, which are always scaled to the same size). For example:



The set of HPDPs are available by direct download<sup>2</sup>, or via the user interfaces of the NASA InfraRed Science Archive (IRSA) and the Herschel Science Archive (v8.2 or later).

Directly downloadable products<sup>3</sup> are packaged in compressed (zipped) TAR archive files.

<sup>2</sup> <http://www.cosmos.esa.int/web/herschel/highly-processed-data-products>

<sup>3</sup> [http://archives.esac.esa.int/hsa/legacy/HPDP/HIFI/HIFI\\_spectral\\_maps/](http://archives.esac.esa.int/hsa/legacy/HPDP/HIFI/HIFI_spectral_maps/)





There are 9 files for the Band 6 and 7 observations (6a.zip, 6b.zip, 7a.zip, and 7b\_a.zip through 7b\_f.zip), 3 for Band 1a (1a\_b.zip, 1a\_c.zip and 1a\_d.zip), 1 for Band 2a (2a.zip), and 2 for Band 4b (4b\_a.zip and 4b\_b.zip). The division of the Band 7b maps keeps the file volumes below 3.5 Gb each, for most efficient data transfer. Appendix A2 gives the list of obsids in each zip file.

### 2.3.2 File naming

The FITS and JPG files for each individually processed observation are named first by **obsid**, followed by information about the data. The filenames have the form

[obsid] \_ [dataType][Spectrometer Data Source] \_ [HIFI Sub-band] \_ [LO frequency] \_ [processDate]. [filetype]

The sub-fields of the file names are not always in the same strict order for all observations, but the information is always transparent. As an example:

1342213340\_cubeWML\_7b\_1899\_2016-08-31T21-29-15UTC.fits

For co-added maps (mosaics), the obsid is replaced by the object name, and an identifier “multiObs” is included in the file name. For example:

S140IRS1\_6a\_1494GHz\_multiObs\_cubeHML\_2016-01-19T09-00-00UTC.fits

Some products have “ContamCorr” in the file name, just before processDate (see Sec. 2.2.1).

**dataType** will be one of: cube, averageSpectrum, integratedMap, or channelMap.

**Spectrometer Data Source** will be one of:

WBS = HIFI WBS or HRS = HIFI HRS

WMU = HIFI **W**BS spectrometer, **M**erged polarizations, **U**pper sideband frequencies.

WML = HIFI **W**BS spectrometer, **M**erged polarizations, **L**ower sideband frequencies.

HMU = HIFI **H**RS spectrometer, **M**erged polarizations, **U**pper sideband frequencies.

HML = HIFI **H**RS spectrometer, **M**erged polarizations, **L**ower sideband frequencies.

**HIFI Sub-band** refers to one of HIFI’s 14 LO sub-bands (not to be confused with the spectrometer IF sub-bands).

**LO frequency** is the average measured frequency of the observation. It is not the observed sky frequency (which has two ranges, of the upper and lower sidebands). However the LO frequency will always be within several GHz of the line frequency of interest, to aid in browsing. For the [C II] line at a rest frequency of 1900.5 GHz, for example, a product named with “\*\_7b\_1898\_\*” will cover that frequency in the upper sideband. Naturally, the



original observer will have used an LO frequency that takes into account the source velocity or redshift, if known when the observation was planned.

**filetype** is either .fits (real data) or .jpg (preview image).

All observations have WMU and WML cubes and spectral averages from each (4 files). If a spectral feature is present, then there will also be a single integrated line intensity map, otherwise a channel map of a continuum or zero baseline (1 file), derived from a WBS cube. If the observation also employed the HRS, then HMU and HML cubes and their spectral averages have also been produced (4 files).

Thus every obsid is accompanied by as many as 9 files (WBS, HRS, with spectral line(s) detection), and as few as 5 data FITS files (WBS only).

A JPG plot is produced from cube averaged spectra for both sideband frequency scales and for each of the WBS and (if present) HRS (so either 1 or 2 plots). A single JPG plot is produced for the line intensity map, with J2000.0 coordinates and an intensity scale (units  $\text{K km s}^{-1}$ ).

### 2.3.3 HPDP queries in the HSA and IRSA

Available HPDPs can be queried through the HSA interface since version 8.2. Query results by position, target name, or obsid indicate if HPDPs are available in a manner similar to the UPDPs, with a clickable column that will open an HPDP summary window. The HPDP summary window for each obsid is similar to that of the UPDPs, containing a title and short summary, and links to the set all FITS and JPG products for that obsid (or mosaicked map), and this Release Note. Similar to the SPG Browse Products for each obsid, the set of HPDPs is downloadable as a tar file with right click.

Similarly, all HPDPs can be queried and browsed by position or target name in IRSA, starting in December 2016.

While the HSA and IRSA user interfaces are most efficient for browsing, filtering, and requesting individual and sets of products, the most efficient means to download the full sets by HIFI band can be done at <http://www.cosmos.esa.int/web/herschel/highly-processed-data-products> as described in Sec. 2.3.1. The list of obsids contained in each compressed file archive is given in the Appendix.

## 3 Acknowledgements and Referencing

HPDPs constructed from spectral mapping observations in Bands 6 and 7 have been carried



out during the post-operations phase by Pat Morris (NHSC, lead), Sylvie Beaulieu (Univ. Waterloo), and Scott Jones (Univ. Waterloo). HPDPs for Bands 1a, 2a and 4b have been carried out by Sylvie Beaulieu (Herschel Science Centre).

Support was provided by Ian Avruch (SRON), Russ Shipman (SRON) and David Teyssier (HSC).

If you are able to use any of the HPDPs in your work, please reference this document, “Herschel/HIFI Spectral Map Highly Processed Data Products Release Note”, P. Morris, S. Beaulieu, & S. Jones, 2016 Herschel-HSC-Doc 2122 v1.2.



## Appendices

### A1. Mapping Observations with spectral feature contamination detected in sky reference measurements.

1. Corrected maps – see Sec. 2.2.1.

Band 7b

1342204527	1342216761	1342244097	1342268765	1342270625
1342216756	1342216762	1342250412	1342269940	
1342216757	1342216769	1342250414	1342269941	
1342216758	1342229851	1342250415	1342270620	
1342216759	1342239625	1342250966	1342270621	
1342216760	1342243684	1342250967	1342270624	

2. Uncorrected maps.

Band 1a

1342190831	1342190832	1342205282	1342205283	1342205489
1342205504	1342205505	1342205524	1342205525	1342207574
1342230181	1342231779	1342239611	1342250745	

Band 4b

1342192235	1342243698
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Band 6a

6b

7a

7b

1342205892	1342200757	1342256468	1342201815
1342205893	1342223434	1342256469	1342205481
1342205894	1342223435		1342208109
1342206599	1342255772		1342246344
1342216664	1342255773		1342257671



## A2. Compressed Archive (TAR) File Properties

\*.zip files at <http://www.cosmos.esa.int/web/herschel/highly-processed-data-products>

**1a\_a.zip:** 66 observations, 794 products, 2.2 Gb compressed

1342180459	1342180460	1342180463	1342180464	1342180465
1342180545	1342190828	1342190831	1342190832	1342192209
1342192210	1342192211	1342194179	1342201689	1342201690
1342201692	1342201694	1342201695	1342201696	1342201697
1342202034	1342202035	1342202036	1342203189	1342203731
1342203752	1342203753	1342205275	1342205276	1342205277
1342205282	1342205283	1342205489	1342205504	1342205505
1342205524	1342205525	1342207574	1342207576	1342208036
1342208037	1342208047	1342210204	1342210209	1342210214
1342210219	1342210224	1342210755	1342210756	1342210763
1342210764	1342213739	1342216309	1342216310	1342216355
1342218528	1342218944	1342219183	1342219192	1342219193
1342219194	1342227173	1342227194	1342230181	1342230185
1342230206				

**1a\_b.zip:** 18 observations, 218 products, 0.6 Gb compressed

1342231522	1342231523	1342231529	1342231777	1342231778
1342231779	1342232814	1342232815	1342235813	1342235825
1342235826	1342235827	1342238589	1342238590	1342238592
1342238625	1342239611	1342239612		

**1a\_c.zip:** 36 observations, 433 products, 1 Gb compressed

1342242812	1342242813	1342242814	1342242815	1342242818
1342242819	1342244307	1342244309	1342244310	1342244311
1342244312	1342244315	1342244317	1342244318	1342244803
1342244804	1342245386	1342245592	1342245593	1342247073
1342247074	1342247191	1342247846	1342248922	1342250724
1342250736	1342250745	1342251218	1342251219	1342256420
1342256428	1342268769	1342269945	1342269946	1342269947
1342269948				

**2a.zip:** 53 observations, 640 products, 0.2 Gb compressed

1342190199	1342190200	1342190237	1342190238	1342190243
1342190734	1342190735	1342190736	1342194152	1342201516



1342201520	1342202039	1342202040	1342202043	1342202045
1342221441	1342221442	1342222325	1342222331	1342222795
1342223446	1342225911	1342225912	1342225913	1342226025
1342227407	1342227408	1342228579	1342229896	1342229898
1342230302	1342230306	1342231500	1342231507	1342231804
1342232691	1342232692	1342233892	1342233893	1342233894
1342235089	1342235810	1342238181	1342238518	1342239300
1342239593	1342239596	1342243671	1342243673	1342244029
1342244031	1342244036	1342244813		

**4b\_a.zip:** 32 observations, 385 products, 1.7 Gb compressed

1342190873	1342192235	1342192260	1342192261	1342192262
1342192263	1342194167	1342201804	1342201805	1342201806
1342201807	1342201808	1342201809	1342201810	1342201811
1342201812	1342204686	1342206121	1342206125	1342206387
1342206392	1342206393	1342206394	1342207370	1342207371
1342207373	1342207383	1342207386	1342208085	1342208091
1342210169	1342210199			

**4b\_b.zip:** 39 observations, 473 products, 1.2 Gb compressed

1342213332	1342214416	1342214421	1342215970	1342215971
1342217728	1342218912	1342218913	1342218916	1342218918
1342219243	1342219244	1342219246	1342219249	1342219304
1342219305	1342219306	1342219307	1342231497	1342231498
1342239309	1342243698	1342247499	1342247500	1342247501
1342247502	1342249021	1342249853	1342249854	1342249864
1342250209	1342253593	1342259750	1342268604	1342269963
1342269964	1342269965	1342269966	1342270617	

**6a.zip:** 89 observations, 1139 products, 2.4 Gb compressed, 6.5 Gb uncompressed

1342201772	1342225947	1342231797	1342246052	1342255769
1342203920	1342226056	1342232677	1342246532	1342255770
1342204691	1342227412	1342234008	1342247032	1342256438
1342204693	1342227413	1342235056	1342247490	1342256439
1342204694	1342229774	1342235775	1342248394	1342257668
1342204695	1342229951	1342238220	1342248890	1342257859
1342205892	1342229952	1342238627	1342249404	1342259744
1342205893	1342229953	1342239298	1342249405	1342262677
1342205894	1342229954	1342239588	1342250479	1342262678



1342206599	1342229955	1342239591	1342250962	1342268188
1342216664	1342229956	1342243668	1342250963	1342268195
1342216665	1342230285	1342243669	1342250964	1342268196
1342221444	1342230286	1342244070	1342252119	1342268197
1342222360	1342230287	1342244071	1342253713	1342268198
1342222361	1342230290	1342244083	1342253714	1342269424
1342223444	1342230300	1342244622	1342254396	1342271188
1342225945	1342231466	1342244623	1342254900	1342271189
1342225946	1342231468	1342245369	1342255763	

Co-added (mosaic) observations: CRL 2688 1495 GHz, CRL 618 1495 GHz, G34.3+0.1 1495 GHz, IRC+10216 1495 GHz, NGC 6302 1495 GHz, NGC 7023 1495 GHz, NGC 7027 1495 GHz, omicron Ceti 1495 GHz, Orion KL 1495 GHz, S140 IRS1 1494 GHz.

**6b.zip:** 52 observations, 576 products, 2.0 Gb compressed, 4.5 Gb uncompressed

1342178894	1342199105	1342214462	1342233003	1342251044
1342179301	1342199106	1342214463	1342235060	1342251054
1342179626	1342199107	1342214464	1342238544	1342251055
1342189649	1342200757	1342218907	1342238545	1342255772
1342190762	1342203949	1342218908	1342238546	1342255773
1342190765	1342207688	1342220507	1342245622	1342262556
1342190811	1342210195	1342222371	1342245623	1342262557
1342192306	1342210196	1342223434	1342245624	1342268212
1342192307	1342212180	1342223435	1342247482	
1342192308	1342212185	1342231769	1342247483	
1342194175	1342212186	1342231772	1342247484	

**7a.zip:** 16 observations, 187 products, 0.1 Gb compressed, 0.4 Gb uncompressed

1342179787	1342190806	1342218424	1342218424	
1342189628	1342192247	1342256468	1342256468	
1342189630	1342192248	1342256469	1342256469	
1342190805	1342194173	1342267146	1342267146	

**7b\_a.zip:** 51 observations, 553 products, 1.9 Gb compressed, 7.0 Gb uncompressed

1342178908	1342194156	1342199675	1342201819	1342203242
1342178909	1342197935	1342199676	1342201836	1342203243
1342179789	1342197936	1342199677	1342201837	1342203244
1342190779	1342197937	1342201642	1342201838	1342203245
1342190780	1342197938	1342201660	1342201839	1342204525
1342190781	1342197939	1342201661	1342201846	1342204526



1342190782	1342197940	1342201662	1342201847	1342204527
1342190783	1342199671	1342201663	1342203238	
1342190786	1342199672	1342201815	1342203239	
1342190787	1342199673	1342201816	1342203240	
1342192665	1342199674	1342201818	1342203241	

Co-added (mosaic) observations: DR21 1898 GHz, NGC 7023 1898 GHz

**7b\_b.zip:** 72 observations, 570 products, 3.6 Gb compressed, 55.6 Gb uncompressed

1342205481	1342208552	1342213156	1342216758	1342219316
1342205482	1342208555	1342213338	1342216759	1342219317
1342205541	1342208556	1342213339	1342216760	1342219318
1342206635	1342210296	1342213340	1342216761	1342219319
1342206636	1342210297	1342213364	1342216762	1342219505
1342206639	1342210788	1342213702	1342216769	1342219519
1342206647	1342210793	1342213712	1342216770	1342220470
1342206648	1342210794	1342213713	1342216771	1342222363
1342206649	1342210795	1342213741	1342216783	1342225907
1342206650	1342210796	1342214315	1342216792	1342225908
1342206651	1342210797	1342214476	1342216793	1342225909
1342206652	1342210798	1342214477	1342218085	1342226035
1342208108	1342210799	1342216755	1342218524	
1342208109	1342210800	1342216756	1342218525	
1342208550	1342213155	1342216757	1342219309	

**7b\_c.zip:** 54 observations, 538 products, 1.4 Gb compressed, 4.3 Gb uncompressed

1342226036	1342229771	1342230227	1342231459	1342235084
1342226053	1342229844	1342230228	1342231461	1342235792
1342229760	1342229845	1342230229	1342231462	1342235804
1342229761	1342229848	1342230230	1342231794	1342235805
1342229762	1342229851	1342231444	1342231795	1342238183
1342229763	1342230221	1342231448	1342232659	1342238567
1342229764	1342230222	1342231451	1342234020	1342238579
1342229765	1342230223	1342231453	1342235020	1342238580
1342229766	1342230224	1342231454	1342235077	1342238660
1342229769	1342230225	1342231455	1342235078	1342238661
1342229770	1342230226	1342231457	1342235079	

**7b\_d.zip:** 37 observations, 344 products, 3.4 Gb compressed, 7.5 Gb uncompressed





1342239296	1342242799	1342244094	1342244533	1342244581
1342239618	1342243680	1342244097	1342244534	1342244582
1342239619	1342243681	1342244098	1342244535	1342244590
1342239623	1342243684	1342244099	1342244536	1342244598
1342239625	1342244085	1342244102	1342244569	1342244954
1342242490	1342244087	1342244391	1342244576	
1342242491	1342244091	1342244531	1342244577	
1342242492	1342244092	1342244532	1342244580	

**7b\_e.zip:** 30 observations, 313 products, 3.2 Gb compressed, 5.1 Gb uncompressed

1342244957	1342246343	1342247521	1342248750	1342249658
1342245313	1342246344	1342247522	1342248751	1342250412
1342246016	1342246537	1342248396	1342249559	1342250414
1342246027	1342246538	1342248399	1342249578	1342250415
1342246341	1342247034	1342248400	1342249579	1342250418
1342246342	1342247520	1342248403	1342249654	1342250419

**7b\_f.zip:** 123 observations, 1042 products, 3.3 Gb compressed, 40.9 Gb uncompressed

1342250420	1342251574	1342253692	1342263050	1342266596
1342250966	1342251575	1342253693	1342263051	1342266600
1342250967	1342251576	1342253825	1342263052	1342266601
1342250968	1342251577	1342253827	1342263053	1342266602
1342250974	1342251578	1342254892	1342263054	1342266603
1342251029	1342251579	1342254896	1342263055	1342266604
1342251073	1342251581	1342255760	1342263056	1342266605
1342251084	1342251583	1342255761	1342263057	1342266606
1342251523	1342251584	1342256342	1342263058	1342268686
1342251524	1342251585	1342256343	1342263059	1342268687
1342251526	1342252140	1342256344	1342263060	1342268688
1342251529	1342252141	1342256345	1342263061	1342268689
1342251531	1342252142	1342256461	1342263062	1342269426
1342251562	1342252143	1342257670	1342263063	1342269430
1342251563	1342252144	1342257671	1342263064	1342269940
1342251564	1342252145	1342257674	1342263065	1342269941



1342251565	1342252146	1342257857	1342263066	1342270381
1342251566	1342252147	1342259732	1342263067	1342270382
1342251567	1342252186	1342259735	1342263069	1342270620
1342251568	1342252187	1342259736	1342263070	1342270621
1342251569	1342252188	1342263044	1342263437	1342270624
1342251570	1342252189	1342263045	1342263438	1342270625
1342251571	1342252190	1342263047	1342263440	1342270626
1342251572	1342252191	1342263048	1342263441	
1342251573	1342252193	1342263049	1342263442	