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DOCUMENT

HIFI Products Explained

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1 INTRODUCTION

This document explains the content of the various products available in the Herschel Science Archive[1] (HSA) for the HIFI instrument. There are indeed multiple ways to access the HIFI products and multiple choices on which products to use. We describe here what is contained in these choices, and highlight which products are the most useful for the different types of observation and science.

Section 2 gives an overview of the possible product flavours offered in the HSA. Those are then described on more details in sections 3 to 6. Section 7 will provide recommendations on the best product to use for a particular observing mode. Finally, we give in the appendix further information regarding meta-data and FITS keywords contained in the HIFI products, as well as how the products can be used in other standard software for heterodyne data analysis such as GILDAS/CLASS.

Note that this document does not discuss in depth the residual artefacts present in the HIFI pipeline products. While science readiness of the HIFI products is addressed in section 7, the reader should refer to the HIFI Quick Start Guide[2], and the HIFI Handbook[3] for further details.

2 The HIFI Products in the HSA

The bulk of the HIFI products present in the HSA are the result of the processing of the HIFI telemetry data with the standard pipeline coded in the Herschel Interactive Processing Environment[4] (HIPE). Those products are also referred to as Standard Product Generation (SPG) output, and are described in the following section.

Additional HIFI products are also served by the HSA:

- User-Provided Data Products (UPDPs) are HIFI products delivered by external users, and corresponding in most cases to observations performed in the context of Guaranteed or Open Key Programmes. These are further described in section 4.
- Highly-Processed Data Products (HPDPs) are products derived from standard pipeline products, either as complementary information relevant to the archive users, or as

[1] http://archives.esac.esa.int/hsa/whsa/index.html#home
[2] http://herschel.esac.esa.int/twiki/pub/Public/HifiDocsEditableTable/HIFI_quickstart_guide.pdf
[3] http://herschel.esac.esa.int/twiki/pub/Public/HifiDocsEditableTable/hifi_handbook.pdf
[4] https://www.cosmos.esa.int/web/herschel/hipe-download

improvement of the pipeline products themselves, usually curated by instrument experts. These are further described in section 5.

- Ancillary Data Products (ADPs) are products compiling complementary or historical information relevant to HIFI both from the scientific or the engineering perspective. This is for example where information about the HIFI beams is recorded. These are further described in section 6.

Note that UPDPs and HPDPs may not only be in the form of spectra or spectral cubes, but can also be catalogues, models, etc.

3 Description of the HIFI Pipeline Products

All Herschel HIFI data come from the HSA in the form of a directory-tree structure organised by processing level. When inspected in HIPE, those levels are referred to as context. A context is a special kind of product, linking other products in a coherent description, and can be thought of as an inventory or catalogue of products. The HIFI processed observation consists of many such contexts enclosed within one Observation Context. The Observation Context is therefore a product container, which is comprised of various layers of science data, auxiliary data, calibration data, and other information about the observation in an onion skin type of structure.

Each HIFI Observation Context is the outcome of the Standard Product Generation (SPG) run in bulk with a given version of the Herschel Common Software System (HCSS). The SPG version, present in the metadata of any Observational Context, reflects the HCSS version of the reprocessing. For HIFI the vast majority of the products served in the HSA have been processed with version 14.1 of the HIPE. About a dozen observations had to be reprocessed with HIPE 14.2 to fix a bug.

3.1 Individual level products from the HIFI observation context

The HIFI data has been processed via the HIFI pipeline in increasing levels of processing, Level 0 being the lowest level products available to archive users, up to the Level 2.5 being the final products. The Science data are found in the Level 0, 1, 2, and 2.5 Contexts and are the result of each stage of the pipeline (data at Level 0.5 are removed in order to save memory, as they are less relevant to the archive user). The content of each level is described as follows. Further details can be found in the HIFI Data Reduction Guide[5] (DRG) and in the HIFI Pipeline Specification document[6].

[5] http://herschel.esac.esa.int/hcss-doc-15.0/print/hifi_um/hifi_um.pdf#hifi-um
[6] http://herschel.esac.esa.int/hcss-doc-15.0/load/hifi_pipeline/html/hifi_pipeline.html

3.1.1 Level 0

Level 0 is the rawest form of the HIFI processed data available for inspection. It has been minimally manipulated into a so-called *HifiTimelineProduct* (HTP). These data contain all the readouts of the HIFI spectrometers (WBS and HRS, for both H and V polarization respectively), as well as satellite pointing information associated with them. They have undergone several sanity checks to flag any incidences such as HouseKeeping (HK) parameters being anomalous. Additionally, information from the *Uplink* product, which contains information fed into, and calculated by HSpot[7] (e.g. spacing between scan legs in a map) is copied to the HTP and its metadata. Level 0 data have units of counts versus channel number.

3.1.2 Level 0.5

At this stage, the pipeline converts the raw spectrometer output into the basic spectral elements of frequency and flux as a function of time. Since the two spectrometers are fundamentally different, there are two separate pipelines: one for the WBS spectrometer and one for the HRS spectrometer. The result of the Level 0.5 pipeline is a time series of integrations per backend spectrometer in instrumental counts as functions of frequency. These products are removed from the observation as soon as the Level 1 products are successfully generated. They can, however, be re-generated if needed. The only product retained in the Level 0.5 is the quality information of the WBS-H and WBS-V comb, and zero quality checks, which are stored in a Quality Product.

3.1.3 Level 1

The purpose of the Level 1 pipeline is to flux-calibrate the HIFI data using the internal load measurements, and to combine the different observing phases corresponding to the referencing scheme that was used for the observation. The observed frequencies are put into the Local Standard of Rest (LSR) velocity frame for fixed targets, and in the reference frame of the moving targets for Solar System Objects (SSOs). It is in this level of processing that integrations taken at different times are then combined. The quality product at Level 1 contains, for each spectrometer used in the observation, the results of the phase checks done by the Level 1 pipeline. At the end of this step of the pipeline, all science spectra have been flux-calibrated to antenna temperature T'_A (in K) and the intermediate frequency (IF) has been adjusted to the LSR velocity (V_{LSR}) reference (still in MHz). At this stage, separate integrations have not been co-added, and calibration spectra (e.g., hot / cold loads) are still present in the timeline of the observation.

[7] http://herschel.esac.esa.int/twiki/pub/HSC/LegacyManuals/hspot-help.pdf

3.1.4 Level 2

The Level 2 pipeline contains spectra for each spectrometer used in the observation. Level 2 data are converted to the antenna temperature scale T_A^* (in K), which corrects for rearward beam losses, and to sky frequency (GHz). Due to the Double Sideband (DSB) nature of the HIFI detectors (see Section 2.1.2 of the HIFI Handbook), products need to be generated both in USB and LSB frequency scales respectively. Spectra are averaged together, for each spectrometer, for each LO setting, and each spatial position in the observation. This results in a single spectrum (for each spectrometer) for point mode observation, individual LO setting for spectral scans, and individual spectra per position and LO setting for maps.

The result of the Level 2 pipeline for non-mapping mode data will be co-added spectra listed either in USB frequency scale or LSB frequency scale with the line fluxes calibrated on the HIFI antenna temperature scale T_A^*. In the vast majority of the cases, the Level 2 products are already appropriate for scientific analysis. In some cases, however, residual instrument artefacts are still present in the data and need to be removed.

3.1.5 Level 2.5

The Level 2.5 pipeline combines the Level 2 products into final observation products and depends on the observing mode. The products created at the end of the Level 2.5 are used to create the "stand-alone" browse products (see also next section).

For **Point Mode**, the spectra are subband stitched, folded (in the case of Frequency Switch), and converted to Simple Spectrum format. WBS spectra have their respective subbands overlapping at the band edges, and are always stitched. HRS data are stitched only in the case that subbands overlap by at least 2 channels in frequency. Those products use the *Simple Spectrum* format, which is simply flux as a function of frequency.

For **Spectral Mapping Mode**, the Level 2.5 HTPs contain spectra that are stitched and folded (in the case of Frequency Switch). A *cubesContext* is also produced containing cubes constructed from the stitched and folded (if applicable) spectra. Stitching of HRS data is done as for Point Mode observations. In the case of mapping observations carried out with a non-zero rotation angle (i.e. not along the RA/Dec frame), a *cubesContextRotated* is also produced, which contains cubes generated from the Level 2.5 HTPs and with the rotation angle applied.

For **Spectral Scan Mode**, the Level 2.5 contains a deconvolved Single Sideband spectra for each polarisation. The sideband deconvolution is performed following the conjugate gradient method described in Comito & Schilke 2002[8]. The deconvolution ignores channels flagged as anomalous, allowing in the case of the HIFI products to discard all major spectral ghosts

[8] http://cdsads.u-strasbg.fr/abs/2002A%26A...395..357C

(spurs) still present in the Level 2 data.

3.2 The HIFI stand-alone browse products

The so-called stand-alone browse products correspond to an automated extraction of some of the results from the standard pipeline, which are made available for every observation. For HIFI these are simply the Level 2.5 products. In order to offer a quick look to the data, those are turned into dedicated images (*postcards*), which are displayed in the HSA User Interface (HUI).

- For **Point Mode**, the postcard shows some of the main observation parameters together with two plots of unstitched Level 2 WBS spectra with the H-polarisation to the left and the V-polarisation to the right. They will list the upper sideband and the lower sideband frequency scales. HRS spectra are not shown. Unless the spectral line is very strong, the images at first glance will only show noise.
- For **Mapping Mode**, the postcard shows sets of map-averaged Level 2 spectra for each subband along with the integrated map for that subband. For each subband, there are images for each polarisation. The spectra are formed by averaging all spectra per map position, while the integrated map is the full integration over the entire subband. The spectra and integrated maps are created with no correction done for any baseline issues. In the cases that the baseline suffers from drifts and/or standing waves, the continuum will dominate the map. The stand-alone browse products associated with the postcards are the spectral cubes with subbands merged per polarisation and spectrometer.
- For **Spectral Scan Mode**, the postcard shows the single sideband solution after deconvolution of the Level 2 WBS spectra. No baseline correction has been done prior to deconvolution. The H-polarisation is shown to the left and the V-polarisation to the right. The gap between the sidebands is shown as a line at 0 K. Note that the images are at significantly lower resolution than the information present in the data and only provide a rough indication of what the data can reveal.

In Table 1 we give the file naming convention of the products that will be provided as a tar-ball when the stand-alone browse products are downloaded from the archive.

Table 1: Naming convention for HIFI stand-alone browse products

Instrument mode	FITS filename
HIFI single point	hhifi[hrs,wbs][h,v][usb,lsb]<obsid>_25ssv20_<time>.fits.gz
HIFI spectral scan	hhifiwbs[h,v]usb<obsid>_25htpv20_<time>.fits.gz
HIFI spectral mapping	hhifi[wbs,hrs][h,v][usb,lsb]<subband><obsid>_25cube_<time>.fits.gz

3.3 The HIFI calibration products

The Calibration products contain all of the data passed to the pipeline for calibration (*Downlink*), the calibration files created by the pipeline (*Pipeline-out*), and information about how the observation was carried out (*Uplink*).

Each of these contexts contains numerous products, which are described in details in section 6.5 of the HIFI Handbook, and section 3.3 of the HIFI DRG:

http://herschel.esac.esa.int/hcss-doc-15.0/load/hifi_um/html/hum_tour_cal.html.

The following products are however of particular interest for users of the archive:

- *Uplink* section: the HifiAORData will compile all parameters set in HSpot in order to execute the observation.
- *Pipeline-out* section: the ReferenceSpectra products contain the isolated OFF position spectra, and the Uncertainty products offer the flux calibration uncertainty budget. Note that both products are also provided as a stand-alone HPDP – see section 5.
- *Downlink* section: of particular interest in this node are the sideband ratio, telescope beam coupling efficiencies (main beam efficiency, aperture efficiency), and beam sizes (HPBW) per polarisation and LO frequency.

3.4 Auxiliary products

The Auxiliary Products are a collection of tables containing information on how the observation was planned and carried out. Most of them were not generated by HIFI (e.g. Orbit files, Ephemerides, Spacecraft-related products such as the pointing products, etc), however, this is also where the *HifiUplinkProduct* is stored. The tables are passed to the pipeline during the different levels of processing. For most data reduction, you are unlikely to need to work directly with the Auxiliary Product, but it is helpful to know what and where the usable information is located in this product in case of tailored reductions needing the same information as in the pipeline.

We do not give here details about each product contained in this context. For this, the reader should refer to section 3.5 of the HIFI DRG:

http://herschel.esac.esa.int/hcss-doc-15.0/load/hifi_um/html/hum_tour_aux.html

3.5 Quality context

This Context contains information about the Quality Flags that were raised automatically by the pipeline, as well as the processing log. It is extended in an additional context called the Quality Summary Context, which is generated manually after inspection of the data, and contains complementary information on the data quality.

Further details about the Quality Flags and their relevance for the data exploitation can be found in section 6.3.2 of the HIFI Handbook, as well as section 10.4 for the HIFI DRG:

http://herschel.esac.esa.int/hcss-doc-15.0/load/hifi_um/html/qf.html

3.6 TrendAnalysis context

This Context contains products useful for tracking systematic changes in instrument response over time. Of possible interest to the archive user are the tables stored in the Statistics tables, which contain information about the spectra moments such as mean and noise RMS among others.

We do not give here details about each product contained in this context. For this, the reader should refer to section 3.7 of the HIFI DRG:

http://herschel.esac.esa.int/hcss-doc-15.0/load/hifi_um/html/notes_about_the_trendanalysis_context.html

4 Description of the HIFI User-Provided Data Products (UPDPs)

4.1 Scope

User-Provided Data Products[9] (UPDPs) are sets of products delivered by observing time

[9] https://www.cosmos.esa.int/web/herschel/user-provided-data-products

holders. In the vast majority of cases those will correspond to data collected in the framework of Guaranteed Time programmes. Since some of those products have been delivered already quite some time ago, they do not always reflect the latest knowledge about the pipeline processing or data calibration. As such they should be used with caution and it is strongly recommended that you read carefully the release notes associated with each of those deliveries.

In order to find out caveats and shortcomings of product generated with earlier versions of the pipeline, please check the following document:
http://herschel.esac.esa.int/twiki/pub/Public/HifiDocsEditableTable/DP-Known-Issues-Old-Products-HIFI.pdf

4.2 The HIFI UPDPs

Because UPDPs are provided by external users on a best effort basis, the complete list of products hosted in the HSA will increase with time. As such we do not provide here an exhaustive list of UPDPs currently available for HIFI. Instead the user should refer to the UPDP web page[8], and check the respective release notes for details about the content of each delivered dataset.

One of the UPDPs we offer for HIFI, however, was prepared by the Herschel Science Centre. We give thereafter a short description of its purpose and content.

- Non-Averaged Level 2 spectra: This UPDP contains the non-averaged Level 2 spectra for all successful HIFI Point Mode observations. They are provided for all available spectrometer and sideband available in a given observation in the form of FITS files containing the so-called HIFI Timeline Products. Such products are particularly relevant in case users would like to make their own assessment of which data might or might not be eligible for averaging of all individual spectra.

5 Description of the HIFI Highly-Processed Data Products (HPDPs)

5.1 Scope

Highly Processed Data Products[10] (HPDP) are sets of products generated by expert scientists, generally from the Herschel Science Centre (HSC), the NASA Herschel Science Center (NHSC), and the Instrument Control Centres (ICC). In the case of HIFI, emphasis is given to products suffering from residual instrument artefacts, mostly in the form of baseline

[10] https://www.cosmos.esa.int/web/herschel/highly-processed-data-products

distortion and standing waves. The provided products in those cases are therefore baseline-subtracted versions of the pipeline products. Other HPDPs offer informati0n that can be considered more complementary than quality-enhanced.

5.2 The HIFI HPDPs

We list in the following the HIFI HPDPs currently served by the Herschel Science Archive:

- HIFI Reference Position Spectra Products: This HPDP compiles all HIFI reference position spectra (also called “OFF positions”) obtained in observations making use of an observing mode for which such data are relevant. These spectra are already generated by default in the pipeline processing, and are stored in products of the calibration context in a format corresponding to the ON-target Level 2 products. The data products provided in this HPDP archive, however, are slightly evolved versions of those spectra, aligned with the structure and processing assumptions applying to the ON-target Level 2.5 products of the HIFI observation contexts.
- HIFI Uncertainty Table Products: This HPDP compiles all HIFI Flux Calibration Uncertainty Tables. Those tables are already provided in the Calibration context of the any observation, but they are provided here as stand-alone to ease their access without having to download the whole observation context.
- Baseline-corrected Spectral Maps: This HPDP provides expert-reduced versions of the HIFI spectral cubes, with particular emphasis in the correction of residual baseline artefacts, and the application of optimal grid cell sizes in the generation of the revisited cubes.
- Baseline-corrected Spectral Scans: This HPDP provides expert-reduced versions of the HIFI Spectral Scans, with particular emphasis in the correction of residual baseline artefacts. They provide separate products for baseline-corrected and isolated continuum deconvolved spectra, which can be used for different scientific applications.
- HIFI Spectral Line Catalogue: This HPDP provides a line catalogue extracted from a large number of HIFI Spectral Scans.

6 Description of the HIFI Ancillary Data Products (ADPs)

6.1 Scope

Ancillary Data Products[11] (ADPs) are data (products, tables, plots, etc) generated in the course of the different phases of the Herschel mission which are not necessarily linked to a

[11] https://www.cosmos.esa.int/web/herschel/ancillary-data-products

particular observation in the HSA, but which contain valuable additional information. For HIFI, ADPs of particular interest are e.g. the planetary models used to calibrate the instrument, or the instrument beams.

6.2 The HIFI ADPs

We list in the following the HIFI ADPs currently served by the Herschel Science Archive:

- Model of Mars emission for HIFI calibration: this Ancillary Data Product provides the Mars surface model generated for each particular Martian observations performed with HIFI (model by Lellouch & Moreno) – see also https://www.cosmos.esa.int/web/herschel/calibrator-models
- HIFI beams: this Ancillary Data Product archive contains the information about the HIFI beam patterns, based on observations in-flight on Mars, and an optical model representative of the Herschel telescope, including obscuration, truncation, and measured wave-front errors.
- HIFI System Noise Temperatures: this Ancillary Data Product archive contains information about the System Noise Temperature (thereafter T_{sys}) characteristics of the HIFI instrument.
- HIFI pre-launch gascell products: this Ancillary Data Product compiles all laboratory data obtained during the pre-launch validation campaign with a gascell.
- HIFI WBS SEU monitoring data: this Ancillary Data Product compiles data acquired over the Herschel "cold" and "warm" mission phases with the HIFI Wide-Band-Spectrometer (WBS) during the so-called "Zero" measurements, which were part of the frequency calibration procedure in this spectrometer. These Zero spectra are used to search for cosmic ray (or other high-energy) impacts on the WBS CCDs.
- HIFI Trend Analysis Products: this Ancillary Data Product archive consists of a subset of HIFI HK information measured from the Operational Day (OD) 241 onwards. Up to 269 HK parameters belonging to the various HIFI Sub-Systems are provided as time series, at the data rate applicable at the time of recording. The overall product archive provides both a quick-view of the parameter behaviour with time as plots, as well as the tables themselves for users who need to perform more sophisticated manipulation to the data.
- HIFI On-board Software and LCU Software: these Ancillary Data Products compile a series of On-board software images used both in the Instrument Control Unit and the Local Oscillator Control Unit.

7 Recommended HIFI products

In most cases, the HIFI Level 2 and Level 2.5 products offer a scientific quality that is sufficient to perform directly further data analysis (e.g. line or continuum intensity extraction).

Whenever residual artefacts remain, they are mostly in the form of baseline distortion of various nature, and can be mitigated following the recipes provided in sections 12 and 13 of the HIFI DRG. We estimate that about 20% of the pipeline products could still be affected by such baseline distortions. As most of those cases can be easily dealt with using standard baseline correction tools, those products are not strictly speaking science-ready, they can be considered at least science-friendly.

Since some of those residual imperfections are actually taken care of in the HIFI HPDPs, the best product to use depends basically on the availability or not of the latter. This will be particularly true for Spectral Scans and Spectral Maps taken in bands 6 and 7, which will account for about half of the residual unruly baselines in the pipeline products. Finally, the HIFI products will usually come with two different spectral resolutions (WBS and HRS data) – we leave it to the user's decision as to which of those data are the most suitable to their science (apart from a couple of exceptions, the data quality will be the same in both spectrometers). The following provides a summary of the products that should be used depending on the observing mode.

7.1 Single Point Mode

No dedicated artifact correction has been performed for this mode in the form of HPDPs, and we estimate that about 20% of all pipeline products taken in this mode could still be affected by residual baseline distortion. One can distinguish the following use cases:

- Unless the data are affected by noticeable platforming or parabolic residual baseline distortion (see section 5.3 of the HIFI Handbook), the Level 2.5 stitched products should be used. Otherwise, Level 2 products are best in order to correct for those residual artefacts on a spectrometer subband basis.
- For users wishing to inspect individual Level 2 products prior to their averaging, the SPG products are not suitable, instead the corresponding User Provided Data Products should be used (see section 4).

7.2 Spectral Mapping

While the first use case above also can apply to HIFI spectral mapping data, HPDPs have been generated for a subset of those products, offering a higher quality level than the standard generation products. We recommend the following:

- Whenever an HPDP exist for a given Spectral Map observation, this product should be primarily used. It will offer both a baseline-cleaned version of the cubes, with cube grid cell sizes optimised for S/N, and integrated intensity maps centred on cherry-picked species of interest belonging to the observation. HPDPs for Spectral Maps are provided for about 1/3 of all maps obtained by HIFI, with a particular emphasis on observations taken in bands 6 and 7.
- If HPDPs do not exist, the Level 2.5 spectral cubes should be used.
- Irrespective of the above, should users wish or need to re-build the spectral cubes with either improved baseline quality, or simply different re-gridding dimension, Level 2 products should be used as input for those manipulations.

7.3 Spectral Scans

Due to the reasonably small number of HIFI spectral data observations (~500 over the whole mission), HPDPs have been created for a large fraction of them. As such we recommend using these as the primary products of this observing mode, when available. The HPDPs offer different sub-products depending on the science to be performed:

- If the users are only interested in the line information, the HPDP will provide a baseline-subtracted spectrum for each polarisation. Note that lines seen in absorption in such data will not be directly exploitable unless the continuum information referred to in the next bullet is used.
- If the continuum information (alone or together with the line) is of interest, the HPDP will also contain the respective isolated continuum and the total spectrum – for this latter, the data quality is usually very similar to that of the SPG and users will most likely need to estimate a monotonic model for the continuum based on the provided inputs.
- Finally, if users would like or need to re-build the deconvolved spectra with either revisited baseline correction, or potentially a different deconvolution algorithm, Level 2 products should be used as input for those manipulations, especially in order to benefit from the flags presents in those data.

8 Appendix

8.1 HIFI products in GILDAS/CLASS

Users of HIFI products might be interested to do their data analysis with the CLASS[12] package offered by the GILDAS software. It is now possible (since release Oct15) to directly read both Level 2 and Level 2.5 products in CLASS.

In this process, a portion of the HIFI header information is lost, however, all fundamental HIFI HouseKeeping parameters have been migrated to either the standard CLASS data header, or alternatively, to a newly introduced variable section called R%HEAD%HER%, that contains information specific to HIFI. Noticeable additions are for example those covering the coupling efficiencies and beam properties. Details about the importer and the new variable section can be found in Bardeau et al. (2015)[13].

One of the most powerful pieces of information in the HIFI products are the various flag categories associated to given channels. Those flags are in particular essential in order to perform proper sideband deconvolution in Spectral Scan observations, so that running the equivalent deconvolution in CLASS would fail if those flags would not be ported to the CLASS data. To this end, a new feature has been introduced in the Oct15 CLASS version, that allows to maintain this flag information into the data. These new associated arrays (Bardeau & Pety 2015)[14] now allow mapping of the HIFI flags for artefacts (typically BAD DATA and IGNORE DATA), and for lines (typically LINE and BRIGHT LINE) into dedicated variables, which can then be used to adequately mask the data:

- The BLANKED Associated Array is an integer flag array indicating if the RY values (i.e. the spectrum) should be blanked (1) or not (0).
- The channels that have been identified as containing lines are stored in the array R%ASSOC%LINE%DATA and they can be used to define baseline masking.

Note that these arrays are currently lost when data are smoothed.

[12] https://www.iram.fr/IRAMFR/GILDAS/
[13] http://herschel.esac.esa.int/twiki/pub/Public/HifiDocsEditableTable/class-herschel-fits.pdf
[14] http://herschel.esac.esa.int/twiki/pub/Public/HifiDocsEditableTable/class-associated-arrays.pdf

8.2 List of acronyms

ADP	Ancillary Data Product
DRG	Data Reduction Guide
DSB	Double Sideband
HCSS	Herschel Common Software System
HK	HouseKeeping
HIFI	Heterodyne Instrument for the Far Infrared
HPBW	Half Power Beam Width
HPDP	Highly Processed Data Product
HRS	High Resolution Spectrometer
HSC	Herschel Science Centre
HTP	HIFI Timeline Product
HSA	Herschel Science Archive
HUI	HSA User Interface
ICC	Instrument Control Centre
IF	Intermediate Frequency
LSB	Lower Sideband
LSR	Local Standard of Rest
NHSC	NASA Herschel Science Centre
SPG	Standard Product Generation
SSB	Single Sideband
SSO	Solar System Object
UPDP	User Provided Data Product
USB	Upper Sideband
WBS	Wideband Spectrometer

8.3 FITS keywords in the headers of HIFI products

Table 2: List of main meta-data used in HIFI products from Level 2 and Level 2.5. Note that some meta-data will not be translated into dedicated FITS keywords in the FITS headers. They will be listed in the header as "META_xx", xx being a running number.

HIPE meta-data name	Description	FITS header keyword
aGeom	Telescope geometric aperture area	AGEOM
aorLabel	AOR Label as entered in HSpot	AOR
aot	AOT Identifier	AOT
AOT	Observation template (same as obsMode)	AOT
apertureEfficiency	Telescope aperture efficiency	ETAA
apid	Application Programme Identifier	APID
attitudeQuaternion	Pointing product quaternion applied	ATTQUATR
author	Author of this product	AUTHOR
badLoBand_1/2	Band 1/2 for some spectra has Bad LO	*Not translated*
badPixels	Number of pixels marked as BAD	*Not translated*
backend	Spectrograph: WBS or HRS	BACKEND
Band	Active band	BAND
bbtype	Building Block Type	BBTYPE
beamEff	Beam efficiency used when applying DoMainBeamTemp	ETAMB
beamUsed	beam size in rad used in the convolution	BEAMUSED
bitshift	Bit Shift	*Not translated*
buffer	Integration buffer	*Not translated*
calVersion	HIFI calibration version	CALVERS
cbbTemp	HIFI internal cold black body temperature	CBBTEMP
channels	Number of channels	NCHANNEL
channelSpacing	Delta of frequency in MHz between 2 points of a HRS/WBS spectrum	*Not translated*
checkComb	All COMBs have been fitted	CHKCOMB
checkZero	Flag for all Zero of the observation	*Not translated*
Chopper	Actual chopper position	CHOP
cmd_chopper	Commanded chopper positions	CMDCHOP
CoordinateSystem	Name of reference frame for ephemeris data	COOSYSTM
comoving	Needed for maps of Solar System Objects. Makes a cube with a map centre that follows the coordinates of a moving target. By default this option is not enabled.	*Not translated*
count_ds	Number of datasets in this product	NDATASET
creationDate	Creation date of this product	DATE
creator	Generator of this product	CREATOR
crossStep	Spectral Map sampling if Nyquist not requested	*Not translated*
cusMode	CUS observation mode	CUSMODE
customMapPointNum	Custom map pointing number	CUSPTNUM
darkFlag	spectrum contains saturated dark	*Not translated*

datasetIndices	Indices of the datasets to be used to create a cube. The values set here will override any input from the datasetTypes parameter.	*Not translated*
datasetNumber	Consecutive number of this Dataset within HTP	*Not translated*
datasetsPerBox	Maximum number of datasets per box	*Not translated*
datasetType	type of the datasets to be read e.g. "science"	*Not translated*
dec	Average of dec in level 2 datasets, quantity = deg	DEC
decError	Average of decError in level 2 datasets	CRDER2
decNominal	Requested Declination of pointing, quantity = deg	DEC_NOM
decoff	Sky reference OFF declination J2000.0	DEC_OFF
description	Name of this product	DESC
diplexerCurrent	FPU: The values of diplexerCurrent are out of limit	*Not translated*
driftNoiseContrib	Drift noise contribution, quantity = %	DRFTNSCT
endDate	End date of the observation	DATE-END
equinox	Equinox of celestial coordinate system	EQUINOX
erpFlagged	An ERP flag table has been provided for this obsid	ERPFLAG
fileName	Filename for exporting purposes	FILENAME
flyAngle	Angle of the map respect to ra/dec axes	FLYANGLE
formatVersion	Version of product format	FORMATV
forwardEff	Forward efficiency used when applying DoAntennaTemp	ETAL
freqFrame	Standard of rest for spectral axis	SPECSYS
frequency_monitor	LSU frequency monitor	FRQMONIT
frequencyGroup	Frequency group of this HifiSpectrumDataset	*Not translated*
frequencyWidth	The spacing of the frequency grids after resampling	FRQWIDTH
fresol	Channel separation, frequency units	*Not translated*
frmon_valid	Valid flag for Freq monitor	*Not translated*
gainMethod	Method used to parametrize the sideband gains coefficients	GAINMETH
gyroAttSuspicious	Suspicious quality of the attitude reconstruction	GYR_SUSP
hbbTemp	HIFI internal hot black body temperature	HBBTEMP
HF_AV2_G_FIF1_V	HF_AV2_G_FIF1_V is out of limit for 12 (100%) spectra	*Not translated*
HF_AV2_G_FIF2_V	HF_AV2_G_FIF2_V is out of limit for 12 (100%) spectra	*Not translated*
HF_AV2_G_SIF1_V	HF_AV2_G_SIF1_V is out of limit for 12 (100%) spectra	*Not translated*
HF_AV2_G_SIF2_V	HF_AV2_G_SIF2_V is out of limit for 12 (100%) spectra	*Not translated*
hkFlag	{HF_AV2_G_SIF1_V=17, HF_AH1_MXBIAS_C=0, HF_AH1_MXMG_C=4, HF_AV2_G_SIF3_V=21, HF_AH1_DPACT_V=10, HF_AV2_G_SIF2_V=19, HF_AH2_G_SIF3_V=20, HF_AH2_G_SIF2_V=18, HF_AH2_G_SIF1_V=16, HF_AH2_G_FIF1_V=12, HF_AH2_G_FIF2_V=14, HF_AV1_MXMG_V=7, HF_AP_SCHS_CT=22, HF_AV1_MXBIAS_V=3, HF_AV1_DPACT_C=27, HL_R_M1_1A_C=28, HF_APR_CH_ROT=8, HF_APR_SCCS_CT=24, HF_AV2_G_FIF1_V=13, HF_AV2_G_FIF2_V=15, HL_R_M1_7A_C=28, HF_AH1_MXMG_V=6, HF_AR_SCHS_CT=23, HF_APR_S2K_CT=25, HL_R_M1_7B_C=28, HF_AH1_MXBIAS_V=2, HF_AV1_MXBIAS_C=1, HF_AV1_MXMG_C=5, HF_DPR_CH_ROT2=9, HF_AH1_DPACT_C=26, HL_R_M2_3B_C=28, HF_AV1_DPACT_V=11}	*Not translated*
hpbw	Azimuthally-averaged half-power beam width	HPBW

hpbwAssumed	HPBW assumed by doGridding, typically unequal to physical HPBW (metadatum hpbw)	HPBWUSED
hrsHscience	Science data are obtained with HRS-H	IS-HRSH
hrsVscience	Science data are obtained with HRS-V	IS-HRSV
ignoreOffs	Ignore datasets from the OFF position. You can include OFF positions by setting this to False	*Not translated*
instMode	Instrument Mode	INSTMODE
instrument	Instrument attached to this product	INSTRUME
integrations	Number of integrations	*Not translated*
integrationTime	Integration duration in seconds	INTEGTIM
isMasked	Bad Pixels have been flagged	*Not translated*
latitude	Latitude (Decl in equatorial coord)	*Not translated*
latitude_cmd	Latitude (Decl in equatorial coord) average H and V	*Not translated*
latitudeError	Latitude errors	TCRD2
last_ds	Last dataset in this product	*Not translated*
level	Pipeline level	LEVEL
LnaFIF1	FPU: The values of LnaFIF1 are out of limit	*Not translated*
LnaFIF2	FPU: The values of LnaFIF2 are out of limit	*Not translated*
LnaSIF1	FPU: The values of LnaSIF1 are out of limit	*Not translated*
LnaSIF2	FPU: The values of LnaSIF2 are out of limit	*Not translated*
loadAll	Data are keep in memory	*Not translated*
loadInterval	Load period in seconds	LOADINT
loFreqAvg	Average LO frequency Doppler-corrected to freqFrame (SPECSYS), quantity = GHz	LODOPPAV
loFreqMax	Max LO frequency of the spectral scan Doppler-corrected to freqFrame (SPECSYS), quantity = GHz	LOFRQMAX
loFreqMin	Min LO frequency of the spectral scan Doppler-corrected to freqFrame (SPECSYS), quantity = GHz	LOFRQMIN
loFrequency	Actual local oscillator frequency, quantity = GHz	LOFREQ
LoFrequency	The LO frequency possibly adjusted for Doppler shifts in the data.	*Not translated*
loFrequencyEnd	Actual end local oscillator frequency, quantity = GHz	LOFRQEND
loFrequencyEndRequest	User requested final frequency of the spectral scan, quantity = GHz	*Not translated*
LoFrequency_measured	Local Oscillator Frequency	LOFMEAS
loFrequencyRequest	User requested local oscillator frequency, quantity = GHz	*Not translated*
loFrequencyStart	Actual start local oscillator frequency, quantity = GHz	LOFRQSTA
longitude	Longitude (RA in equatorial coord)	*Not translated*
longitude_cmd	Longitude (RA in equatorial coord) average H and V	*Not translated*
longitudeError	Longitude errors	TCRD1
loThrow	The LO frequency throw	LOFTHROW
lsbGain	Sideband gain level applied in the given lower side band spectrum.	LSBGAIN
lsb/usbGain_0	Sideband gain polynomial coefficients 0 applied.	LSBGAIN0/USBGAIN0
lsb/usbGain_1	Sideband gain polynomial coefficients 1 applied.	LSBGAIN1/USBGAIN1
lsb/usbGain_2	Sideband gain polynomial coefficients 2 applied.	LSBGAIN2/USBGAIN2
lsb/usbGain_3	Sideband gain polynomial coefficients 3 applied.	LSBGAIN3/US

		BGAIN3
mapHeightCommanded	Spectral map scan length requested	*Not translated*
mapHeightGridded	The DEC size of the Map in arcmin	MAPHEIGR
mapHeightObserved	The DEC area that the telescope has scanned over all ON cycles	MAPHEIOB
mapLineStep	Map line spacing	*Not translated*
mapReadoutSep	Line readout spacing	*Not translated*
mapSize	Map size in pixels	MAPSIZE
mapWidthCommanded	Spectral map cross-scan length requested	*Not translated*
mapWidthGridded	The RA size of the Map in arcmin	MAPWIDGR
mapWidthObserved	The RA area that the telescope has scanned over all ON cycles	MAPWIDOB
missionConfig	Mission configuration	MISSIONC
mixerCurrent	FPU: The values of mixerCurrent are out of limit	*Not translated*
mixerVoltage	FPU: The values of mixerVoltage are out of limit	*Not translated*
MJC_Hor	Calibrated mixer junction current, horizontal band 1	MIXCURH
MJC_Ver	Calibrated mixer junction current, vertical band 1	MIXCURV
modelName	Model name attached to this product	MODELNAM
naifId	Solar system object NAIF identifier	NAIFID
naxis1	Size of first axis	*Not translated*
naxis2	Size of second axis	*Not translated*
naxis3	Size of third axis	*Not translated*
noBaseline	No off baseline could be calculated.	*Not translated*
nodCycleNum	Switching/nodding cycle number	NODCYDEN / NOD_NUM
noiseRefFrequency	Noise reference frequency, quantity = GHz	NSREFFRQ
nrbytes	Number of Bytes	*Not translated*
nyquistSampling	Spectral Map Nyquist sampling requested	*Not translated*
object	Target name	OBJECT
obsFreqLsbMax	Observed max frequency for LSB in freqFrame (SPECSYS), quantity = GHz	LFREQMAX
obsFreqLsbMin	Observed min frequency for LSB in freqFrame (SPECSYS), quantity = GHz	LFREQMIN
obsFreqMax	Observed max frequency in freqFrame (SPECSYS), quantity = GHz	FREQMAX
obsFreqMin	Observed min frequency in freqFrame (SPECSYS), quantity = GHz	FREQMIN
obsFreqUsbMax	Observed max frequency for USB in freqFrame (SPECSYS), quantity = GHz	UFREQMAX
obsFreqUsbMin	Observed min frequency for USB in freqFrame (SPECSYS), quantity = GHz	UFREQMIN
obsMode	Observation mode name	OBS_MODE
OBS-patch	On Board Software patch level	OBSWPATC
OBS-revision	On Board Software revision	OBSWREVI
OBS-version	On Board Software version	OBSWVERS
obsState	One of CREATED, LEVEL0_PROCESSED, LEVEL0_5_PROCESSED, LEVEL1_PROCESSED, LEVEL2_PROCESSED, LEVEL2_5_PROCESSED, LEVEL3_PROCESSED	OBSSTATE

obsTime	Observation Time (corrected)	*Not translated*
observer	Observer name	OBSERVER
obsid	Observation identifier	OBSID
odNumber	Operational day number	ODNUMBER
offsetsTable	It use an external table of x/y points for each spectrum to set the center of the map	*Not translated*
orbitEphemerisSourceFile	Name of the file from where data was extracted	ORBITFIL
origin	Site that created the product	ORIGIN
packetTime	Packetization Time	*Not translated*
pattAngle	Spectral map rotation angle, quantity = degrees	PATT
Pipeline applied	Define which pipeline modules have been applied to the data.\u000A bit 0 = not used \u000A bit 1 = Scan count correction \u000A bit 3 = Dark correction \u000A bit 4 = Non Linearity correction \u000A bit 5 = Zero correction \u000A bit 6 = Frequency calibration applied \u000A	*Not translated*
pixelOffset	Pixel offset position	PIXOFFS
pixelSaturated	Maximum number of saturated pixel detected in a single spectrum	*Not translated*
pixelSize	Regular grid pixels size in rad	PIXELSIZ
platforming	Platforming present in overlapping subbands	
pmDEC	Target's proper motion Dec (arcsec/yr) as given by the observer, quantity=arcsec a-1	PMDEC
pmRA	Target's proper motion RA (arcsec/yr) as given by the observer, quantity = arcsec a-1	PMRA
pointingMode	Pointing mode	POINTMOD
Pol_S	Polar used : H/V	
posAngle	Spacecraft pointing Position angle, quantity = deg	POSANGLE
posAngleError	Average of posAngleError in level 2 H datasets	POSANGER
prime_redundant	prime or redundant	PRIMERED
processingMode	Processing mode selected to execute the pipeline	PROCMOD
proposal	Proposal name	PROPOSAL
Ra	Average of ra in level 2 datasets, quantity = deg	RA
raDeSys	Coordinate reference frame for the RA and DEC	RADESYS
raNominal	Requested Right Ascension of pointing, quantity = deg	RA_NOM
raoff	Sky reference OFF right ascension J2000.0	RA_OFF
radialVelocity	Spacecraft velocity along the l-of-s of the telescope wrt the LSR, quantity = km s-1	VFRAME
rasterColumnNum	Raster Column number	RASTCOL
rasterLineNum	Raster line number	RASTLINE
redshiftFrame	Proposal target redshift frame	SYSSRC
redshiftType	Proposal target redshift type	REDSHFT
redundancy	Spectral Scan redundancy requested	REDUNDCY
refPixelCoordinates	Reference pixel in longitude/latitude coordinates	REFPIX
regular_grid_wcs	WCS used to build the RegularGrid	*Not translated*
resolution	Mean resolution from all combs spectra	RES / COMBRES

resolution_resampled	Approximate resolution after resampling.	FREQRES
rfreq	Frequency of the central channel of the USB	*Not translated*
rmsDSBMax	Rms DSB Noise at maximum bandwidth H and V polarizations averaged, quantity = K	RMSMAXD
rmsDSBMin	Rms DSB Noise at minimum bandwidth H and V polarizations averaged, quantity = K	RMSMIND
rmsDSBNative	Rms DSB Noise rescaled to native WBS resolution H and V polarizations averaged, quantity = K	RMSNATD
rmsMaxLsb	Rms Noise LSB at maximum bandwidth H and V polarizations averaged, quantity = K	RMSMAXL
rmsMaxUsb	Rms Noise USB at maximum bandwidth H and V polarizations averaged, quantity = K	RMSMAXU
rmsMinLsb	Rms Noise LSB at minimum bandwidth H and V polarizations averaged, quantity = K	RMSMINL
rmsMinUsb	Rms Noise USB at minimum bandwidth H and V polarizations averaged, quantity = K	RMSMINU
rmsNativeLsb	Rms Noise LSB rescaled to native WBS resolution H and V polarizations averaged, quantity = K	RMSNATL
rmsNativeUsb	Rms Noise USB rescaled to native WBS resolution H and V polarizations averaged, quantity = K	RMSNATU
rmsNoiseHV	One of the two polarisations is noisier than the other by more than SQRT(2). Their noise ratio is given in the value column	NSRATIHV
rmsNoiseHvVsTsys	The noise ratio of the two polarisation exceeds that expected from the measured Tsys ratio by more than 10%. Their ratio is given in the value column.	*Not translated*
rmsSSBMax	Rms Deconvolved SSB Noise at maximum bandwidth H and V polarizations averaged, quantity = K	RMSMAXS
rmsSSBMin	Rms Deconvolved SSB Noise at minimum bandwidth H and V polarizations averaged, quantity = K	RMSMINS
rmsSSBNative	Rms Deconvolved SSB Noise rescaled to native WBS resolution H and V polarizations averaged, quantity = K	RMSNATS
rowflag	Flag for erroneous scan counts in calibration data-frames	*Not translated*
rowflag_8	HK could not be aligned with DataFrames value = 256	*Not translated*
scancount	Integrated Scan Count	*Not translated*
scanCountErr	Error on integrated scan count	*Not translated*
scanLineNum	Scan line number	SCANLINE
scanRate	Line scan rate of the telescope	SCANRATE
sds_type	Generalized Building Block type	*Not translated*
sideband	Status: lower or upper sideband	SIDEBAND
slewTime	Predicted start time for slew before the observation	SLEWTIME
smoothFactor	A smoothing factor to expand the kernel size for X and Y directions	*Not translated*
solarAspectAngleMean	Mean Solar Aspect Angle, quantity = degrees	SAAMEAM
solarAspectAngleRms	RMS Solar Aspect Angle, quantity = degrees	SAARMS
spur	Spur lines detected in the cold spectra.	*Not translated*
startDate	Start date of the observation	DATE-OBS
subbands	Number of subbands	*Not translated*
Switch_S	Status of the input IF Switch : H/V	*Not translated*
telescope	Name of telescope	TELESCOP
temperatureScale	Temperature scale in use	TEMPSCAL
tmbReference	Temperature (main beam) at noise reference frequency,	TMBREFFQ

	quantity = K	
totNoiseEfficiency	Total noise efficiency, quantity = %	TOTNSEFF
tsys_median	Median of the Tsys array - subbands concatenated.	MEDTSYS
type	Product Type Identification	TYPE
unalignedHKdata	Maximum percentage of Dataframes which have unaligned HK	*Not translated*
Unit_ID_S	Unit used : QM/FM	*Not translated*
upConvert_H/V	Up convert factor for bands 6 & 7	UPCONVH/V
Valid	HRS spectrum contains at least one subband	*Not translated*
velocityDefinition	The velocity definition and frame	VELDEF
velocity_hso_1	Velocity of S/C in SSBC frame.	HSOSSBVX
velocity_hso_2	Velocity of S/C in SSBC frame.	HSOSSBVY
velocity_hso_3	Velocity of S/C in SSBC frame.	HSOSSBVZ
vlsr	Proposal target redshift value (km/s if redshiftType is optical or radio)	*Not translated*
wavedescription	Description of WaveColumn	WAVEDESC
wavename	Actual name of the WaveColumn	*Not translated*
waveunit	Units of the WaveColumn	WAVEUNIT
wbsHscience	Science data are obtained with WBS-H	IS-WBSH
wbsVscience	Science data are obtained with WBS-V	IS-WBSV