Herschel Products Definitions Document - Part I

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Herschel Products Definitions Document - Part I

by

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Table of Contents

Part I. Herschel Products Description

Chapter 1. Introduction

1.1. Purpose and scope

The data from the Herschel Space Observatory is provided to the astronomical community as standard products. Standard products are generated systematically by the Herschel Science Centre through the Herschel Data Processing system, and are stored in the Herschel Science Archive to be accessed by the astronomical community and for legacy. In addition, the Herschel Data Processing package distributed by the Herschel Science Centre, allows the users to reduce the data and generate scientific products through interactive analysis. Highly processed products are expected to be delivered by the observers to the Herschel Science Centre for their inclusion in the Herschel Science Archive. For a further description of the Herschel ground segment context for standard products, please refer to the Herschel Observers' Manual [RD-1]. For an overview of the Herschel Data Processing, see the Herschel DP User's Manual [RD-2], and the Herschel DP Architecture and Design document [RD-3].

The purpose of this document is to provide an overview and detailed descriptions of the Herschel standard products. These products encompass different levels of processing of the observational data, and cover also calibration, auxiliary and quality control data required in the observations data processing. For the document purposes, the term observation and AOR are considered equivalent.

The document is organised as follows. Chapter 2 provides a high level description of the data products that are available to the users of the Herschel Space Observatory. Chapters 3, 4 and 5 describe the HIFI, PACS and SPIRE products, respectively. Chapter 6 provides an overview of the Auxiliary, Catalogue, and Quality Control products. Chapter 7 and and the following contain the definition tables of the implemented products.

Note from the authors: This draft gathers the current information and knowledge of the definition of the Herschel products. However, it must be regarded as a snapshot of the work in progress. It is expected that as a result of the Commissioning and Performance Verification phases, Herschel products will be modified and improved.

1.2. References

- RD.1 Herschel Observers' Manual, issue 2.1, 1 August 2007, Herschel-HSC-DOC-0876
- RD.2 Herschel Data Processing Basic User's Manual, draft 0.25, 30 January 2009, Herschel-HSC-DOC-0517
- RD.3 Herschel Data Processing Architecture and Design, draft 1.0, 5 August 2008, Herschel-HSC-DOC-0957
- RD.4 HIFI standard data product specification, draft 0.3, 24 March 2005, ICC/2002-002.
- RD.5 Herschel Spectral Line List Product specification, issue 1.0, 16 May 2007, HIFI-ICC-2007-03
- RD.6 Herschel Source List Product specification, issue 1.0, May 2007, PICC-KL-TN-026
- RD.7 Herschel Pointing Product Specification, issue 1.7, 30 July 2008, HERSCHEL-HSC-DOC-0662
- RD.8 Herschel Orbit Product Specification, issue 1.4, 31 October 2008, HERSCHEL-HSC-DOC-0767
- RD.9 SIAM product specification, issue 1.4, 31 October 2008, HERSCHEL-HSC-DOC-0716
- RD.10 Herschel Auxiliary Products Specification, issue 1.0, 31 October 2008, HERSCHEL-HSC-DOC-0816

- RD.11 Quality Control Report Product Definition, draft 0.5, 15 January 2007, Herschel-HSC-DOC-0660
- RD.12 Herschel SREM Products Specification, issue 1.0, 31 October 2008, Herschel-HSC-DOC-0991

1.3. Acronyms

AOR	Astronomical Observation Request
DP	Data Processing
HIFI	Heterodyne Instrument for the Far Infrared
HIPE	Herschel Interactive Analysis Processing Environment
HRS	High Resolution Spectrometer
HSA	Herschel Science Archive
PACS	Photodetector Array Camera and Spectrometer
RD	Reference Document
SPIRE	Spectral and Photometric Image REceiver
TAI	Temps Atomique International
TBD	To Be Defined
WBS	Wide Band Spectrometer
WCS	World Coordinate System

Chapter 2. Herschel products

2.1. Generalities

A Herschel product consists of metadata keywords, tables with the actual data, and the history of the processing that generated the product. Metadata keywords have been specified to allow an optimal identification and characterisation of the products, both for information to the users, and to provide the required items to the processing software. They have been defined so that compatibility with standard keywords used in Astronomy and commonality across Herschel products are ensured. Whenever possible, product formats have been defined to be consistent with similar scientific products used by the astronomical community (e.g. images, point source catalogues). The definition of Herschel products meets the requirement of compatibility with the Virtual Observatory.

2.2. Herschel product types

The following types of Herschel products are defined:

1. Observational products

Observational products contain the scientific data resulting from the Herschel observations. Observational products are classified depending on the level of the processing of the data they contain, ranging from raw data (level-0) to highly processed scientific data (level-3) (see below for the definition of product levels). Observational products are generated per observation (or AOR, Astronomical Observation Request), although highly processed products may result from the combination of data from several observations. Browse products will also be available in the Herschel Science Archive to allow the user to quick look at the contents of the data. The browse products are generated automatically. Therefore, especially in the earlier phases of the mission, observers should be aware that the quality of these products is not good enough for science analysis. For this purpose, an interactive reduction of the data following the instrument Handbooks instructions is mandatory.

2. Calibration products

These products contain the parameters that characterise the behaviour of the satellite and the instruments. There are uplink and downlink calibration products. Uplink calibration products are used for the specification of the commands that are uplinked to the satellite for the execution of the observations. Downlink calibration products are used in the processing of the raw data to produce astronomically calibrated products in which the instrument artifacts have been removed. In this document, only the downlink calibration products will be described.

3. Auxiliary data products

These products contain all Herschel non-science spacecraft data required directly or indirectly in the processing and analysis of the scientific data. Auxiliary data products are normally generated per Herschel Operational Day, with the exception of the Uplink product, that is generated per observation.

4. Quality Control products

Each observation is associated with a Quality Control product, which gathers the information required to evaluate the technical quality of the executed observation and of the products generated, and provides a global quality assessment.

5. Catalogue products

Catalogue products are derived from the scientific data, and contain lists of astronomical objects or spectral features with their characterisation. They are the result of highly advanced processing of the data, and may be based on one or several observations.

6. User generated products

It is expected that astronomers, especially observers involved in the Herschel Key Programs, will provide highly processed products to the Herschel Science Centre. These products will be stored in the Herschel Science Archive and will be made available to the astronomical community. When applicable, the format of these products should follow the formats defined in this document. The specific metadata keywords and guidelines for the user generated products will be provided elsewhere.

2.3. Observational products levels

Depending on their processing level, the Herschel observational data products are defined as follows:

- **Level-0 data product:** Raw telemetry data as measured by the instrument, minimally manipulated and ingested as Data Frames into the mission data base/archive.
- **Level-0.5 data product:** Raw data processed to an intermediate point which is adequate for inspection or to start interactive analysis at a more advance stage than level-0.
- **Level-1 data product:** Detector readouts calibrated and converted to physical units, in principle instrument and observatory independent. It is expected that level-1 data processing can be performed without human intervention.
- **Level- 2 data product:** Level-1 data further processed to such a level that scientific analysis can be performed. For optimal results many of the processing steps involved to generate level-2 data may require human interaction, based both on instrument understanding as well as understanding of the scientific aims of the observation. These data products are at a publishable quality level and should be suitable for Virtual Observatory access.
- **Level-3 data product:** These are the publishable science products where level-2 data products are used as input. These products are not only from the specific instrument, but are usually combined with theoretical models, other observations, laboratory data, catalogues, etc. Their formats should be Virtual Observatory compatible and these data products should be suitable for Virtual Observatory access.

While the generation of level-0 and level-1 data products will be automatic, proper quality level-2 and level-3 data products may require interactive processing. It is expected that the degree of human intervention necessary to generate these products will decrease with time as the knowledge of the instruments' behaviour increases during the mission. This is the same as saying that the quality of the automatically generated product will be progressively enhanced. However, in many cases it will not be possible to discard interactive processing, especially in the derivation of level-3 data products.

2.4. Herschel product generic definition

2.4.1. Product basic structure

A product is defined in the Herschel Data Processing system as the highest level of data structure, which contains the following components:

- Metadata
- Zero or more tables or "datasets", which can also have their own metadata
- A processing history of the product

Herschel products have an internal structure representation in the Herschel Data Processing system or HIPE. When the products are stored on disk, they can be saved with this Herschel Data processing internal structure, or they can be exported as FITS files. In this case, a proper translation of the metadata

keywords and of the tables and datasets takes place to ensure consistency with the standard. Products are distributed through the Herschel Science Archive (HSA) as FITS files, or can be loaded from the HSA directly in HIPE.

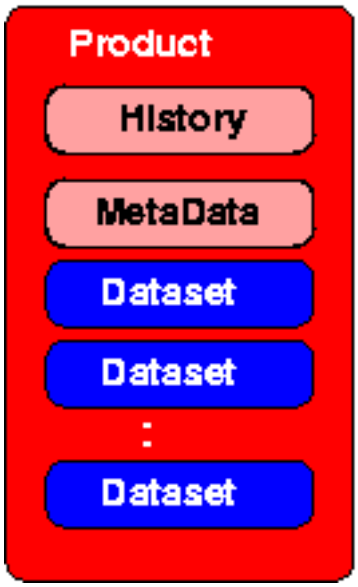

Figure 2.1. Herschel generic Product structure

2.4.2. Datasets in Herschel products

Dataset structures provide the mean to relate sets of data arrays in a table, and to qualify or annotate their contents with, for example, units and metadata. The Herschel Data Processing system provides three generic datasets:

- **Array Dataset**: A quantifiable dataset containing array data.
- **Table Dataset**: A dataset containing a collection of columns. Each column contains a quantifiable array data (e.g., data vector, array, cube). All columns have the same number of rows.
- **Composite Dataset**: A dataset containing a collection of named datasets. This allows arbitrary complex structures, as a child dataset within a composite dataset may be a composite dataset itself.

2.4.3. Spectrum specialised datasets

2.4.3.1. Spectrum1d

Spectrum1d contains a one-dimensional representation of a spectrum. It consists of a Table Dataset with the following columns:

- A flux column (double 1D)
- A wavelength/frequency column (double 1D)
- A weight column (double 1D)
- A segments column (double 1D). The values within this array indicate to which segment the corresponding flux/weight/flag/wave belong. The spectrum can be made of several segments or smallest spectrum component dealt with by the DP system. For example, a spectral segment can be an extracted piece of a spectrum to be used for fitting purposes.
- A flag column (integer 1D).

A Spectrum1d can also have metadata (header information) added. In general the meaning of the flags is stored in the metadata.

2.4.3.2. Spectrum2d

For multiple spectra taken in an observation, a 2D structure is required. The components of a Spectrum2d dataset are similar to that of a Spectrum1d dataset, except for having a second dimension. An additional component is the ability to contain subbands. Subbands are vertical splits in the Spectrum2d columns equivalent to the segment column in Spectrum1d. A clear example of its usefulness is the storage of the output from the HIFI spectrometers where several CCD or autocorrelator readouts lead to several "chunks" (subbands) of spectra in one data frame.

Spectrum2d consists of a Table Dataset with the following columns:

- A flux column (double 2D), where the first axis runs over the spectral dimension and the second axis runs over e.g. time.
- A wavelength/frequency column (double 2D)
- A weight column (double 2D)
- A flag column (integer 1D). In general the meaning of the flags is stored in the metadata.
- (Optional) a subband start column (integer 1D), which indicates where in the arrays a subband starts.
- (Optional) a subband length column (integer 1d). Indicates the length of the array section that a subband covers.

A Spectrum2d can also have metadata (header information) added.

2.4.4. Image and cube generic products

2.4.4.1. SimpleImage product

The SimpleImage product contains a standard two-dimensional image, in particular the following arrays:

- Image in an array 2D (e.g. double, integer)
- Error in an array 2D (e.g. double, integer)
- Exposure in an array 2D (e.g. double, integer)
- Flag in a short integer array 2D

It also contains metadata that provide unit and World Coordinate System information (for further details see section 4.12 in the Herschel DP Basic User's Manual [RD-2]).

2.4.4.2. SimpleCube product

The SimpleCube product allows us to store three-dimensional images (or multiple stacked 2D images). In particular it contains the following arrays:

- Image in an array 3D (e.g. double, integer)
- Error in an array 3D (e.g. double, integer)
- Exposure in an array 3D (e.g. double, integer)

- Flag in a short integer 3D array

SimpleCube has the depth as the first (most slowly varying) index. It also contains metadata that provide unit and World Coordinate System information (for further details see section 4.12 in the Herschel DP Basic User's Manual [RD-2]). A single WCS only can be applied to the SimpleCube. For example, it is not possible to provide different WCS's for each image in an image stack.

2.4.4.3. SpectralSimpleCube product

SpectralSimpleCube is an extension of the SimpleCube product. SpectralSimpleCube can contain [1D, 2D] and 3D ArrayDatasets. The 3D sets store spectral stacks of images with dimensions [x3,x2,x1], where x3 is the spectral index. 2D sets are of dimension [x2,x1] and are interpreted as images. 1D sets are of dimension [x3] and are interpreted as spectra. SpectralSimpleCube also contains metadata information that provide unit and World Coordinate System information (for further details see section 4.12 in the Herschel DP Basic User's Manual [RD-2]).

2.4.5. Context products

Herschel products can exist as simple products and as context products. Contexts are special types of products that contain references to other products stored. This enables a mean to build complex data structures. Context products also contain the required metadata as applicable to the group of products that contains. There are two "standard" types of context products provided: ListContext (for grouping products into sequences or lists) and MapContexts (for grouping products into containers with access to each one by key).

2.4.6. Product metadata keywords

The following metadata keywords are required to be present in all Herschel products. In the Data Processing system these keywords are referred to as "attributes":

Table 2.1. Herschel products attributes

Herschel DP keyword name	Type	Description	FITS keyword
creationDate	Fine time	Date of product creation	DATE
creator	String	The name of the software that created the product	CREATOR
description	String	Full name of product	DESC
instrument	String	Instrument name	INSTRUME
modelName	String	Instrument Model Name	MODELNAM
startDate	Fine time	Start date of observation	DATE-STA
endDate	Fine time	End date of observation	DATE-END
type	String	Product type identification	TYPE

Fine Time is the internal DP representation that holds the value of time. Fine time is defined as the atomic time (SI seconds) elapsed since the TAI epoch of 1 January 1958 UT2. In the DP system the resolution provided is microseconds. When the value of a Fine Time keyword is displayed on a GUI or exported to FITS, the parameter is transformed to a String value, formatted according to the rules as defined by the TIMESYS keyword. Per default, TIMESYS='UTC', so the format will then be YYYY-MM-DDTHH:MM:SS.ssssss.

In addition to the product attributes, observational products (e.g. level-0, level-0.5, level-1 and level-2 products) contain those metadata keywords that identify the product and the observation that is associated with. In particular, the main metadata keywords are:

Table 2.2. Main metadata keywords in observational products

Herschel DP keyword name	Type	Description	FITS keyword
obsid	Long	Observation identifier	OBS_ID
bbid	Long	Building block identifier	BBID
observer	String	Name of observer	OBSERVER
proposal	String	Proposal name	PROPOSAL
aot	String	AOT identifier	AOT
obsMode	String	Observation mode name	OBS_MODE
cusMode	String	CUS observation mode	CUSMODE
aorLabel	String	AOR label as entered in HSpot	AOR
odNumber	Long	Mission operational day number	ODNUMBER

The "obsid" uniquely identifies an observation for all mission phases. The "obsid" relates all observational products associated with an AOR. The "obsid" is normally displayed as hexadecimal number.

The "bbid" identifies uniquely each building block in an observation. Building Blocks are the key components of the observations for the instrument commanding point of view. An observation execution will always be defined as a flat sequence of Building Blocks. The bbid is particularly important in the Herschel product definitions because large products (e.g. level-0, level-0.5) are sliced per building block. That is, a product or context product is provided for each building block in the observation.

Both the "obsid" and the "bbid" are essential to link the uplink commanding and the downlink telemetry.

"observer", "proposal", "aot", "obsMode" and "aorLabel" are derived from the proposal information and AORs as entered in HSpot.

"cusMode" is an internal uplink keyword that associates the observation requested with the corresponding pipeline processing. This keyword is mainly used in the SPIRE data processing.

"odNumber" is the number that identifies the Operational Day in the mission since launch. An Operation Day is defined as the interval between the start of two contiguous satellite ground contact periods. The duration of an Operational Day is in average around 24 hours, but it can also be shorter or longer, depending on operational constraints. The "odNumber" is an important key for the identification of those Auxiliary products that are generated per OD.

A complete list of the compulsory metadata keywords in the Herschel observational products can be found in Appendix 1.

2.5. The Herschel Observation Context

The Herschel Data Processing system uses the Observation Context as organisational product unit. An Observation Context is a container of products applicable to a specific observation. It provides associations to products which are specific to a single observation (e.g. Level-0 products) as well as associations to products that are applicable to multiple observations (such as the calibration or auxiliary products). An Observation Context may have a state of completeness, which is defined by the processing of the data for that Observation, for example "scheduled", "Auxiliary data attached", "Calibration data attached", "Level0 data generated", "Level1 data generated". Thus the Observation Context changes its nature along the way of processing.

An Observation Context is generated per AOR, except for the SPIRE PACS parallel mode for which two Observation Contexts are produced, containing the SPIRE and PACS data respectively.

The Observation Context consists of the following contexts and products, which have been defined following the product types described in Section 2.2.

- Telemetry Context: This context is not distributed by default. Telemetry products will only be provided when the Herschel Science Centre deems it to be necessary because of a serious problem in the processing to level-0 data.
- Level-0, level-0.5, level-1, level-2 level-3 (optional) contexts
- Calibration Context
- Auxiliary Context
- Quality Context
- Browse product
- Trend Analysis Context

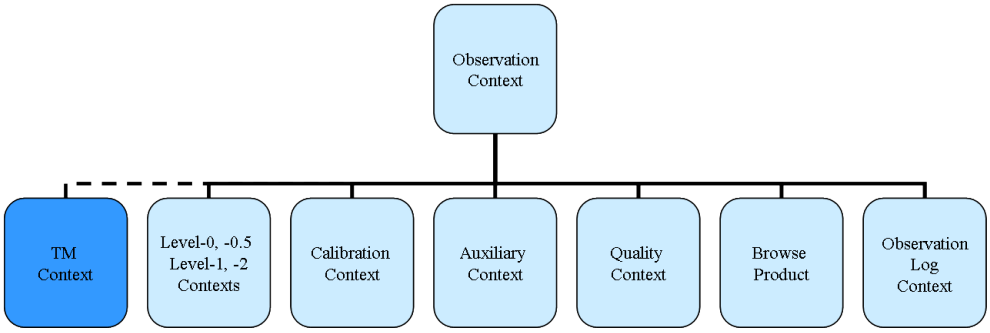

Figure 2.2. Observation Context structure

2.6. Product naming convention for exported FITS files

The Herschel products naming convention for exported FITS files takes the following format which depends on the type of product and whether the product has data for one observation, one operational day or several or more versions throughout the mission.

The generic format is as follows although not all of the items are present in all filenames. See following subsections for the specific formats for the different groups of products.

```
h<product/instrument><subinst><obsid/
od>_<bbid>_<level><xxxxx>_<yyy>v<NN>
```

where

- `h` stands for Herschel, `<product/instrument>` will be the product type such as *aux* for auxiliary products or the instrument name either *hifi, pacs or spire* (note that all letters in the filename are lowercase).
- `<subinst>`: this is only relevant for instrument data. A letter will appear to indicate what instrument or mode was used. For SPIRE or PACS data a *p* will be appear when the Photometer sub-

instrument is used and *s*will be displayed for the Spectrometer sub-instrument. For HIFI the letter indicates the mode or the spectrometer depending on the type of product.

- <obsid/od>: The observation ID given in decimal format. For data valid for one operational day the number of that day will be given instead.
- <bbid>: Some observational products are split up into logic parts of the observation such as building blocks. When this occurs the bbid will be given in hexadecimal format.
- <level>: The level of the product is presented here, level 0 products will be represented by 00, level 1 by 10 and level 2 by 20. Further levels may exist with appropriate numbers.
- <xxxxx>: Here will be 3 to 5 letters that indicate the type of product, such as *psc* for point source catalogue, *sll* for spectral lines list, or the type of the AUX products the file is. A full list of the acronyms and their meaning will be provided in the future.
- <yyy>: When data from an observation need to be split up further than by building block or in a way unrelated to building block, the number of the slice is given here. If 100 or less products result from the split then two digits (yy) will represent the slices (in time order). For more than 100 slices then three digits (yyy) will be used.
- v<NN>: Gives the version number of the pipeline used to generate the product. For some auxiliary and calibration files for which there are few version through the mission and apply to many observations, the version number of the product is used instead of <obsid/OD>

The ordering of the parameters is designed to give a logic ordering of the filenames when listed in a directory.

The specific formats per product are given in the following sections.

2.6.1. Observation products

The filenames of observation products take the generic form of (products split into building blocks and slices):

```
h<instrument><subinst><obsid>_<bbid>_<level><xxxxx>_<yyy>v<NN>
```

For products that contain data from the whole observation (i.e., not split up at all) the generic form is:

```
h<instrument><subinst><obsid>_<level><xxxxx>v<NN>
```

For example, hpacsp3221226224_00hpptv10 is PACS Photometer Timeline level 0 data from observation 3221226224 generated with version 10 of the pipeline.

For products that contain data for one whole building block the generic form is

```
h<instrument><subinst><obsid>_<bbid>_<level><xxxxx>v<NN>
```

For those split up into slices but not building blocks

```
h<instrument><subinst><obsid>__<level><xxxxx>_<yyy>v<NN>
```

where the items are as described above but with the following differences.

For HIFI, the <subinst> is *p* for single point observations, *r* for rasters, *o* for on the fly and *s* for spectral scans.

HIFI split first xxx into observing "sub-modes": *psw* for position switch, *dbs* for double beam switch, *fsw* for frequency switch. The last two xx differentiate the type of spectrum: *ds* for double side band and *ss* for single side band.

2.6.2. Calibration products

Calibration products have the addition of **cal** in the filename, the generic form is

```
h<product/instrument><subinst>cal<obsid/od>_<xxxxx>v<NN>
```

For calibration products associated with a particular observation or operational day the generic forms are respectively:

```
h<inst><subinst>cal<osbid>_xxxxxvNN
```

and

```
h<inst><subinst>cal<OD>_xxxxxvNN
```

For HIFI here <subinst> will be either *w* for WBS or *h* for HRS.

2.6.3. Auxiliary products

The filenames of auxiliary products take the generic form:

```
haux<obsid/od>_<level><xxxxx>v<NN>
```

For products associated with one obsid the form is

```
haux<osbid>_xxxxx<vNN>
```

Those with data for one operational day take the form

haux<OD>_xxxxx<vNN>

and products of which there are a few version through the whole mission the form is

haux_xxxxx<vNN>

Here NN is the version of the product (in the case that the product is generated by the pipeline then it could be the pipeline version),and xxxxx is used to say which of the AUX products the file is.

Example: haux_siam_v08

2.6.4. Quality Control

The filename for the quality control report is:

h<instrument><obsid>_qcr_v<NN>

For the quality control report summary:

h<instrument><obsid>_qcrs_v<NN>

For the quality logs:

h<instrument><obsid>_qclogs_v<NN>

2.6.5. Catalogue products

For catalogues using data from the whole mission the format will be

h_<level><xxxxx>_v<NN>

For products that involve a selection of data the definition of the filename is under discussion and will be similar format to the user provided products.

<level> =30 or 40

xxxxx is *psc* for point source catalogue, *xsc* for extended source catalogue, *sll* for spectral lines list...

v<NN> is the version of the pipelines used to make the products or perhaps the version of the catalogue - TBD.

2.6.6. Trend Analysis products

This section is TBD

2.6.7. User provided products

This section is TBD

Chapter 3. HIFI Products Description

3.1. HIFI observational products

3.1.1. HIFI level-0, level-0.5 and level-1 contexts

The HIFI level-0, level-0.5 and level-1 contexts contain one type of context. Its global structure does not change when the data is processed between level-0 and level-1. The HIFI levels 0, 0.5 and 1 contain the HIFI Timeline product, which is a mapcontext that groups a number of HIFI Spectrum Datasets, wrapped in Products, normally one per building block.

Product description	**Product type**
HIFI level 0 context	HifiRawData
HIFI WBS-H context	HifiTimelineProduct
WBS-H product per building block	HifiSpectrumDataset
HIFI WBS-V context	HifiTimelineProduct
WBS-V products per building block	HifiSpectrumDataset
HIFI HRS-H context	HifiTimelineProduct
HRS-H products per building block	HifiSpectrumDataset
HIFI HRS-V context	HifiTimelineProduct
HRS-V products per building block	HifiSpectrumDataset

- HIFI level 0.5 context: Globally the level 0.5 context has the same structure as the level 0 product. Backend (HRS or WBS) specific effects are removed as much as possible. A frequency scale has been added.
- HIFI level 1 context: As mentioned above, the level 1 context still has the same global structure but now the flux columns are calibrated. Each row in the HIFI Spectrum Dataset corresponds to a calibrated single on-board integration. The integrations are not added in the standard processing.

3.1.2. HIFI level-2 context

A high level description of the HIFI level-2 products is given here. Depending on the AOT different products will be made. Broadly there are 3 kinds of HIFI AOTs: Single point observations, spectral scan observations and mapping observations. The first two of these will produce one or more single spectra while the last will produce a spectral cube.

HIFI Single Point Observation

By processing the data in a HifiTimelineProduct by e.g. removing the reference, averaging the on-source spectra and concatenating subbands smaller SpectrumDatasets are obtained. All of these products are full HifiSpectrumDatasets and as such except for the number of spectra fundamentally identical to the spectrum data sets generated in level-1 processing. In general only one spectrum will be contained in the HifiSpectrumDataset. The meta information associated with these data sets is more extended than what is available for the level-1 spectrum data set. The overall container of these reduced HifiSpectrumDatasets is still a HifiTimelineProduct.

HIFI Spectral Scan Observation

A spectral scan observation contains several point observations at different LO settings such that they might form a single continuous spectrum, when deconvoluted. As deconvolution is still beyond level-2 spectral scan observations are similar to the single point observations of the previous paragraph.

HIFI Mapping Observations

HIFI on the fly mapping and raster data are three dimensional in nature; the data contain spectra corresponding to a (fairly) regular position grid on the sky. Normally OTF cq. raster data is processed from a HifiSpectrumDataset into a regularly gridded data cube with equally spaced pixels in position and frequency coordinates. Such data cubes are stored as a HififSpectralCube product which will be directly derived from the generic SpectralCube data product.

3.1.3. Beyond HIFI level-2

HIFI line list products

By fitting line shapes to HIFI spectrum data the observed lines can be characterised. For storage of such line parameters typically line identification, rest frequency, fitted central frequency and/or velocity, amplitude and width with error estimates a dedicated line list data product is defined. This product is based on the generic Herschel line list product.

HIFI image products

For some science goals images need to be generated from HIFI data. The clearest examples are total line intensity or line velocity images derived from on the fly SpectralCube. Other examples are position velocity images (again from OTF data) but also time-frequency images showing the variations of spectral behaviour as a function of time. All of these images are stored as HIFI image data products which will be directly derived from the generic Herschel image data product.

3.2. HIFI calibration products

There are two kinds of Calibration products. Products which are provided in advance and products which are derived from the HifiTimelineProduct and are used at the same time. These latter products are saved in the ObservationContext and can (later) be used for trend analysis and quality control.

A note about nomenclature: A calibration product specific for HRS starts with CalHrs... and one specific for WBS starts with CalWbs... When it only starts with Cal it is generic.

3.2.1. HIFI calibration products 1: Predefined calibration products

Product class	**Product Description**
CalBbid	A table containing the meaning of the different building blocks types, some attributes and their meaning
CalCoupCoeff	Product that contains for each (physical band) the coupling coefficients eta_hot and eta_cold (for a given freq grid)
CalForwardEff	Product containing baseline ripple model from OFF scans. Every ripple model has a time tag and quality.
CalHKTable	A table containing the HK items which should be selected in the HifiSpectrumDatasets for the different backend and in different situations.
CalUpConvertLO	It contains the upconverter factor needed for the frequencies in bands 6 and 7.
CalHrsPowCorr	A product containing values for the power gain non-linearity correction. It has 2 tables: PowCorrVSigma which is the vSigma vector and PowCorrGain which is the gain vector.
CalHrsQDCFast	Only MetaData containing the values for the fast Quantization distortion correction.

Product class		Product Description
CalHrsQDCFull		A product containing values for the full Quantization distortion correction. It has 5 datasets. • QDCFullMSigma: Tabledatset containing mSigma vector. • QDCFullRo: Tabledatset containing ro vector. • QDCFullVSigma: Tabledatset containing vSigma vector. • QDCFullGridDim: Tabledatset containing grid dimensions. • QDCFullGrid: Tabledatset containing grid or 3d table.
CalHrsBadChans		Product which contains the bad channels table for HRS
CalWbsBadPixel		Product which contains the bad pixels table for WBS
CalWbsFreq		The frequency calibration context for the WBS
	CalWbsFreqCoeff	It contains one Table Dataset with 5 columns, one for time and for each of the four CCD's, a set of polynome coefficients that define how to convert pixel index to IF frequency for that time.
	CalWbsFreqTuning	
CalWbsLinearCoeff		Contains the coefficients for the non linearity correction of Wbs bands.
CalWbsZero		

3.2.2. HIFI calibration products 2: Calibration products derived from the HifiTimelineProduct

Product class	Product Description
FreqRanges	Product containing the measures for frequency drifts potentially occurring during an observation.
CalHotColdFlux	A context produt containing the hot-cold calbration.
CalOffBaseline	Product containing the baseline spectra obtained by by the MkOffSmooth module which processes off data sets
CalPhases	Product that contains information about the different phases observed with an observation. Phases are identified (depending on the observing mode) from the Chopper / buffer or the LoFrequency / buffer.

3.3. HIFI Quality control products

Product class	Product Description
QHtpLevel0	Level 0 Quality product
QWbsFreq	Level 0.5 Quality context that contains all the Comb Quality Product for the specific observation.

Product class	**Product Description**
QWbsComb	Level 0.5 Quality context that contains the 4 single CCD-Comb Quality Product
QWbsCcd	Level 0.5 Qiality product that Contain the result of the Comb fitting analysis for the specific CCD
QWb-sSpikes	
QWbsZero	Level 0.5 Quality product that contains the zero's "maximum","minimum","average","variance"
CalPhases	Product that contains information about the different phases observed with an observation. Phases are identified (depending on the observing mode) from the Chopper / buffer or the LoFrequency / buffer.

Chapter 4. PACS Products Description

4.1. PACS observational products

4.1.1. PACS photometry level-0 context

The PACS photometry level-0 context is called Herschel-PACS Photometer Timeline (type HPPT). It contains contexts products respectively associated with the timelines of the averaged bolometer signals, associated mechanism positions, detector timing information, selected housekeeping parameter measures and engineering products to monitor the health of the instrument and assess the proper execution of the observation. Each context product contains a number of products or "slices". Slices are defined such that the data does not cross building block boundaries, and the resulting product does not exceed a certain size limit. The structure of HPPT is as follows (the product "type" is given in brackets):

Product description	**Product type**
Herschel-PACS Photometry Timeline - Level 0 Context	HPPT
Photometry Raw Blue Context	HPPRAWB
Photometry Raw Blue Slice	HPPRAWBS
Photometry Raw Red Context	HPPRAWR
Photometry Raw Red Slice	HPPRAWRS
Photometry Averaged Blue Context	HPPAVGB
Photometry Averaged Blue Slice	HPPAVGBS
Photometry Averaged Red Context	HPPAVGR
Photometry Averaged Red Slice	HPPAVGRS
Photometry raw DecMec status Blue Context	HPPDMCB
Photometry raw DecMec status Blue Slice	HPPDMCBS
Photometry raw DecMec status Red Context	HPPDMCR
Photometry raw DecMec status Red Slice	HPPDMCRS
Photometry Nominal Housekeeping Context	HPPHK
Photometry Housekeeping Slice	HPPHKS
General Housekeeping Context	HPGENHK
General Housekeeping Slice	HPGENHKS
Diagnostic Housekeeping Context	HPDIAGHK
Diagnostic Housekeeping Slice	HPDIAGHKS
Engineering Context	HPENG
Telecommand verification Slice	HPTCVERS
Telecommand history Slice	HPTCHISTS
Event Slice	HPEVENTS
TM Packet Report	HPTM_PACKET_REPORT
	HPTIME_VERIFICATION
	HPOBCP_STATUS
	HPOBCP_LIST

Product description	Product type
	HPMEMORY_DUMP
	HPMEMORY_CRC
	HPLINK_CONNECTION
	HPACT_OBCP_LIST
OGSE housekeeping Context	HPOGSEHK
PACS OGSE housekeeping Slice	HPOGSEHKS
CDMS simulator context	HPCDMS
PACS CDMS simulator slice	HPCDMSS

4.1.2. PACS photometry level-1 context

The following level-1 products are under definition for the PACS photometry AOTs. Slices are defined such that the data does not cross building block boundaries, and the resulting product does not exceed a certain size limit. (this list is TBC)

Product description	Product type
PACS Photometry - level-1 Context	
Photometry level-1 Frames Blue Bolometer Context	HPPAVGB
Photometry level-1 Frames Blue Slice	HPPAVGBS
Photometry level-1 Frames Red Bolometer Context	HPPAVGR
Photometry level-1 Frames Red Slice	HPPAVGRS

4.1.3. PACS photometry level-2 products

Product description	Product type
PACS Photometer - level-2 context	
Photometer level-2 Frames Blue Bolometer Context	HPPAVGB
Photometer level-2 Frames Blue Slice	HPPAVGBS
Photometer level-2 Frames Red Bolometer Context	HPPAVGR
Photometer level-2 Frames Red Slice	HPPAVGRS

4.1.4. PACS spectroscopy level-0 context

The PACS spectroscopy level-0 context is called Herschel-PACS Spectrometer Timeline (HPST).It contains It contains contexts products respectively associated with a timeline of the averaged integration ramps, associated mechanism positions, detector timing information, selected housekeeping parameter measures and engineering products to monitor the health of the instrument and assess the proper execution of the observation. These contexts contain a number of products or "slices". Slices are defined such that the data does not cross building block boundaries, and the resulting product does not exceed a configured size limit. The HPST structure is as follows (the product "type" is given in brackets):

Product description	Product type
Herschel-PACS Spectroscopy Timeline - Level 0 Context	HPST
Spectroscopy Raw Blue Context	HPSRAWB
Spectroscopy Raw Blue Slice	HPSRAWBS

Product description	Product type
Spectroscopy Raw Red Context	HPSRAWR
Spectroscopy Raw Red Slice	HPSRAWRS
Spectroscopy Averaged Blue Context	HPSAVGB
Spectroscopy Averaged Blue Slice	HPSAVGBS
Spectroscopy Averaged Red Context	HPSAVGR
Spectroscopy Averaged Red Slice	HPSAVGRS
Spectroscopy Slope fitted Blue Context	HPSFITB
Spectroscopy Slope fitted Blue Slice	HPSFITBS
Spectroscopy Slope fitted Red Context	HPSFITR
Spectroscopy Slope fitted Red Slice	HPSFITRS
Spectroscopy raw DecMec status Blue Context	HPSDMCB
Spectroscopy raw DecMec status Blue Slice	HPSDMCBS
Spectroscopy raw DecMec status Red Context	HPSDMCR
Spectroscopy raw DecMec status Red Slice	HPSDMCRS
Spectroscopy Nominal Housekeeping Context	HPSHK
Spectroscopy Housekeeping Slice	HPSHKS
General Housekeeping Context	HPGENHK
General Housekeeping Slice	HPGENHKS
Diagnostic Housekeeping Context	HPDIAGHK
Diagnostic Housekeeping Slice	HPDIAGHKS
Engineering Context	HPENG
Telecommand verification Slice	HPTCVERS
Telecommand history Slice	HPTCHISTS
Event Slice	HPEVENTS
TM Packet Report	HPTM_PACKET_REPORT
	HPTIME_VERIFICATION
	HPOBCP_STATUS
	HPOBCP_LIST
	HPMEMORY_DUMP
	HPMEMORY_CRC
	HPLINK_CONNECTION
	HPACT_OBCP_LIST
OGSE housekeeping Context	HPOGSEHK
PACS OGSE housekeeping Slice	HPOGSEHKS
CDMS simulator context	HPCDMS
PACS CDMS simulator slice	HPCDMSS

4.1.5. PACS spectroscopy level-1 products

Product description	Product type
PACS Spectroscopy - level-1 Context	HPS3D
PACS Spectroscopy Calibrated Frames	HPSCF

Product description	Product type
PACS Spectral Cube - Blue Spectrometer	HPS3D
PACS Spectral Cube - Red Spectrometer	HPS3D

4.1.6. PACS spectroscopy level-2 products

Product description	Product type
PACS Spectral Cube - level-2 Context	HPS3DR
Rebinned 3d Cube - Blue Spectrometer	HPS3DR
Rebinned 3d Cube - Red Spectrometer	HPS3DR

4.2. PACS calibration products

4.2.1. PACS Common Calibration Products

Product type	Description
PacsCalCommon	*PACS Common Calibration Context*
ChopperAngle	Relation between the digital field plate readout and physical angle of the chopper mirror with respect to the PACS focal plane unit.
ChopperAngleRedundant	Relation between the digital field plate readout and physical angle of the redundant chopper mirror with respect to the PACS focal plane unit.
ChopperSkyAngle	Conversion factor for chopper physical deflection angle with respect to the FPU to angle on the sky.
ChopperJitterThreshold	Thresholds in arcmins for the required position accuracy of the final chopper positions for the science and calibration window. This product is used to determine if detector signals are on a stable chopper plateau.
FilterWheel2Band	Conversion of filter wheel position to photometer or spectrometer band seen by the detectors.
ObcpDescription	Contains human-readable descriptions of the on-board control procedure on-board numbering scheme.
Siam	Spacecraft-instrument alignment matrices for the different PACS virtual apertures.
TimeDependency	Defines time dependency for calibration products.

4.2.2. PACS Photometer Calibration products

Product type	Description
PacsCalPhot	*PACS Photometer Calibration Context*
Absorption	Transmission as a function of wavelength for the entire photometer chain system.
ArrayInstrument	Photometer detector array to Instrument alignment.
BadPixelMask	Bad pixels mask for the photometer.
CalSources	Flux per pixel from the (CSs) in the blue and red channel.
CorrZeroLevel	Zero-level of the bolometer arrays.

Product type	Description
CrosstalkMatrix	Crosstalk matrices for the red and blue photometer.
DetectorSortMatrix	Mapping PACS SPU-internal detector number to pixel coordinate in the PACS focal-plane.
DiffCS	CS1-CS2 used as reference
FilterTransmission	Measured filter transmission profiles for the different bandpass and order selection filters in the PACS spectrometer and photometer chain.
FlatField	Pixel-to-pixel response variation for the PACS bolometer arrays.
Gain	Digits to Volts conversion of the bolometer signals.
Invntt	Inverse noise to noise correlation for MadMap
InvnttBL	BL band inverse noise to noise correlation for MadMap
InvnttBS	BS band inverse noise to noise correlation for MadMap
InvnttRED	RED band inverse noise to noise correlation for MadMap
Masks	PACS blue and red channel bad pixel map.
PhotometricStabilityThreshold	Thresholds used to raised an alert on bad photometric stability
Responsivity	Responsivity for bolometer
SatLimits	Saturation limits for the bolometer arrays.
SubArrayArray	Alignment of the different photometer sub-matrices with respect to the entire detector array.
TimeDependency	Defines time dependency for calibration products.

4.2.3. PACS Spectrometer Calibration Products

Product type	Description
PacsCalSpec	*PACS Spectrometer Calibration Context*
ArrayInstrument	Array to Instument coordinate conversion
BadPixelMask	Bad pixels mask for PACS spectrometer.
CapacitanceRatios	Contains the capacitance ratios for the red and the blue array
ChopperThrowDescription	Defines the chopper position readout versus a verbal description.
CrosstalkMatrix	Crosstalk matrices for the red and blue spectrometer arrays
DetectorSortMatrix	Mapping PACS SPU-internal detector number to pixel coordinate in the PACS focal-plane.
DiscardRampHooks	Specifies the number of readouts to discard at the start of each photoconductor integration ramp.
EffectiveCapacitance	The effective capacitance of the 4 possible commandable capacitances of the spectrometer detector integrating readout circuits.
GprHall	Grating position versus Hall sensors readback. This conversion is used in the degraded operating mode of the grating, in case of contingent functioning of the inductosyn position readout.
GprHallRedundant	Defines the redundant grating position versus Hall sensors readback.
GratingJitterThreshold	Thresholds in position readouts for the required accuracy of a stable grating position. These are used to determine the start and end of long grating slews.

Product type	Description
FilterBandConversion	Defines the wheel position readout to band conversion
KeyWavelength (TBC)	Lists the key wavelength intervals - these are wavelength ranges at which the internal calibration sources are visited inside the AOT, as well as sky calibration sources during dedicated absolute flux calibration measurements. The absolute flux of every PACS spectrum is tied to external flux calibrators via observations at these wavelengths.
LabelDescription	The status of PACS mechanisms and detector readout timing is sampled at the detector readout frequency and encoded in a label. This calibration table contains the definition of this encoding.
LittrowParameters	Parameters for the littrow equation describing the PACS grating position to wavelength calibration. The present version assumes the same calibration for all spatial pixels; in future versions this calibration will be available for every spatial pixel.
LittrowPolynomes	Grating wavelength calibration: Littrow equation parameters/polynome approximation for alpha per pixel
ModuleArray	Module to Array coodinate conversion calibration object
NonLinearity	Contains coefficient of second order polynomial to linearise signals for the red and blue array
Psf	Point spread function of the spectrometer.
RampModel	Fixed parameters of the IMEC analytical model for the spectrometer integrating ramps.
RampSatLimits	Signal saturation limits (voltage/digits) for the red and blue channel.
Readouts2Volts	Digits to Volts conversion for the spectrometer readout values.
Rsrf	Relative Spectral Response Function - wavelength-dependent response per pixel for each spectral band.
Sensitivity	Contains the line and continuum RMS noise fluctuations for 1 second integration time
SignalSatLimits	Saturation limits of the spectrometer detector arrays
SpecProperties	Spectrometer constants to calculate spectral resolution vs. wavelength
TelescopeBackground	SED of the telescope background
TimeDependency	Defines time dependency for calibration products.

Chapter 5. SPIRE Products Description

5.1. SPIRE observational products

5.1.1. Level-0 products

The generic Herschel definition of Level-0 data products is the following:

- *Raw telemetry data (TMPackets) as measured by the instrument, minimally manipulated and ingested as Data Frames into the mission data base/archive. Typically, readings are in binary units versus detector pixel number*

The SPIRE definition of Level-0 data products differs from the Herschel-wide definition in the format. In fact, SPIRE Level-0 data products are implemented as IA Products (or subclasses) that contain raw telemetry values as extracted from SPIRE Data Frames.

The format of Level-0 data products is defined to be as simple as possible. Each product will contain data coming from only one Building Block of a specified Observation. Moreover, each product will contain data coming from only one TM packet type. All Level-0 products are made from the `BuildingBlockProduct` java class.

Each product will contain only one TableDataset, identified with the name of the TM packet type; this table has a number of Columns, one for each quantity stored in SpireDataFrames of the specified TM packet, i.e. a column for each TM parameter contained in the specified TM packet. However, some TM parameters that are not useful for data processing (e.g. FrameIDs) are not stored in SpireDataFrames and will be not present in Level-0 data products. The "`sdfTime`", "`packetTime`" and "`seqCount`" are defined as the the SpireDataFrame time, the TM packet time and the TM packet Sequence Count; these quantities are used to compute the sample time, to check its validity and to check the correct time ordering of the telemetry.

The last column in the following table defines which in pipeline each product is used. The pipelines for different observing modes are defined as follows:

- POF2: Photometer 7-point jiggle
- POF3: Photometer 64-point jiggle
- POF5: Photometer Scan Map
- POF9: SPIRE/PACS Parallel Mode
- SOF1: Spectrometer sparse map, single pointing/raster
- SOF2: Spectrometer jiggle map, single pointing/raster

Product description	**Product type**	**TM Packets**	**POF2**	**POF3**	**POF5**	**POF9**	**SOF1**	**SOF2**
Raw Photometer Detector Timeline	RPDT	`PHOTF`, `PHOTSW`, `PHOTMW`, `PHOTLW`	y	y	y	y		
Raw Photometer Offset Timeline	RPOT	`PHOTOFF`	y	y	y	y		

Product description	Product type	TM Packets	POF2	POF3	POF5	POF9	SOF1	SOF2
Raw Spectrometer Detector Timeline	RSDT	SPECF, SPECSW, SPECLW					y	y
Raw Spectrometer Offset Timeline	RSOT	SPECOFF					y	y
Raw Nominal Housekeeping Timeline	RNHKT	NHK	y	y	y	y	y	y
Raw Critical Housekeeping Timeline	RCHKT	CHK	y	y	y	y	y	y
Raw Beam Steering Mirror Timeline	RBSMT	BSMNOMINAL	y	y				
Raw Spectrometer Mechanism Timeline	RSMECT	SMECSELECT, SMECSCAN					y	y
Raw Subsystem Control Unit Timeline	RSCUT	SCUNOMINAL	y	y	y	y	y	y

The SPIRE level-0 context is defined as follows:

Product description	Product type
SPIRE Level-0 Context	Level0Context
Level-0 Building Block context (each block is generated per observation building block)	Level0BlockContext
Level-0 products (as given in the table above)	

5.1.2. Level-0.5 products

Product description	Product Type	POF2	POF3	POF5	POF9	SOF1	SOF2
Photometer Detector Timeline	PDT	y	y	y	y		
Photometer Offset Timeline	POT	y	y	y	y		
Spectrometer Detector Timeline	SDT					y	y
Spectrometer Offset Timeline	SOT					y	y
Nominal Housekeeping Timeline	NHKT	y	y	y	y	y	y
Critical Housekeeping Timeline	CHKT	y	y	y	y	y	y
Beam Steering Mirror Timeline	BSMT	y	y				
Spectrometer Mechanism Timeline	SMECT					y	y
Subsystem Control Unit Timeline	SCUT	y	y	y	y	y	y

The SPIRE level-0.5 Engineering Data Processing (EDP) context is defined as follows:

Product description	Product type
SPIRE Level-0.5 EDP Block context	
Level-0.5 Building Block context (each block is generated per observation building block)	
Level-0.5 product (as given in the table above)	

5.1.3. Level-1 products

Product description	Product type	POF2	POF3	POF5	POF9	SOF1	SOF2
Pointed Photometer Product	PPP	y	y				
Photometer Scan Product	PSP			y	y		
Spectrometer Detector Interferogram Product	SDI					y	y
Spectrometer Detector Spectrum Product	SDS					y	y

5.1.4. Level-2 products

Product description	Product type	POF2	POF3	POF5	POF9	SOF1	SOF2
Jiggled Photometer Product	JPP	y					
Photometer Map Product	PMP		y	y	y		
Spectrometer Cube Product							y

5.2. SPIRE calibration products

A separate set of calibration products is defined for each of the two sub-instrument on SPIRE, the Photometer and the Spectrometer. These are indicated by `Spec` or `Phot` in the type name after `SCal`.

The following tables summarise the calibration products required. The next section then gives details of the format and origin of the data to be stored in each one.

5.2.1. Calibration History Products

These products are not strictly calibration products as they contain the history information for certain parameters. However, they are used by the pipeline in the same way as normal calibration products. They are filled using either dedicated pre-processing pipelines during Operational Day Processing, or filled by information generated by the pipeline.

Product type	Product Description
SCalResetHist	DPU Counter Reset History
SCalPhotOffsetHist	Photometer Signal Offset History
SCalSpecOffsetHist	Spectrometer Signal Offset History
	PCAL History

Product type	Product Description
SCalPhotPcal	Photometer PCAL Output Table
SCalSpecPcal	Spectrometer PCAL Output Table

5.2.2. Photometer Calibration Products

Product type	Product Description
SCalPhotChanNum	Channel Number Mapping Table
SCalPhotChanMask	Channel Mask Table
SCalPhotInstModeMask	Instrument Mode Mask Table
SCalPhotChanTimeOff	Channel Time Offset Table
SCalPhotChanGain	Channel Gain Table
SCalPhotBolPar	Bolometer Parameter Table
SCalPhotChanNomRes	Blank Sky Measurement (Rd-nom)
SCalPhotBsmPos	BSM Position Table
SCalPhotBsmOps	BSM Operations Table
SCalPhotDetAngOff	Detector Angular Offset Table
SCalPhotElecCross	Electrical Crosstalk Matrix
SCalPhotLpfPar	Low Pass Filter Parameter Table
SCalPhotFluxConv	Flux Conversion and Non-linearity Correction Coefficients
SCalPhotTempDriftCorr	Temperature Drift Correction Coefficients
SCalPhotChanTimeConst	Detector Time Constant Correction Function
SCalPhotOptCross	Optical Crosstalk Matrix
SCalPhotChanNoise	Detector Noise Spectrum
SCalPhotBeamProf	Photometer Beam Profiles
SCalPhotSpecIndex	Spectral Index Conversion
SCalPhotRsrf	Photometer RSRF
SCalPhotPcalPar	PCAL Input Parameters

5.2.3. Spectrometer Calibration Products

Product type	Product Description
SCalSpecChanNum	Channel Number Mapping Table
SCalSpecChanMask	Channel Mask Table
SCalSpecChanTimeOff	Channel Time Offset Table
SCalSpecChanGain	Channel Gain Table
SCalSpecBolPar	Bolometer Parameter Table
SCalSpecBolParSky	Blank Sky Measurement (Rd-nom)
SCalSpecBsmPos	BSM Position Table
SCalSpecBsmOps	BSM Operations Table
SCalSpecDetAngOff	Detector Angular Offset Table
SCalSpecElecCross	Electrical Crosstalk Matrix
SCalSpecFluxConv	Spectrometer Flux Conversion Table

Product type	**Product Description**
SCalSpecLpfPar	Low Pass Filter Parameter Table
SCalSpecOptCross	Optical Crosstalk Matrix
SCalSpecDetTimeConst	Detector Time Constants Table
SCalSpecNonLinCorr	Non-linearity Correction Coefficients
SCalSpecTempDriftCorr	Temperature Drift Correction Coefficients
SCalSpecSmecZpd	Optical Encoder and LVDT DC at ZPD
SCalSpecSmecStepFactor	SMEC Step Factor to convert from MPD to OPD
SCalSpecModEff	Modulation Efficiency as function of OPD
SCalSpecInterRef	Reference Interferogram
SCalSpecBandEdge	Spectral Band Edges
SCalSpecNlp	Non-linear (Optical) Phase
SCalSpecRsrf	Spectrometer RSRF
SCalSpecSmecStepFactor	Spectrometer Step Factor Table
SCalSpecSmecZpd	Spectrometer Optical encoder at ZPD Table
SCalSpecIls	Instrument Line Shape
SCalSpecBeamProf	Spectrometer Beam Profiles
SCalSpecPcalPar	PCAL Input Parameters

Chapter 6. Auxiliary, Catalogue and Quality Products Description

6.1. Auxiliary products

Name	Product type	Description
Auxiliary Context		
Herschel Pointing product	HPP	The pointing product contains time-dependent spacecraft attitude information and will be built using information provided in the Attitude History File (AHF) furnished by the Flight Dynamics System (FDS). This product is defined in [RD-7]. It is generated per Operational Day (OD).
Orbit Product	auxOrbitp auxOrbitr	The predicted and reconstructed products have identical format and contain time-dependent S/C state vector information as provided by FDS as Orbit Ephemeris Message (OEM) data. Defined in [RD-8]. Generated per OD.
SIAM Product	auxSiam	This product contains the Spacecraft/Instrument Alignment Matrices transforming vectors in the Herschel spacecraft reference frame to/from vectors in the different instruments' frames. Defined in [RD-9]. The SIAM product is valid for a given period of time in the mission until a new measurement is done and the product is updated.
Time Correlation Product	auxTimec	The Time Correlator component within the HPMCS maintains the correlation between the spacecraft on-board time and ground time, providing interfaces to correlate OBT to UTC and vice-versa. The Time Correlation product should contain all the relevant information produced by the Time Correlator component and stored in the SCOS-2000 Time Correlator Coefficient packets. Defined in [RD-10]. It is generated per OD.
Out of Limits Product	auxOol	The HPMCS SCOS-2000 BEHV performs behaviour checking for all parameters specified in the MIB OCF table. This information furnished to the HSC by means of DDS auxiliary TM data products. The Out-of-limits product shall pack all the information provided therein. Defined in [RD-10]. It is generated per OD.
Missing Telemetry Product	auxMissTM	This product contains information of missing TM packets after ingestion in the HSC. It has been designed to contain the minimum information required to unambiguously identify the missing TM packets. Defined in [RD-10]. It is generated per OD.
Mission Timeline Summary Product	auxMtls	This product packs the information provided within the EPOS summary file: pointing requests data, reaction wheel profile data, ground station

Name	Product type	Description
		coverage and DTCP data and delta-V manoeuvre data. Defined in [RD-10]. It is generated per OD
Events Log Product	auxEvLog	The events log product is intended to provide with a uniform product containing event reports from either the instruments or the spacecraft. Defined in [RD-10]. It is generated per OD.
Telecommands History Product	auxTch	This product contains information of telecommand history as furnished by the Herschel MCS by means of DDS service. Defined in [RD-10]. It is generated per OD.
Calibrated SREM Data Product	auxCalSREM	The Standard Radiation Environment Monitor (SREM) detects and counts electrons, protons and cosmic rays with a coarse spectral resolution and some 20 degrees angular resolution. This product contains the calibrated accumulation and acquisition data, including the proton/electron count rates in the three detectors, fitted particle spectra and total dose in the internal RadFET. It is generated per OD. Defined in [RD-12].
Raw SREM Data Product	auxRawSREM	Contains raw SREM accumulation and acquisition data, including readings from the different channels of detectors and internal RadFET, temperature and voltage data, etc. It is generated per OD. Defined in [RD-12].
Orbit Events Products	auxOrbEvp/r	These products have identical format and contain the predicted/reconstructed orbit events data furnished by Flight Dynamics (FDS) in the (short term) orbit events file. Events include Acquisition/loss of TM/TC signal at the ground station and eclipse events information. It is generated per OD. Defined in [RD-10].
Uplink Data Product	auxUpl	This product contains uplink information, including: proposal data, observation request data and observation block execution data. It is generated per observation. Defined in [RD-10].
Satellite Housekeeping data Product	auxSatHK	This product is intended to pack housekeeping telemetry information from the S/C. Currently comprises monitoring data from the Cryostat Control Units A/B (CCUA/B). It is generated per OD. Defined in [RD-10].

6.2. Quality control

The Quality Control Report is a product to gather, combine and distribute information on the quality of the observation science data. Quality Control will include, per observation, the assessment of the execution of the observation by the spacecraft and the instruments, the evaluation of the success of the data processing, the outcome of the systematic inspection of the Quick Look product and, if required, the instrument specialist and community support astronomer analysis. The quality control product distributed to the astronomer, the so-called Quality Control Report Summary, will be an extract of the Quality Control Report.

The Quality Control Report is implemented in the HCSS system as a single class named *QualityContext*. An instance of the *QualityContext* class will be automatically created during the Standard Product

Generation process for each observation. This instance will be accessible though the "quality" field of the *QualityContext* representing the processed observation. The Quality Control Report Summary will be generated at the end of the quality control analysis as a result of this process. It will be implemented in the HCSS as a new instance of a *QualityContext* and it will be accessible through the "quality summary" field of the same *QualityContext* containing the original Quality Control Report.

The Quality Control Report contains the data automatically generated in the Standard Product Generation process and the inputs resulting from the Quality Control analysis. Besides the "attributes" listed in Section 2.4.3, the Quality Control report will also contain the following fields:

- **Observation Id:** Reference to the observation this instance belongs to
- **Software version:** HCSS version, pipeline version...
- **State:** Define the state of the observation from the point of view of quality. Possible states are:
  - Pending
  - Passed
  - Failed
- **Action:** Legal actions depend on the value of the "State" field:

  When State=Passed the only possible action is NONE

  When State=Failed possible actions are:

  - Delivered for Rescheduling
  - Delivered for Reprocessing
  - Discarded

  When State=Pending possible actions are:

  - Delivered for Quality Control Analysis at level 1
  - Delivered for Quality Control Analysis at level 2
  - Delivered for Quality Control Analysis at level 3
- **SPRs:** If applicable, reference to the SxR (number and title) reporting system.
- **Quality Flags:** Quality flags are pre-defined list of fields of simple data types (strings, numbers and booleans) defined per instrument. These fields will be stored as metadata into the Quality Report. Some of their characteristics are:
  - Quality flags can be declared of any of the legal metadata types
  - The metadata tag is just a flag identifier which follows the Product Definition Group conventions
  - Quality information is included as a string, number or boolean into the metadata value

  Quality flags can be tagged as public or private.
- **Pipeline logs:** A table containing all the logs produced during pipeline's execution, including those in the pre- and post-processing SPG phases
- **Preview:** Quick look (browse) products associated to the observation
- **User's comments:** Comments on the quality data written by the different actors involved in the Quality Control of the observation. The fields stored for every comment are:

- Time stamp: When the comment was created
- User: Identifier of the person writing the comment
- Text: the comment itself as a string

Every comment can be tagged as public or private.

The Quality Control Report Summary is a copy of the Quality Control Report which contains only the fields declared as public.

6.2.1. Quality Flags

The first set of Quality flags populating the Quality Control Report are derived from the auxiliary products which contain the Spacecraft and Instruments information reported by the MOC. The current defined flags (the FITS equivalents are shown in parentheses) are listed below. They are all of string type.

- **Missing Telemetry (TMLOSSES)**

  The following columns of the Missing TM product are checked and the values written in the Quality Report logs field:

  - Missing Packets
  - Last valid packet time
  - Next valid packet time

- **Out of Limits (OOL)**

  The following columns of the Out of Limits product are checked and the values written in the Quality Report logs field:

  - OOL Time
  - Parameter name
  - Parameter state

- **Event (EVENT)**

  The following columns of the Events log product are checked and the values written in the Quality Report logs field:

  - Event Id
  - Report Subtype
  - Event description

- **Telecommand Errors (TCERRORS)**

  The following columns of the Telecommand History product are checked and the values written in the Quality Report logs field:

  - TC name
  - TC short description
  - Verification status

- **High glitch rate (GLITCHES)**

  The following columns of the SREM product are checked and the values written in the Quality Report logs field:

  - Proton alarm
  - Electron alarm
  - Heavy ions

- **Pointing Problem / Suspicious Pointing (POINTING)**

  The following columns of the Pointing product are checked and the values written in the Quality Report logs field:

  - On-target flag
  - Off-position flag
  - Out of field flag
  - Quality flag

The second set of flags are generated by the instrument specific pipelines (TBD)

6.3. Catalogue products

Catalogue products are common to the three Herschel instruments. The following catalogue products have been defined:

- Spectral Line List product. See [RD-5].
- Source List product

6.3.1. Spectral Line List product

The Herschel Spectral Line List Product is aimed at holding relevant information on the properties of spectral lines extracted from Herschel spectra. This product will be the output of automatic extraction tools, and interactive tools (TBD). It is expected that only information directly derived from Herschel data are stored within this Spectral Line List Product. For external information no standard provisions are supplied. However as TableDatasets are expandable products new Columns always can be added without crippling the existing possibilities. It is likely that additional columns are defined in the course of the development of the Herschel DP spectral line extraction package(s). Columns that contain parameters that can be derived from other columns are not included in the product.

It is assumed that spectral lines in this product can be extracted from different spectra (with different frequency scales and distortions). It is also assumed that all spectra are reduced to the same standard of rest. This information is included in the header. It is also assumed that the positional parameter determination is done using the same method for all lines. This is also documented in the metadata.

The flux extraction is also expected to be done using the same method, therefore this information is not repeated per source, but rather documented in the metadata. Here it is assumed that the lines are defined (were derived) using a 3 parameter model (e.g. Gaussian) with a position, a width and an amplitude. This model sits on top of an unspecified background model. If a model with more parameters is needed to specify lines in a Herschel spectrum, then of course all these parameters need to be present in this Product and more (or other) Columns will ensue.

Metadata

Keyword	Type	Description
id	string	Product identifier
author	string	Author of the product
type	string	Herschel product type (set to "HSLL")
description	string	Product description (set to "Herschel Spectral Line List Product")
creator	string	Name of the S/W that produced the product
creationDate	date	Date of the creation of the product
positionalType	string	Type of positional derivation (e.g. isophotal or windowed)
sourceId	string	Name of the source
longitude	double	Longitude of the source in degrees
latitude	double	Latitude of the source in degrees
coordinateSystem	string	Name of the coordinate system
localStandardRest	string	Local standard of rest
ctype1	string	Wavelength type, default = "frequency"
cunit1	string	Unit axis 1, default = "GHz"
profile	string	Line extraction method (e.g. Gaussian, Voigt, etc.)
fluxUnit	string	Unit of the fluxes (default = W/m2, K)
backgroundType	string	Type of background determination (global/local/polynomial)
references	string	References, e.g. Herschel observations/products
explanatoryTest	string	Additional comments

Spectral Line List: TableDataset

Keyword	Type	Description
name	double	Identifier / source name
position	double	Barycentric world position (WCS units - GHz)
peakpos	double	World coordinate of pixel with highest intensity
stdpos	double	Uncertainty in position in WCS units
width	double	Width of the line in WCS units
stdwidth	double	Uncertainty on width in WCS units
flux	double	Integrated line flux
stdflux	double	Uncertainty of the flux
saturation	double	Saturation level
stdsaturation	double	Uncertainty in saturation level
background	double	Background flux (at the position of the line)
stdbackground	double	Uncertainty of the background estimation
noisescale	double	Local noise scale

Keyword	Type	Description
evidence	double	Probability of a source present divided by not present

Double side band spectra (HIFI) extra columns

Keyword	Type	Description
position_image	double	Baryocentric pixel position in the image sideband
peakpos_image	double	Peak position in the image sideband
flux_image	double	Integrated line flux (if in image sideband)
probability_image	double	Probability of the line being in the image sideband
probability_signal	double	Probability of the line being in the signal sideband

Other possible additional columns

Keyword	Type	Description
Transition	string	Spectral transition
Species	string	(Molecular) species
position_pixel	double	Barycentric pixel position (pixel units)
peakpos_pixel	double	Pixel coordinates with highest intensity
stdpos_pixel	double	Uncertainty in position in pixel units
width_pixel	double	Width of the line in pixel units
stdwidth_pixel	double	Uncertainty on width in pixel units

6.3.2. Source List product

The Herschel SourceList Product is aimed at holding relevant information on the properties of sources extracted from Herschel images. This product will be the output of automatic extraction tools, and interactive tools (e.g. aperture photometry / psf fitting GUI).

Metadata

Keyword	Type	Description
id	string	Product identifier
author	string	Author of the product
type	string	Herschel product type (set to "HSLP")
description	string	Product description (set to "Herschel Source List Product")
creator	string	Name of the S/W that produced the product
creationDate	date	Date of the creation of the product
author	string	Author of the product
detThreshold	double	Detector threshold
fwhm	double	Width of the default gaussian beam profile
pixelRegion	double	Pixel region considered for processing

Keyword	Type	Description
cornerMinRa	double	Minimum RA of corner enclosing rectangle
cornerMinDec	double	Minimum Dec of corner enclosing rectangle
cornerMaxRa	double	Maximum RA of corner enclosing rectangle
cornerMaxDec	double	Maximum Dec of corner enclosing rectangle
algorithm	string	Extraction algorithm used
references	string	References, e.g. Herschel observations/products
explanatoryText	string	Additional comments

Source List: TableDataset

Keyword	Type	Description
ra	double	Right Ascension
dec	double	Declination
raPlusErr	double	RA plus error
decPlusErr	double	Dec plus error
raMinusErr	double	RA minus error
decMinusErr	double	Dec minus error
flux	double	Source flux
fluxPlusErr	double	Source flux plus error
fluxMinusErr	double	Source flux minus error
size	double	Source size
sizePlusErr	double	Source size plus error
sizeMinusErr	double	Source size minus error
sharpness	double	Source sharpness
roundness	double	Source roundness
background	double	Background
bgPlusErr	double	Background plus error
bgMinusErr	double	Background minus error
quality	double	Quality

Appendix A. Common metadata keywords in Herschel products

The following table lists the main Herschel metadata keywords, their description, and their expression in FITS.

Herschel DP Name	Description	FITS-Name
acmsMode	ACMS mode	ACMSMODE
activeStrId	identification of the active STR	ACTIVSTR
aorLabel	AOR label as entered in HSpot	AOR
aot	AOT Identifier	AOT
aperture	Instrument aperture in use	APERTURE
apid	Application Programme Identifier	APID
arrayName	Name of Detector Array	DETECTOR
author	Author of the data	AUTHOR
averaging	Averaging operator	AVERAGIN
band	Band	BAND
baselineModel	Baseline Model	BASEMOD
baselineParams	Parameters of Baseline model	BASEPAR
bbCount	Building Block Count	BBCOUNT
bbid	Building Block Identifier	BBID
bbType	Building Block Type	BBTYPE
bbTypeName	Building Block Type Name	BBTNAME
biasVoltage	Bias voltage factor	BIASVOLT
bitPos	Bit position of this mask	BITPOS
calFileId	Calibration file ID	CALFILE
calFileVersion	Calibration file version	
calThreshold	Specified position accuracy threshold for a plateaux in calibration	THRESHOL
camera	Name Camera/ detector array	CAMERA
cameraModel	Model of the camera (CQM, FM, Sixpack,...)	CAMMODEL
cd1_1	CD1_1 element of CD matrix	CD1_1
cd1_2	CD1_2 element of CD matrix	CD1_2
cd1_3	CD1_3 element of CD matrix	CD1_3
cd2_1	CD2_1 element of CD matrix	CD2_1
cd2_2	CD2_2 element of CD matrix	CD2_2
cd2_3	CD2_3 element of CD matrix	CD2_3
cd3_1	CD3_1 element of CD matrix	CD3_1
cd3_2	CD3_2 element of CD matrix	CD3_2
cd3_3	CD3_3 element of CD matrix	CD3_3
cdelt1	pixel size in axis 1	CDELT1

Herschel DP Name	Description	FITS-Name
cdelt2	pixel size in axis 2	CDELT2
changelog	Logging of changes	CHANGLOG
chopperPlateau	Indicates the chop plateau within sequence	CHOPPLAT
constVelFlag	Constant velocity flag	CONVELF
conversionFactor	conversion factor from chopper deflection (degrees) to angle on sky	CONVFACT
creationDate	Date of product creation	DATE
creator	The name of the software that created the product	CREATOR
crota2	rotation angle	CROTA2
crpix1	CRPIX1 reference pixel of axis 1	CRPIX1
crpix2	CRPIX2 reference pixel of axis 2	CRPIX2
crval1	axis 1 coordinate at tangency	CRVAL1
crval2	axis 2 coordinate at tangency	CRVAL2
ctype1	type of coordinate axis eg RA---TAN	CTYPE1
ctype2	type of coordinate axis eg DEC—TAN	CTYPE2
cusMode	CUS observation mode	CUSMODE
dataAnalyst	Name of data analyst	ANALYST
dec	Actual Declination of pointing	DEC
decNominal	requested declination of pointing	DEC_NOM
decObject	Declination of target object	DEC_OBJ
deltaPix	Correction of output angle per pixel unit offset to central pixel	DELTAPIX
description	Full name of product	DESC
endDate	End date of observation	DATE-END
endWavelength	End of wavelength interval	END_WL
epoch	equinox of celestial coordinate system	EPOCH
equinox	equinox of celestial coordinate system	EQUINOX
error	Error on signal	ERROR
explanatoryText	Explanatory text on the data	EXP_TEXT
fileName	name of exported file	FILENAME
filter	Filter name [SHORT/LONG/none]	FILTER
fineTime	Time of signal sampling	FINETIME
formatVersion	Version of product format	FORMATV
gyroPropQualIdx	Gyro-propagated quality index	GYROPQI
instMode	Instrument mode	INSTMODE
instrument	Instrument name	INSTRUME
interpMethod	Recommended interpolation method to be applied	INTERPM
jiggleId	Jiggle Identifier	JIGGLEID
keyWavelength	Key Wavelength	KEY_WAVE
maxWavelength	Maximum wavelength	MAX_WAVE
minWavelength	Minimum wavelength	MIN_WAVE

Herschel DP Name	Description	FITS-Name
missionConfig	Mission configuration	MISSIONC
modelName	Instrument Model Name	MODELNAM
naifId	SSO NAIF identifier	NAIFID
nodCycleNum	Switching/nodding cycle number	NODCYDEN
numChopCyc	Number of chopping cycles	
numHifiSaa	Number of HIFI reference Solar Aspect Angles	NHIFSAA
numJigglePos	Number of jiggle positions	NJIGGPOS
numNodCyc	Number of nodding cycles	NNODCYC
numPacsSaa	Number of PACS reference Solar Aspect Angles	NPACSSAA
numRasterCol	Number of raster columns	NRASTCOL
numRasterLines	Number of raster lines	NRASTLIN
numScanLines	Number of scan lines	NSCANLIN
numSpectra	Number of Spectra	NSPECTRA
numSpireSaa	Number of SPIRE reference Solar Aspect Angles	NSPIRESA
object	target name	OBJECT
objectType	astronomical object type	OBJTYPE
observer	name of observer	OBSERVER
obsid	Observation Identifier	OBS_ID
obsMode	Observation mode name'	OBS_MODE
odNumber	operational day number	ODNUMBER
offPosFlag	Off-position flag	OFF_POS
onTargetFlag	On-target flag	ONTARF
origin	site that created the product	ORIGIN
outOfFieldFlag	Out-of-field flag	OUTFIELD
pc1_1	PC1_1 element of PC matrix	PC1_1
pc1_2	PC1_2 element of PC matrix	PC1_2
pc1_3	PC1_3 element of PC matrix	PC1_3
pc2_1	PC2_1 element of PC matrix	PC2_1
pc2_2	PC2_2 element of PC matrix	PC2_2
pc2_3	PC2_3 element of PC matrix	PC2_3
pc3_1	PC3_1 element of PC matrix	PC3_1
pc3_2	PC3_2 element of PC matrix	PC3_2
pc3_3	PC3_3 element of PC matrix	PC3_3
pixelRow	Pixel row index	PIX_ROW
pointingMode	Pointing mode identifier	POINTMOD
posAngle	Position Angle of pointing	POSANGLE
productNotes	Notes describing this product	PRODNOTE
proposal	proposal name	PROPOSAL
ra	Actual Right Ascension of pointing	RA
raDeSys	Coordinate reference frame for the RA and DEC	RADESYS

Herschel DP Name	Description	FITS-Name
raErr	Error on Right Ascension of actual pointin	RA_ERR
raNominal	requested RA of pointing	RA_NOM
raObject	RA of target object	RA_OBJ
rasterColumnNum	Raster column number	RASTCOL
rasterLineNum	Raster line number	RASTLINE
readouts	sample readouts for one ramp	READOUTS
references	References	REFEREN
refPixel	Reference Pixel	REFPIXEL
roll	Spacecraft roll angle	ROLL
saa	Reference SAA value in the range 0-180 degrees	SAA
saturation	Fraction of saturated samples	SATURATE
satValuesSigned	Saturation values signed modes	SAT_SIGN
satValuesUn-signed	Saturation values unsigned modes	SAT_UNSG
scanLineNum	Scan line number	SCANLINE
sedVersion	Version of the SED	SED_VER
serendipityFlag	SPIRE serendipity mode flag	SERENDIP
siamId	Reference to the applicable SIAM	SIAM_ID
skyResolution	Spatial resolution	SKY_RES
slewFlag	Slew flag	SLEWFLAG
source	Source packet	SOURCE
sourceDetector	Detector Source Packet	SRC_DETC
sourceSmec	SMEC Source Packet	SRC_SMEC
specNum	Spectrum Number	SPEC_NUM
spectralResolution	Spectral resolution of data	SPEC_RES
startDate	Start date of observation	DATE_OBS and DATE-OBS
startWavelength	Begin of wavelength interval	START_WL
status	Pixel Status	PIX_STAT
status	Channel Status	CH_STAT
strInterlacingSta-tus	STR interlacing status	STR_I_ST
strQualIdx	STR quality index	STR_Q_ID
subinstrumentId	Sub-instrument identifier	SUBINST
subsystem	Instrument Subsystem	SUBSYS
telescope	Name of telescope	TELESCOP
temperature		TEMPERAT
type	Product type identification	TYPE
variability	Information on object variability	VARIABLE
version	version of product	VERSION
versionNotes	Notes specific to this version	VER_NOTE

Herschel DP Name	Description	FITS-Name
wavelengthId	Key Wavelength ID	WAVE_ID
wcsReference	Reference of Coordinate System	WCS_REF
wcsType	Type of Coordinate System	WCS_TYPE
wheelPos	Wheel position	WHEELPOS
zeroPointOffset	Zero point offset	ZERO_OFF