

SPIRE

SUBJECT: Calibration Tables For SPIRE IA

PREPARED BY: Tanya Lim

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APPROVED BY:

K. King

B. Swinyard

R Gastaud

M. Fox

AGREED BY:

M. Savage

Date:

Distribution

Helen Bright	IC
Dave Clements	IC
Matt Fox	IC
Rene Gastaud	CEA
Matthew Graham	IC
Steve Guest	RAL
Maohai Huang	Trieste
Ken King	RAL
Marc Savage	CEA
Sunil Sidher	RAL
Jason Stevens	ATC
Bruce Swinyard	RAL
Toshinobu Takagi	IC

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Glossary

CQM	Cryogenic Qualification Model
IA	Interactive Analysis
ICC	Instrument Control Centre
PFM	Proto-Flight Model
ZPD	Zero Path Difference

1. SCOPE

Several threads of SPIRE calibration have been progressing semi-autonomously and have now reached the point where a single framework needs to be developed. The framework adopted (see figure 3.1) involves developing a detailed description of the calibration tables needed for the three areas of calibration, uplink, downlink (IA) and the time estimator.

The aim of this document is to add the next level of detail to the high level ICC IA use cases and to propose a set of calibration tables needed for IA. It currently also uses the performance test specification to expand on how the test data or subsystem delivery packages will enable the proposed tables to be produced. It is expected that this information will later be moved to the ground calibration plan where this document will be applicable. The in-flight calibration is not currently considered and it will either be added to this document or written in the calibration plan at a later date i.e. once CQM testing has established basic instrument operating parameters.

It is important to note this document is not intended to make any statements about how the tables will be implemented in the IA system (files, objects etc.). It is only intended to deal with the content and layout of the tables to be produced by the calibration team and delivered to the observations and data analysis team.

As this is the first version of this document, it is written with an incomplete and naïve understanding of the instrument therefore it can be anticipated that the document may evolve significantly as both IA is defined and developed and our instrument understanding improves through testing.

2. DOCUMENTS

2.1 Applicable Documents

AD1	SPIRE Science Requirements
AD2	SPIRE Calibration Requirements
AD3	SPIRE ICC Use Cases

2.2 Reference Documents

RD1	SPIRE Calibration Plan
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3. INTRODUCTION

The SPIRE calibration framework is based on developing three strands of calibration documentation, relating to the time estimator, the uplink calibration requirements and the downlink calibration requirements. These three strands are then combined into the calibration plan where all the SPIRE calibration tables are outlined. In order to develop the requirements for the three calibration areas information from several sources with different heritages within the SPIRE consortium need to be developed.

The calibration document tree is shown in figure 3.1 with this document highlighted in red. The IA use cases define IA functional requirements in terms of high level user interactions with IA. This document then analyses these use cases in terms of calibration tables needed. In order to do so, assumptions have needed to be made about the actual IA data flow and hence a set of flow diagrams have been developed.

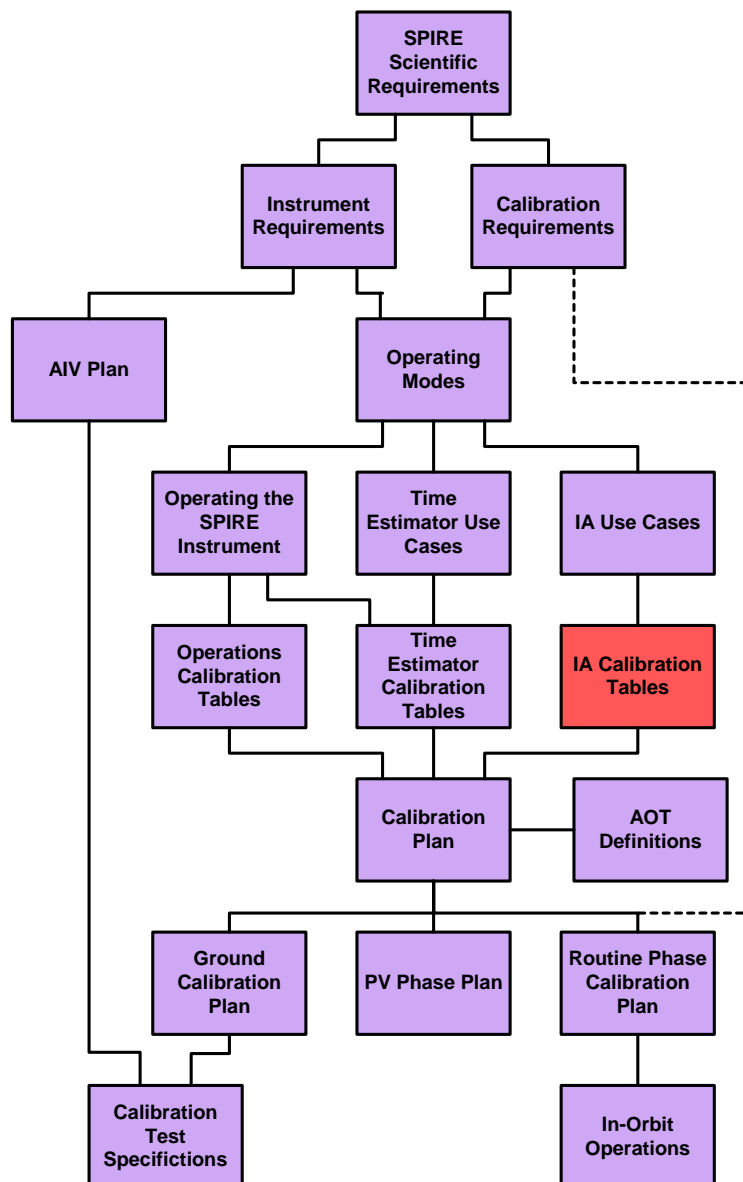


Figure 3.1

The following section takes the list of IA related use cases and separates these into those which may require an input from the calibration team and those that do not.

The use cases are not numbered in a way which is easy to understand in terms of an IA data flow, therefore section 5 which describes the steps necessary to process SPIRE data, has been organised to reflect the actual dataflow rather than the use case numbering and a cross-reference to this re-ordering is given in the use case table in section 4. In Section 5 the high level use cases are expanded to give more details on what each activity entails and the type of calibration information which is needed. Section 6 then lists a possible set of calibration tables required by IA which is used as an input to the calibration plan. Finally section 7 shows the data flow diagrams assumed.

4. IA RELATED USE CASES

Table 1 lists potential IA processing steps and those use cases relating to the IA. The table is organised in the order the use cases appear in AD3 with the first column referencing the use case, the next column detailing an IA processing step and the final column giving the section reference for the analysis of this step below.

The table is also sub-divided into those steps which 'may' require calibration information and those steps which will not require calibration information. The steps which 'may' require calibration information are analysed in section 5.

IA Use Cases That May Require Calibration Input		
Use Case	IA Step	Section
UC-DAC-101	Identify and flag bad data	5.2
UC-DAC-102	Filter data on any criteria	5.2
UC-DAC-102, UC-FTS-112	Deglitching	5.11
UC-DAC-103	Remove electrical crosstalk	5.14
UC-DAC-103	Removal of optical crosstalk	5.15
UC-DAC-104	Flatfield	5.18
UC-DAC-105	Identify and flag data on any criteria	5.2
UC-DAC-106	Subtract astronomical background	5.24
UC-DAC-107	Re-construct pointing	5.6
UC-DAC-107	Correct for telescope pointing drift	5.6
UC-DAC-108, UC-FTS-109	Removal of time dependant responsivity drift	5.9
UC-DAC-108	Adjust to absolute reference responsivity	5.19
UC-DAC-108	Convert to janskys	6.20
UC-DAS-101	Correct for analogue electronics, remove gains add offsets etc.	5.3
UC-DAS-101	Extract raw data	5.1
UC-FTS-104	Convert from position counter to mechanical position	5.4
UC-FTS-106	Convert from mechanical position to OPD	5.5
UC-FTS-107, 113	Phase correct and apodise	5.20
UC-FTS-108	Re-grid, if necessary, to get a sample on the ZPD	5.16
UC-FTS-110	Correct for time varying drift in flux from SCAL or the telescope	5.7
UC-FTS-111	Correct for position dependent variation in the flux	5.8
UC-FTS-115	Remove telescope calibration emission (spectrometer)	5.17
UC-FTS-118	Detect and identify lines	5.27
None	Remove time dependency in spectral response of instrument	5.22
UC-PHT-108	Map Generation	5.26
UC-PHT-108	Averaging	5.13
UC-PHT-110, UC-PHT-111	Colour correct	5.25
UC-PHT-113	Detect sources	5.28
UC-PHT-121	Demodulation	5.12
IA Related Use Cases Which Will Not Require Calibration Team Input		
UC-ENG-003	Store data	N/A
UC-FTS-103	Reconstruction of each scan/interferogram	N/A
UC-FTS-105	Generate array of signal vs position	N/A

UC-FTS-114	Fourier transform	N/A
UC-FTS-116	Produce a spectrum per sky pixel	N/A
UC-FTS-117	Produce 3-D data cube	N/A
UCF 489	Retrieve archive artifact	N/A
UC-DAS-101	Separate data by nod, jiggle, raster position, and/or scan map scans	N/A
UC-DAS-108	Visualise any data product	N/A
UC-DAS-102	Import non-IA format data	N/A
UC-DAS-103	Conversion of output data to popular data formats	N/A
UC-DAS-104	Examine observation and data reduction history	N/A
UC-DAS-105	Information and messaging system	N/A
UC-DAS-106	Interactive Analysis Documentation	N/A
UC-DAS-107	Record Data Reduction History	N/A
UC-PHT-108	Sort out rastering	N/A
UC-PHT-108	Sort out jiggling	N/A
None	Sort out nodding (not covered)	N/A

Table 4.1

5. IA PROCESSING STEPS

5.1 Extract Raw Data and Re-Construct Timeline

Description

The raw data will be retrieved in the form of data frames. The format of these frames is still TBD and a decision is not expected until after CQM testing. From the packet level the data will need to be extracted and re-constructed onto a common timeline. For the FTS, if not done in data frame construction, this will require interpolation between SMEC position and detector readout time.

Main Steps

- User selection of data
- User selection of data source (local disk, database etc)
- User/Automatic selection of IA version
- Database query/file read
- Organisation of input data into types appropriate for the observation(s), detector data, PCAL data, BSM data etc

Calibration Information/Files Needed

We may need some sort of configuration table which tells IA the time or version validity of the calibration tables. This will allow automatic selection of set of calibration tables for a particular observation while allowing the choice of any table for interactive use.

ICC Use Cases

UC-DAS-101 – Read and prepare data frames for IA processing

5.2 Identify, Flag and Filter Data on Any Criteria

Description

It is possible that there will be either single, or groups of, dead pixels. If this occurs prior to launch it will be immediately picked up in standard tests where the whole array is illuminated and it is expected that a dead pixel mask will be applied at the start of processing.

Main Steps

The IA use cases mentioned here also allow user selected bad pixels e.g. they might wish to ignore a particularly noisy pixel, other criteria given include...

- User-specified bolometer numbers.
- Outside or inside a user-defined region (spatial and/or temporal).
- Below a user-specified intensity level.
- Fitting trends to the data (e.g. gradients).
- Statistical definition (e.g. 2 sigma around median).
- Logical/mathematical expression using temporal, spatial and intensity

coordinates.

Calibration Information/Files Needed

We may need to define a few different masks so the list below may expand...

IACR-001 Bad pixel mask for each array, each mask just contains a flag indicating which detector(s) should not be used.

IACR-002 NEP for each detector, divided into separate tables for each array.

IACR-003 Identifiers for the vignetted pixels at edges of the FOV

IACR-004 As the BSM moves away from centre, depending on direction, some pixels will get vignetted and IA will need a way of identifying these.

ICC Use Cases

UC-DAC-101 – Identify and flag bad data

UC-DAC-102 – Filter data on any criteria

UC-DAC-105 – Identify and flag data on any criteria

5.3 Engineering unit conversion

Description

Needs ADC conversion, gains and offsets.

Main Steps

- Convert ADU to analogue units
- Convert detector volts out the instrument to volts out the detectors: My current understanding is that the algorithm for the photometer is:
 - $V_{\text{signal}} * 0.95 = (V_{\text{raw}} + 12 * V_{\text{offset}} - 3168 * V_{\text{bias}}) / 3168$,
and for the spectrometer use 1368 instead of 3168.

The fixed numbers may change slightly but exact algorithm maybe unimportant as another ‘unit conversion’ will occur when we do the photometric calibration (i.e. conversion to astrophysical units) and it is this we have to set up the calibration for.

Calibration Information/Files Needed

Depends on the implementation of IA. The values of V_{bias} , V_{raw} and V_{offset} are available from the TM and as this is a simple algorithm which is hardcoded in the electronics, it is likely be hardcoded in the data processing.

There is the issue of sensitivity at different biases frequencies but I would expect this to be dealt with in the astronomical unit conversion (see section 5.21).

ICC Use Cases

UC-DAS-101 – Read and prepare data frames for IA processing

5.4 Conversion from position counter to mechanical position

Description

The IA step to transform from the mirror position to counter number to mechanical position using a calibration table to do so. An optical incremental (relative) counter is used to determine the position; it can happen that some steps are missed. If the missing point is in the travel range covered by the absolute sensor (LVDT), its information can be used to correct from missing step(s) of the optical relative counter. This step is applied to every interferogram.

Main Steps

- Convert position counter to position using the calibration tables

Calibration Information/Files Needed

The calibration table referred to in this use case is a one to one correspondence between the SMEC position counter and the actual physical position of the SMEC. This can only be defined in ground

testing. The usecase also alludes to the LVDT-Position table which will also be defined in ground testing.

IACR-005 – Lookup table to convert mirror position counter to mechanical position

IACR-006 – Lookup table to convert LVDT position to mechanical position

ICC Use Cases

UC-FTS104 – Convert position counter to mechanical mirror position

5.5 Conversion from mechanical position to OPD

Description

Once we know the mechanical position we need to apply another lookup table to convert this to actual optical path difference.

Main Steps

- Convert position to OPD using the calibration tables

Calibration Information/Files Needed

IACR-007 – lookup table giving mechanical position against OPD. We will probably need this for every detector

ICC Use Cases

UC-FTS-106 – Convert mechanical position to OPD for each detector

5.6 Pointing re-construction and correction for any pointing drift.

Description

Assign an astronomical coordinate such as RA and Dec to each detector for each individual spacecraft pointing. The co-ordinates assigned will be either a default, probably RA, Dec or will be user-specified e.g. b,l.

Main Steps

- Determine S/C position and roll angle for each point in the timeline
- Group data according to S/C pointing
- Sub-group data depending on BSM position
- Assign position of array centre in RA/Dec or other appropriate coordinate system according to S/C pointing
- Apply offset appropriate for BSM position
- Assign an astronomical coordinate such as RA and Dec to each detector for each individual spacecraft pointing at each point in the timeline.

Calibration Information/Files Needed

Spacecraft pointing information – this will indicate the absolute pointing of the spacecraft for that observation. For observations requiring more than one pointing e.g. nodding, jiggling and rastering, we will have to group the data according to each position and obtain an ‘average’ pointing plus error.

If the pointing error is large, we may need to think about other ways of combining data.

If the pointing drifts we may need to correct this as a separate processing step.

IACR-008 - detector spatial offset positions. An offset will be needed for each detector which will relate that detector’s pointing to the spacecraft boresight. This could be either supplied as an absolute offset for each detector or one absolute offset for a given detector in an array plus the relative offsets for the other detectors.

ICC Use Cases

UC-DAC-107 – Transform between sky and spacecraft coordinate systems

5.7 Telescope or SCAL temperature drift correction

Description

Either the telescope temperature may drift or the SCAL temperature might drift, this drift will need to be corrected in processing.

Calibration Information/Files Needed

We will need to know the temperature history of both the telescope and SCAL. This can't be determined from detector output as it would be impossible to deconvolve it with any responsivity changes. However presumably any drifts would lead to incomplete nulling and it is the level of nulling that we might be able to calibrate for. I need to think about this one a bit more!

IACR-009 – Telescope temperature drift history file

IACR-010 – SCAL temperature drift history file

ICC Use Cases

UC-FTS110 – Correct for time-dependent variation in flux

5.8 Correct for position dependency

Description

I'm not sure what is meant by this use case which states 'The efficiency of the interference of the two beams is not uniform over the spatial range covered by detectors'.

I'm assuming that it refers to the fact that optical paths not going through the central part of the system may have an error in their ability to interfere, so as the movable mirror moves away from the ZPD the amplitude of the fringes (of a delta function) will decrease and there may be a phase shift which is also dependant on mirror position. This unwanted apodisation will also introduce noise.

Calibration Information/Files Needed.

IACR-011 – Apodisation map for each pixel.

IACR-012 – Table giving delta OPD as a function of pixel position, this could be folded into the mechanical position to OPD table and make it a separate table for each pixel.

Another type of position dependency might be an anisotropy the background telescope emission (I'm assuming this will not occur with SCAL?). As we set SCAL for the whole FOV this may lead to incomplete nulling in some parts of the FOV. If this situation is stable, which is likely at L2 with the sun remaining in a fixed position then we may be able to do something in the calibration.

ICC Use Cases

UC-FTS-111 - Correct for position-dependent variation in flux

5.9 Removal of responsivity drift

Description

The responsivity of each detector will evolve with time and this will be tracked via the PCAL illuminator flashes. We will need to reconstruct the drift using flashes over a given time period. This could either be done within IA itself assuming all flashes are non-proprietary (a problem initially with ISO) or we could retrospectively construct calibration files to do this. It is not clear whether any ground testing will shed light on the situation as it will be in space. Note the absolute responsivity correction is a separate step.

Calibration Information/Files Needed

Assuming all illuminator observations are available to the IA system no calibration file will be needed from the ground testing.

IACR-013 – Drift coefficients or records of PCAL responses.

ICC Use Cases

UC-DAC-108 - Convert from engineering units to astrophysical units (covers this step for the photometer?)

UC-FTS-109 - Correct responsivity

5.10 Removal of PCAL drift

Description

The PCAL output for a given commanded current may drift over time. We will need to correct for this before correcting for detector response.

Calibration Information/Files Needed

IACR-014 – PCAL drift coefficients

ICC Use Cases

None

5.11 Deglitching

Description

Deglitching is not specifically covered in any photometer use cases but is likely to need to be applied, possibly at more than one stage, while running IA. Knowledge of bolometer performance in the space environment is fairly scarce at present but it is likely that SPIRE data will be glitched by particle hits. The glitches should show up as data spikes (rather than rises with decaying tails for photoconductors) and as the spider web design offers a small cross section, the frequency of the glitch spikes should be minimised.

I would expect we will need to work on the deglitching strategy once SPIRE is in flight but I would expect two possible methods to be applied in IA. One possible method may be to detect a spike by say differentiating the time series of data. This could be difficult with FTS data and photometer scanning but may be our only ‘automated’ approach. For photometer pointed observations we will probably use a statistical rejection technique such as median clipping.

Calibration Information/Files Needed

The only calibration information I can see here is default values for both approaches. I would expect we would only have one default for the statistical deglitching but we may have a ‘mode’ dependant default if we adopt the search for a spike approach.

ICC Use Cases

UC-DAC-102

UC-FTS-112

5.12 Demodulation

Description

De-modulation here refers to chopped observations either using the photometer or using the spectrometer in step and look mode. There are several ways demodulation may be done. The on source

minus off source approach is likely to be adopted for the spectrometer step and look but for the photometer, particularly when scan drifting, we may look at using more advanced signal processing techniques. Note it also likely that this step may need to consider the fact that the BSM and detector readout systems are running asynchronously.

Calibration Information/Files Needed

I'm assuming for now that the actual demodulation will be purely algorithmic.

For pointed chopped observations there may be information needed by this processing stage related to the set of pixels chosen. If we apply this step after we've removed instrumental effects such as pixel to pixel sensitivity then we should be OK. We may also need to consider effects due errors in the chop throw.

There is the issue of what we do about the fact that the detectors have time constants and we may want to chop at more than one frequency. How we deal with this depends on how the demodulation and calibration are setup but if we setup the calibration at one frequency we may need a table to refer the demodulated signal at other chop frequencies to the reference frequency.

IACR-015– A table giving factors to reference the demodulated signal at various frequencies to the signal at the calibrated frequency.

IACR-016 - Table relating BSM chop and jiggle positions to position on the detector or position in detector coordinates

ICC Use Cases

UC-PHT-121 - Subtract off-source data (demodulate data)

5.13 Data Averaging

Description

This only refers to averaging data at a single pointing, e.g. demodulated photometer data or a set of spectral scans. Spatial averaging is considered to be part of the map construction step.

Calibration Information/Files Needed

I can't see any for now.

ICC Use Cases

UC-PHT108: Resample and combine data spatially and/or temporally

5.14 Electrical Crosstalk Removal

Description

Electrical crosstalk may happen between adjacent wires in the cryoharness. As far as I understand these are grouped in sets of four and we can detect electrical crosstalk by looking for unusual signals in the other three members of a wiring group when we illuminate a single pixel. This will be determined in ground testing and providing the instrument meets its requirements will not be needed in IA.

Calibration Information/Files Needed

I'm not yet sure how we would go about removing this but I could envisage that for each detector or detector group there will be a lookup table giving the level of crosstalk between that detector and its neighbours. There may be more than one way of dealing with this information in terms of developing an algorithm.

IACR-017 – Electrical crosstalk table

ICC Use Cases

UC-DAC103: Remove effects of instrument cross-talk

5.15 Optical Crosstalk Removal

Description

This is crosstalk due to light falling on adjacent pixels to the pixel being illuminated.

Calibration Information/Files Needed

As with the electrical crosstalk this will be determined from illuminating a single pixel in ground tests. As with the electrical crosstalk I'm not clear on the best way to treat this information, we could put this in to a file with either all pairs considered or a single correction factor for each pixel.

IACR-018 – optical crosstalk given per pixel pair or as one factor (considering all pairs) per pixel

ICC Use Cases

UC-DAC103: Remove effects of instrument cross-talk

5.16 Re-grid to get point on the ZPD

Description

One measurement point of each interferogram must correspond to the ZPD (zero path difference). If no point fulfills this constrain, the interferogram must be re-grided as the Fourier transform result is calibrated by the value of the ZPD point.

Calibration Information/Files Needed

IACR-019 - A lookup table relating detector number to the optical encoder ZPD position for that detector will be needed.

ICC Use Cases

UC-FTS108 - Re-grid data to obtain a ZPD point

5.17 Remove telescope calibration emission (spectrometer)

Description

This use-case describes how the instrument signature is removed. The observed data contains both the scientific observation of some sky point, and the emission from the telescope and the calibrator. This part of the signal needs to be removed. This step may need to be performed before Fourier Transform

Calibration Information/Files Needed

We will need to know for each SCAL setting and the power spectrum from SCAL (so we can subtract the FT of this?). Given there are two emitters with effective emissivities of 2% and 4% each independently being commanded in temperature, there is a large parameter space to explore. For now I'm envisaging a power setting lookup table but another alternative might be to have a model and we will have to put some effort into developing the scheme for this in the ground testing.

IACR-020 – SCAL power output spectrum lookup table

ICC Use Cases

UC-FTS-115 Remove instrument signature

5.18 Flat fielding

Description

Flat fielding here is taken to mean spatial flat fielding i.e. pixel to pixel variations. Removal of the spectral response function, sometimes referred to as a spectral flat field is dealt with in section 6.21. Each detector in an array will have a responsivity which will vary with time. As PCAL operates at the pupil image variations in responsivity of a given detector between two time periods can be tracked using the response of the array to PCAL.

Assuming SPIRE observes a calibration source (say Uranus) in one pixel then a full array source (say PCAL) then the difference in responsivity across the array at that time can be used as the reference flat field file. We may actually derive a reference flat field by scanning a known point source across the array as this would give higher S/N.

Calibration Information/Files Needed

IACR-021 – Photometer flat fields, response of each detector referred to one detector in the same array

IACR-022 – Spectrometer flat field, response of each detector referred to one detector in the same array at a given SMEC position

If we use different bias settings we may need a flat field at each bias setting. This is with the assumption that as we change the bias the resulting responsivity change is different from one detector to the next. As we have an array of individual detectors I would imagine this is likely.

ICC Use Cases

UC-DAC104: Remove pixel-to-pixel sensitivity variations (flat-field)

5.19 Absolute responsivity correction

Description

This refers to correcting for the difference in responsivity of the array at the given time to a reference time when an absolute calibrator was observed. This could be done for the whole array in a single operation (applying an absolute flat field) or the ratio could be determined for a single pixel.

Calibration Information/Files Needed

IACR-023 – File containing identifier of reference pixel and response (flux) to reference source (probably PCAL) at the reference time. One reference pixel per array.

IACR-024 – Non-linear correction

ICC Use Cases

UC-DAC108: Convert from engineering units to astrophysical units

5.20 Apodisation

Description

This use-case describes the step which removes outlying points in the frequency domain which do not contain scientific information. This must be done before executing the Fourier transform.

Calibration Information/Files Needed

An apodisation map will be produced for each detector.

IACR-025 – Apodisation ranges for each spectrometer resolution setting, one set per resolution setting should be sufficient as I can't see the need for one value per array.

IACR-026 - SMEC vignetted pixel mask, will need to scan each point in the beam.

ICC Use Cases

UC-FTS113: Apodise (remove outlying frequency signals)

5.21 Conversion to astronomical Units

Description

Assuming we've done all the responsivity time and spatial corrections right what we will have is each pixel giving a flux (say in volts) at a given reference responsivity. Now we know the flux given by that pixel at the time of the reference measurement so to get the flux of our source we just have to ratio the two values, or put another way, divide the whole array by one number.

Calibration Information/Files Needed

Assuming we do it this way we will need a file containing the magic number, one per array. As we are essentially doing the same thing we could fold this in with the absolute response correction.

IACR-027 – Astronomical flux conversion factors, one per array

It is still to be decided whether we use more than one bias value in flight but it is conceivable that we will and we will have to investigate responsivity as a function of bias on the ground. It may also be possible to repeat this measurement in flight.

IACR-028 – Correction factors for non-nominal bias frequency, this could be a single array value if we also have different bias flat fields or it could be one value per detector.

Another issue which we may need to consider is the detector behaviour as a function of operating temperature. The minimum temperature is predicted to be 287 mK and we will set up the instrument at this minimum temperature. In flight this temperature may be higher and we will attempt to cover this parameter space on the ground so we are able to adjust to flight conditions.

IACR-029 – Detector responsivity as a function of operating temperature, may need one value per detector at a nominal bias frequency.

ICC Use Cases

UC-DAC108: Convert from engineering units to astrophysical units

5.22 Remove Time dependency in Spectral Response of the Detectors

Description

After conversion to the spectral domain we may still need apply a correction for a non-uniform spectral response of the detectors. Also this spectral response function might be time dependant.

Calibration Information/Files Needed

We will need a spectral response function calibration file and this is likely to be a single value per (highest?) resolution element per detector obtained from the ground testing. If this varies with time we could either use correction factors or response files applicable to a particular time period.

IACR-030 – Spectrometer spectral response, one value in spectral domain per resolution element in high resolution mode.

IACR-031 – Possible correction factors for changes in the spectral response with time.

ICC Use Cases

None?

5.23 Correct for SMEC Speed

Description

Spectral response vs SMEC speed

Calibration Information/Files Needed

IACR-032

ICC Use Cases

None

5.24 Subtract Astronomical Background

Description

The usecase describes the removal of background signal (spacecraft, telescope, 'sky') from science and calibration data by user specified criteria. The removal of background signal can be performed interactively or automatically as part of a pipeline. Examples of selection criteria are:

- User-specified bolometer numbers.
- Outside or inside a user-defined region (spatial and/or temporal).
- Fitting trends to the data (e.g. gradients).
- Logical/mathematical expression using temporal, spatial and intensity coordinates.

Calibration Information/Files Needed

There are many ways of determining a background but I can't think of any for the moment which would require a calibration file except possibly some sort of temperature history of the telescope for reducing scan drift photometer observations.

ICC Use Cases

UC-DAC106: Subtract a background

5.25 Colour Correction

Description

As a photometer measures the flux over a broad spectral bandpass, the relationship between the flux at the effective wavelength of the filter, and the amount of flux recorded by the bolometer, will be a function of the intrinsic spectrum of the target.

A colour correction is required to determine the monochromatic flux of an object or to transform the measurement to the photometric system of another instrument. Default spectra for common types of astronomical source should be provided so that users do not have to go to the trouble of obtaining such spectra. If the user has colours for sources, for example from the SPIRE photometers, but does not know what their spectra really should be, then some empirical colour correction will be required.

Calibration Information/Files Needed

The use case specifies the need for the filter response curves for SPIRE to be available. We will certainly need to provide these although it is unlikely that all response curves for the photometer will be measured on the ground due to lack of testing time. I'm not yet sure what to do with the non-measured pixels. If everything else is known to good accuracy we could determine a relative colour correction in-flight although this could be tricky. Another approach could be to assume the instrument/filter/detector response is similar enough across the array that we could adopt a 'standard' response curve.

IACR-033 – Spectral response curves of photometer pixels.

An IA user may not know the spectrum of the source he/she is studying and may wish to use a standard spectral shape in IA. An open issue on the use case is what sort, and how many default spectra should the IA contain? Someone has to calibrate the empirical colour corrections for each spectral shape, and/or decide what algorithms might be useful for this purpose.

IACR-034 – Reference spectra or default colour corrections for a given spectral type

The colour corrections could be determined from the colours of the sources in another photometric system. In this case IA will have to compute a colour correction individually for each source in the list and store it in a fashion that can be interpreted by a person and by the 'Apply colour correction' task (UC-PHT-111). Also, if the user wishes to convert to a different photometric system, the response curve for that system need to be available.

IACR-035 – Response curves for another photometric system?

ICC Use Cases

UC-PHT 110: Determine colour correction

UC-PHT 111: Apply colour correction

5.26 Map generation

Description

As both instruments are capable of imaging data from both could be re-sampled into maps.

Calibration Information/Files Needed

I don't have much of a feel for what is needed here in terms of calibration. Almost certainly the PSF will be needed but I'm not sure what other information is required. I'm assuming the conversion to sky co-ordinates of every pixel has been done in step 6.6 hence the relative pixel positions on the sky is known.

Not sure yet of the best way to present the PSF, what was done for CAM, SCUBA?

IACR-036 – PSF associated with each pixel in each array

ICC Use Cases

UC-PHT108: Resample and combine data spatially and/or temporally

5.27 Detect and Identify Lines

Description

This use-case describes how lines in a reduced FTS spectrum are detected. Then the lines are either identified or a redshift is determined. To allow these steps to be taken IA must apply velocity correction to a reduced spectrum and may apply a redshift correction. A line detection algorithm must be applied. A line fitting algorithm must be applied. For line identification a line database will be needed.

- Selection of line detection criteria
- Apply automated line detection or apply manual line detection and flag lines.
- Instrument velocity correction
- Selection of line database.
- Automated redshift determination: the astronomer doesn't know the redshift of the source and searches for it through correlation of the detected lines with positions in the database.
- Automated line identification: the astronomer knows the velocity of the source and needs to identify the detected lines.

Calibration Information/Files Needed

Spacecraft velocity

The spacecraft velocity will be provided in the spacecraft telemetry. Applying this should simply be a matter of IA taking the information directly.

Line database:

However for these purposes the default (official IA) line database might be considered as a calibration table. This will be generated/imported from standard sources e.g. the JPL spectral line catalogue.

IA-LDB-037 – Line database, nabbed from elsewhere then converted to IA format.

ICC Use Cases

UC-FTS118: Detect and identify lines

5.28 Detect Sources

Description

This refers to IA running an algorithm on a map which then detects point (and extended?) sources in the map and reports them to the user.

Calibration Information/Files Needed

The algorithms chosen may require calibration information but I'm not sure what this might be at this stage.

ICC Use Cases

UC-PHT113: Detect sources

6. CROSS REFERENCE TABLE BETWEEN IA CALIBRATION REQUIREMENT AND OBSERVATORY FUNCTION

Observatory Functions

- POF1 – Chop without jiggling
- POF2 – Seven-Point jiggle map
- POF3 – n-Point jiggle map
- POF4 – Raster map
- POF5 – Scan Map without chopping
- POF6 – Scan Map with chopping
- POF7 – Photometer peakup
- SOF1 – Point Source Spectrum, continuous scan
- SOF2 – Fully sampled spectral map within FOV, continuous scan
- SOF3 – Point source spectrum, step and integrate
- SOF4 – Fully sampled spectral map within FOV, step and integrate

Identifier	Need	Description	P01	P02	P03	P04	P05	P06	P07	PO8	S01	S02	S03	S04
IACR-001	Y	Bad pixel mask for each array, each mask just contains a flag indicating which detector(s) should not be used.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-002	Y	NEP for each detector, divided into arrays, may be needed for several bias values	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-003	P	Identifiers for the vignetted pixels at edge of FOV	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-004	P	Identifiers for vignetted pixels by BSM position	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-005	Y	Lookup table to convert mirror position counter to mechanical position									Y	Y	Y	Y
IACR-006	Y	Lookup table to convert LVDT position to mechanical position									Y	Y	Y	Y
IACR-007	Y	Lookup table giving mechanical position against OPD, probably need this for every detector									Y	Y	Y	Y
IACR-008	Y	Detector spatial offset positions. One set of offsets will be needed for each detector and these will relate that detector's pointing to the spacecraft boresight.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-009	P	Telescope temperature drift history file	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-010	P	SCAL temperature drift history file									Y	Y	Y	Y
IACR-011	Y	Apodisation map for each pixel and possibly for each spectral resolution setting.									Y	Y	Y	Y
IACR-012	P	Table giving delta OPD as a function of pixel position, this could be folded into the mechanical position to OPD table and make it a separate table for									Y	Y	Y	Y

		each pixel.												
IACR-013	P	Detector response temporal drift	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-014	P	PCAL output drift history file	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-015	P	A table giving factors to reference the demodulated signal at various frequencies to the signal at the calibrated frequency	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-016	Y	Table relating BSM chop and jiggle positions to position on the detector or position in detector coordinates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-017	P	Electrical crosstalk table	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-018	P	Optical crosstalk given per pixel pair or as one factor (considering all pairs) per pixel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-019	Y	A lookup table relating detector number to the optical encoder ZPD position for that detector will be needed									Y	Y	Y	Y
IACR-020	Y	SCAL power output spectrum lookup table or model									Y	Y	Y	Y
IACR-021	Y	Photometer flat fields, response of each detector referred to one detector in the same array	Y	Y	Y	Y	Y	Y	Y	Y				
IACR-022	Y	Spectrometer flat field, response of each detector referred to one detector in the same array at a given SMEC position									Y	Y	Y	Y
IACR-023	Y *	File containing identifier of reference pixel and response (flux) to reference source (probably PCAL) at the reference time. One reference pixel per array. *Will not be needed if we adopt an absolute flat field.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-024	Y	Non-linear correction	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-025	P	Apodisation ranges for each spectrometer resolution setting, one set per resolution setting should be sufficient as I can't see the need for one value per array.									Y	Y	Y	Y
IACR-026	P	SMEC vignetted pixel mask									Y	Y	Y	Y
IACR-027	Y *	Astronomical conversion factors, one per array *Will not be needed if we fold this in with absolute response correction	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-028	P	Correction factors for non-nominal bias, this could be a single array value if we also have different bias flat fields or it could be one value per detector.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-029	P	Detector responsivity as a function of operating temperature, may need one value per detector	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-030	Y	Spectrometer spectral response, one value in spectral domain per									Y	Y	Y	Y

		resolution element in high resolution mode.												
IACR-031	P	Possible correction factors for changes in the spectral response with time.									Y	Y	Y	Y
IACR-032	P	Spectral response vs SMEC speed									Y	Y	Y	Y
IACR-033	Y	Spectral response curves of photometer pixels.	Y	Y	Y	Y	Y	Y	Y	Y				
IACR-034	P	Reference spectra or default colour corrections for a given spectral type	Y	Y	Y	Y	Y	Y	Y	Y				
IACR-035	P	Response curves for another photometric system?	Y	Y	Y	Y	Y	Y	Y	Y				
IACR-036	Y	PSF associated with each pixel in each array	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IACR-037	P	Line database, nabbed from elsewhere then converted to IA format.									Y	Y	Y	Y

