Herschel Calibration Report

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To Herschel User's Group #3, ESAC, 3 May 2011.

Outline of Presentation

1. General Items Regarding Calibration
2. Instrument Calibration
   a. PACS
   b. SPIRE
   c. HIFI
3. Pointing
4. Conclusions

General Items Regarding Calibration

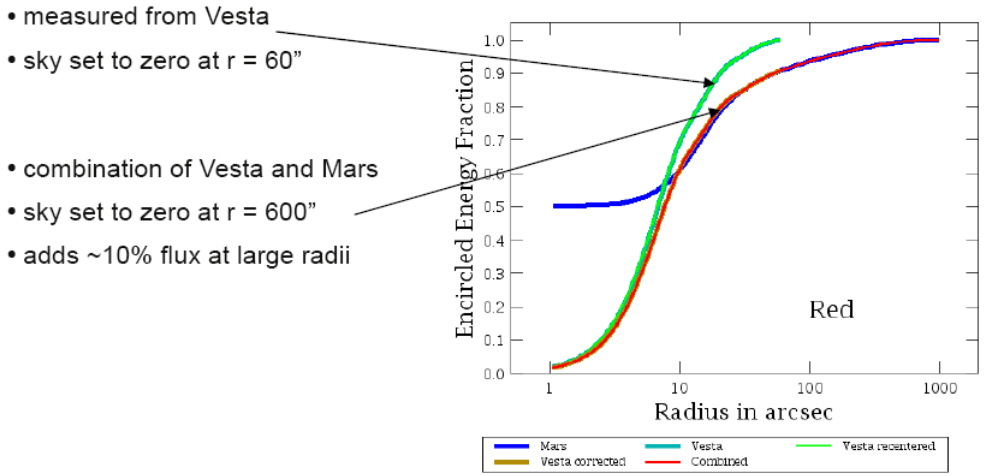
- ***Herschel Calibration Steering Group meeting#28 took place 13 April.***
  - ***General reporting (see later)***
  - ***Date of next workshop – 7-9 December 2011 – spectrometer centred.***
  - ***Twiki site at http://herschel.esac.esa.int/twiki/bin/view/HCalSG/WebHome***
- ***HIFI routine calibration plan draft 0.9 submitted and updated on Twiki***
  - ***Includes more on cross-calibration and routine observations of line sources.***
- ***PACS routine calibration plan v1.5 submitted and updated on Twiki***
  - ***Mainly an update on past time usage and expected calibrations in the future.***
- **Full calibration review intended for later part of 2012.**
- Observer's manuals for all three instruments (plus large part of the Observatory manual) updated for the GT2 call.
- Instrument Twiki pages continue to be updated.
- **Calibration Source Database** – being updated with hundreds of individual asteroid models calculated for specific calibration observations by Thomas Mueller. Has a view in HIPE and now available to the community generally (needs documentation at user level).
- **One of three positions being unblocked (TBC) for hiring into the team in the next few months.**

PACS

- General:
  - Documentation updates including the Observer's Manual (OM).
  - Twiki contents recent updates:
    - Point source flux cal (12 April)
    - Colour corrections (12 April)
    - Extended emission information: two documents on photometry and surface brightness comparisons to IRAS and MIPS (11 March and 12 April)
    - Bright line unchopped mode release note (15 April)

PACS-P

- Updated routine phase plan available (PICC-MA-PL-002). So far 469 hours of calibration observations made.
- Updated PACS-P calibration scheme document that includes all the updates involving extended emission that are now available (PICC-ME-TN-037, available on web)
- Color corrections updated (PICC-ME-TN-038, available on web)
- Pipelines updated in HIPE v7, not being used in current bulk reprocessing, together with an aperture correction task including all information that is now only documented.



PACS-P Cont.

Target name	blue obs/model no.	med.	mean	stdev	green obs/model no.	med.	mean	stdev	red obs/model no.	med.	mean	stdev
β And	2	—	**1.132**	0.017	2	—	**1.166**	0.012	2	—	**1.169**	0.022
α Cet	3	—	**1.132**	0.009	3	—	**1.159**	0.006	3	—	**1.179**	0.033
α Tau	4	—	**1.106**	0.013	4	—	**1.127**	0.009	5	—	**1.147**	0.014
α Boo	3	—	**1.120**	0.013	3	—	**1.151**	0.011	3	—	**1.182**	0.014
γ Dra	24	**1.103**	1.101	0.011	9	**1.151**	1.143	0.017	30	**1.193**	1.195	0.051
mean/stdev		1.119±0.014				1.151±0.015				1.174±0.017		

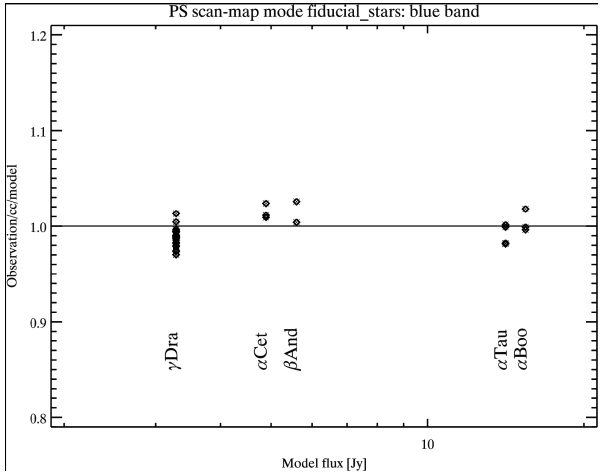
Table above shows effects of corrections on 5 calibrators

Leads to following PACS-P error estimates:

70 micron: 2.64%

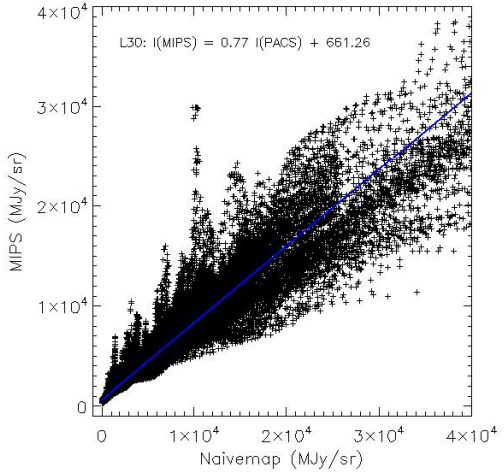
100 micron: 2.75%

160 micron: 4.15%



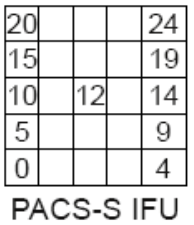
PACS-P Cont.

- **Non-linearity starts at around 100Jy.**
  - Bright asteroids being used (vary with time and modeling shown to be very accurate).
- **Extended emission:**
  - Believed resolved through interactions with a number of individual KP teams.
  - Two reports posted on instrument Twiki web site on photometry and surface brightness comparisons to IRAS and MIPS. Remaining differences can be attributed to uncleaned artifacts, colour corrections and errors in convolution kernels.
  - Convolution kernels to come + explanation



PACS-S Calibration

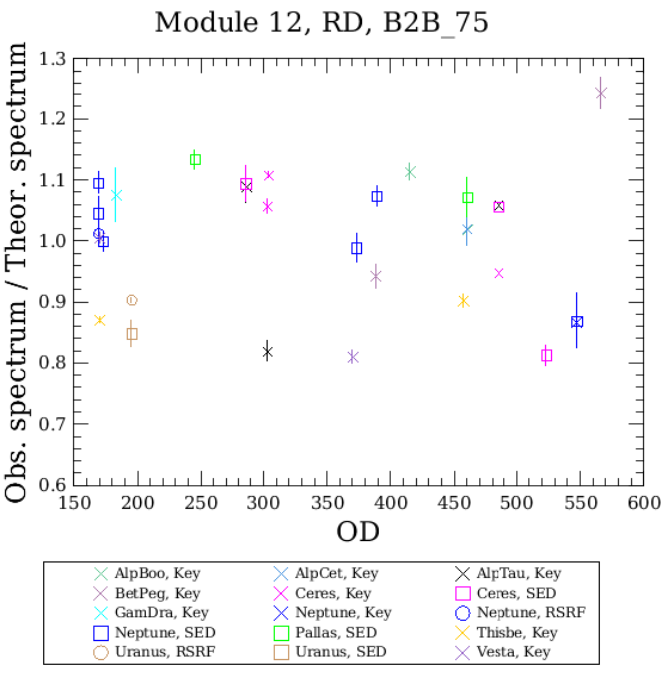
- Bright unchopped line mode made available.
- Latest calibration including calibration blocks →Slight improvement for total flux error.



For example – from 12 to 10% flux consistency in central spaxel.

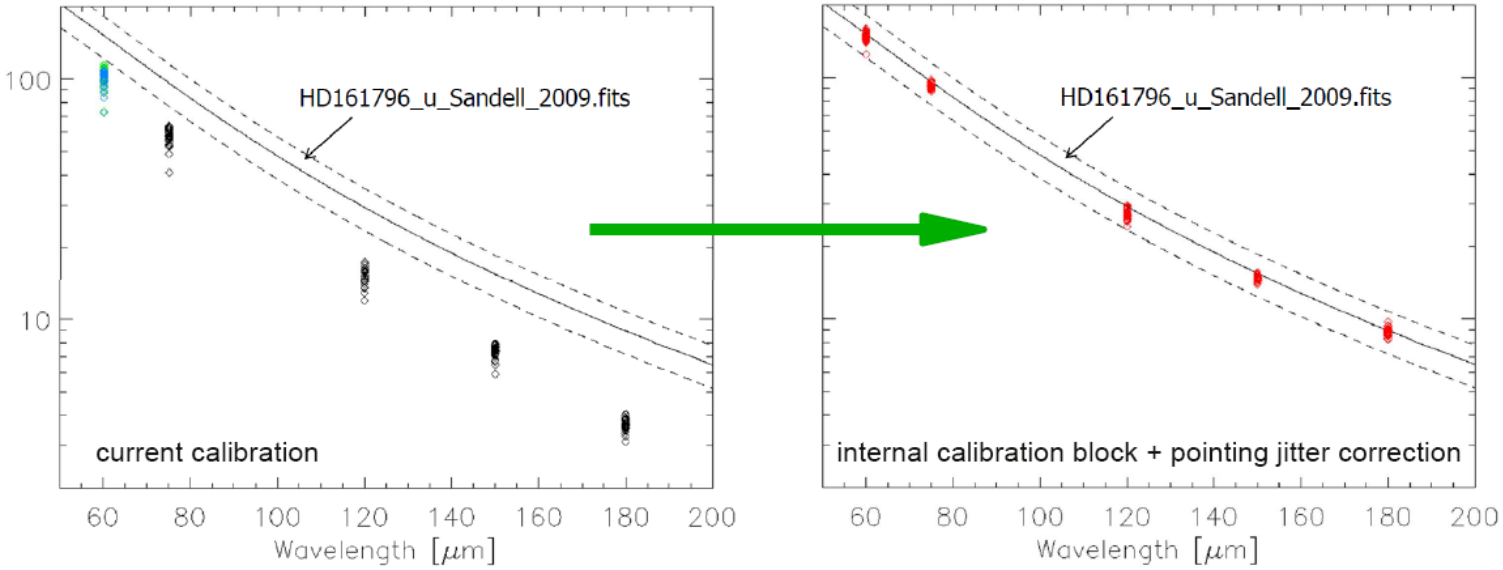
But remaining error mostly due to pointing jitter.

Overall – 20-30% flux error estimate.



PACS–S Calibration Cont.

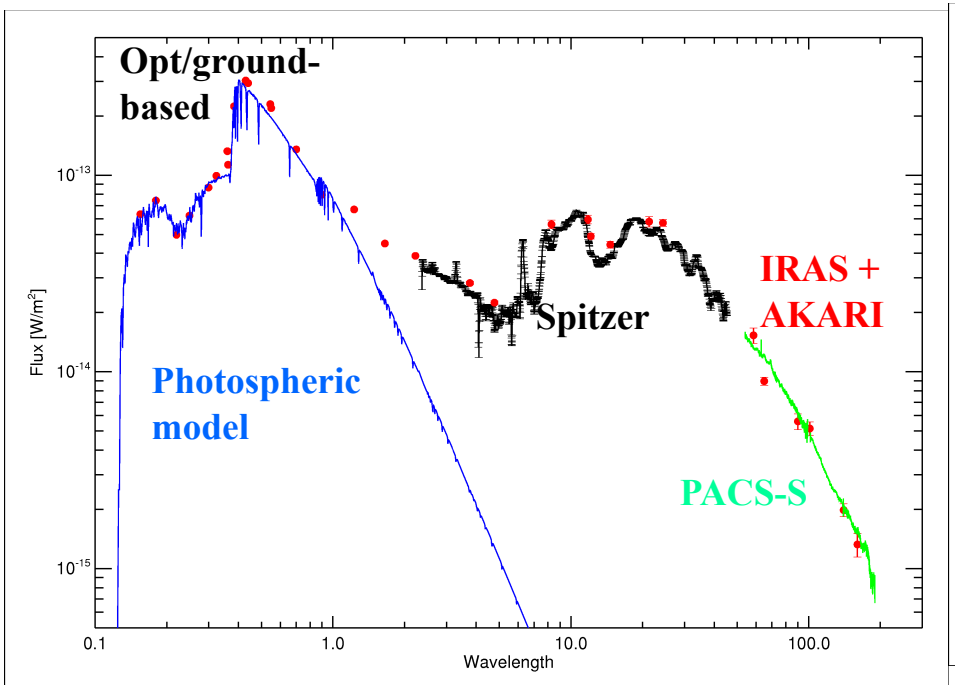
- Pointing jitter correction:
  - Use bright source (e.g. Neptune) measurements to determine the fraction of flux missing from central spaxel, depending on object position. Carried out in recent cycle 38 measurements on Neptune.
  - Apply to database of flux standard measurements.



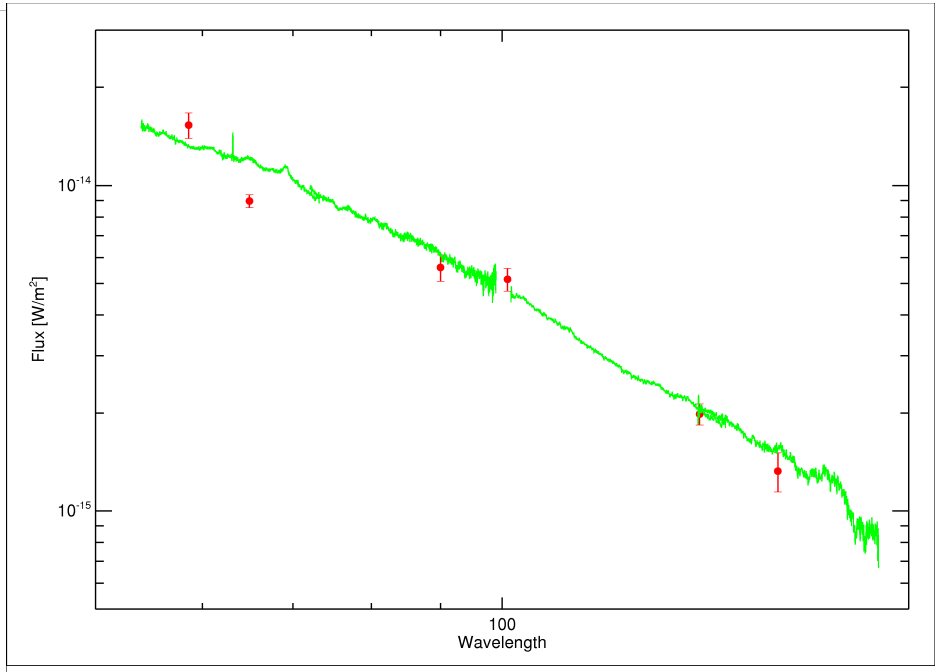
PACS Spectrometer Cont.

- CP raster measurements.
  - Final tests being carried out to see if relative pointing can be improved.
  - This time using Spectrometer.
  - First of 2 tests on Friday 29 April. Initial results suggest a bad drift and the second test is expected to be postponed.

PACS-S Cross-calibration



PACS-S calibrated against background model of telescope



PACS-S calibrated against Neptune model (esa3)

PACS-S Calibration and Mapping (HUG issues)

- *Fully-calibrated long-range spectra* can be produced with the available interactive pipeline scripts in HIPE 6.0 and later versions.
  - The interactive flat-field task is doing most of the "de-fringing" work on the data but it was (so far) decided that this task should be kept out from the standard (SPG) pipeline. Task documentation is available in the PACS Data Reduction Guide
- *Processing of spectral maps.* The current 7.0 pipeline provides a simplistic but robust solution to finite element discretization, i.e. the individual IFU cubes can be projected onto a spatially and spectrally resampled cube.
  - We realize this is just the first step of creating reliable spectral maps of physical measures in the interest of the observer. The instrument team is working on advanced spectral cube reconstruction algorithms (see HSC reply to HUG#2 recommendations).

Documentation and Scripts Updates:

- **SPIRE OM in particular had major overhaul end 2010, minor adjustments then for GT2.**
- **Data Reduction Guide now up to date and shipped with HIPE.**
- **SPIRE Photometry Cookbook now being made available.**
- **New script in HIPE merges/mosaics 2 or more maps together (Photometer_Map_Merge.py)**
- **HIPE v7 has destriper and alternative baseline removal.**

Current Wiki page contents:

Observers' Manual

Instrument and calibration A&A papers

Latest calibration tree

Photometer

- **- AOT release notes**
- **- Beams and RSRFs**
- **- Neptune and Uranus models (standards)**
- **- Link to HIPE documentation**
- **- Advice and guidance on mapping and source fitting**
- **(including timeline-based fitter script)**

FTS

- **- AOT release notes**
- **- Guidance on calibration and data processing**
- **- Before OT2: instrument line shape, FTS mapping information and guidelines.**
- **- NOTE: The existence of a FTS User's Group to actively help users with the SPIRE spectrometer data analysis, which is still quite expert in places.**

SPIRE Photometer

Quoted **calibration accuracy is 7%** (5% model plus 2% calibration error) but:

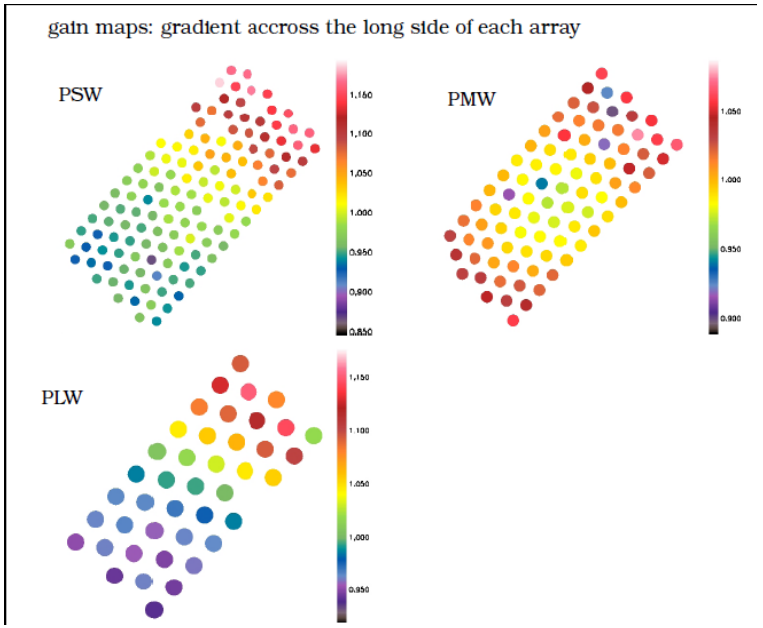
- **Neptune flux currently systematically ~2-3% too low**
- Bright source mode calibration not yet optimal – not yet ready for Neptune/Uranus comparison with photometer
- Small maps yield same flux as large maps
- A lot of effort has gone into looking at sources of photometric errors
  - Adjustments to fitter parameters < 1%
  - Wrong position given to fitter < 1%
- Putting background sources into maps => calibrator star Gamma Dra small far-IR excess is real

- **Photometric accuracy ~ 2%** verified by standard deviation of asteroid and stars

SPIRE-P extended sources

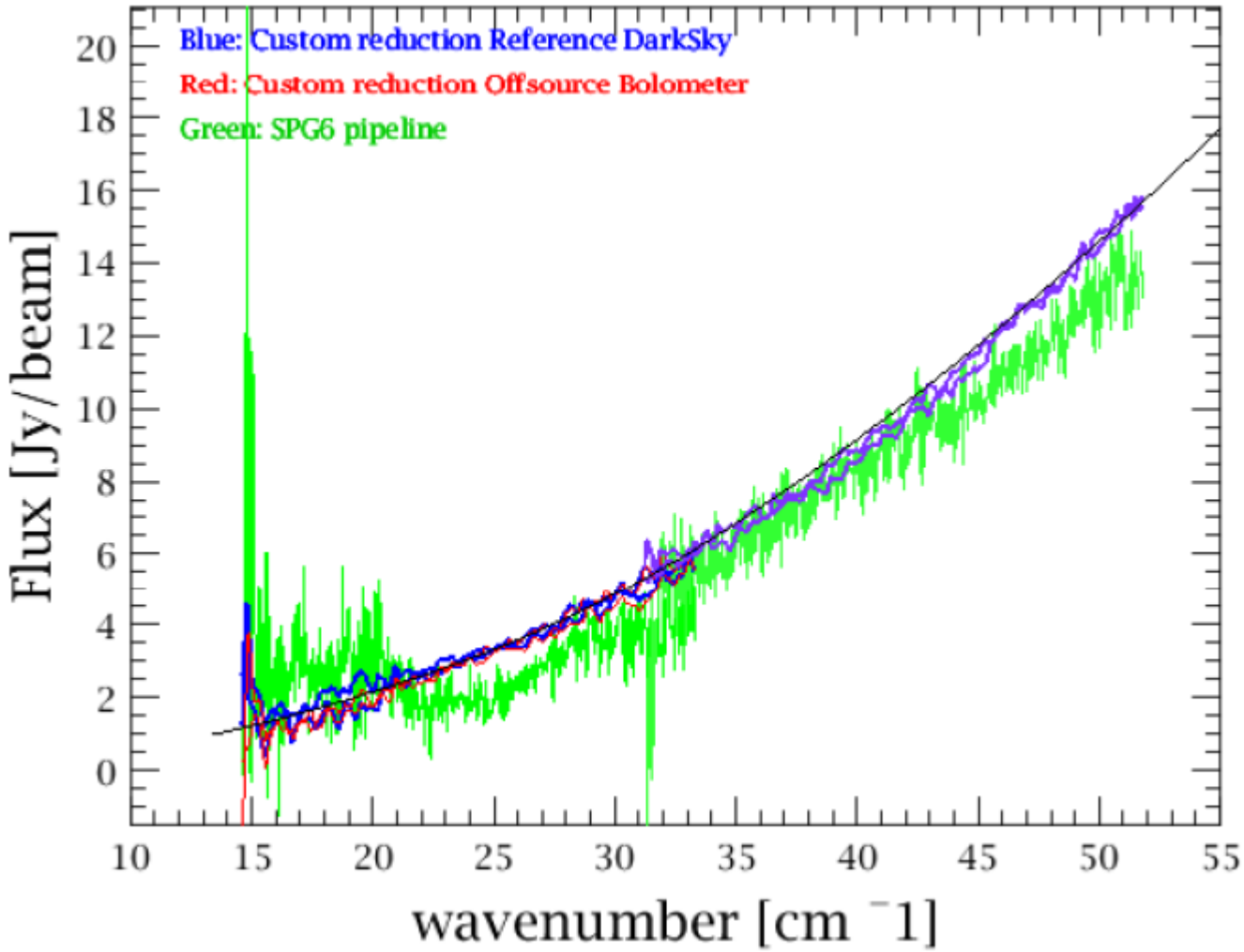
- **Normalisation of beam areas now updated**
  - **Makes a small difference for extended source calibration (1 – 2.5%)**
  - **More correct method of taking into account beam profile variation with wavelength**
    - **Work started on evaluation**

- **Relative gains for extended emission.**
  - ***Currently, beam area for each band is averaged across the array***
  - ***Beam area variation from detector-detector has been characterised***
  - ***Will allow better flat-fielding for extended emission***
  - ***Optional routine will be developed***



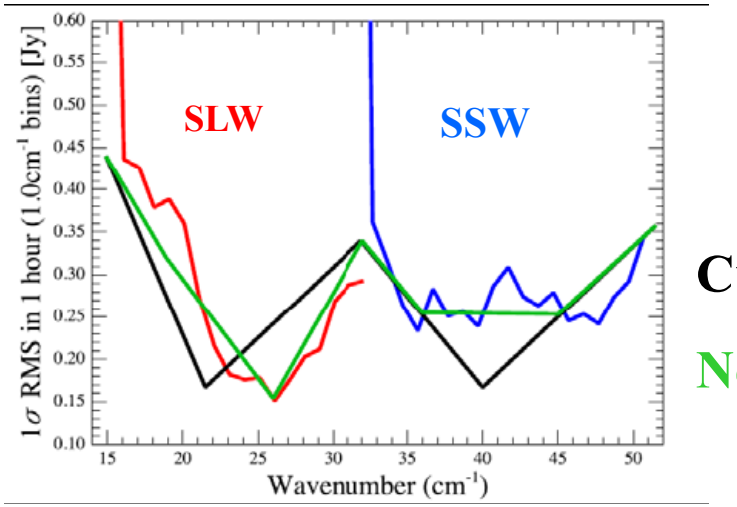
SPIRE-S

- No updates to current calibration accuracy
  - Repeatability not yet quantified but within a few percent
  - Ongoing work:
    - Re-derived spectrometer sensitivities
    - Generation of a validation framework - establishing metrics to validate pipeline improvements
- Ongoing
  - Testing of temperature based pipeline (using telescope mirror temperature information)
  - Beam profile: Neptune is a better source (not Uranus, slightly elliptical) for future beam profile observations, even though it is fainter
  - Dark subtraction improvements


Blue: Custom reduction Reference DarkSky
Red: Custom reduction Offsource Bolometer
Green: SPG6 pipeline
Flux [Jy/beam]
wavenumber [cm ¯1]
0
2
4
6
8
10
12
14
16
18
20
10
15
20
25
30
35
40
45
50
55

SPIRE-S

- **Detailed assessment of FTS sensitivity carried out**
- **Similar but not identical results to current HSpot**
- **Shift of the SLW min. from 21 to 26 cm-1**
  - **Flattening of the SSW**
- **minimum near 40 cm-1**
  - **HSpot will be updated for OT-2**
  - **Current users and GT-2 teams are being advised of the change**



Current HSpot

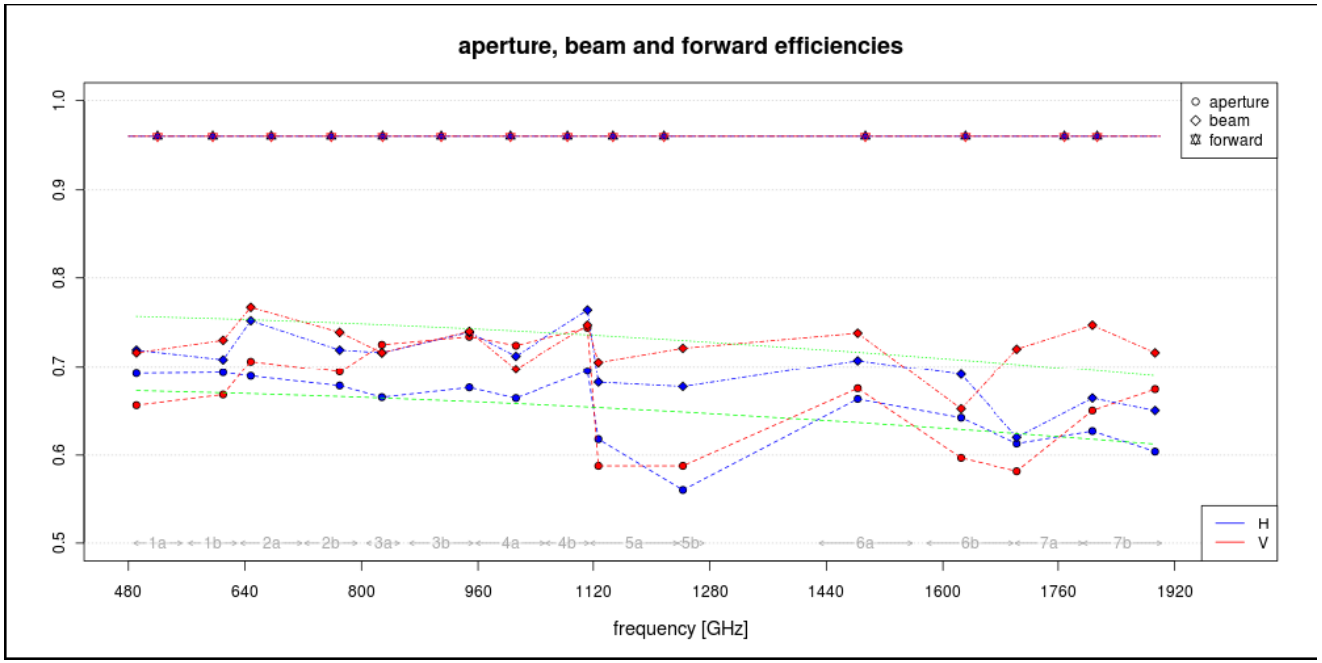
New HSpot

HIFI:

- **General:**
  - Observer's Manual updated for GT2.
  - In the planning to add a new section to our HIFI web page, to provide more recommendations on e.g. standing wave, intensity calibration and/or side-band ratio updates.
  - HIFI now (and for a while) has a cookbook as the first part of its User's Manual under HIPE.
  - HIFI error information is provided to user's in the Observer's Manual. However, more is being done on this topic, e.g. effects of standing waves.
  - Sideband ratio: The HIFI ICC has initiated in January a dedicated working group in side-band ratio assessment. The goal of this group is to consolidate all the knowledge gathered prior to launch on side-band ratio measurement (plus some in-flight measurements), and feed this into the calibration tree for automatic application in the pipeline. Currently only small part of band 2a has non-unity values.
    - A big step forward could be achieved with the completion of a PhD work that was partially dedicated to the extraction of the frequency- dependent structure of the ratio.
  - Fringes/standing waves: At downlink level, important progress have been made on the removal of the so-called electrical standing waves present in most of the bands 6 and 7 data.
    - A dedicated working group lead by the HIFI ICC has now made available a prototype scripts that could be checked by some KP users with very promising results. This script has not yet reached the user-friendliness needed for a full public roll-out, so the level of distribution of this code is still limited to a very small number of users.
    - The working group (which is slowly turning into an interest group as it is mostly composed of users) is now working towards a public version to be made available as "user script" under HIPE.

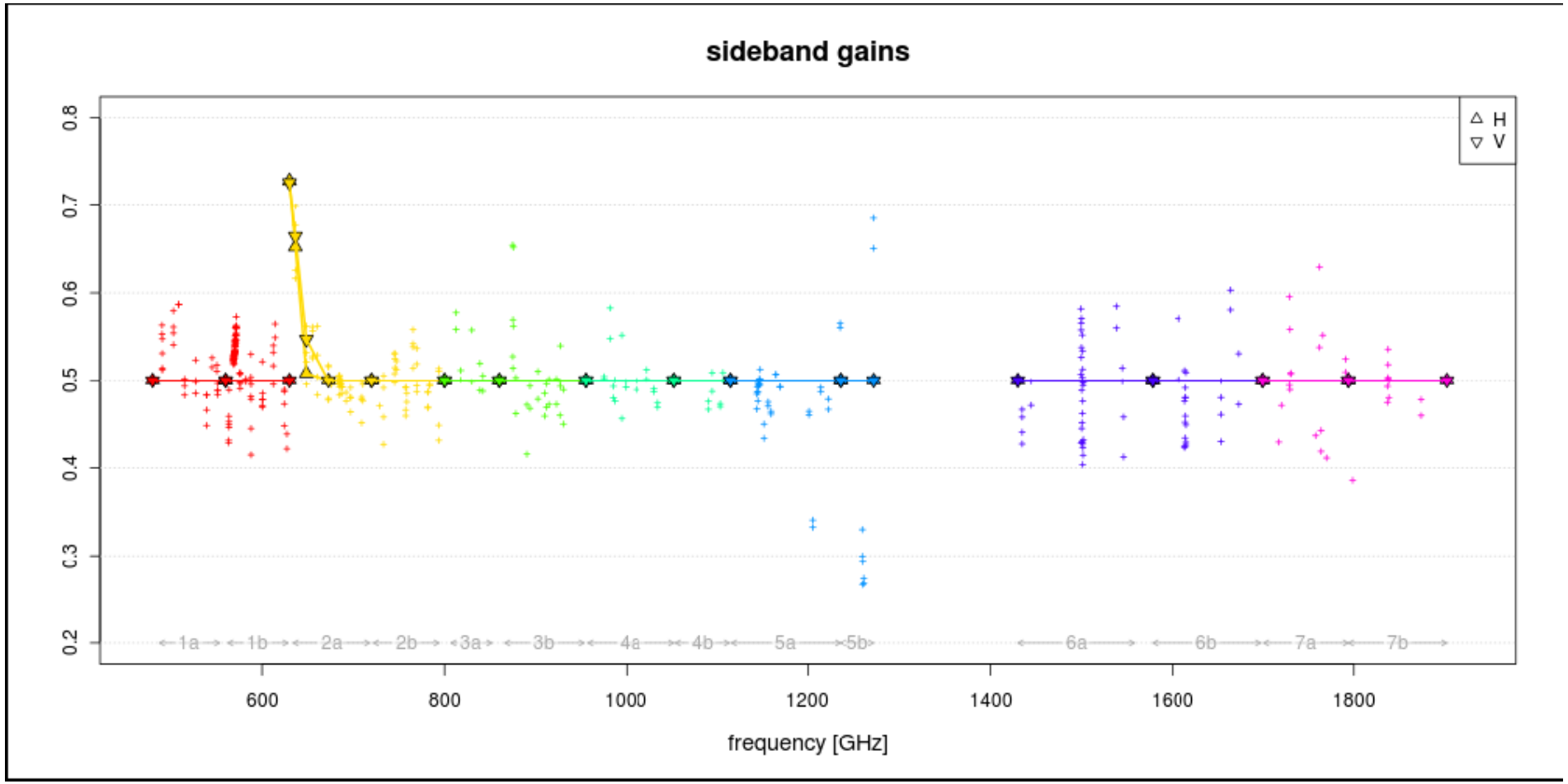
HIFI Calibration: Efficiencies

- All available via the caltree available in the Herschel Archive.
- Forward efficiency taken as 0.96 for all cases.
- Planets becoming available again. Beam measurement checks to be done.



HIFI Calibration: Sideband Ratios

- Largest source of error.
- Bi-weekly telecons of SBR working group.
- Focussing on collecting all available data and methods to eventually populate the CalTree with side-band ratio values.
  - Main data source is gas-cell analysis (thesis Ronan Higgins)
  - Also possibly use gain fit output from the deconvolution algorithm
  - Comparison of line intensities when tuned in either LSB or USB
  - Re-check mixer gain FTS measurements from End Item Data Package and new measurements on Flight Spare
  - Saturated absorption lines from KP (e.g. PRISMAS)
- Some values being put into CalTree right now.


sideband gains
H
V
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
7a
7b
600
800
1000
1200
1400
1600
1800
frequency [GHz]

HIFI: Polarization Imbalance

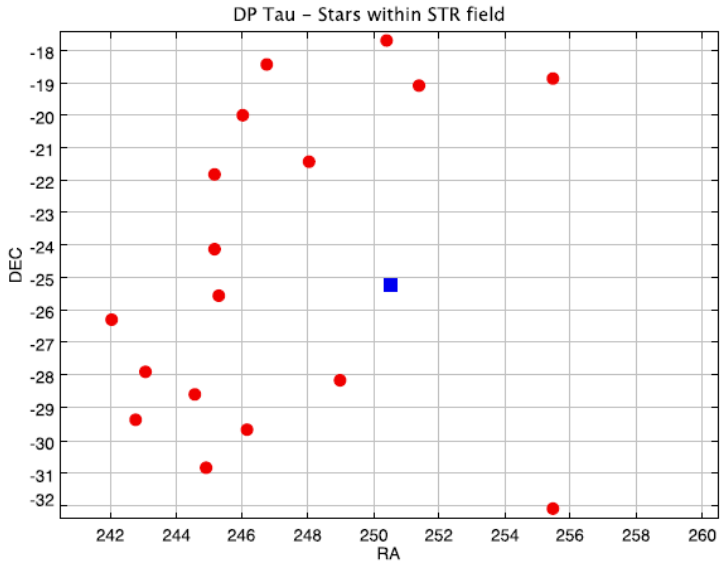
- Several sources of error:
- Pointing (H and V have different apertures on sky, typically synthesized is used for pointing)
- LO power optimized for H in 50% but H more sensitive in most cases.
- IF imbalance then corresponding to
  - standing wave patterns
  - difference in sideband gains
  - difference in beam efficiencies
- Conclusion from a number of investigations:
  - Observations will be affected typically by combinations of these effects.
  - Technical note to be written to explain these issues to the user.

Pointing Overview

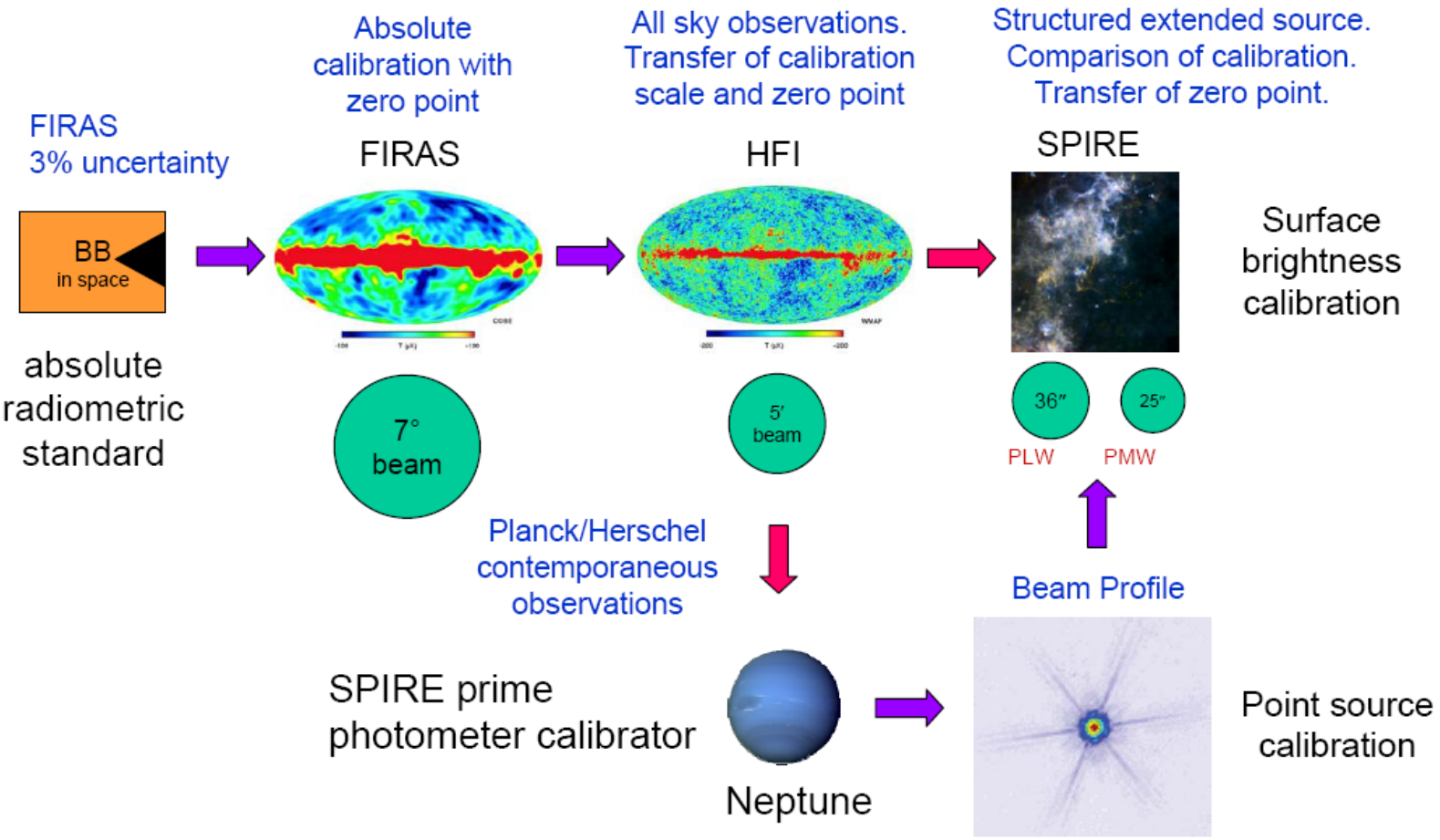
- Routine Phase observatory pointing calibration plan implementation on-going. To date, 229 observations (cycles 15 to 36) have been performed.
- While some previous results suggested a degradation of Herschel's pointing accuracy, the last period examined (cycles 33-36) *indicated that the current performance is aligned with the results obtained in PV phase (APE ~ 2").*
- The PACS scan map APE has been measured for the first time and found well aligned with the stare pointing one.
- *Speed bumps' update: no events found in the periods examined within the range OD440 - OD650 .*
- Implementation of speed bump detector/corrector on-going (to fix pre-OD320 scan map observations affected by this problem).

Pointing Issues

- Several requests for checks. Often require individual attention.
- However, the number of truly unruly cases are very small (<10!!!).
- Odd case of Gamma Draconis (calibration standard)
- But: suggestion that the focal length value for the startracker lens could be slightly wrong (information from FDS) and could lead to incorrect positions for guide stars of several arc seconds (we use many, so diluted).
  - Possible case of offset in Taurus under investigation.



Cross-cal: Absolute scaling…..using Planck for SPIRE extended emission offsets, agreement made.



Conclusions

- Calibration improvements have been made in all areas, notably with spectrometers and much is coming through in HIPE v6.
- Updates on extended emission and associated overall calibration for PACS.
- New extended emission processing by SPIRE.
  - Spectral mapping meeting at ESAC 26/27 May for all 3 instruments to address overall extended emission analysis.
- Key issues on calibration:
  - PACS-P: extended emission finishing up on analysis plus convolution kernels.
  - PACS-S: pointing jitter for point sources. Looks promising for bringing down errors on calibrations.
  - SPIRE-P: extended emission maps background removal improvements and cross-calibration with Planck for offsets work started.
  - SPIRE-S: Re-derived spectrometer sensitivities, dark sky subtraction improvements and possible temperature based calibration scheme. Accurate wavelength-dependant beam maps should improve extended emission maps.
  - HIFI: Crucial sideband ratio values beginning to become available plus means of dealing with standing wave/fringe issues.
- Documentation:
  - Dealt with more thoroughly in HUG2 responses from the HSC. Plus several change requests in the system to improve documents and linking. Some rationalization will take place.