Herschel Calibration Report for HUG#5.

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To Herschel User's Group #5, ESAC, 6-7 September 2012.

Outline of Presentation

1. General Items Regarding Calibration
2. Calibration Models
3. PACS Instrument Calibration
4. SPIRE Instrument Calibration
5. HIFI Instrument Calibration
6. Cross-calibration
7. Pointing
8. Conclusions
9. HUG actions list – pending actions on calibration

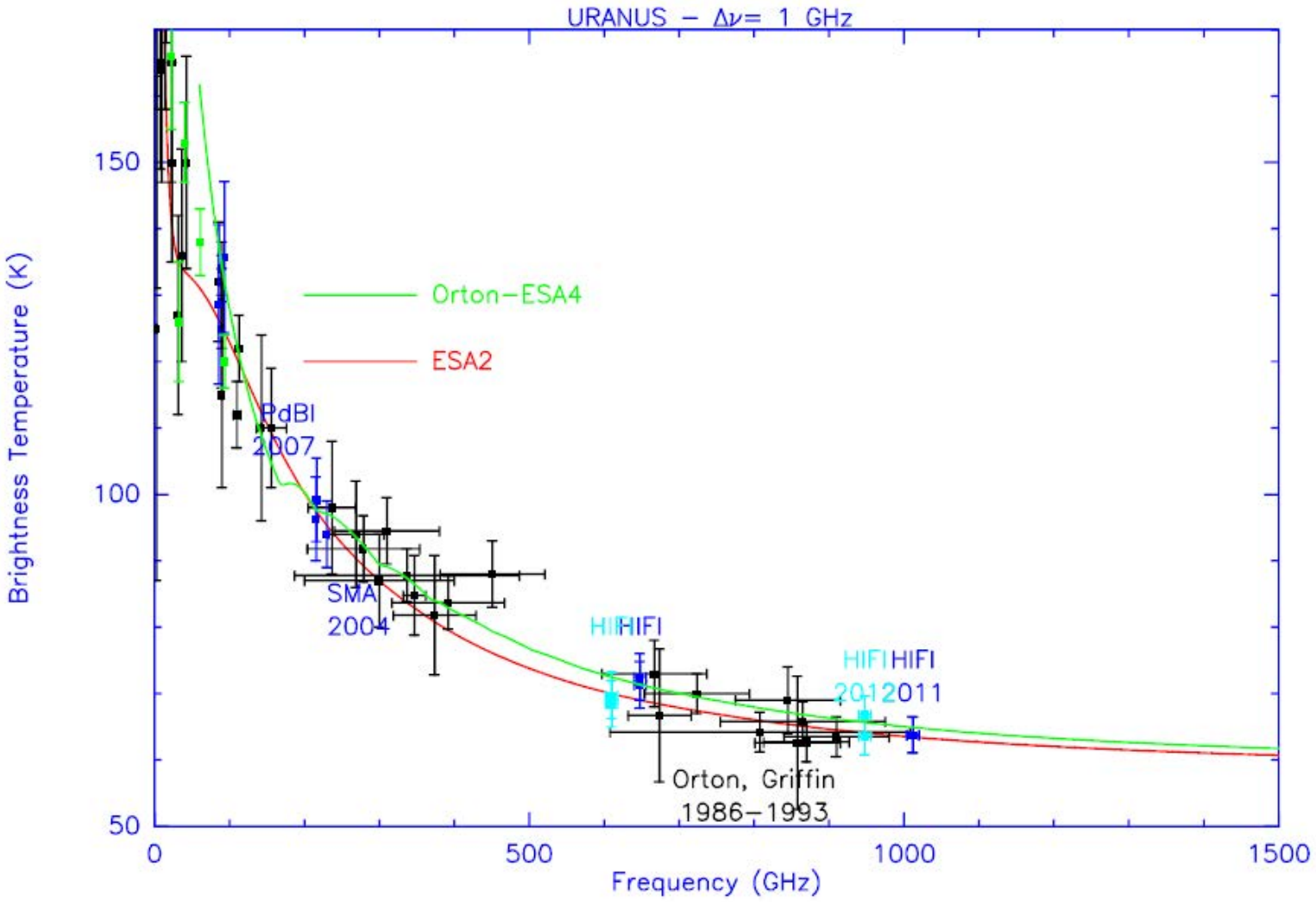
1. General Items Regarding Calibration

- Herschel Calibration Steering Group meetings #30 and 31. Leading to improved planetary calibration models (e.g. Uranus ESA4 model now being used by SPIRE-S).
  - *Instrument calibration workshop – 18-20 January 2012* **(see HUG#4 action 5)** *– spectrometer centred. But feedback on previous photometer issues and cross-calibration.*
  - *Twiki site containing minutes and connection to all presentations at http://herschel.esac.esa.int/twiki/bin/view/HCalSG/WebHome*
- **Public calibration workshop intended for March 2013 (see HUG#4 action 5).**
- **Instrument Twiki pages** continue to be updated, e.g. with full pointing history information and STR updates history. See later report on pointing aspects.
- **Calibration Source Database** – asteroid measurements in place for much of the mission (hundreds). More recent asteroid models to be included shortly. Also updated planetary models. All available via the "Calibrators" view in HIPE.
- **Instrument Data Reduction Guides** – significant updates and overhaul of data reduction documents and their accessibility in HIPE. Continuing, but major improvements due to the work of the Herschel Editorial Board.
- **See later for calibration highlights and updates included in HIPE.**

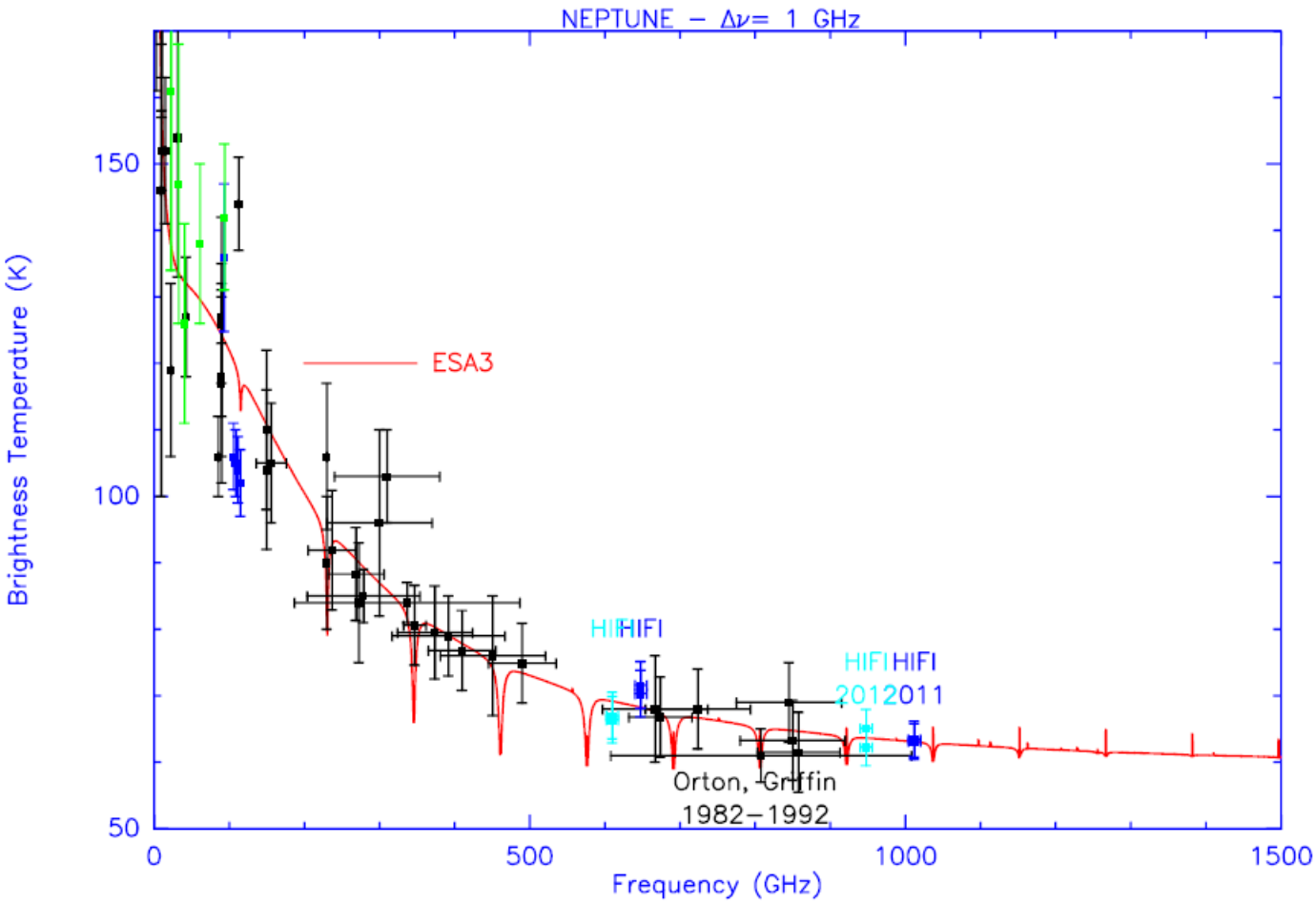
2. Calibration Model Updates

- Calibration of all instruments is done against models of planets (notably HIFI and SPIRE), stars (notably PACS).
- Main planetary calibrators are Uranus and Neptune. **Recent update of Uranus model (ESA4).** Currently given as 5% absolute error.
  - Update for Neptune (ESA4) still pending. Including more feedback of PACS and SPIRE spectral line measurements for constraining planetary atmosphere → 2-3% error.
  - Planetary models are within 2% agreement of each other!
- Stellar models are unlikely to change, but better handle on input parameters being gained.
- Asteroid models are more secondary calibrators but shown to be good enough that 4-5 being looked as possible future primary calibrators (**Herschel calibration legacy**).

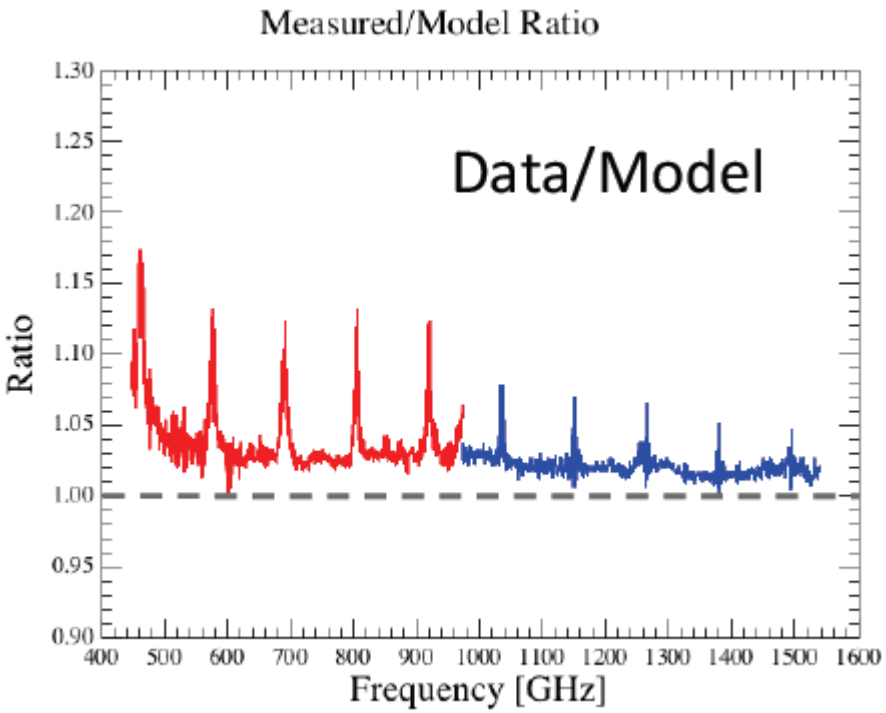
Uranus comparison with Mars



Neptune comparison to Mars



Neptune model – need CO line improvement



SPIRE-S measurements indicate that the Neptune model could handle CO lines better → ESA4 model (pending)

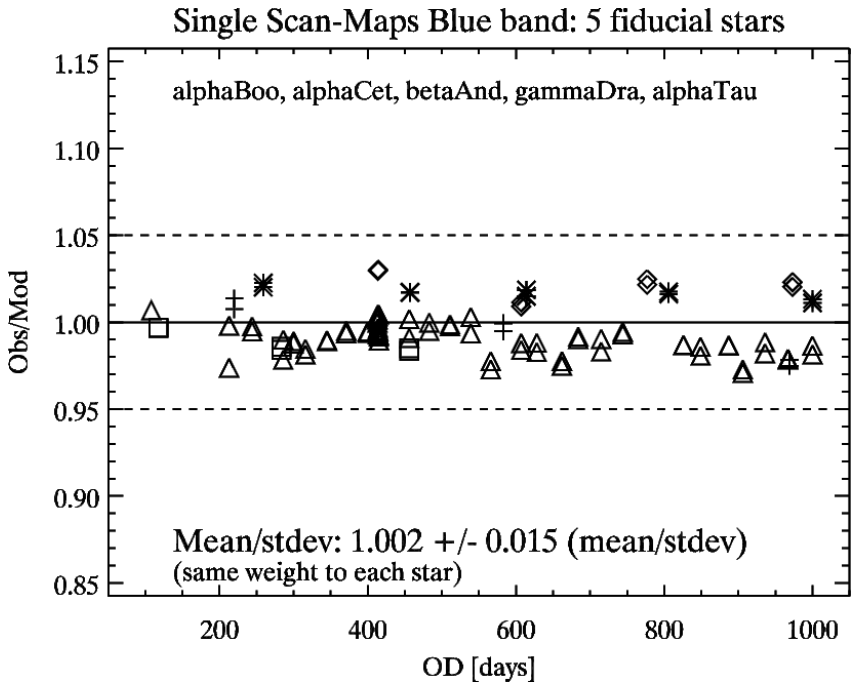
3. PACS Instrument Calibration

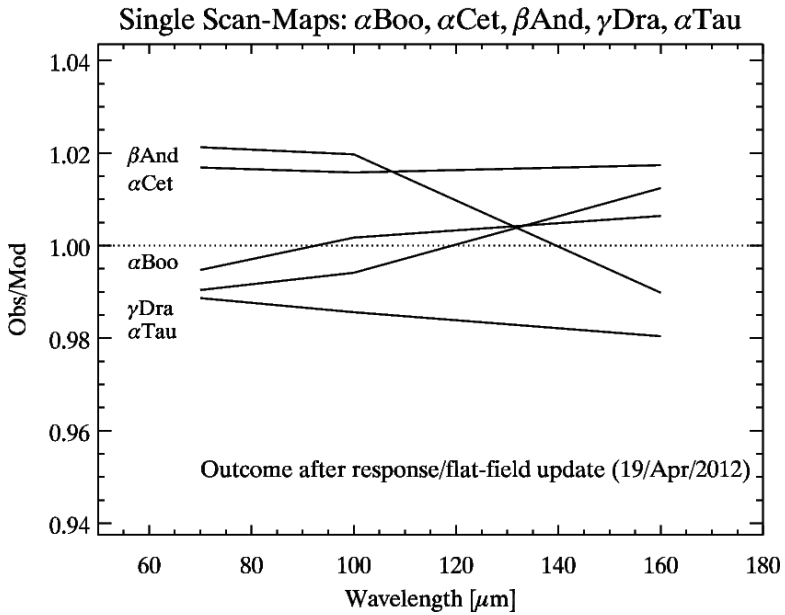
- General:
  - PACS Data Reduction Guide. Many updates and improvements.
  - Calibration improvements
    - Final interactions with KPs regarding PACS-P extended emission.
    - With PACS-S the calibration accuracy is now 11-12%.
    - Improved pointing accuracy enabled improved PACS-S calibration. Now improvement with intra-observation pointing adjustments.

3.1 PACS-P updates

- updated flat field correction
- updated Encircled Energy Fraction/aperture correction
- non-linearity correction included with updated correction matrix
- omitted observations obtained at high bolometer temperatures
- implemented in HIPE 9

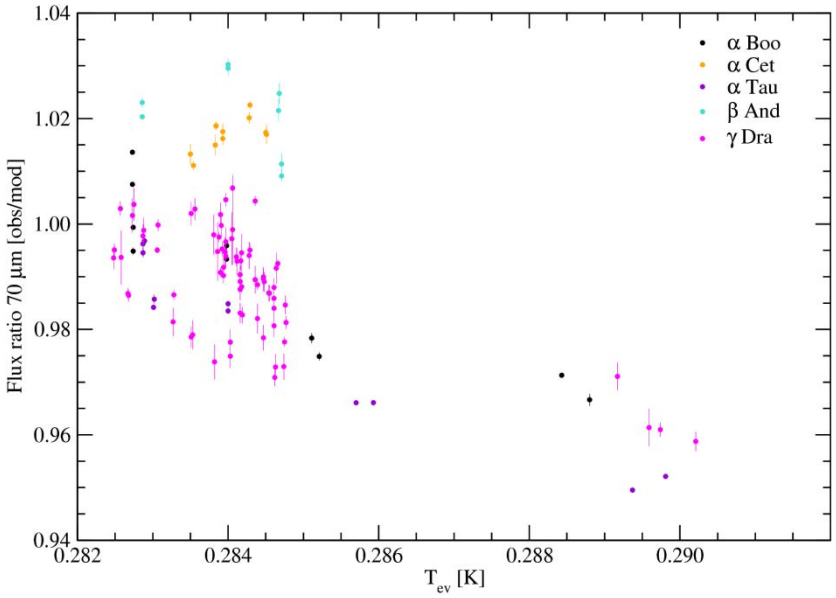
	70 µm	100 µm	160 µm
HIPE 8	0.996 ± 0.018	0.994 ± 0.021	0.980 ± 0.029
HIPE 9	1.002 ± 0.015	1.003 ± 0.014	1.001 ± 0.016



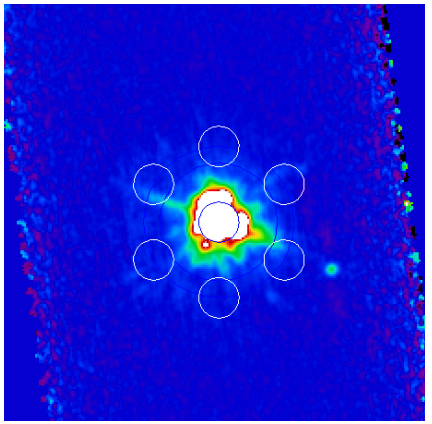


PACS-P updates Cont.

- **Evaporator temperature rise towards end of cooler recycle**. Effect on flux calibration can be calibrated out
  - Also seasonal effect of M1 temperature changes seen. Affects responsivity (2% effect at 70mic).



- **Error Maps:** Moving towards trustable error maps in HIPE 9 including correlated noise. However, aperture photometry task provided by PACS software in HIPE is still recommended way to go.

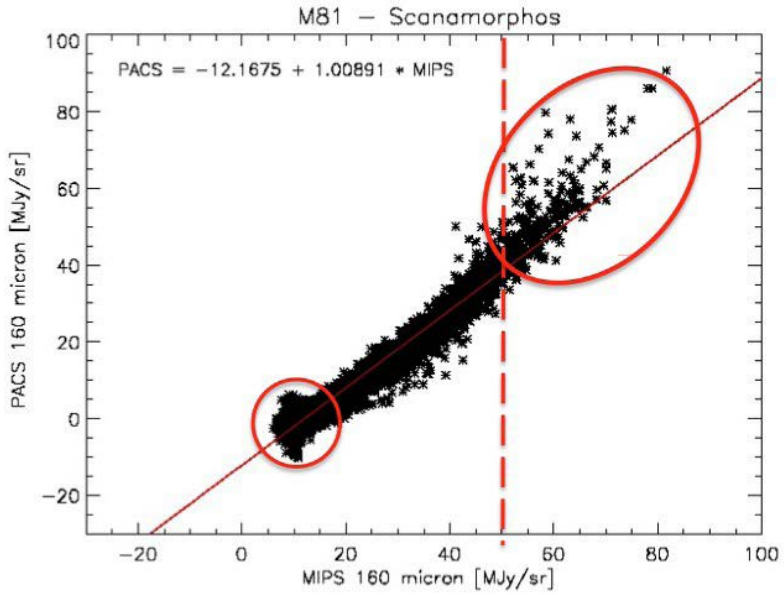


PACS-P Updates Cont.

- **Extended emission and mapping routines:**
  - **– Final information included in set of reports provided in the Herschel website for the PACS instrument.**
  - –M81 data with PACS and Spitzer/MIPS. See report: PICC-NHSC-TN-034
  - – NHSC worked directly with main KP group involved until they were happy!
  - – Convolution kernels and information on Twiki/Herschel website. More information to be made available (also looking at possible deconvolution of Herschel images).

Mapping workshop: Overall proliferation of mapping routines. A PACS/SPIRE mapping workshop is being provided at ESAC in January 2013 to review the various methods

- Scanamorphos mapping routine made available as a HIPE "plug-in".



PACS-P Future

- Proliferation of mapper routines.
  - Workshop 18-20 January 2013 in ESAC to discuss various merits to determine the best mapper to use.
- Error maps: complete inclusion of correlated noise for case of filtered products.
- Pointing updates (see later). To later include updates associated with removing n-dimensional distortions in the STR CCD field.

3.2 PACS-S Calibration Improvements

Telescope Background Normalization – A new calibration model for the telescope background has been introduced for flux calibration using the background normalization method.

Error estimates correction -- A correction of the error estimation of the capacitance of the blue spectrometer array.

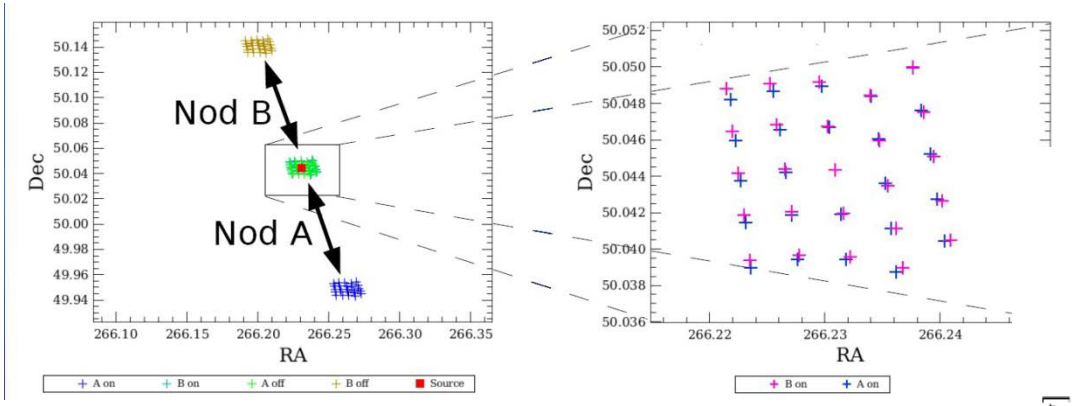
Improved flux calibration application –

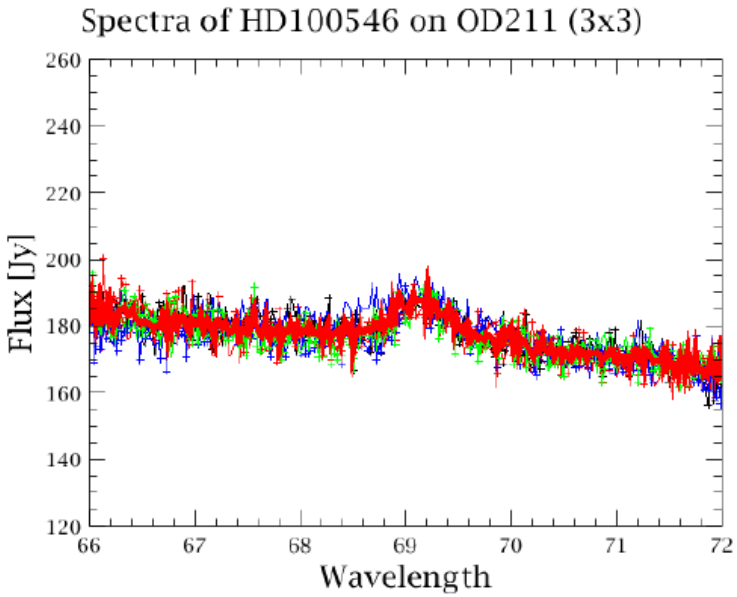
A new calibration product used for calculation of the detector responses computed from the observation of astronomical standards at every key wavelengths.

An update of the calibration sources flux product.

Improved documentation and user friendliness of the pipeline tasks within HIPE 9.

PACS-S Cal improvements Cont.





Chopped SED scans

Incomplete telescope background removal

Pointing jitter produces artificial flux variations – can be corrected by new script ChopNodPointingCorrection.py which adjusts for flux losses for bright sources.

Net result is SEDs all agree within 5% (typically).

PACS-S: Now available in HIPE 9

- Spectral drizzling (over a few microns wavelength range) now available and well described in chapter 7 of the PACS Data Reduction Guide.
- New PointSource loss calibration file - now includes correction from 3x3 spaxel sum to total power in the beam
- New BeamSize product, used to determine spatial resolution for spectral drizzling
- New calibration files, used in experimental tasks to correct flux loss due to pointing: spectrometer beams and telescope background on-off ratio

PACS–S Calibration Future

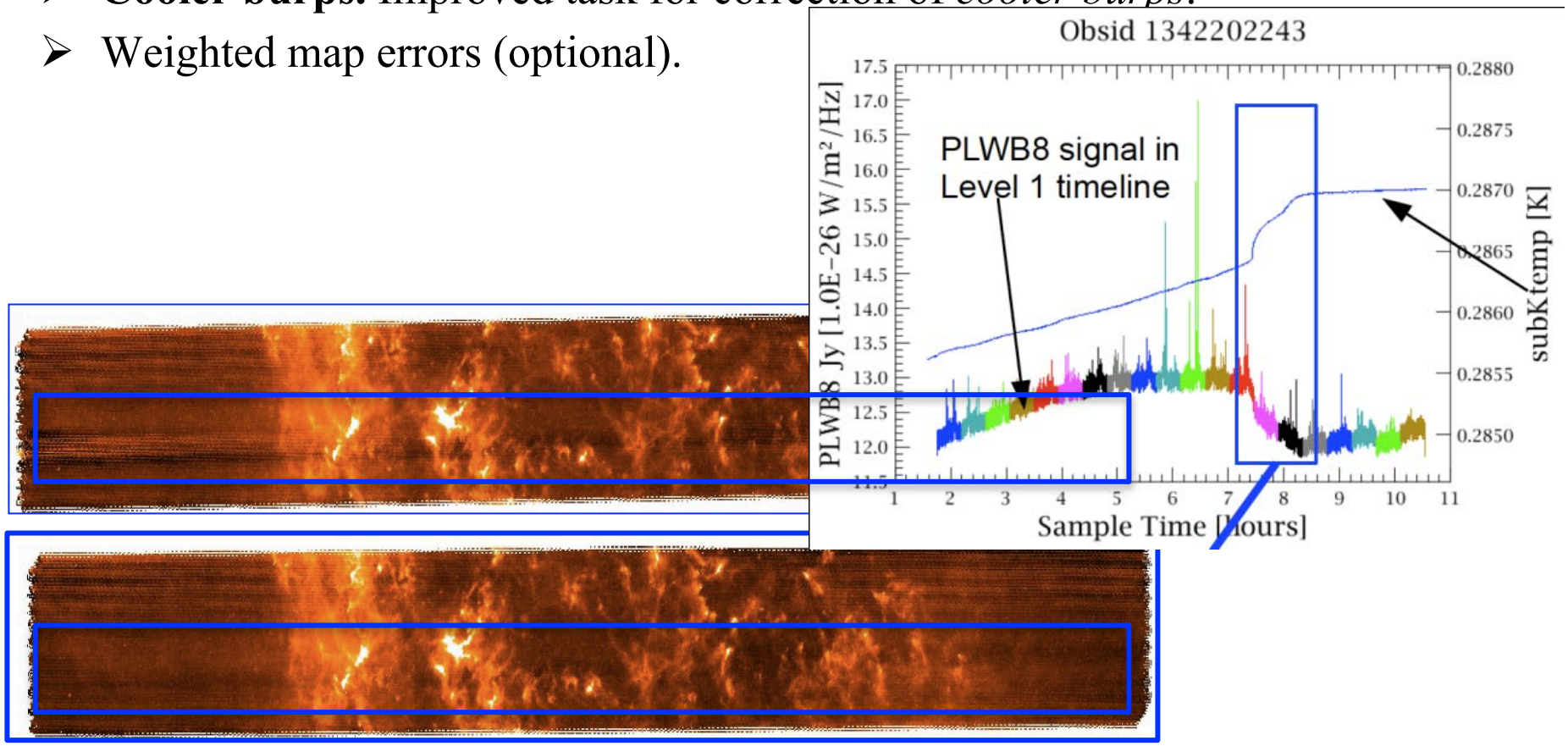
- Some time-dependent telescope background changes – ageing, differences in telescope temperature.
  - Possible modeling of this in the future.
- Working to improve RSRF (continually). Time dependent RSRF likely to be included in HIPE 10 and available for several modes.

4. SPIRE Instrument Calibration

- General Information
  - SPIRE FTS Users Group continues direct interactions with users (Ivan Valtchanov, HSC, chair)
  - Several calibration papers still planned for refereed publication.

4.1 SPIRE-P updates

- **Faster processing.** Improved processing speed using multi-threading.
- **Cooler burps.** Improved task for correction of *cooler burps*.
- Weighted map errors (optional).

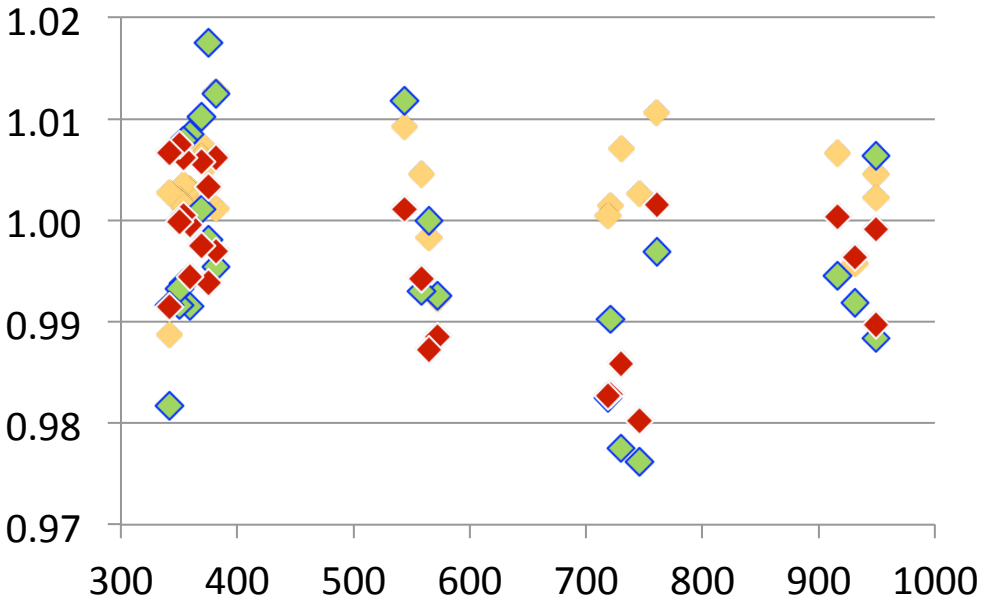


SPIRE-P Updates Cont.

- Electrical Crosstalk Correction
  - Re-instated Electrical Crosstalk correction for bolometer-thermistor crosstalk only
  - Bright Source Calibration will follow in HIPE 10
- Destriper
  - Iterative baseline Removal, Significant speed increases, Maintenance and fixes, Better memory usage, Multithreading Implemented
- Turnaround Data
  - SPIRE pipeline allows user to include the end of scan line turnaround data in their processing
  - Also allow user to specify what turnaround speeds to use Can provide as an optional input to the mapmaker

SPIRE Photometer Overview and Future

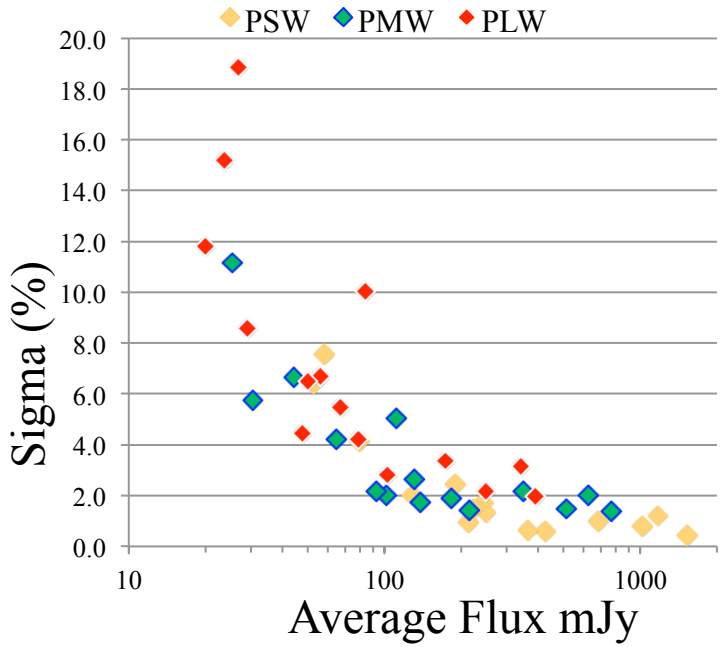
- Quoted **calibration accuracy is 7%** (5% model plus 2% calibration error)
- **Neptune flux currently appears systematically ~2-3% too low.** Still looking towards a planetary model update based on planet measurements being made when Neptune ESA4 model is available.
- **Photometric accuracy ~ 2%** verified by standard deviation of asteroid and star measurements.

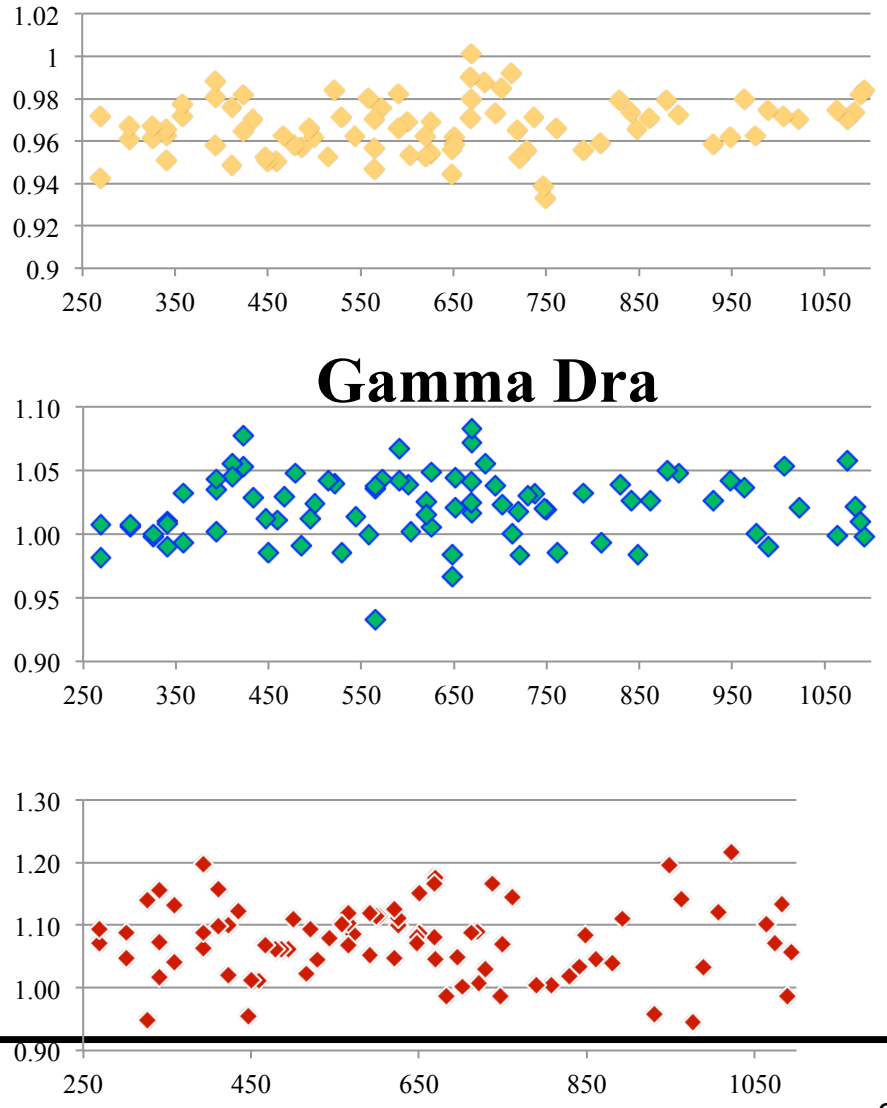


Neptune Obs/model ratio Std Dev:
PSW=0.005,
PMW=0.011,
PLW=0.008

SPIRE Fluxes of Standard Stars

- Ratio of flux to stellar models v. close to 1.0 when taking stellar calibrators as a whole.





4.2 SPIRE-S calibration updates – data taking

- **Moved from calibration resolution to high resolution** for calibration observations: dark sky, Uranus, secondary calibrators.
  - Calibration observations (dark sky, Uranus, secondary calibrators) are now also explicitly observed in LR, this improves the LR observations (previously extracted from CR obs).
- **Decided not to calibrate medium resolution**: the effort of calibrating this mode was considered too much for the few science observations, which have been converted to high resolution (paid by the project scientist).

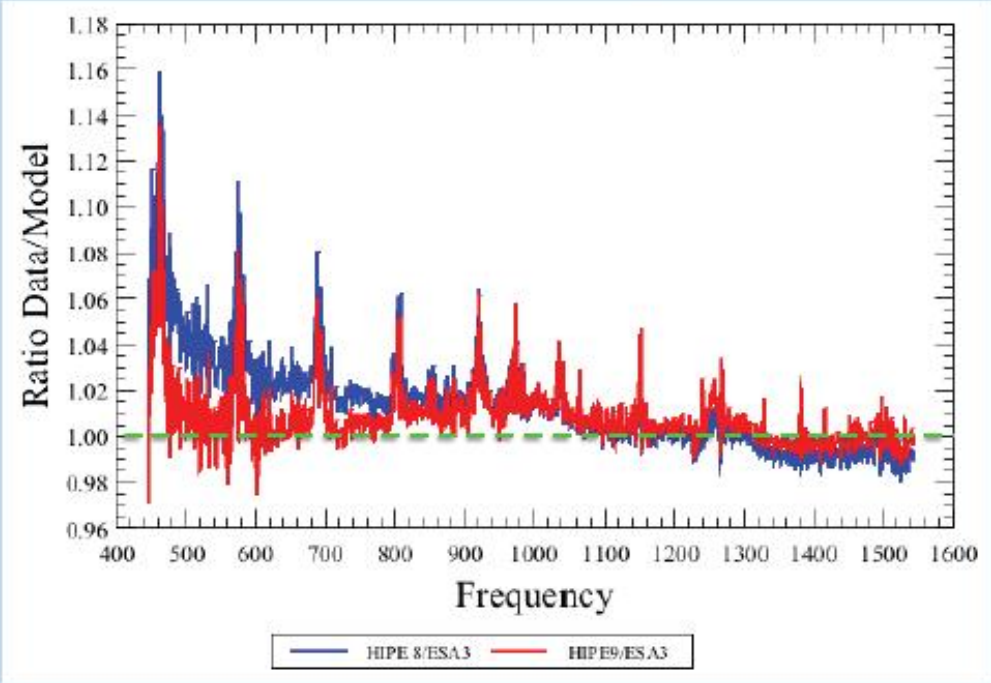
SPIRE calibration – improvements in HIPE 9

- **Improved Level-1 calibration**, based on improved telescope RSRF calibration products:
  - better signal-to-noise by averaging more data from recent dark sky observations (adding to the "deep" teleRsrf)
  - improved telescope model using an empirical correction to the telescope emissivity (residuals now ~0.5 Jy, whereas previously 1.5 Jy)
  - separated LR and HR calibration products - now only derived from data with the same resolution (previously both from CR observations). This improves LR calibration.
- **Improved Level-2** calibration, based on improved point source conversion factors:
  - updated Uranus model used to Glenn Orton's latest model (only small difference to overall calibration: SSW +0.5%, SLW up to -5% at the low frequency end).
- **Mapping observations:** point source flux calibration now available for off-axis detectors - allows users to make a point source calibrated map (using interactive analysis)
- **Improvements to the final Level-2 products using interactive analysis**: "useful script" for subtracting residual background using off-axis detectors or dark sky.
- **Improvements to PCAL flash processing** - affects the calibration of Bright Mode data

SPIRE-S check calibration against Neptune

Uranus model update

Check with Neptune from OD382



HIPE 8 pipeline

BLUE: *using Neptune ESA3*

HIPE 9 pipeline

RED: *using Neptune ESA3*

New Uranus calibration improves shape at low frequency for Neptune with ESA3 model

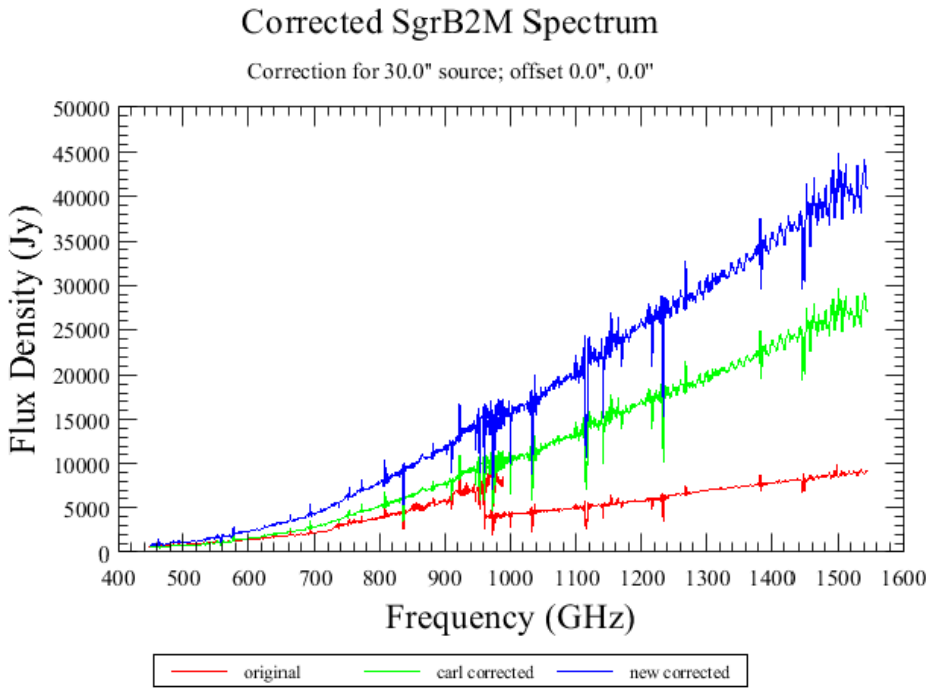
5

SPIRE-S semi-extended sources (in progress)

Now at prototype stage but with requirements for a user tool written.

To be coded in Java. MAY be available in HIPE 10.

Could be made available for particular cases. Feedback useful.

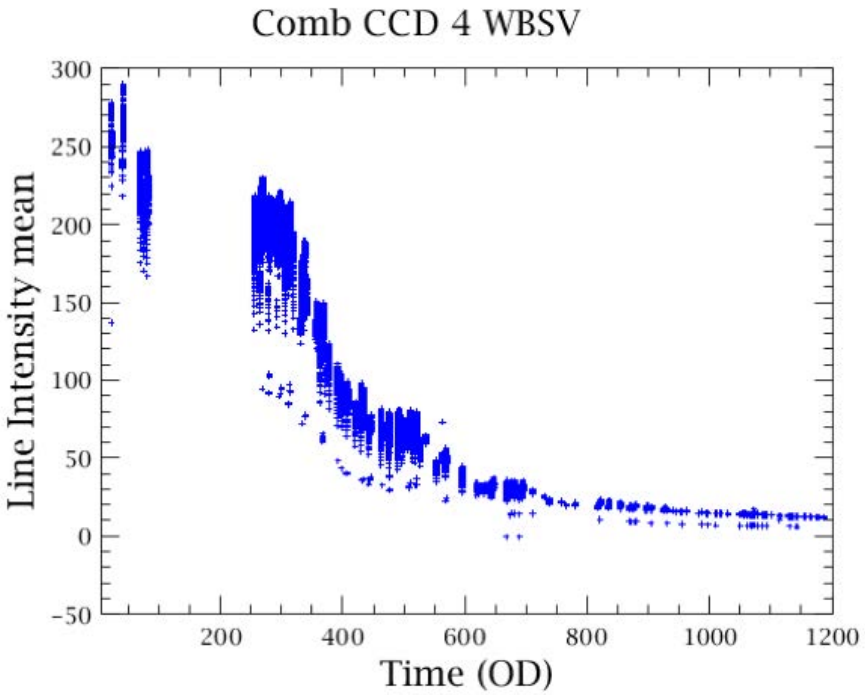


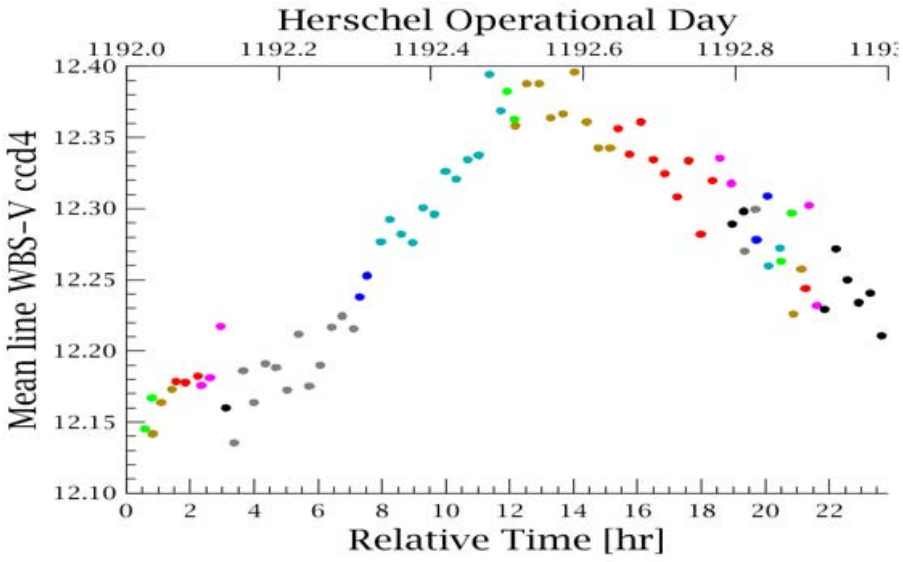
5. HIFI Instrument Calibration

- **General:**
  - Significant documentation updates with HIPE 8 and now in HIPE 9.
  - V polarization comb dying. Still on standby, may now last to the end of the mission (?).
  - HIFI downlink calibration updates (calibration tree).
  - Sideband ratio: Slowly being filled, but this is not something that is overall going to be consolidated until postops. So far, bands 2 and 5 handled (band 1 in the works).
  - HIFI beam measurement updates. Potential T_{mb} conversion updates.
  - Electrical 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.
  - Fringes for bright continuum sources: largely able to be dealt with using alternative calibration available for HIFI in HIPE, plus standard HIPE/HIFI fringe removal tools.

5.1 HIFI Instrument: status of COMB-V hardware

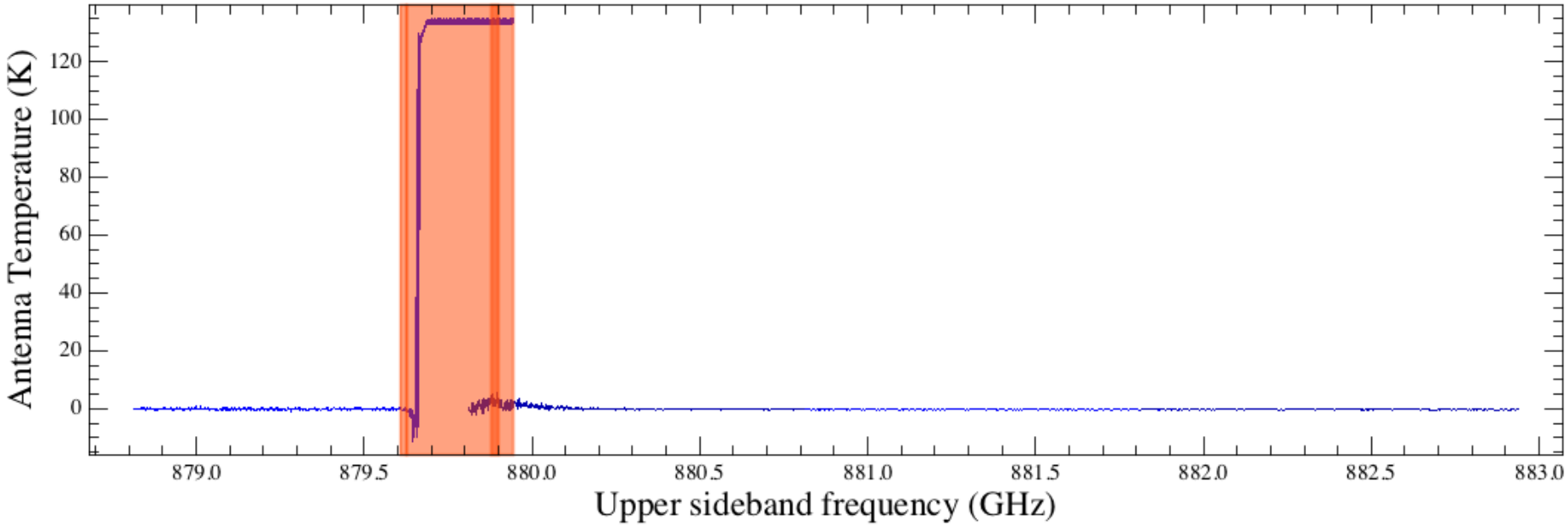
- **It is known since pre-launch that the COMB-V sub-unit has a decaying output power**
  - Power decay occurs in unpredictable – possible loss before end of He.
  - An alternative calibration scheme exist, both in uplink and down-link. Downlink frequency cal will suffer slightly.
  - COMB level are monitored almost on-the-fly for every HIFI OD





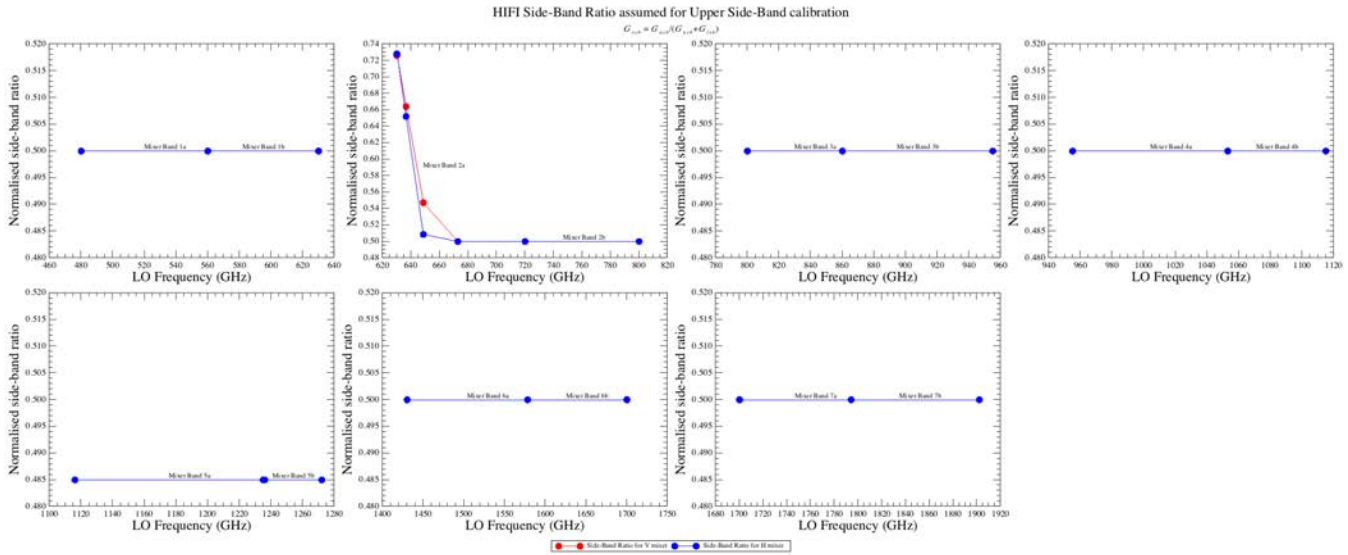
5.2 HIFI Instrument Calibration: cal tree updates

- **HIFI_CAL_8_0: released for 8.1 Bulk Reprocessing (Feb. 2012)**
  - Update of IF saturation table, in use to automatically flag affected spectral ranges



HIFI Instrument Calibration: cal tree updates (cont'd)

- **HIFI_CAL_9_0: released with 9.0 (July 2012)**
  - Introduction of a table of known corrupted data-frame, for automatic removal in the pipeline (currently ~ a couple of dozen cases)
  - Implementation of non-unity side-band ratio in bands 5a and 5b

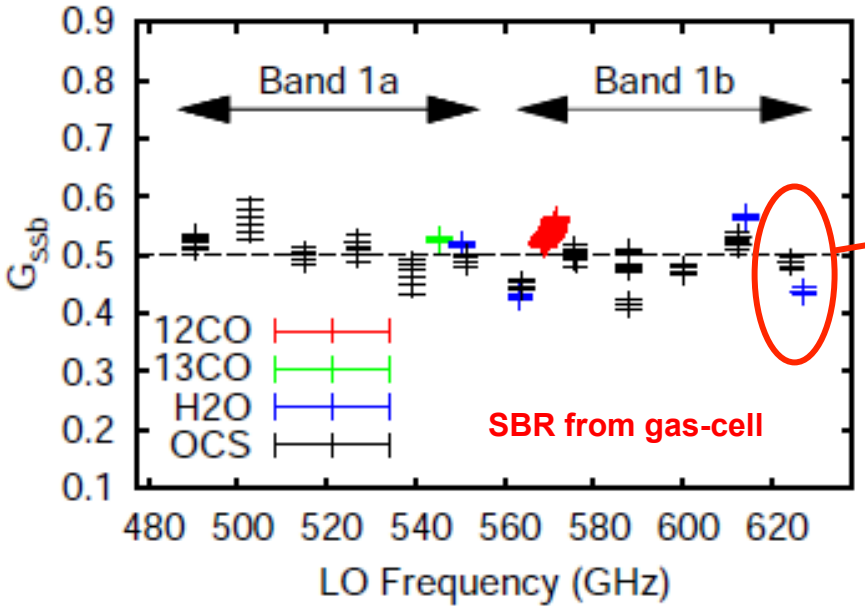


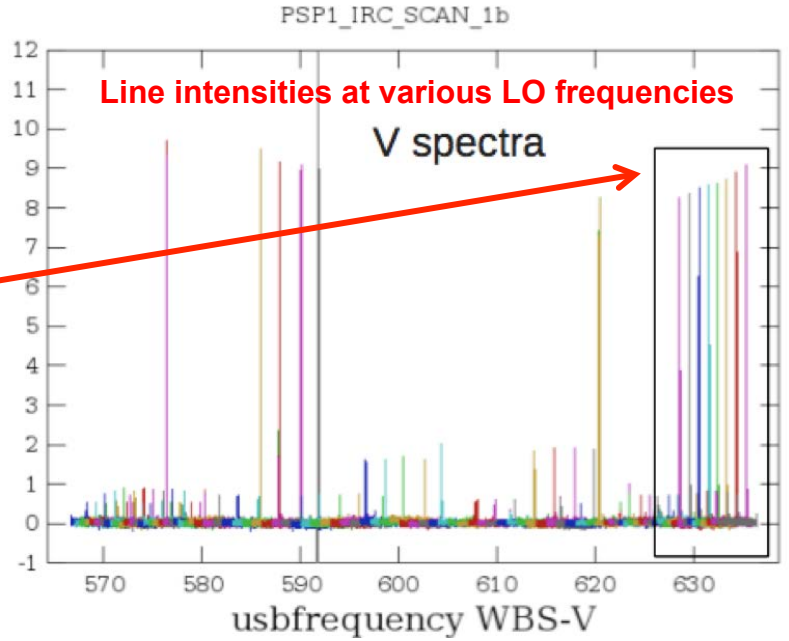
HIFI_CAL_10_0: expected use in 9.x Bulk Reprocessing (fall 2012)

- Introduction of a calibration table collecting uplink parameters applicable to each obsid, to be backfilled into the observation context (part of it is e.g. used to derive the effective cube map dimensions, etc)
- Updates in threshold for instrument HK quality checks
- Update of table of known corrupted data-frame, for automatic removal in the pipeline

5.3 HIFI Instrument Calibration: Side-band ratio

- **Big effort currently done on the band 1a/1b**
  - Noticeable frequency dependence is expected from mixer design, as confirmed by some few laboratory measurements
  - Development of a new side-band ratio extraction method, combining both pre-launch data (gas-cell), and line intensity trends as measured in Spectral Scans of science data now being used.
  - Figure of merit of the best model is based on Bayesian evidence

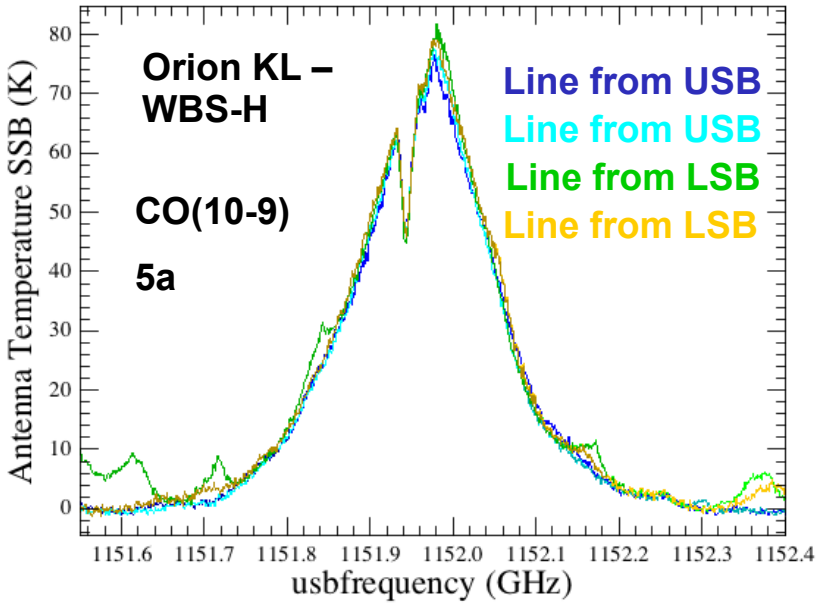




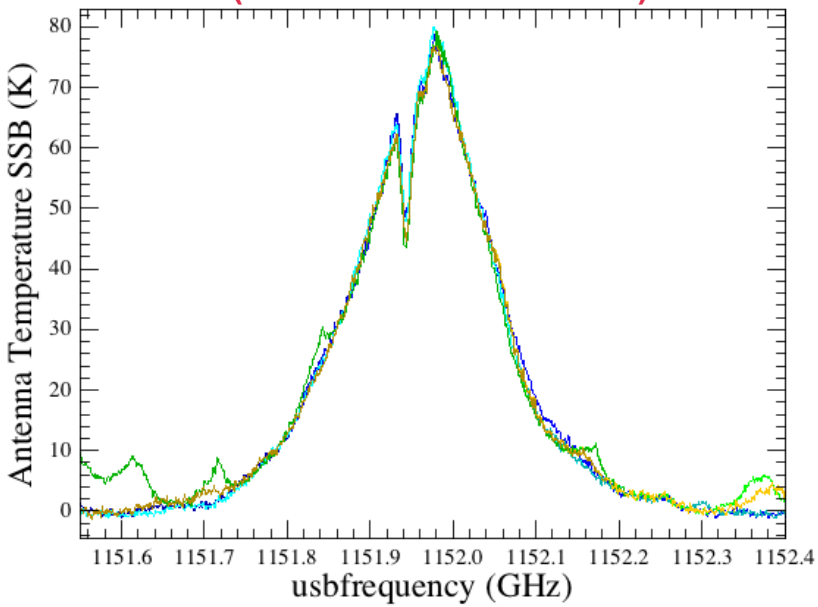
HIFI Instrument Calibration: Side-band ratio (cont'd)

- **Roll out of non-unity side-band ratio in band 5**
  - Assumed to be constant over the whole band, as suggested by constant T_{sys} slope (6% imbalance, LSB favoured over USB)
  - The trend has been checked in several lines observed both in the USB and the LSB – one would expect the latter to always be stronger that the former

Level2 uncorrected (continuum-subtracted)

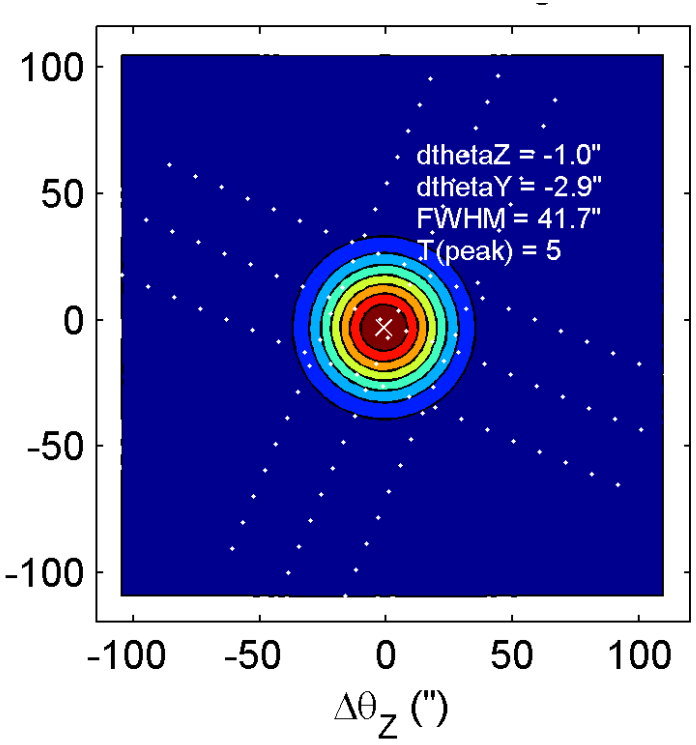


Level2 SBR corrected (continuum-subtracted)

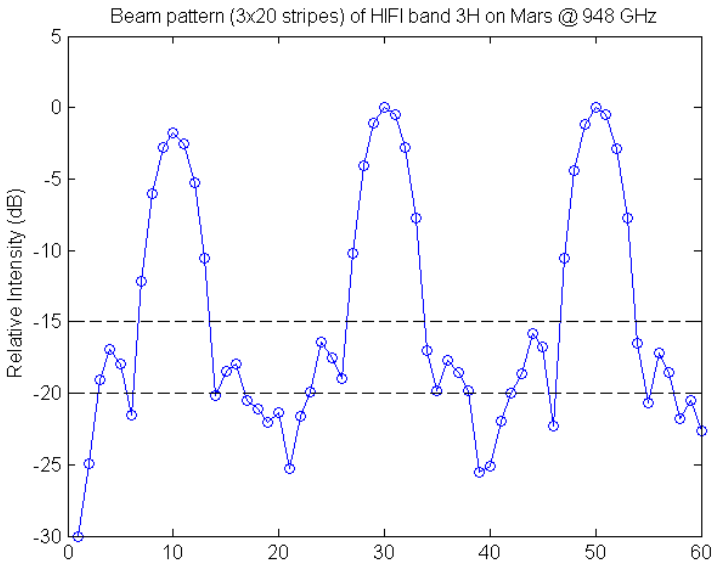


5.4 HIFI Calibration: Beam Pattern and efficiencies

- Four dedicated beam measurements campaigns on Mars:
  - Runs 1 and 2 done at the time of PV phase
  - Run 3 in the Fall 2011, with a revised, finer, map sampling, at the expense of full (2D) coverage
  - Run 4 in May 2012 (last chance to catch Mars – observations combined with Uranus/Neptune conjunction in Spring), only 3 bands (1, 5, and 7)

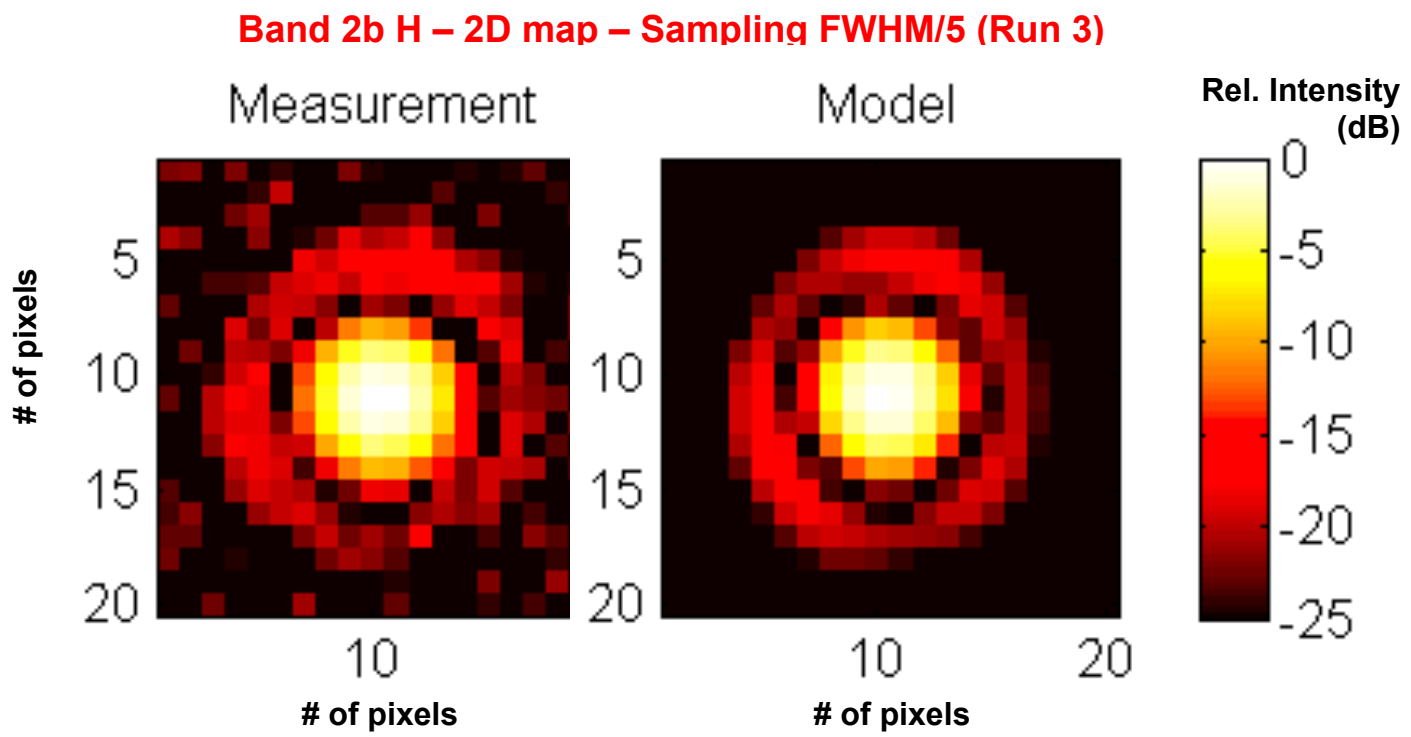


Band 3b H – 1D cuts – Sampling FWHM/5
Run 3



HIFI Calibration: Beam Pattern and efficiencies (cont'd)

- Run 3 confirmed several items (cont'd)
  - As a consequence, beam efficiencies from runs 1/2 may be over-estimated by up to ~10% - **when this is confirmed, this will change the calibration to T_{mb} scale**, but not so much the conversion to Jy
  - The first side-lobe ring was detected for the first time (~ -18 dB)



HIFI Calibration: Beam Pattern and efficiencies (cont'd)

- Future work on beam maps
  - Analysis from run 4 is on-going
  - Overall approach consists in propagating the ILT model (including post-launch telescope model) to the sky, and compare all four runs consistently – **NOTE** that this is NOT a fit but a pure forward projection problem
  - *On the mid-term, the goal is to deliver synthetic beam maps as calibration files – probably not feasible before the POPS phase*
  - Question of the model distribution is under discussion among the three instruments – indeed the beams are asymmetric, so their orientation on the sky is date-dependent – some associated tools need to be designed for use of beam maps.

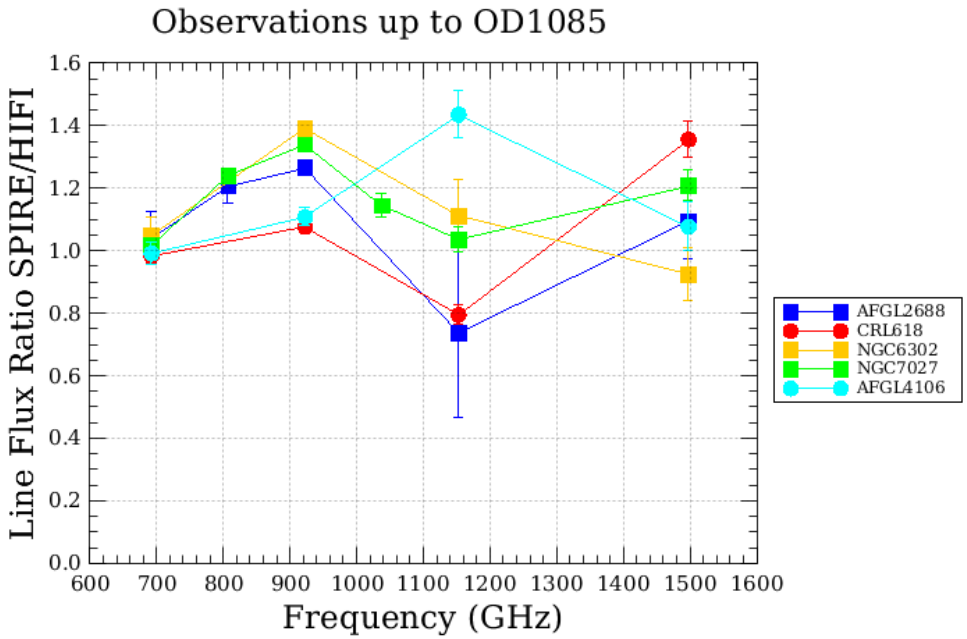
5.5 HIFI: matching technique (HEB StWv)

- **This is the work of dedicated HIFI ICC group.**
- **A prototype code is now part of the expert build for HIPE 9.1:**
  - A version already existed in HIPE 9.0 but it was buggy
  - The current code only contemplates Dual-Beam-Switching observations – extension to other modes is currently on-going
  - The current code can only use the OFF frames from within one obsid.
  - An upgraded script exists at the HIFI ICC, making use of a larger data-base of OFF frames – it's broader use is currently hampered by possible proprietary issues for distribution. A general discussion on how to speed up release of calibration data is overdue
  - User support currently provided by the HIFI ICC on request on an observation by observation basis

- A more flexible and robust standing wave parameterization, leading to the selection of best OFF measurements (from a database) for the removal of electrical standing waves, is being tested in HIPE 10.

6. Cross-Calibration

- Activities based around cross-calibration plan (HERSCHEL-HSC-DOC-1720, August 2010)
- Twiki page collecting information:
  http://herschel.esac.esa.int/twiki/bin/view/HCalSG/CrossCalibration
- Second version of cross-calibration report formulated this summer (HERSCHEL-HSC-DOC-1935, draft 2; 12 June 2012)



SPIRE-HFI (Planck) Cross-calibration

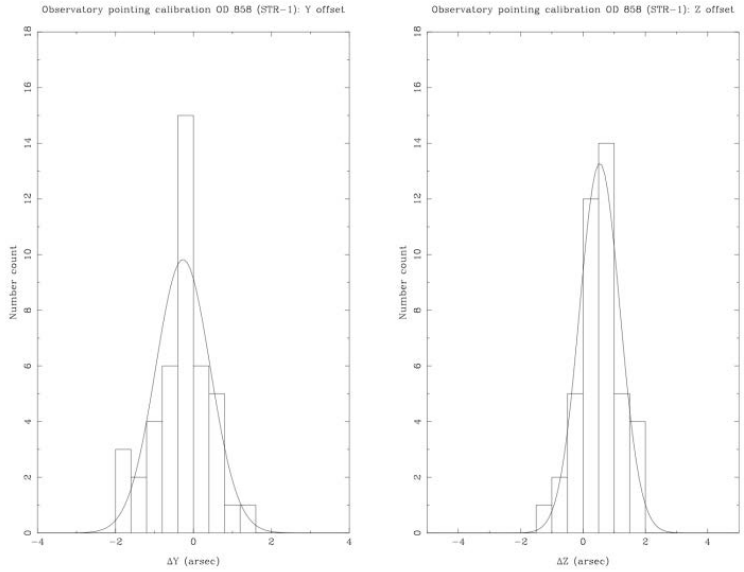
- Ongoing work coming to fruition with the availability of an offset calculated from Planck HFI data for any SPIRE map on the sky.
- Will use Planck HFI products to be delivered later this year.
- Planck products themselves are not supplied to the user.
- …at the same time very useful for cross-calibration of the flux gain of both SPIRE and HFI (check/recheck of beams).
  SPIRE beam updates in the future…

7. Pointing Overview

- *Speed bumps' update: no events found since reducing STR temperature.*
- *Regular updates made to on-board defective pixel table by MOC to identify bright pixels not to be used for pointing.*
- However --- after a number of reported anomalous pointings apparent in data it was realised that the STR had changed around time of temperature reduction.
  - Effective focal length of optics (free parameter in the attitude and control system of the spacecraft) was well away from correct value when known and measured positions of stars tracked taken into account.
  - Later realised that full nD distortion of the STR could be mapped (note that this has not been possible for the redundant STR).

7.1 Current Pointing Performance

- Pointing performance information is available on the website at http://herschel.esac.esa.int/twiki/bin/view/Public/SummaryPointing
- Pointing calibration measurements are made regularly. Following 2D correction parameters to on-board star tracker.
- Final updates to STR made in February (OD1011). APE now measured at ~1.”1 as opposed to 2.”3 measured prior to onboard STR parameter updates.



7.2 Pointing Improvements for Past Observations

- Worked on two tools.
  - Speedbump removal from observations in early phase of the mission.
    - Needs final testing
  - (priority) Adjustment of pointing information for all observations based on the distortion imposed by the incorrect 1D and 2D parameters on board (up to 28 September 2011/ OD761).
    - Adjustments being checked against products. Report this week.
    - Expected availability for imminent round of bulk reprocessing using HIPS 9.1.

- Further investigations.
  - PACS looking into different filtering schemes to improve the pointing reconstruction that is then applied in the pipelines. Again – this would be applied after the fact.

7.3 Pointing Product Corrections

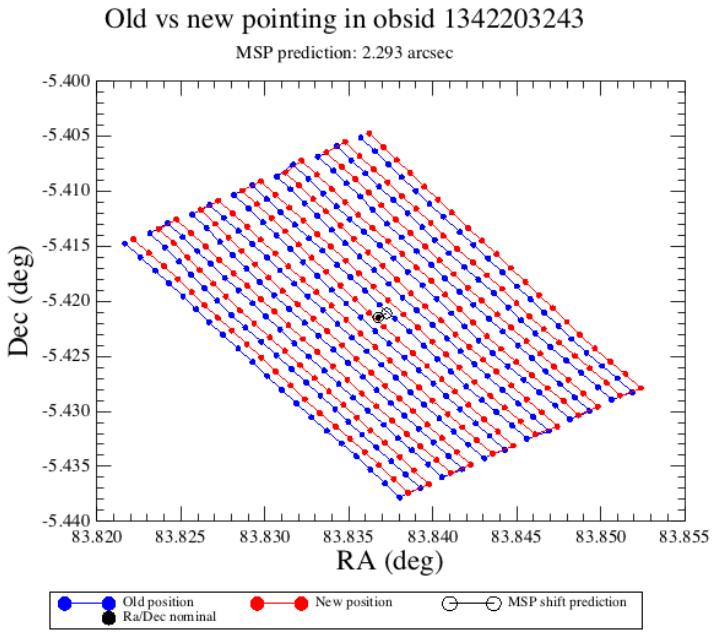
- The pointing information is being updated for observations taken in the time period OD320 to OD761
- Tests being completed but shown expected shifts, in some areas of several arcseconds. Pointing star checks indicate reconstruction gets to 1.”5 APE.
- http://herschel.esac.esa.int/twiki/bin/view/Public/HowToUseImprovedPointingProducts

Star UZ Tau – shift applied to compensate for STR error → on SIMBAD position.

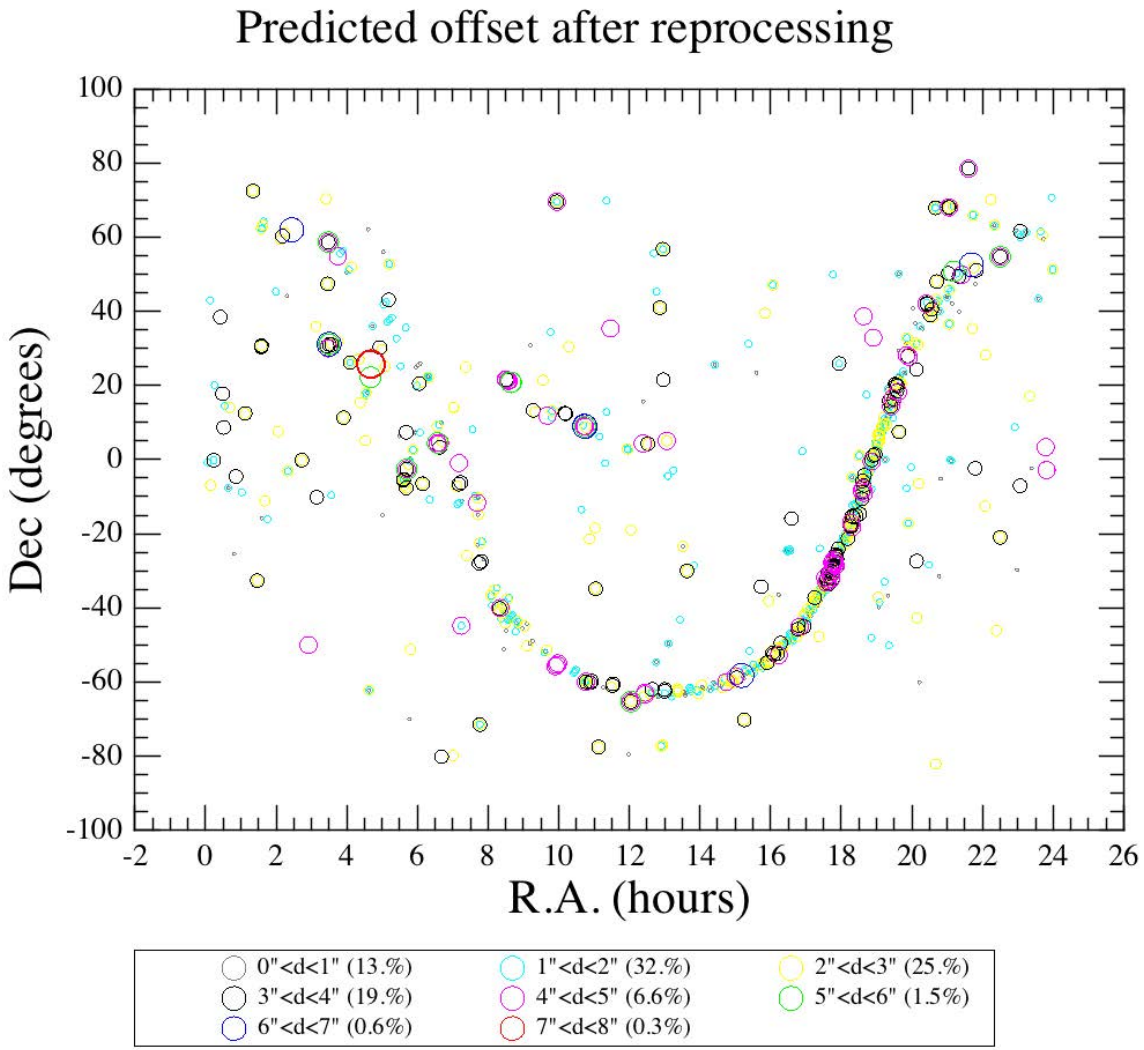
Looking to update again using smaller 2D+ STR distortion corrections in the future (likely in postops).

7.4 HIFI: improved reconstructed pointing

- New pointing products have been computed for the period OD 360-761, when an improper STR focal length was used on-board the s/c.
- The overall position shift of the observation was predicted for all ~ 4000 HIFI obsids falling in this time slot by M. Sanchez-Portal
- Offsets are predicted to be as high as ~ 8” with respect to the original pointing reconstruction – the worst offsets are in the Taurus region, but not only. But less than 1% more than 6” in offset.
  - Note that still consistent with 2.”3 (1 sigma) pointing
- HIFI has run a bulk reprocessing of ~ 4000 obsids with the new pointing products.
- Less than 2% show any deviation (>1”) shift in processing as opposed to predictions. These are explainable.
- **Net result: no issues with pointing products seen.**



HIFI: improved reconstructed pointing (cont'd)



8. Conclusions

- Calibration improvements steadily being made for all sub-instruments.
  - More of these appearing in pipeline updates and downlink calibration updates, although in some areas this is not as fast as we may like. *But some are still difficult problems (e.g. sideband ratios, correct error files for extended emission).*
  - Improvements to tasks based on calibration work continuing to appear more in HIPE.
- Absolute photometer errors limited by calibration models. Feedback of Herschel data to models → Go to ~3% errors.
- Spectrometers showing clear calibration improvements and now of order 7-15%.
- Cross-calibration with Planck now coming to a successful conclusion allowing offsets for all SPIRE observations in the database (following reprocessing.
- Pointing has improved significantly and new pointing for most affected set of observations will be applied in next bulk reprocessing (barring any late issues).

9. HUG Actions List – Pending Actions

- HUG#2 action 3: HIFI Sideband Ratio Calibration, De-fringing and Baseline Stability:
  - See sections 5.3 and 5.5
- HUG#2 action 4: PACS-P extended emission
  - See section 3.1
- HUG#3 action 1.4.1b: PACS-S spectral distortion for extended objects
  - TBD
- HUG#3 action 1.4.1c: Flux and distortion for sources not well centred.
  - See section 3.2
- HUG#3 action 1.4.3, as per HUG#4 action 6.4
- HUG#4 action 6.1: PACS-S improvements.
  - See section 3.2
- HUG#4 action 6.2: SPIRE-S improvements
  - TBD
- HUG#4 action 6.3: PACS-P extended emission
  - See section 3.1 (slide 13)
- HUG#4 action 6.4: HIFI standing waves and bright object spectroscopy
  - See sections 5 and 5.5