Herschel Calibration Report

Anthony Marston,
Herschel Instrument and Calibration Scientist Team Lead,
ESAC.

To Herschel User's Group #2, ESAC, 24 February 2011.

General Items Regarding Calibration

- Workshop under the auspices of the HCalSG took place 13-15 December 2010 in ESAC mainly concerned with photometer flux accuracies and models being used
  - Recommended updates/removal of "contaminated" stellar sources (low-level chromospheric emission).
  - **Agreed we all move to "esa3" model of Neptune.** This makes a small flux increase for PACS and SPIRE.
  - **Model accuracy moving to 1-3%.** Updates available from feedback of Herschel results.
  - Issue with extended emission calibration of PACS appeared a big problem. Investigation team set up (Babar Ali, chair). Convolution kernels solve issue? Interactions with KP groups taking place. ***Meeting to be held in ESAC 11/12 April.***
  - Bottom line(s):
    - Point source photometer calibration excellent (few 3-5 per cent).
    - Current spectrometer measurements are in very good agreement with photometer measurements.
    - Models are in excellent shape and through cross-checks are good to levels approaching 1%. Some "contaminated" stellar sources (since removed from PACS calibrations).
- Further workshop, more spectrometer based, to take place in the middle of this year (via HCalSG).
- **Full calibration review intended for early part of 2012.**
- Documentation/instrument manuals to be updated for the GT2 call.
- Instrument Twiki pages available directly from main HSC web page. Links to calibration files, pipeline scripts and relevant DP documentation is now provided through these pages.

Instruments: PACS photometer

- *PSF identified to have important wings outside of 1'. PSFs now measured very accurately out to 10'.* Improved PSFs available for some time. These are available from HSC web site.
- Now determined that (together with removal of some "contaminated" stellar calibrators) that
  - overall calibration is <u>good to 3%.</u> Estimate 2% systematic error from model/ assumed calibrator fluxes and 1% from the measurements of those calibrators.
  - (for point-sources below 100 Jy: 3/3/5% in blue/green/red)
- Convolution kernels being developed for the following.
  - convolution between any of the 6 Herschel photometer bands (PACS/SPIRE)
  - convolution between Spitzer MIPS/PACS bands.
  - these, together with instructions on their use should be available in the near future.

PACS Photometer Calibration Issues 1/2

- **1) Flux calibration.**
  - Revised responsivity calibration file based one the 5 most reliable fiducial stars <u>only</u> and the new PSF normalized at 10' instead of 1'. As there is about10% of the flux between 1' and 10' , the EEF (encircled energy fraction) curves are going down, hence sensitivity is being adjusted accordingly.
  - With the new calibration, the flux reproducibility of the 5 stars is 1% in the blue bands and 3.5% in the red band. **Dominated by the flux uncertainty in the model**, estimated to be 2% (normalized SED in the K band).
  - This new calibration will not be available in HCSS/HIPE 6.0, but hopefully shortly afterwards, as it can be imported via a calibration file update.
    - **updated responsivity cal file.**
    - **new EEF curves to be made available as a new calibration file**
    - **the PSFs are already available on the PACS instrument web pages.**
- **2) Extended emission calibration**
  - Plan to have a TN on the status of extended emission will be issued by the PACS ICC (M. Sauvage/B Ali) by April 2010
  - Extended emission comparison with other missions is a very delicate issue and depends on the convolution
  - Kernels used especially to compare with MIPS. But the main message is that currently there is no reason to worry, with the new PSF/associated convolution kernels, the agreement is already very good.
- **3) Pipeline**
  - MADmap maps should come back in the so called **extended pipeline in level 2.5, combining scan and cross-scans**, About 1200 obsid pairs have been identified, by running query & association scripts on the HSA DB.
  - For HCSS 7.0 a major update/improvement of the photProject maps is under work, making use of the **second order deglitching** (spatial) instead of the timeline (MMT) deglitching that does a poor job on maps at high scan speeds.

4) Convolution Kernels

– To be made available at some point, under the lead of Marc Sauvage, but probably not before March.

5) Flat-Field

– New flat fields are being generated and tested, but they will not make their way yet into the system..

6) Non-linearity

On-going work/testing to correct non-linearities for the (few) source brighter than 100Jy, still we are only talking of a **correction of a few % only.**

7) Astrometry.

On-going work to derive/characterize the **residual time shift between pointing products and PACS frames,** that leads to some systematic shift (but variable) for source detected in odd versus even legs. In parallel mode we have to deal with the additional effect of the time constants of the bolometers

PS chop−nod mode: blue band
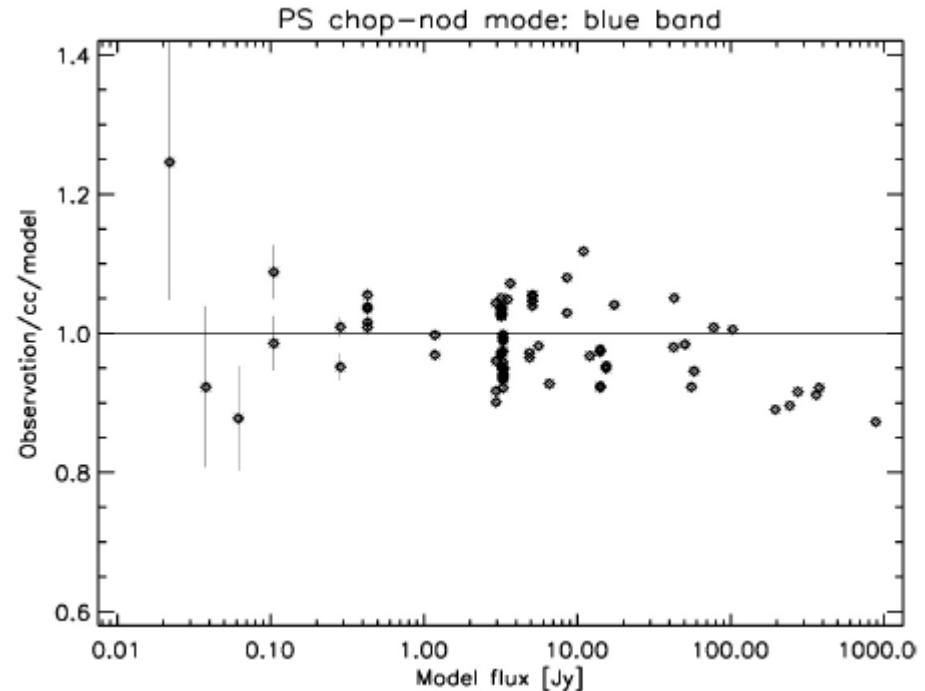
PACS Spectrometer Issues 1/2

- Unchopped spec bright source mode requested being tested now and should be on-line shortly. AORs on hold waiting for this version of the mode. Expected to be available in HSpot 5.3. Full performance information not available until late March.

- 1) In the recent calibration tree for HIPE 6.0 (PCAL-12):
  - The calibration sources absolute flux tables are flat-fielded and scaled to fit to the flux of standard objects.
  - The 1.3 and 1.1 correction factors to bring the ILT responses to flight performance are included in the NominalResponse calibration. Also, improvements in the flatfield are included in the NominalResponse calibration file (based on internal TNs of PACS).

- 2) SED mode calibration issues
  - Flat-fielding works fine in HIPE 6.0 interactive scripts what may significantly reduce the 'fringing' pattern due the systematic response variations among the 16 spectral pixels.
  - A prototype code for flux calibration with telescope normalization is available.

- 3) PACS H_SC-70 anomaly statistics update after mitigation (on-board software change in OD 500):
  - 22 anomalies detected in 43 Spectroscopy ODs (compare 53 anomalies in 93 ODs before OD 500)
  - None with science signal loss *AFTER initial error lost some days of science time*.
  - Note, repair (DMC reset) within OD allows us to see anomalies we would not have seen before OD 500
  - QC decision tree has been implemented to identify what part of the observation needs to be re-scheduled in case of affected science
  - Conclusion: not critical but we need to keep an eye

Calibration issues and methods what has been recently investigated but not yet conveyed to HIPE/ DP:

- **4) Ongoing activities what have been recently prototyped but not yet available to the community:**
  - **Point-source flux correction and pointing reconstruction.** This method applies an accurate PSF fitting of observed point-source continuum to high-resolution Neptune rasters, the derived pointing offset is used to estimate flux correction on the central spaxel.
  - **The method can significantly reduce the uncertainty on the absolute flux scale of the Spectrometer**, factors 2.5-3.0 have been measured on HD161796 key-wavelength test measurements. This method may effect individual science observations as well as the flux calibration of the instrument when applied to calibration observations.

- **5) Spectrometer ghosts**
  - Two ghosts in spectrometer observations have been reported at the last PACS ICC meeting **around 108 and 123 micron**. The ghosts have been seen so far only on sources which have strong atomic fine structure lines. In extragalactic observations, the ghost wavelengths change in agreement with the redshift of the sources.
  - Spatial ghosts. **Spatial ghosts in the PSF are found at 62 + 124 and 75 +150 μm**. The ghost was seen strongest in the red section but it is present also in the blue section.

- **6) The long-range spectroscopy unchopped grating scan** mode has now indicators of ON/ OFF positions, this information will be used in the extended pipeline to automatically combine ON/OFF OBSIDs even for clustered observations

SPIRE photometer issues

- PMW calibration changed of ~0.4%: the change took into account a change in the PMW RSRF used for calculating the Neptune fluxes on which the flux conversion is based.

- Moving to **updated flux model of Neptune (esa3)** which increases fluxes slightly.

- SPG pipeline now includes a **jump detection task**: this automatically corrects data in case of jumps in the thermistors timelines (which caused annoying stripes in maps)


Neptune Measured/Model Flux Densities

Triangles: Small scan map
Squares: Large scan map
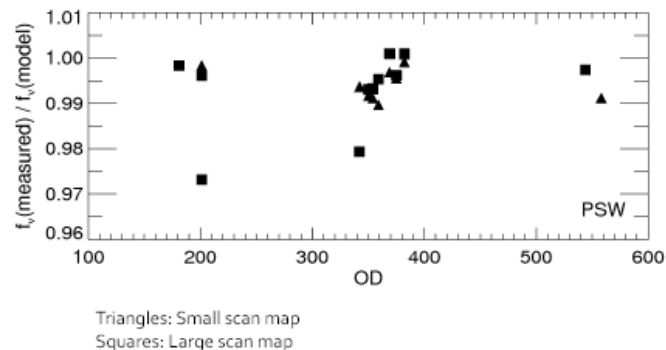
- SPIRE photometer good to ~3% but requires **optimum flux extraction**. Script now available but is being prepared as a tool in HIPE (extracts flux from the timeline of observations rather than the final map).

SPIRE Spectrometer Issues

- Bright source spectrometer mode available.
- HIPE 4 to 5 improvements. Two wavelength sections now have consistent flux scaling.
- Processing with proper version of dark sky usage makes major difference. Now standard in pipeline.
- **Use of telescope as absolute calibrator.** Checks show totally consistent with planetary models (Neptune) currently being used to calibrate the SPIRE products.

- **HIPE pipeline updates:**
  - Version 6 involves a major change to calibration tree structure with some new product definitions, and so *this update will be incompatible with previous versions of the HCSS.*
  - Improved phase correction module in the pipeline no longer requires a calibration file. The final correction should be better using the new method.
  - **Telescope and instrument RSRFs and beamParam updated** to follow the new v6 pipeline scheme and use improved phase correction - *should lead to improvement in shape of final spectra.*
  - BeamParam file modified to improve information for IA - updated beamAreas and added point source RSRF - this should have no effect on the SPG pipeline.
  - OpdLimits added to clean up the pipeline script - should have no effect on data.

Even better with HIPE 6.0
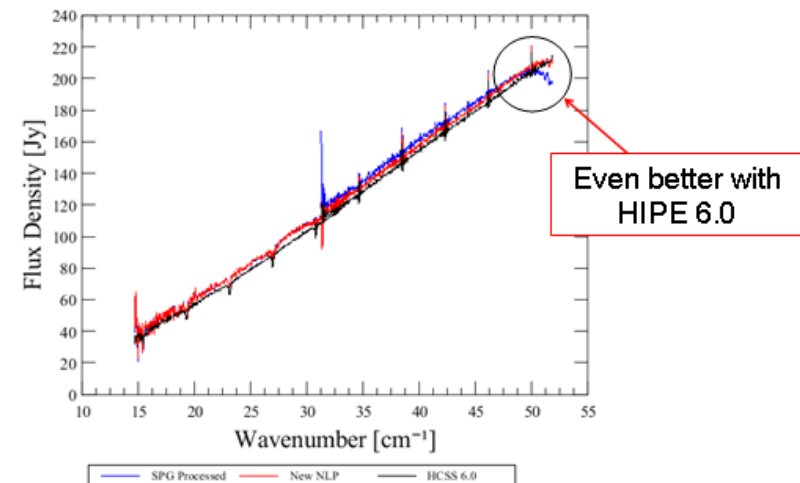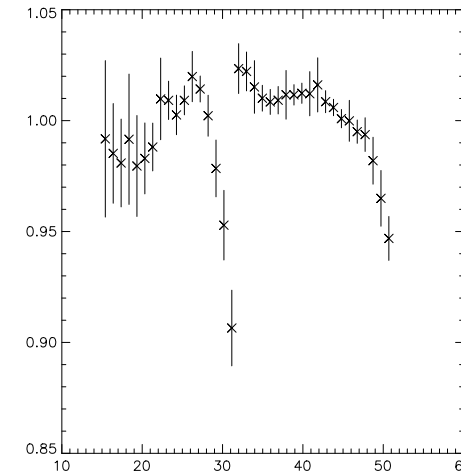
- **Calibration scheme includes all efficiencies known** -- including forward efficiency of 0.96 in most recent pipeline.

- **Beam position information** in calibration information and separate H and V polarization maps now possible through pipelines. Usage of beam offsets.

- **Sideband Ratio (SBR)** -- receiving more attention. Group fully resuming meetings/telecons.
  - Ph.D. recently submitted containing the best known information on SBR measurements from on-ground ILT measurements.
  - Report on gain estimates from deconvolution techniques (need to take this with a piece of salt -- for instance SBR varies across the IF, notably for the diplexer bands), not just a single number at a single frequency!
  - This is the largest overall source of error in the **HIFI error budget (15-30%).**
  - In certain observations the value is measurable. Combination of on-ground and space measurements being used to get the overall situation.
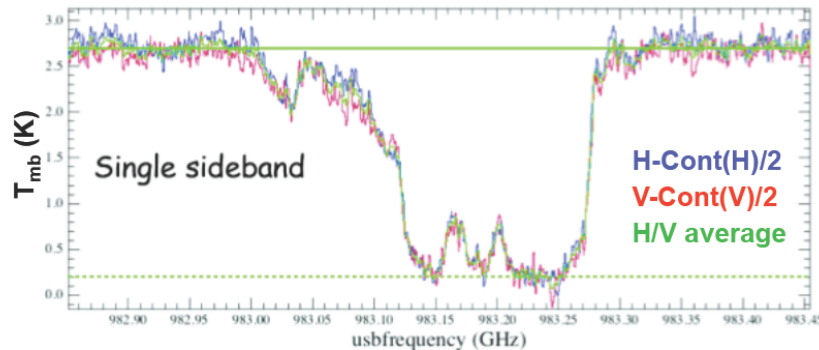
Should be at OK – SBR not 1.

- **Note:** Irregular single event upsets (SEUs) occur (average 1 / 2 weeks or so). Requires manual intervention during a DTCP. New recent event found the updates can get corrupted. Solution worked. Generally does not disrupt science measurements.

- **1. Progress on existing calibration issues**
  - **Purification of bands 5a and 5b complete,** spur removed from band 1a. Updates to sensitivities in HSpot/HCSS/documentation.
  - We have **updated the beam efficiencies** in all bands. This is reflected in the HIFI cal tree in HIPE and within HSpot.
  - **WBS spectrometer COMB-V still dying** -> alternative cal. scheme being refined – good prospect these will work well if needed.
  - **Incorrectly working heater on oscillator source (OCXO).** This leads to varying supply current to the local oscillator source unit. Working within specified range but unclear if it will fail in the future.

- **2. New calibration issues**
  - **Spur in band 7b around 1834 GHz** (affects an OH line) was not fully propagated to users (it escaped our current detection scheme). On short term we will check possibly affected past and future AORs. On mid term, spur shall be removed by setting adjustment.
  - **Purity issues at upper end of band 5a** that were not fully appreciated at the time of releasing the first HIFI observations ~ a year ago. Correction factor are been worked out
  - *Usage of AGB stars for calibration monitoring is inadequate in many lines due to variability. Monitoring needs to be done a more regular basis to follow light curve. New science result.*
  - **Smoothing algorithm for OFF subtraction in FSW and LChop with Ref was not optimal** -> consequence on standing wave and noise at leve2 (not exactly a cal issue but this is pipeline-related). This is being fixed for HIPE 6, so will be in for bulk-reprocessing

Cross calibration

- **Observations:**
  - Cross-calibration information available through regular observations and calibration measurements.
  - **SPIRE and PACS photometer calibrations include cross-calibration targets, including asteroids** (also shared with Planck crossing times – part of a larger scheme of cross-calibration with Planck, should improve offsets in flux [e.g. HIGAL extended emission]).
  - Models and calibrator information used is contained in central **calibration source database** (CalSDB). Publicly available but needs more user documentation.

- **Cross-calibration measurements taking place**:
  - PACS-SPIRE photometer
  - PACS-P and PACS-S, SPIRE-P and SPIRE-S
  - HIFI and SPIRE-S line emission.
  - Very limited PACS-S and HIFI line emission (mainly anecdotal).

Cross-Cal Example Cases
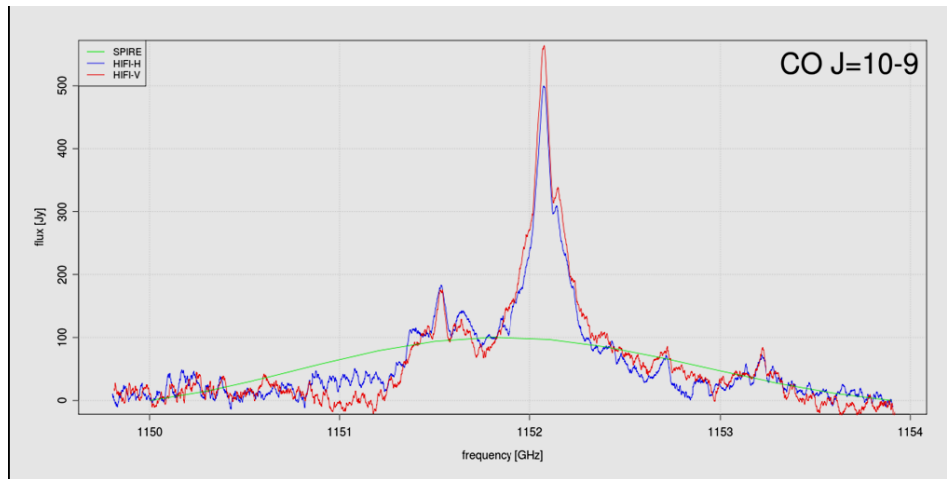
SPIRE-S -HIFI line measurements, CRL618. Initial results within 14%.

gamma Dra Herschel photometry
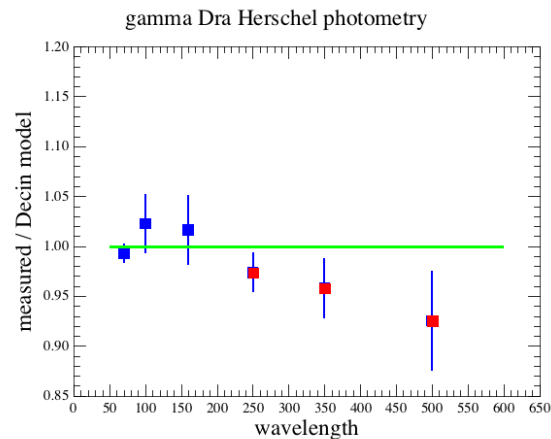
SPIRE-PACS photometer measurements compared to Decin model of γ Dra.

Pointing Issues

- Loss of STRs before Christmas. Jupiter moving towards the edge of the STR FOV? Rare but indicates issue of offset between use of the 2 STRs.

- **Pointing generally** -- being monitored regularly (now using scans rather than PACS PS mode). API generally consistent, some suggestion there could be some degradation -- need to be careful -- scan versus pointed mode observations.

- Pointing improvements are available for many objects with the use of **interlacing of the STRs** (use of up to 18 instead of 9 stars).

- **Pointing using gyros -- CP raster tests.** So far, drifts during time on GYRs make this less useful. Second test just performed suggests nothing improved with changes to setup. Situation degrades when moving on from an initial observation too. Awaiting a final report on this.

Conclusions

- Calibration is generally excellent for all instruments!

- **Photometers probably pushing as far as we can go with flux cal.**

- **Spectrometers some way to improve.** HIFI errors estimates likely to come down considerably when sideband ratios become available.

- Model sources used for calibration can be limiting factor but at high accuracy now and show consistency with absolute calibration being used with the telescope.

- **Cross-calibration measures show excellent consistency**, within the errors of the instrument measurements (especially when using the same calibrator models!).