



Herschel Calibration Report for HUG#4.

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To Herschel User's Group #4, ESAC, 15 December 2011.

Outline of Presentation



- 1. General Items Regarding Calibration**
- 2. PACS Instrument Calibration**
- 3. SPIRE Instrument Calibration**
- 4. HIFI Instrument Calibration**
- 5. Cross-calibration**
- 6. Pointing**
- 7. Conclusions**

1. General Items Regarding Calibration



- *Herschel Calibration Steering Group meeting#29 took place 9 September.*
 - *Important planetary cross-checks later in the year and cross-calibration efforts and organisation were two key points*
 - *Date of next workshop changed – 18-20 January 2012– spectrometer centred.*
 - *Twiki site containing minutes and connection to all presentations at <http://herschel.esac.esa.int/twiki/bin/view/HCalSG/WebHome>*
- *PACS routine calibration plan v2.2 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 updated** for all three instruments (plus large part of the Observatory manual) were updated for the OT2 call.
- **Instrument Twiki pages** continue to be updated, especially "Observatory" area (pointing). In middle of a major review and overhaul of HIFI area with HIFI ICC.
- **Calibration Source Database** – 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 with the release of HIPE 8, and includes user documentation
- **HIPE 8 released now and bulk reprocessing of the archive using it will start in the new year. So please note this where updates are indicated in the text**

2. PACS Instrument Calibration



- General:
 - Documentation updates including the
 - Observer's Manual (OM)
 - PACS Data Reduction Guide. Many updates and improvements
 - Calibration improvements
 - With PACS-S the calibration accuracy is now 11-12% rather than 20-30%.
 - Improved pointing accuracy should enable consistently improved PACS-S calibration improvement.

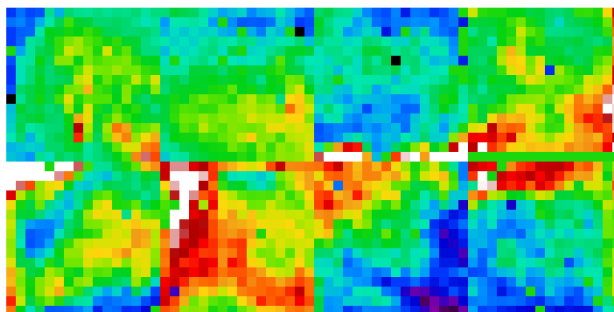
2.1 PACS-P updates



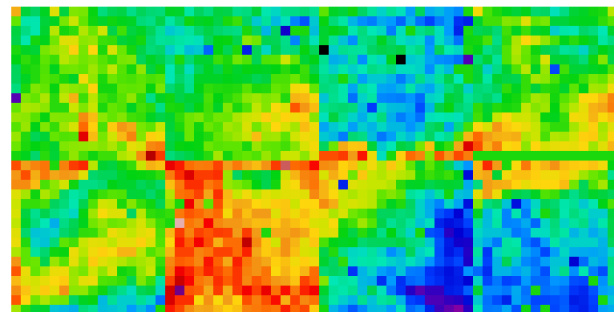
- Updated routine phase plan available ([PICC-MA-PL-002, v2.2](#)). So far 633 hours of calibration observations made.
- Pipelines updated in HIPE v7, now being used in current bulk reprocessing with HIPE v8.
- An aperture correction task available to users.
- **Non-linearity implementation in HIPE v8 for sources brighter than ~ 50 Jy. This also affects the PSFs measured – typically a few percent in the core. Formal PSF $\sim 3\%$ broader.**
- Possibility to **remove the point-source artifacts** of bright sources for MADmap maps (will be applied in SPG8 bulk re-processing).
- A new task to mitigate cross-talk artifacts on bright sources.

PACS-P updates Cont.

- **Flat fields:** New photometer flatfields based on observations of NGC 6543. No calibration change but slight improvement on noise in frames.

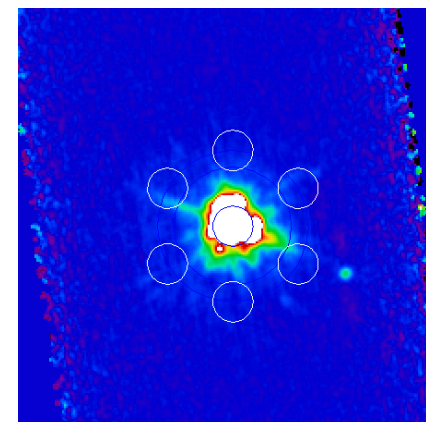


blue default



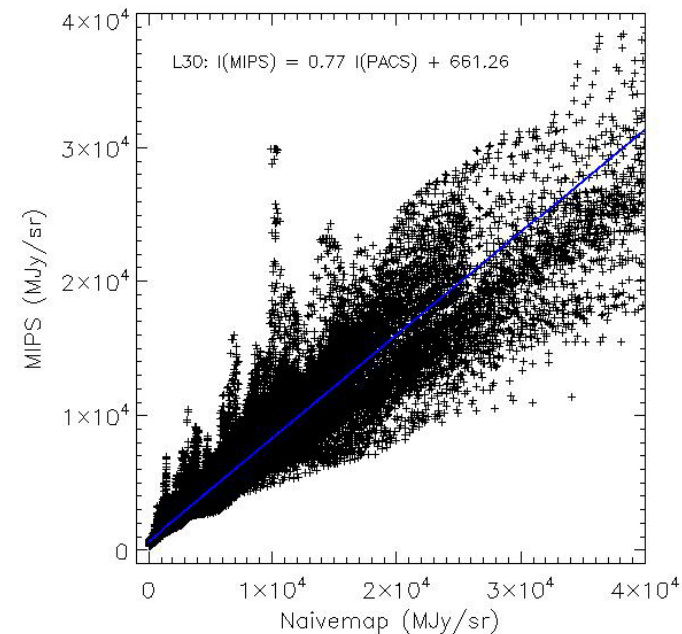
blue new

- **Error Maps:** Due to correlated noise, error maps not totally reliable. Task provided in HIPE 8 that provides reliable aperture photometry with errors.





- **Extended emission (from last time):**
 - 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. More to be made available on Twiki area.



PACS-P Calibration Accuracy

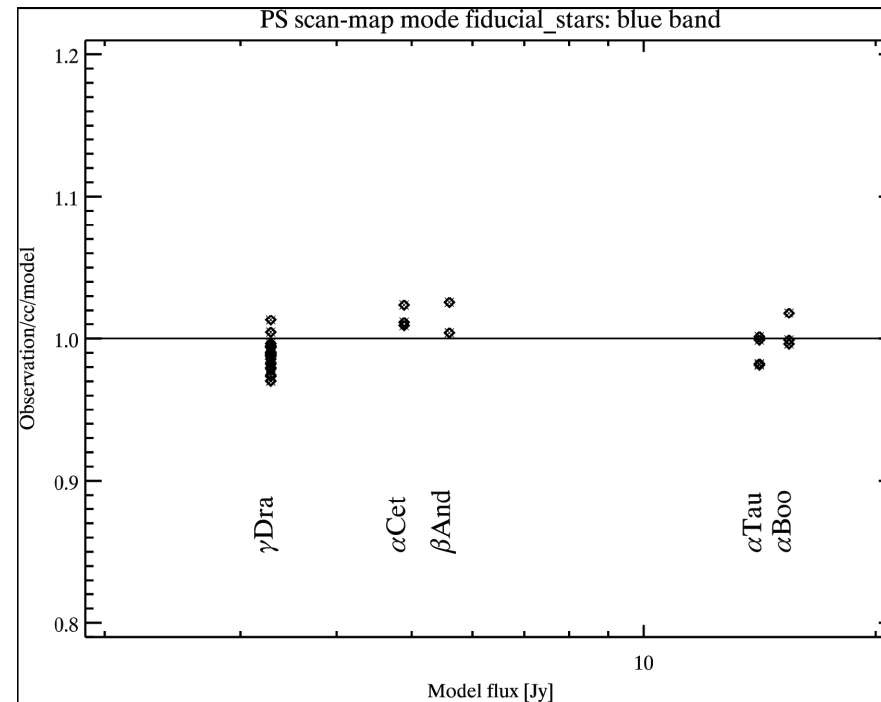


Current PACS-P error estimates have basically not changed much:

70 micron: 2.64%

100 micron: 2.75%

160 micron: 4.15%





- A slight update of the 70 micron photometric calibration is planned
 - But care due to slight sensitivity variations seen towards end of currently used hold times
 - Together with associated Encircled Energy Fractions of a few %, as the PSF calibrators were already in the non-linear regime.
- A new flat-field has been made available internally to PACS ICC and should be distributed soon. But no major difference expected.
- Error maps: the major problems suffered here is with correlated noise (e.g., due to filter applications). So current error maps have not greatly improved. Unclear on future improvements although it is clearly a user wish.
- Pointing will be a 'calibration' issue for some time to come ...

2.2 PACS-S Calibration Improvements



- **Response and flat-fielding updates** – the following will improve noise performance.
 - The improved short-range flat-fielding and the use of instantaneous response estimate from the calibration block are available in v8.0. Now, a point-source spectrum - at least for high S/N sources - can be extracted from the central 3x3 spaxels rather than applying a pointing offset correction.
 - Pointing offset correction method on the central spaxel to be included in HCSS/HIPE 9 anyway.
- **An alternative calibration** is provided for line-spectroscopy data where source flux is expressed in units **of telescope background** instead of using a standard response calibration. Observers are encouraged to explore both ways of calibrating PACS Line Spectroscopy data and adopt the higher S/N reduction for flux extraction.
- **Error propagation** is implemented in the Level 2 PACS rebinned cubes product (STDDEV dataset).
- The decommissioned wavelength switching SPG pipeline is merged with the unchopped pipeline and the original removed. The interactive wavelength switching script remains available in the HIPE pipelines menu.
- **Improved documentation** and user friendliness of the pipeline tasks within HIPE in v8.

PACS-S Cal improvements Cont.

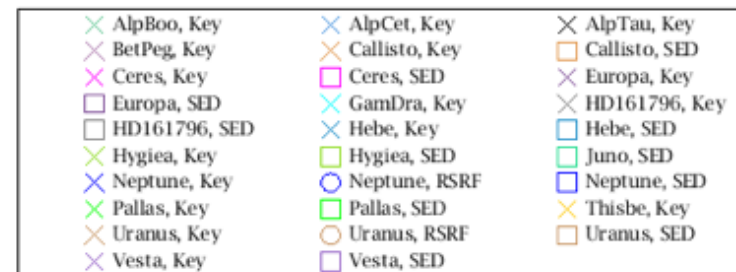
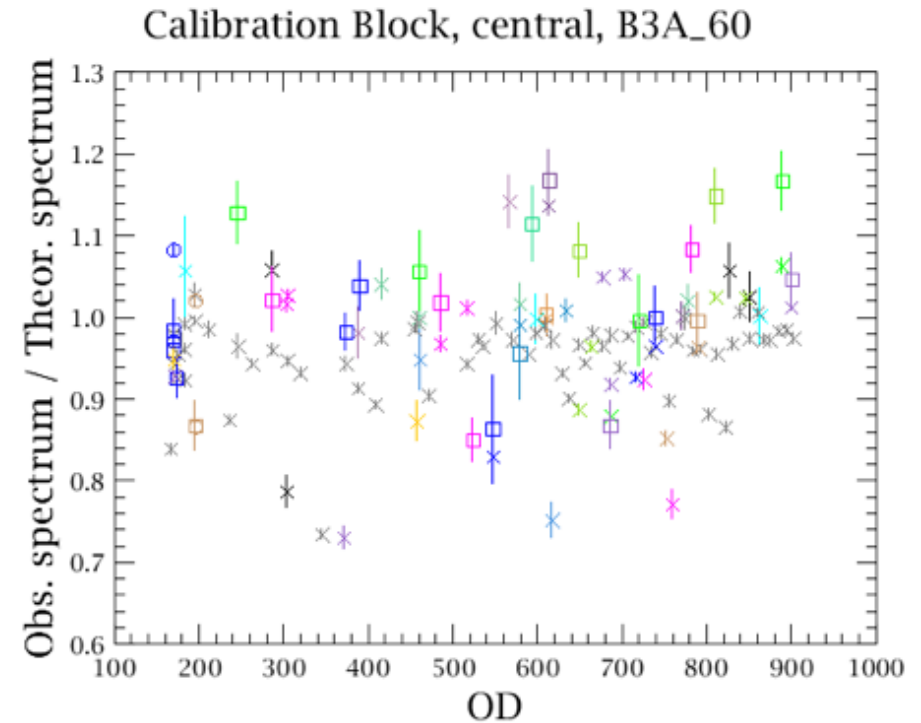
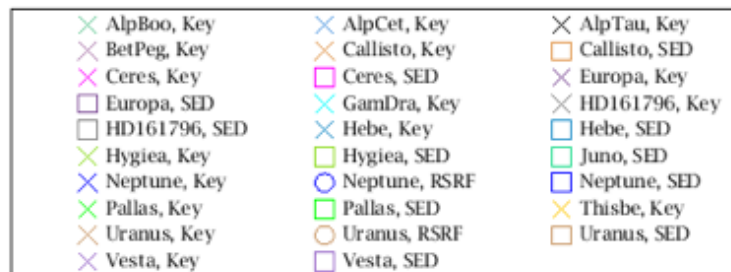
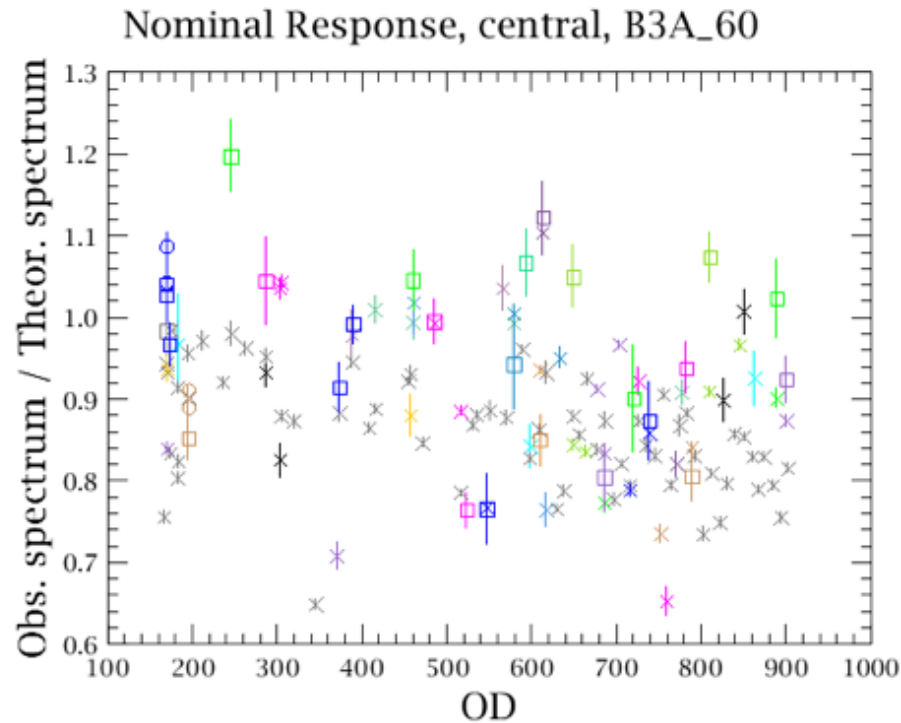


- Calfiles in standard reduction include:
 - **Spatial flat field**, OFF central spaxel better calibrated.
 - Observed response averaged over all absolute flux calibrations
 - Calsourceflux [Jy], measured from all calibration block measurements [V/s] made within all calibration observations.
- Overall improved repeatability. Especially with 3x3 integration of central spaxels.
- Overall flux calibration error now 11% RMS in B2A and B3A, 12% RMS in B2B & R1.
- Adapted interactive pipeline scripts available with HCSS 8.
- On the uplink side there are revised spectrometer sensitivities in the 51-55 micron short-blue edge of the PACS range. Originally 2.5-3.0 overestimation in the published sensitivities. Will require some few re-estimates in OT2 phase 2.



- Additional functionalities in development:
 - Wavelet-based baseline removal and continuum noise estimator script for long-range datasets.
 - **Error bars for significance tests of line detections.** This functionality is especially important for line spectroscopy and short-range detections where the continuum RMS noise is systematically changing with the depth of coverage along the observed wavelength range.
 - A prototype of **new wavelet-based adaptive flat-field method** has been made available with the aim to improve unresolved line detectability for both chopped- and unchopped datasets.
- CP raster measurements for improved pointing offsets for PACS-S.
 - All tests using PACS photometer and spectrometer showed short-term variations that lead to no relative pointing improvements. CP raster mode will not be used in operations.
 - BUT: pointing improvements achieved with the star-tracker in recent months make this less necessary (see pointing calibration later).

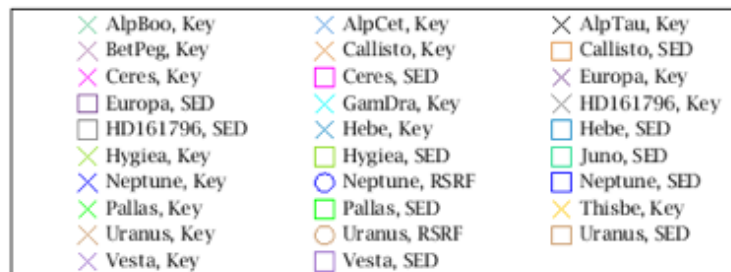
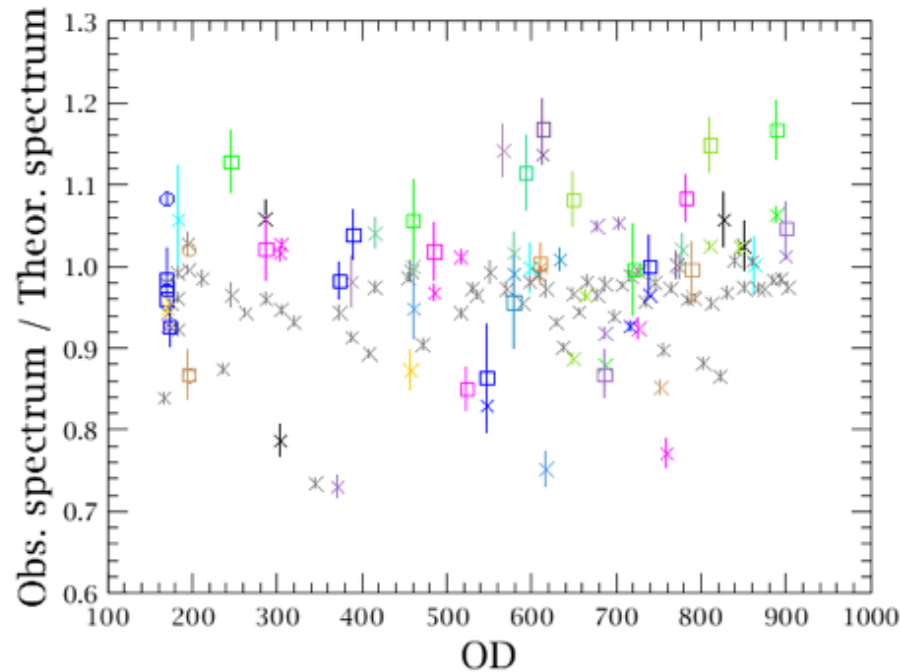
PACS–S: nominal response vs. cal-block (B3A)



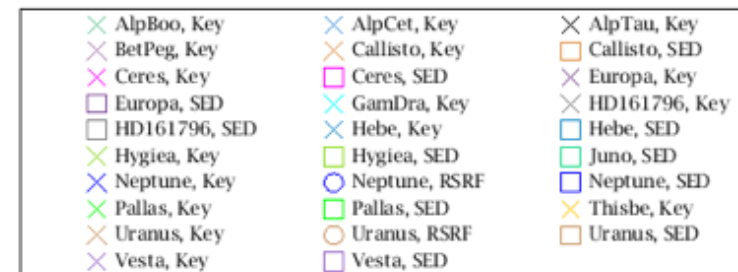
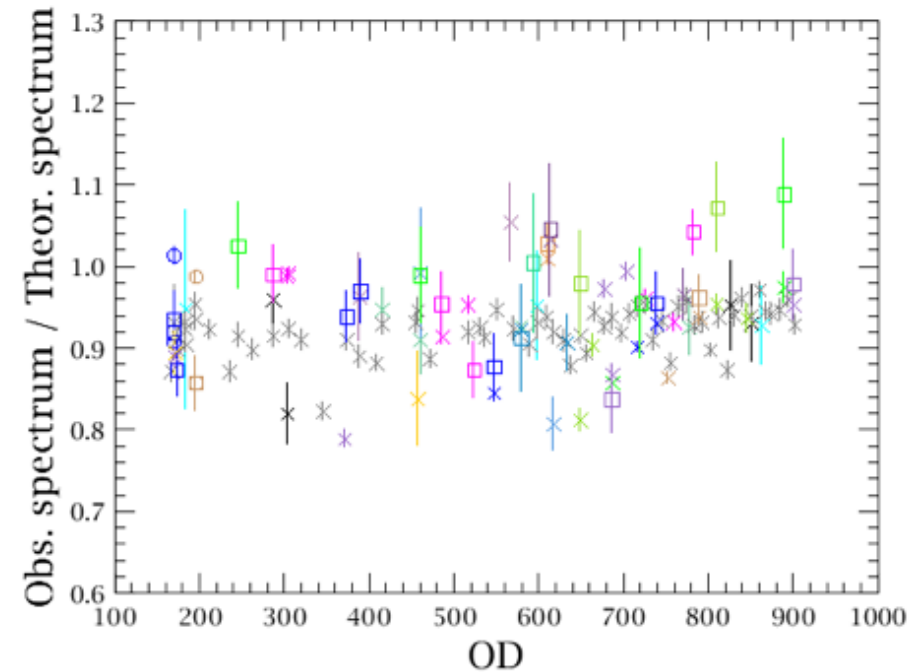
PACS–S: cal-block central vs. 3x3 (B3A)



Calibration Block, central, B3A_60



Calibration Block, 3x3, B3A_60



PACS–S: summary



Band	Sigma (central)	N	Sigma / SQRT(N)
B3A_60	0.094	74	1.1%
B2A_60	0.093	72	1.1%
B2B_75	0.118	72	1.4%
R1_120	0.128	74	1.5%
R1_150	0.119	99	1.2%
R1_180	0.133	101	1.3%

- From the flux calibrators observations, systematic error below 2%
- From the reproducibility observations, stochastic error of 5%

- Calibration uncertainty now << reproducibility error
- Abs. Flux Cal by Normalization / cal. block are nearly the same
- Calibration accuracy now ~ 20 %
- Outliers still exist when looking at central spaxel only, work on pointing correction is high priority
- 3x3 already provides much better accuracy, requires specific 3x3 vs. 5x5 Point Source Correction



Scientific

- Abs. Flux Calibration
- Spectral flatfielding
- Unchopped LineScan update
- Error dataset

Cosmetic

- Use of PacsProducts
- Unified internal structure
- Structure of hipec menu

PACS–S: pipeline improvement in 8.0



Spectral flatfield

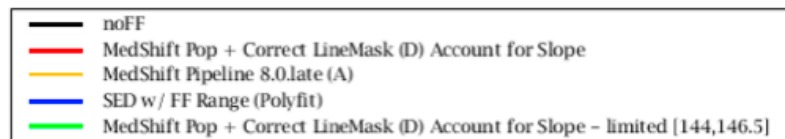
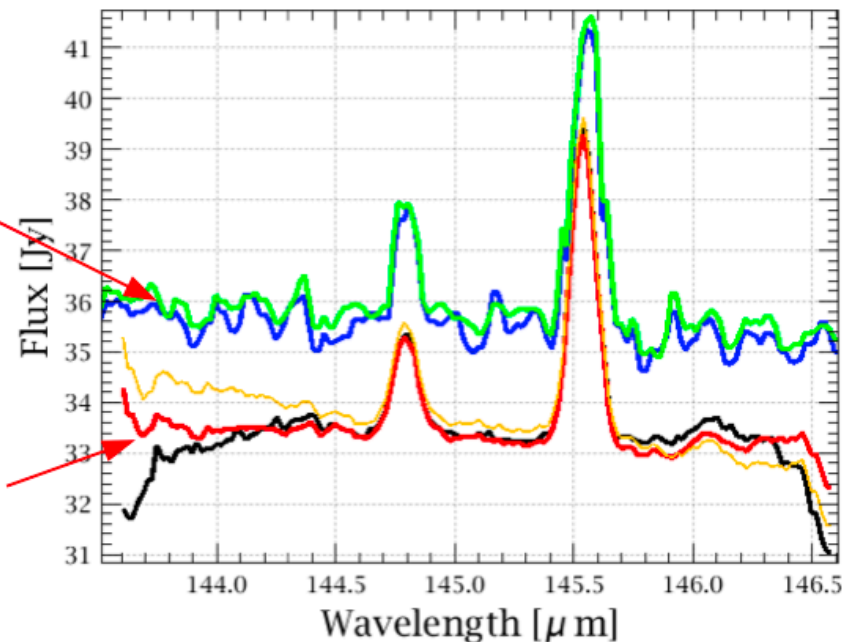
specFlatFieldLine

1342188437

FF Comparison

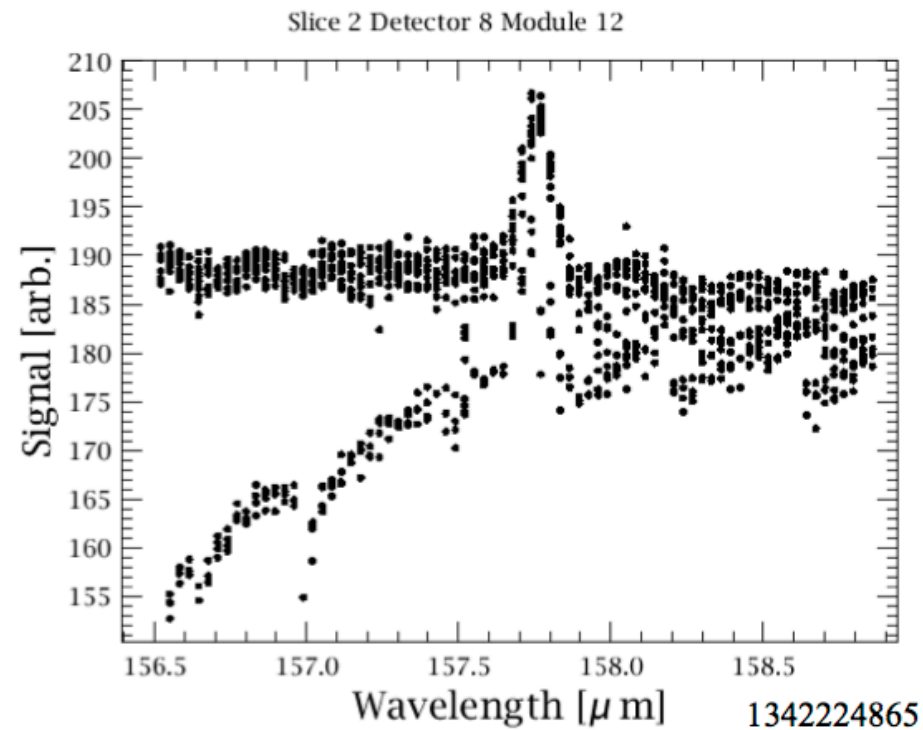
Also applicable
locally in SEDs

specFlatFieldLine



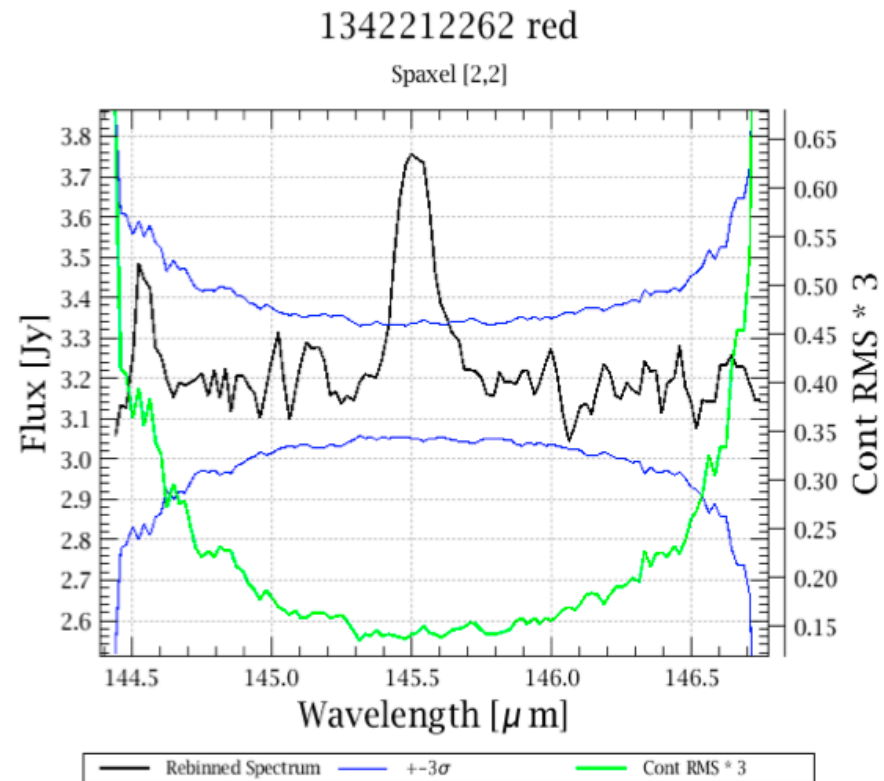
Unchopped LineScan

SpecLongTermTransient



Error propagation

plotCubesStddev – LineScan

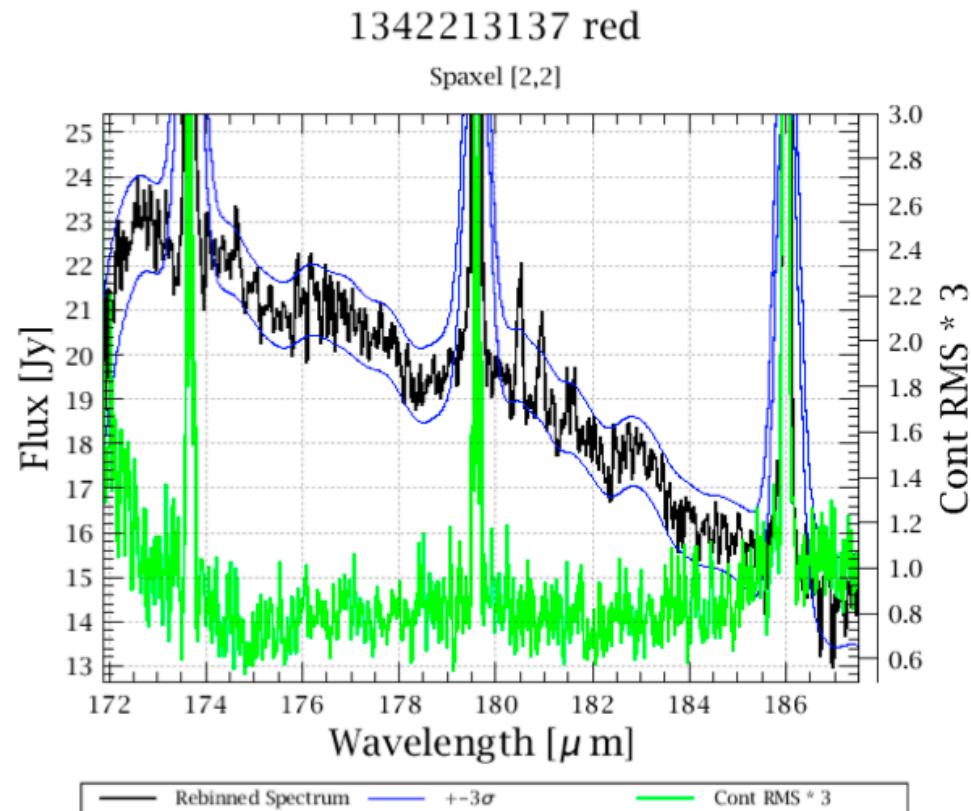


PACS–S: pipeline improvement in 8.0



plotCubesStdev – RangeScan

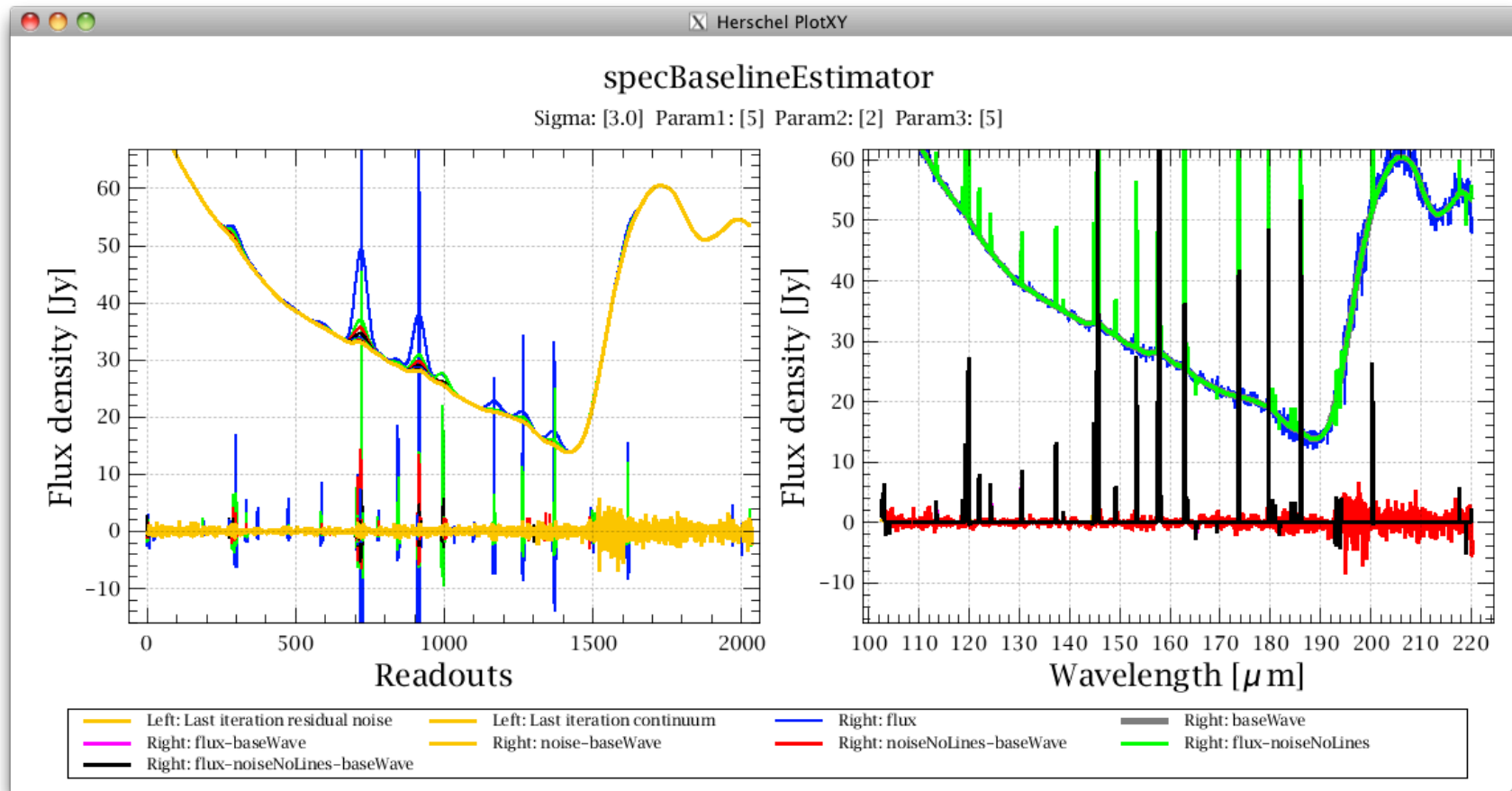
Error propagation



PACS–S: pipeline improvement in 8.0



Baseline estimator tool (wavelet engine)



Blue: rebinned data (scale invariant resolution)

Green: baseline + spectral lines

Red: noise cube

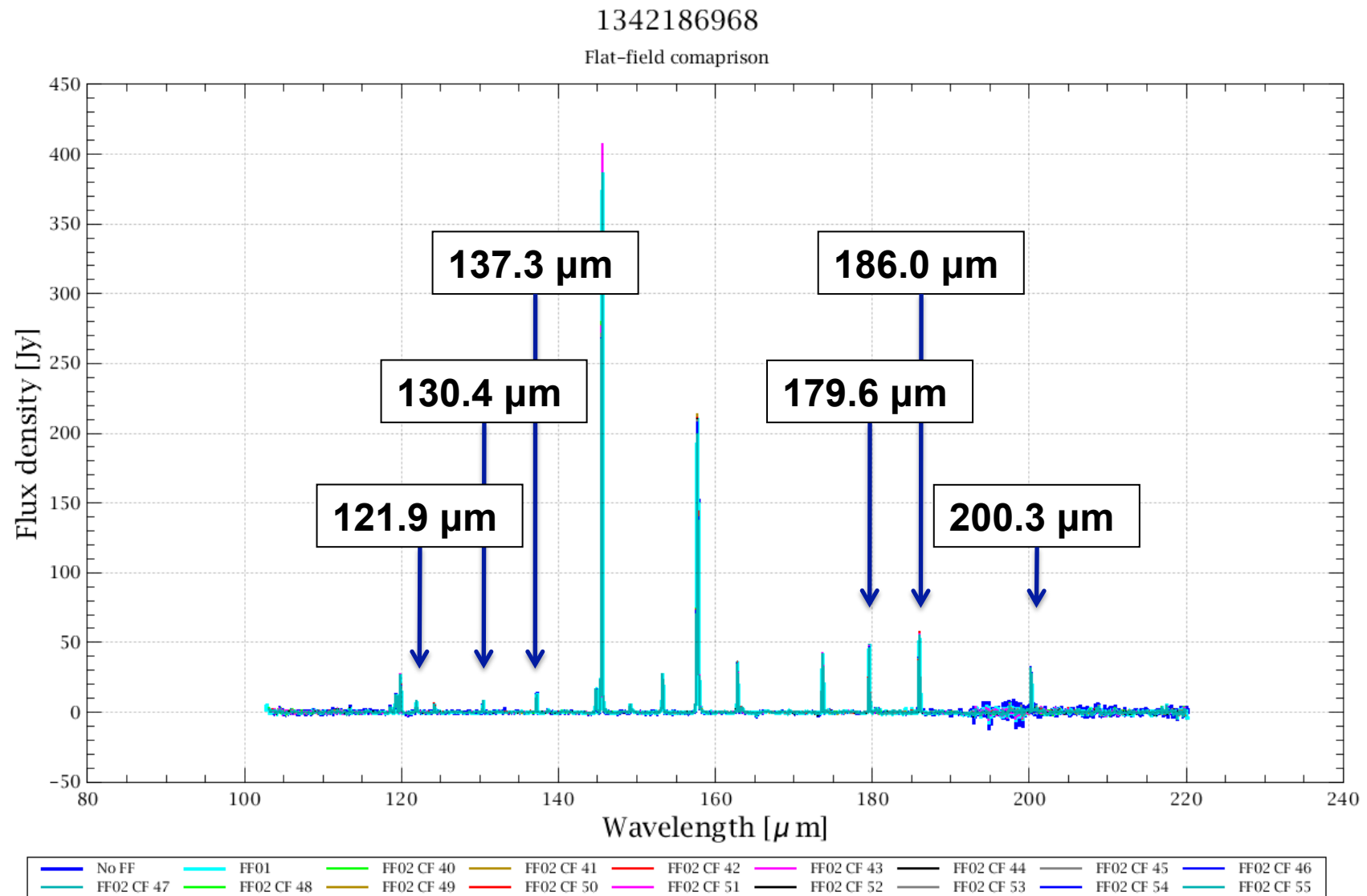
Black: outliers (lines) cube





- Pointing correction → impact on abs. Flux cal. and broad band shape
- Update spectral FF for range scan
- Drizzling: under test → prototype exists

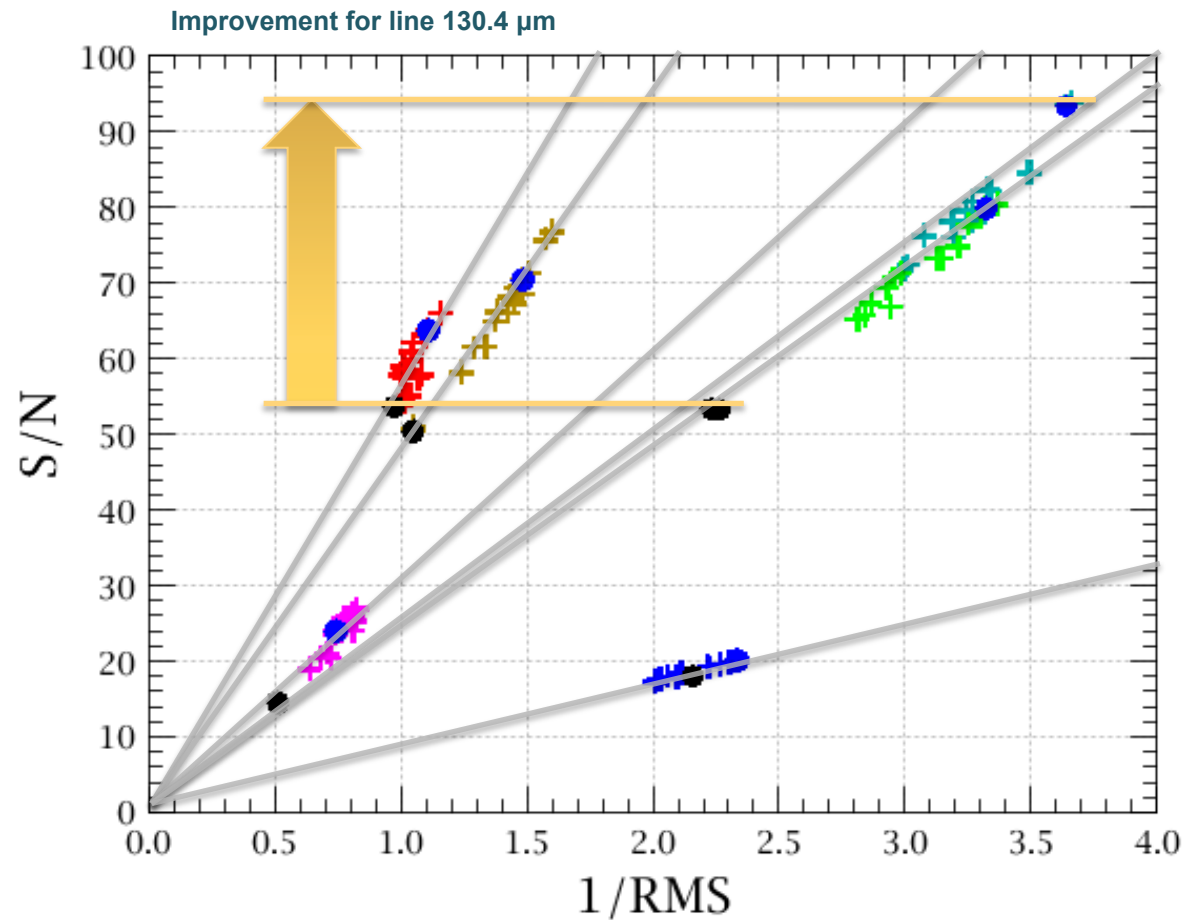
New range flat-field: lines selected for performance evaluation



PACS–S: next steps



*New range flat-field:
performance improvement*



+ Line:121.9	+ Line:130.4	+ Line:137.3
+ Line:179.6	+ Line:186.0	+ Line:200.3
● FF1 Line:121.9	● FF1 Line:130.4	● FF1 Line:137.3
● FF1 Line:179.6	● FF1 Line:186.0	● FF1 Line:200.3
● Line:121.9	● Line:130.4	● Line:137.3
● Line:179.6	● Line:186.0	● Line:200.3

- **Expected flux distribution**
- **SpecProject results**
- **Best fitting drizzling results:**
 - **(upsample=1, pixfrac=0.4, pixel size=3")**
- **Worst drizzling :**
 - **(upsample=3, pixfrac=1.0, pixel size=3")**

Drizzling

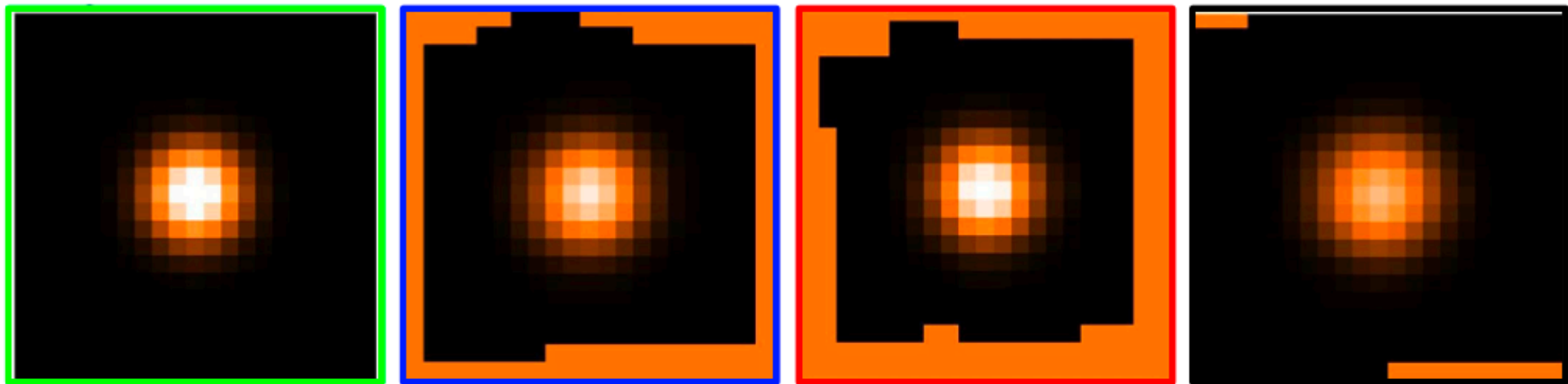


Figure 1: Drizzling results



3. SPIRE Instrument Calibration

- General Information
 - Documentation and Scripts Updates:
 - **Data Reduction Guide** further significant overhauls with HIPE v8.
 - **SPIRE Photometry Cookbook** available.
 - SPIRE FTS Users Group continues direct interactions with users (Ivan Valtchanov, HSC, chair)
 - Significant work started on cross-calibration issues (see later)
 - Several calibration papers planned for publication.



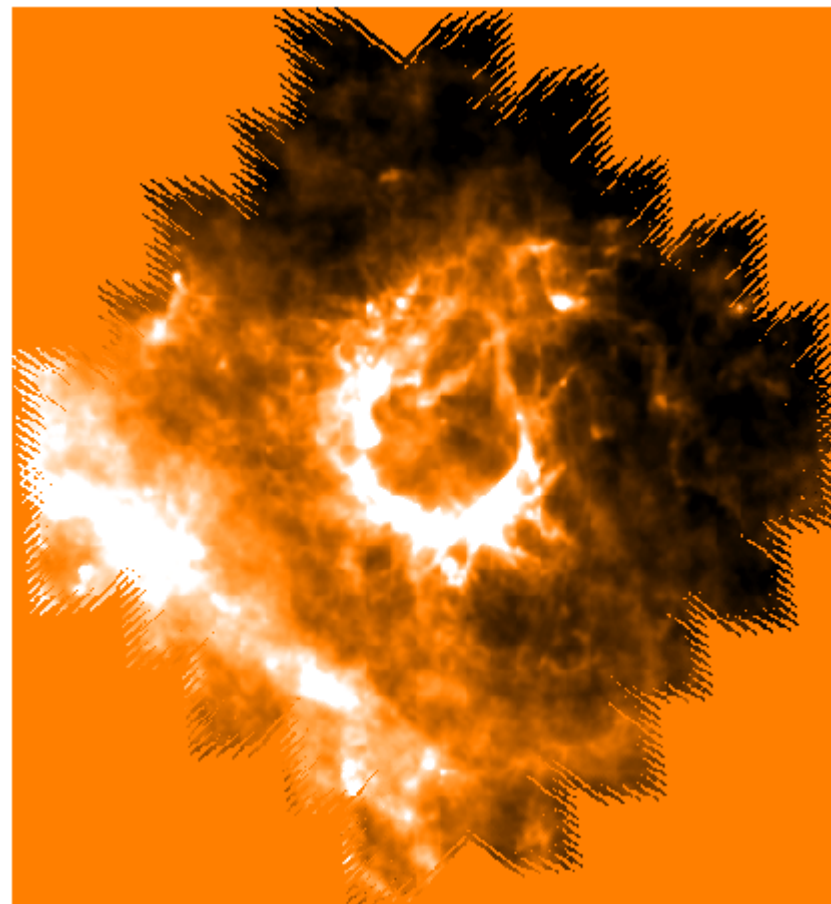
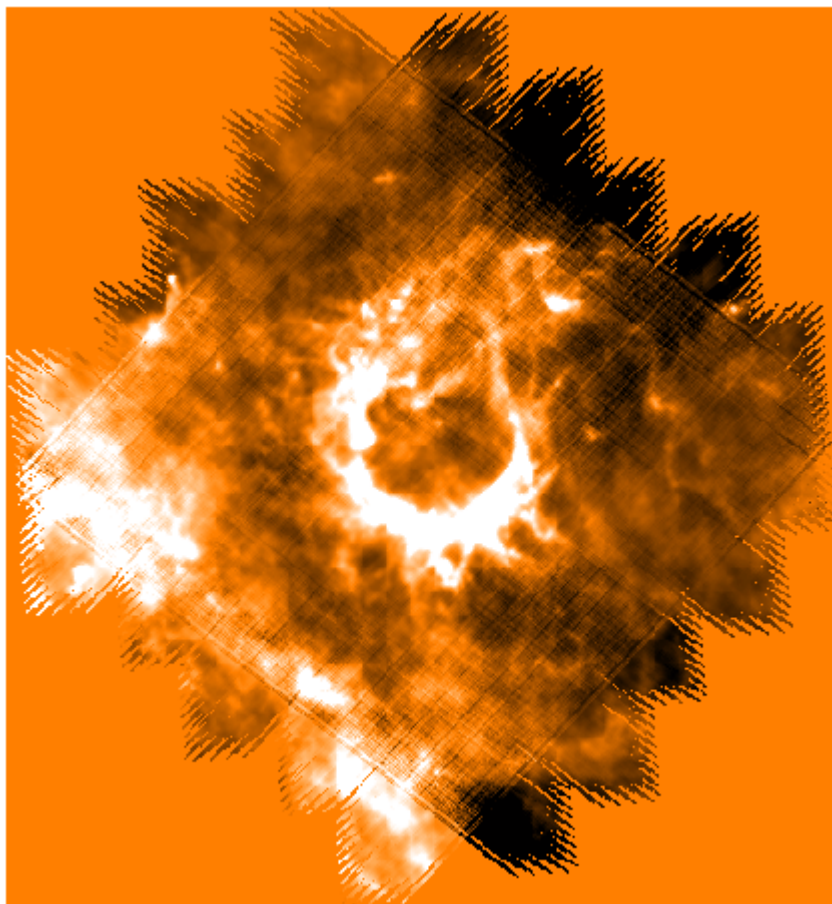
3.1 SPIRE-P updates

- **Refactored SSO Moving Objects script**, will included in Useful Scripts Menu of HIPE v8.
 - **Extended Calibration** – new scheme in place for version 8, treats beam size variation with wavelength in a formally correct manner, previously folded into RSRF
 - **Destriper**, in HIPE v8, correction of gains allowing stripes to be removed from final SPIRE maps.
 - Considered as good as using MADmap.
 - Best results on extended sources if include correction for differing beam sizes across array.
 - **Electrical Crosstalk**, first version in HIPE 8.0, Work for Version 9.0 with new version of Electrical Crosstalk with new versions of Flux Calibration and Thermistor Jump correction
-

SPIRE-P destriper improvements



Left w/o destriper, right with destriper



SPIRE Photometer Overview and Future



- Quoted **calibration accuracy is 7%** (5% model plus 2% calibration error)
- **Neptune flux currently systematically ~2-3% too low.** Still looking towards a planetary model update based on planet measurements being made at the end of 2011.
- **Photometric accuracy ~ 2%** verified by standard deviation of asteroid and star measurements.

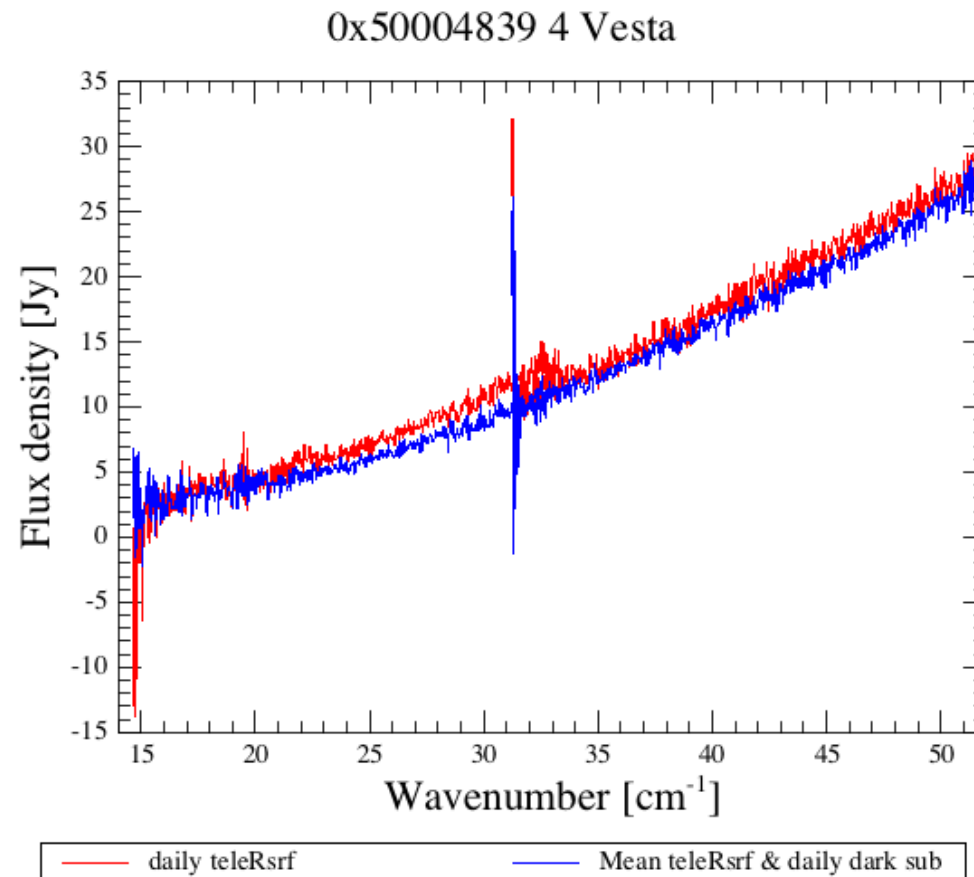
Future: need to improve knowledge of offset level for observations in extended emission of the galactic plane. Ongoing cross-calibration project with HFI/Planck to allow this to be applied. Ongoing.

3.2 SPIRE-S updates

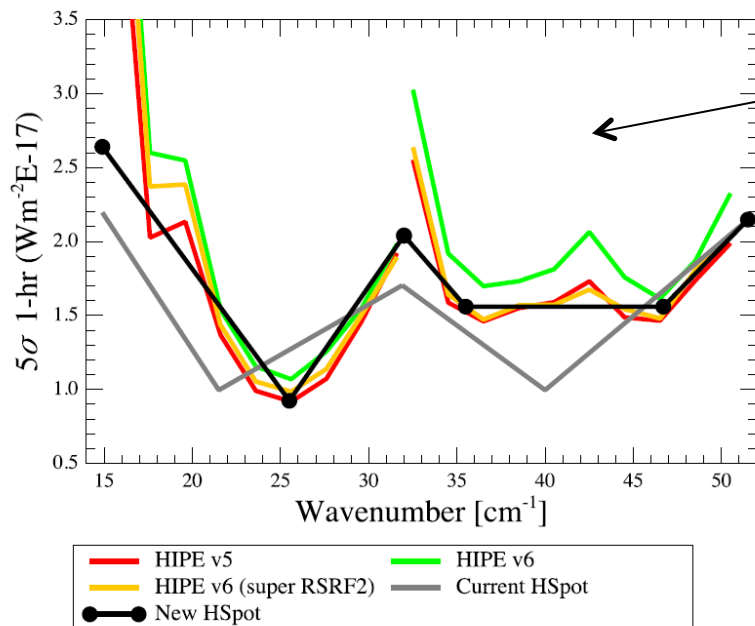


- In the process of changing the pipeline to run in temperature units
 - (advantage is that the same pipeline will run nominal and bright modes)
- Plan to use a mean telescope RSRF for v8, rather than one from a specific day (better overall across ODs, lower noise)
 - In v7 telescope RSRF based on single dark sky observation
 - In v8 it will be based on mean of all dark sky observations
- Point source calibration measured on Uranus on off-axis detectors
 - Released in updated calibration product used for HCSS/HIPE v8 pipelines.
- Cross calibration with HIFI ongoing in a major way.

SPIRE-S mean telescope RSRF improvements



Observations reduced using the daily telescope RSRF (red) compared to a reduction using the mean telescope RSRF with an additional dark sky subtraction (blue).



- Red from v5 using a mean RSRF
- Green derived from OD557, v5->v6 thinking was that a mean RSRF was not a good thing to do.
- Orange shows change for v8 where we switched back to a mean RSRF (this was tested with v6 in this plot)
- Grey/Black lines before/after HSpot change

Quoted calibration accuracy is 7%. For mapping you can add 10-15% for uncertainties in the characterization of the spectrometer array.

4. HIFI Instrument Calibration



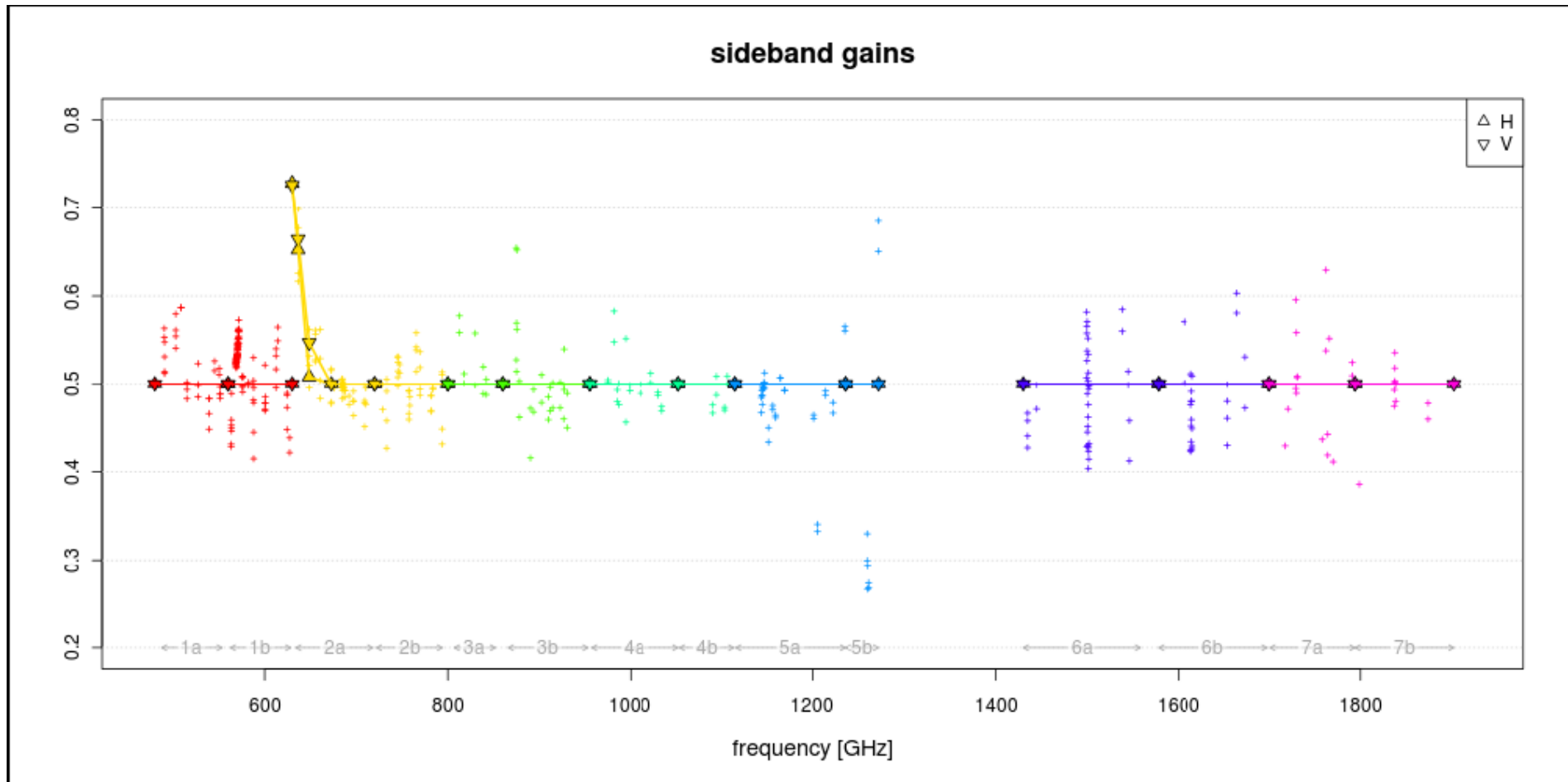
- **General:**
 - Observer's Manual updated for OT2.
 - Significant documentation updates with HIPE v8.
 - **Sideband ratio:** Currently only small part of band 2a has non-unity values and included in pipelines but very slowly adding well established sideband ratios to the HIFI calibration information used by the pipelines.
 - **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 but this is being made more available. Looking to include in next version of the HCSS/HIPE.
 - **Improved processing of band 6 and 7 spectral scan data means a reduction in the noise of approximately 40% plus improved baselines. Available in HIPE v8 and in bulk reprocessing.**



4.1 HIFI Calibration: Sideband Ratio Progress

- Earlier calibration tree had been updated for band 2
- At present focus on band 1 and 5
- Need to be aware of impure LO settings
- Correlation with T_{sys} being investigated
- Collaboration with HEXOS KP team on absorption line spectra
- Treat SBR as free parameter in deconvolution, e.g. Sgr B2, not clear this is getting any further clues.
- Band 5 has frequency dependent loss, slope in T_{sys} ; currently awaiting further analysis by mixer experts
- Dedicated observation of OH^+ in W49N planned.
- Deviations from unity may be small and masked by standing wave effects.

HIFI Pipeline: Currently Used Sideband Gains



**Symbols indicate current values used for sideband ratio in HIFI data processing.
Colored points indicate measurements from various sources.**

4.2 HIFI Calibration: Beam Pattern and Coupling

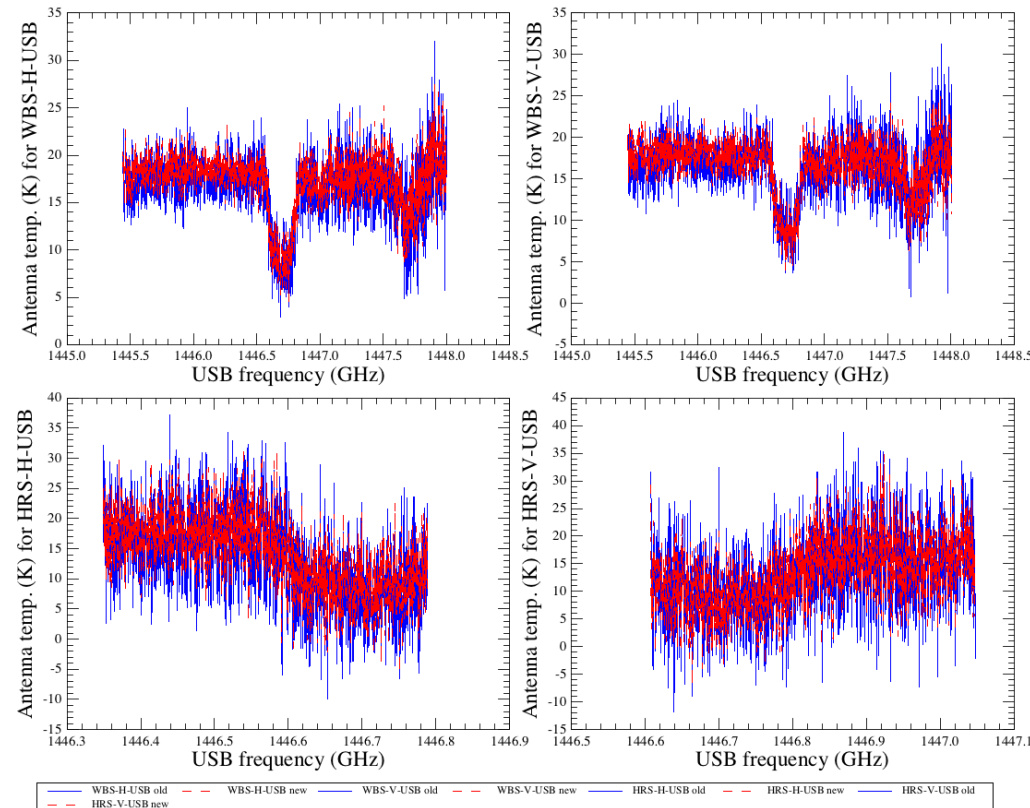


- Being redone with dedicated Mars observations in October - December 2011.
 - Also cross-calibration with Neptune/Uranus, prime calibrators for SPIRE and HIFI.
- Band 5 appears to be clearly offset in coupling values (also noted with cross-calibration effort). This is to be confirmed.

4.3 HIFI: Calibration Improvements



- Improvement in noise and baseline quality of SScans in ands 6 and 7 (pipeline fix). The picture below illustrates this at a random frequency point in a survey. Black is HIPE 6, red is HIPE 8. Also see Stephan's DP presentation.



HIFI: Calibration Improvements Cont.



- A lot of work put in the code used to automatically create cubes in the pipeline. Cubes dimensions are now more representative of the way the map was effectively taken rather than resampled.
- More user-friendly way to reprocess with a different calibration version and **alternative calibration for bright continuum sources** that significantly reduces ripples.
- Diagnostic information of the **deconvolution** outputs has been upgraded. Fast and robust under both HIPE and CLASS. Consistent with deconvolution “by hand” results from KP teams that took months (takes 10 minutes in HIPE), but more cross-comparisons being made.
- **Fringe removal/baselines**: The HifiFitFringe and FitBaseline have been improved, they are more robust and offer new features
- A number of **automatic quality checks** have been added and should help identifying better data potentially affected by e.g. saturation, spurs, or impurity.
- Calibration accuracy marginally improved due to improved pointing performance (see following slides on pointing).



5. Cross-Calibration

- New team member at HSC (Elena Puga) is now leading what had been ad hoc cross-calibration efforts. Notably for the spectrometers.
 - Previously indicated that cross-calibration between PACS and SPIRE photometers and the planetary/stellar calibrators was good to within a few per cent (being worked on and is probably associated with calibrator models assumed).
 - Initial cross-calibration report due in January to the Herschel operations coordination group.
 - 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>
 - BOTTOM LINE: We are within errors on cross-comparisons so far EXCEPT in the PACS leak region, 190-220 microns. There is a good chance that cross-calibration can really help here particularly.
-

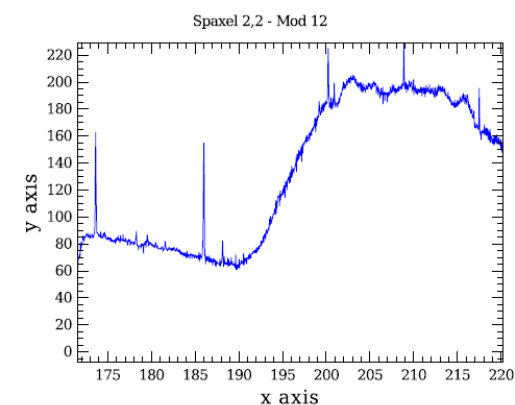
Agreed spectral cross-calibration targets and coordinates



Source	R.A. (J2000)	DEC (J2000)	Type	Comments
AFGL 2688	21h02m18.78s	+36d41m41.2s	Point Source	
CRL 618	04h42m53.64s	+36d06m53.4s	Point Source	
AFGL 4106	10h23m19.47s	-59d32m04.9s	Point Source	Faint lines
NGC 7027	21h07m01.59s	+42d14m10.2s	Extended	

- Will also use IRC+10216.
- Existing and planned HIFI spectral scans (including science observations).
- After combing archives, request for 30 hours of Herschel time for cross-calibration purposes.
- Will look at specific lines also.

Especially useful for issues such as PACS-S leak at long wavelengths (190-220 microns – see right). Clear mismatch with HIFI/SPIRE measurements (not very surprising).

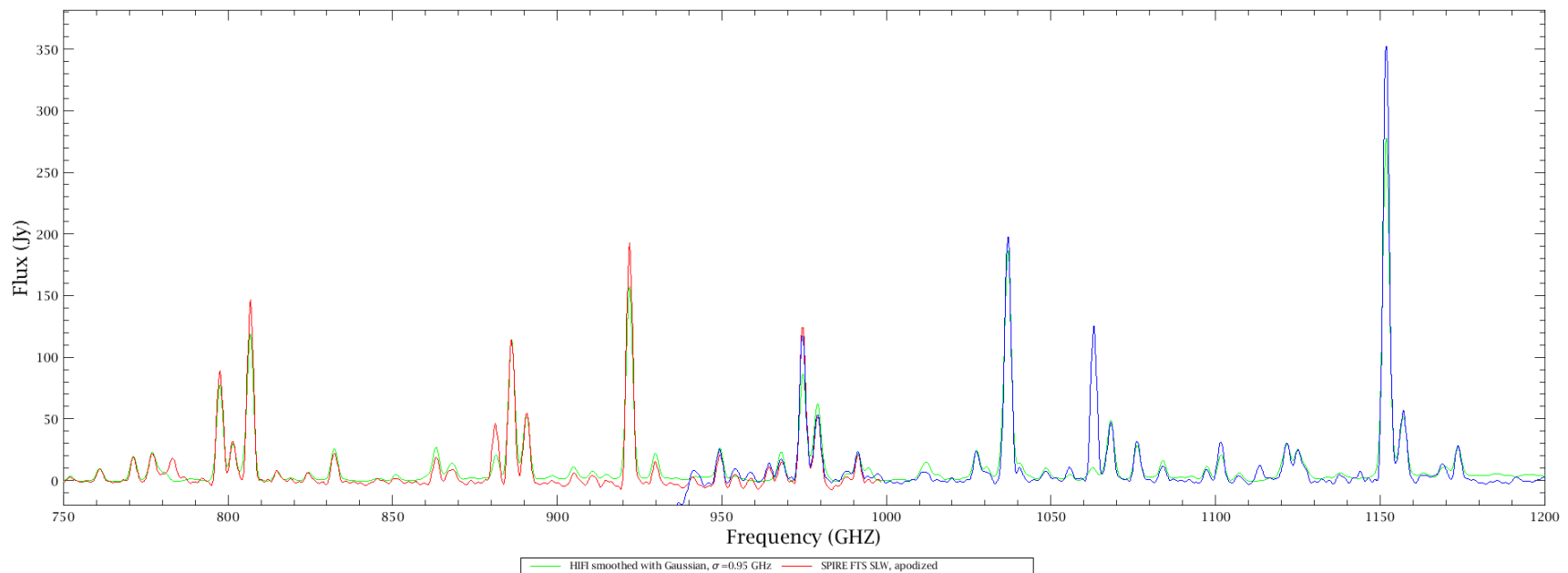


HIFI and SPIRE spectral scans



Green – HIFI deconvolution

Red and **Blue** – SPIRE short and long wavelength modules



There are differences. The source is variable, and there are some places where there was zero information in the HIFI scans (NaNs).

6. Pointing Overview

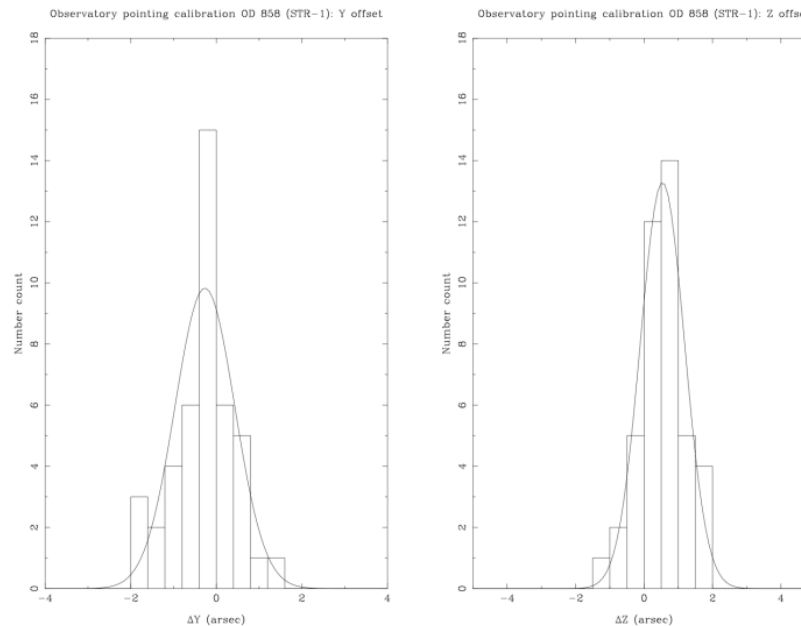


- *Speed bumps' update: no events found since reducing STR temperature.*
- *Regular updates made to on-board defective pixel table by MOC to identify bright pixels not to be used for pointing.*
- However --- after a number of reported anomalous pointings apparent in data it was realised that the STR had changed when temperature reduced.
 - Unexpected, assured by industry this should not happen
 - 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.
 - Effective focal length changed on-board. Later pointing measurements indicated pointing of order 1."34.
 - Further updates investigated by FDS at MOC and PACS ICC indicated that further 2D improvement for STR (removal of a "tilt") could improve further. This was put on board the spacecraft in late September.

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.
- Currently measured at $\sim 1."$





Pointing Improvements for Past Observations

- Working on two tools.
 - Speedbump removal from observations in early phase of the mission.
 - 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).
- Further investigations.
 - Further dimensional improvements. Distortion maps have been produced for the four eras of pointing that we have by the PACS ICC. Looking to see if these are consistent. If so, we should be able to add in this distortion correction too.
 - Looking into different filtering schemes to improve the pointing information that is then applied in the pipelines. Again – this would be applied after the fact.
 - Investigations involve PACS ICC, MOC (FDS team), and the HSC.



7. 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 simply difficult problems (e.g. sideband ratios, correct error files for extended emission).*
 - Improvements to tasks based on calibration work now appearing more in HIPE.
 - Spectrometers showing clear calibration improvements and now of order 10% rather than 20%.
 - Cross-calibration work is starting in a major way. But earliest checks indicate only the PACS leak region is clearly out with respect to the other instruments (which is not surprising as the PACS ICC considers this region uncalibrated).
 - Pointing has improved significantly and improvements should be able to be incorporated into all observations made by Herschel
-