PACS photometer - Prime and Parallel scan mode release note

version 1.1

The PACS ICC

1 Point spread function

The photometer PSF (see Figure 1) is characterised by:

- A narrow core which is round in the blue bands but slightly elongated in spacecraft Z direction in red.
- A tri-lobe pattern seen at the several % level in all bands, most clearly in the blue with its strongest signal, and ascribed to imperfect mirror shape.
- Knotty structure at sub-percent level, clearly seen in blue and indicated in green.

For fast scans in normal and parallel mode, this PSF structure is smeared by detector time constants and data averaging. Quantitative information on the PSF is given in Table 1.

Table 1: Results of fitting 2-dimensional gaussians to the PSF. Note these are fits to the full PSF including the lobes/wings. Position angles (east of North) are listed only for beams with clearly elongated core. The scan angle was 63° for these observations.

Band	Speed arcsec/sec	FWHM arcsec	PA deg
Blue	10	5.26×5.61	
Blue	20	5.46×5.76	
Blue	60	5.75×9.00	62.0
Blue	60/para	5.86×12.16	63.0
Green	10	6.57×6.81	
Green	20	6.69×6.89	
Green	60	6.89×9.74	62.3
Green	60/para	6.98×12.70	63.0
Red	10	10.46×12.06	7.6
Red	20	10.65×12.13	9.3
Red	60	11.31×13.32	40.9
Red	60/para	11.64×15.65	53.4

These PSFs and derived quantities reflect the intrinsic optical quality of Herschel+PACS. In a scanmap reduction they will be smeared, in particular at short wavelengths, according to telescope pointing jitter and drifts.

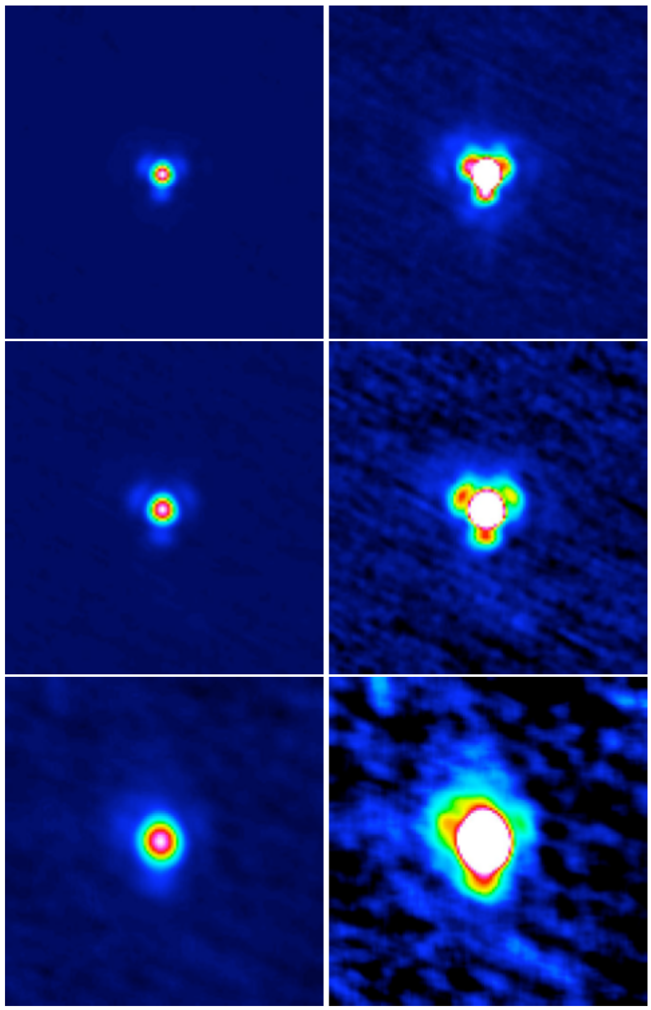

Figure 1: The photometer PSF in blue, green and red (top to bottom) derived from scans performed at 10 ″/s. Left-hand panels display the image with a linear scale up to the peak, while right-hand panels show up to 10% of the peak.

2 Flux calibration

The flux calibration factors currently in place in the PACS photometer pipeline are still those defined in the ground-based calibration campaign. It should be noted that flux calibration of PACS photometer data is a three-stage process: the data have to be flat-fielded, engineering units are converted to Jy/pixel (the responsivity correction), and pixel gains are corrected with respect to a reference consistent with both the flat-field and the responsivity calibration products (to account for small gain drifts with time).

We estimate that this ground-based flux calibration scheme leads to a factor of 2 uncertainty on the measured fluxes. This large uncertainty will be significantly decreased when in-flight calibration data replace the ground-based ones, which should happen toward the end of the Science Demonstration Phase (SDP).

3 Sensitivity estimate

The currently achieved sensitivity is heavily dependent on the photometer band, scan strategy and data processing. We observe performances that range from slightly better than the HSpot prediction up to a factor 1.5 worse than the HSpot prediction. This is not due to increased noise in the instrument. The most likely causes of this are: (1) a too simple approach in the sensitivity estimate in the presence of strong $1/\sqrt{f}$ noise, (2) a possible decrease of the response (whose origin is still under investigation), (3) the actual optical coupling of the instrument to the sky, (4) combination of the three latter causes.

The noise spectrum is such that higher sensitivities are reached for faster scan speed and thus the ICC recommends using scan speeds of $20''$/s at least when sensitivity is an issue.

The PACS ICC also recommends using cross-scans systematically as a method to reduce the $1/\sqrt{f}$ noise artefacts in the reconstructed maps.

4 Pointing

Deviations of the actual telescope pointing from the scan trajectory that is reported in the pointing product cause a smearing of the PACS PSF in the reconstructed scanmap, in particular in the blue/green bands. Quantification of this effect under different conditions is ongoing.

5 Calibration blocks

Interspersed within the observational day, calibration blocks are executed. These allow to follow the evolution of the bolometers' gains during the day. There is one such block at the beginning of each PACS photometer AOR. We are working to implement a logic such that the maximum time in between blocks would be 4 hr but this is not yet in place. The ICC recommends not scheduling scanning observations longer than 4 hr until this mechanism is in place.

In the case of the parallel mode, we are following SPIRE's calibration frequency and perform one calibration block each time SPIRE is performing one. The calibration period is currently 1 hr, but it will be increased to 4 hr.

6 Digitization

Because of datarate issues, we have had to add a supplementary compression stage called bit-rounding before the data is downlinked. This means that while we average 4 images on board (8 in the parallel mode case), we also round the last n bits of the result. The default value for n is 2, and this means that high-gain observations performed with bit-rounding of 2 are effectively digitized with a step of $2\,10^{-5}$ V, or 4 ADU. The PACS ICC is currently experimenting with dispensing with this compression step in some observing modes, e.g. using bit rounding of 1, or even 0. Finalisation of the bit-rounding mode will occur during the Science Demonstration Phase.

Note that parallel mode observations have to fit in an even smaller bandpass, and thus we do not foresee relaxing the bit-rounding of 2 in this mode.

7 Pipeline status

The pipeline data-processing steps (apart from the obvious ones such as unit conversion and astrometry addition) are:

- Cosmic rays removal
- Cross-talk correction
- Responsivity and flat-field correction
- Gain drift correction
- Offset drift correction
- Map reconstruction

Cosmic rays removal is performed with a multi-resolution approach. In the case of bright point sources this can create problems (masking of the source's core). Future version of the data processing system will include second-order deglitching at the map reconstruction stage. Cross-talk correction (affecting mostly one column on both red matrices) is not implemented yet as we are deriving the calibration file needed for the pipeline module. Responsivity, flat-field, gain drift corrections use ground-based version of the calibration product and will be updated in the course of the SDP. Offset drift correction is performed by applying a simple high-pass filter on the data. This is adequate for point source fields, but not for structured field and may result in dark halo artefacts. Increasing the filter window so that it covers a scan leg length already improves the map in the case of structured objects. Map reconstruction is a simple projection of the data cube.

An alternate map reconstruction algorithm, MadMap, is available but still relies on a description of the noise properties that need to be updated.

8 Level 2 pipeline products for scan maps generated with HCSS 1.2

There are 3 types of products in the level 2 produced by the pipeline for the PACS photometer in scan map mode.

These maps are produced by automatic pipeline scripts and shall only be considered as a preview, and not for science directly.

Warning : if a repetition factor has been used, there will be one map produced for each scan. No combined map for the AOR is generated with HCSS 1.2 . Extended Data Processing is to be used for this purpose. In later HCSS versions a combined map shall be produced.

8.1 HPPPMAP

HPPPMAPB & HPPPMAPR stands for "Herschel Pacs Photometer PhotProject MAP Blue/Red"

This refers to maps produced by the photProject task, i.e. a simple projection of each frames (10Hz), after running a temporal high-pass filter with a width of n=20 (i.e subtracting a median with a width of 2*n+1 frames.) This allows to filter a significant part of the 1/f noise at the expense of removing completely ALL spatial scales larger than this width (i.e. typically larger than 1 arcmin), and creating negative undershooting around bright sources along the scan direction.

To preserve extended emission, the pipeline script shall be re-run with higher width in the high pass filtering and masking bright source when necessary or an alternative map-making algorithm/tool.

This processing is mostly targeted to detect point-sources with good sensitivity.

Scan maps are in Jy/pixel but the flux scale is off: too low. The band-dependent factor are estimated to be close to 1.5

8.2 HPPMMAP

HPPMMAPB & HPPMMAPR stands for "Herschel Pacs Photometer Mad Map Blue/Red"

This is the java implementation of MADmap. MADmap uses a maximum-likelihood technique to build a map from an input Time Order Data (TOD) set by solving a system of linear equations. It is used to remove low-frequency drift ("1/f") noise from bolometer data while preserving the sky signal on all spatial scales. However this algorithm is not tuned to the best yet for in-flight data, mostly because the InvNtt calibration file (inverse time-time noise covariance matrix) calibration file is still based on ground tests. Hence MADmap is not yet operational in HCSS, but some recent test are very promising for the future.

8.3 HPPNMAP

HPPNMAPB & HPPNMAPR stands for for "Herschel Pacs Photometer Naive Map Blue/Red"

Averaged signal map after pixel-to-pixel offset correction. This image is used by MADmap as its first value for the sky map and is subsequently improved and optimized iteratively as described above, hence the full optimized matrix inversion has not been performed on the data.