PACS Photometer - Point/Compact Source Observations: Mini Scan-Maps & Chop-Nod

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We recommend to use the mini scan-map technique in all science cases related to point-sources, compact sources and also in cases of faint extended emission around point-sources.

The point-source chop-nod mode is still available and perfectly calibrated, but less sensitive for the same AOR execution time. The originally offered "Small-source chopped-nodded 2×2 raster mode" and the "Large-source chopped raster mode" are not available anymore.

In this document we give implementation and performance details for the mini scan-map technique and the chop-nod technique. We also discuss advantages and caveats for both modes.

Contents

1 PACS scan map mode for point-sources (mini scan-maps)

Although originally not designed for point-source observations, we recommend the scan-map technique now in all cases. Despite the large overheads for the satellite turnarounds between the short scans, this option has a better performance with respect to point-source S/N within the same AOR execution times.

1.1 Scan map mode implementation for point-sources

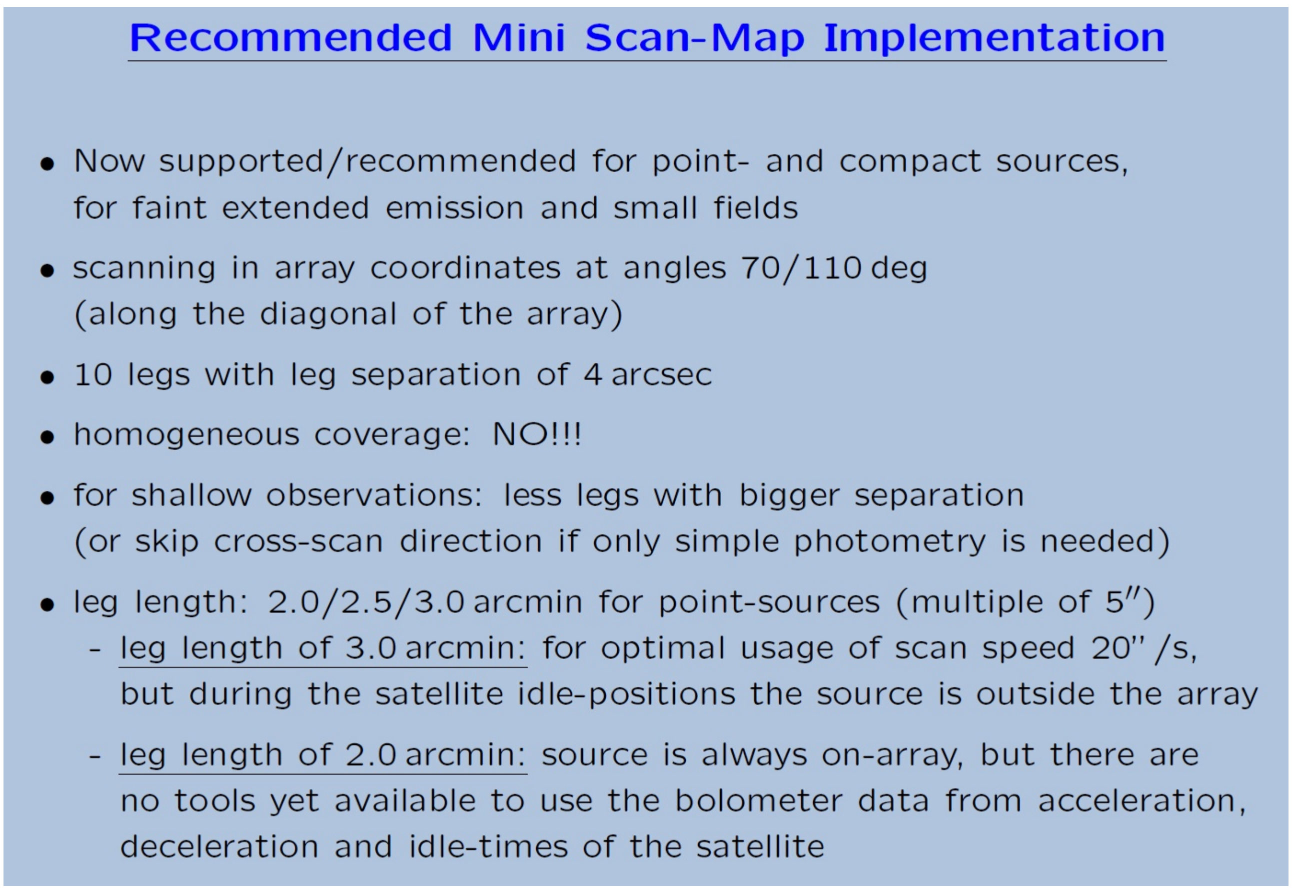

Figure 1: Summary of the recommendations for mini scan-map implementation for point-sources.

For the implementation of the scan map mode for point-sources and very small fields we propose the following configuration:

- medium scan speed ($20''/s$)
- scan angle in array coordinates along the array diagonal: 110° or 70° (in case of cross-scans: 110° and 70°)

- scan lengths: 2.0, 2.5, 3.0, 3.5 or 4.0′ (the array diagonal has about 4.0′), the scan leg lengths should be a multiple of 5″
- small and even number of scans: 4, 6, 8, 10, ... (for minimisation of satellite movements and a match to the array diagonal)
- small leg separation: 2...5″ with the smaller separation for a larger number of scan legs and vice versa (to have the source on-array in all legs). Examples: 8 scan legs of 3′ lengths and 4″ separation. This map would then match a sky region with the width of about 3×FWHM$_{red}$ with very high coverage.
- repetition factor: as needed to reach the required sensitivity
- cross-scan maps allow to apply all kinds of map-making techniques (MadMap, scanamorphous, ...) and not just the high-pass filtering. Cross-scan AORs are also recommended for higher quality photometry and better spatial characterisation in the near source vicinity (faint extended emission). It is recommended to group/concatenate the 2 (or more) cross-scan AORs to minimise slew overheads. Each AOR will have its own 30 s calibration block, followed by a 5 s wait-time (see Sect. 5).
- for higher redundancy and a better focus on very faint extended emission it might be useful to implement more than 2 scan directions; another option would be to concatenate several AORs, each with a slightly different target position.
- Note that the option "homogeneous coverage" has to be set to "NO"!

Note: Part of the satellite turnarounds are still containing useful information: For the 20″/s scan speed it is possible to use, in addition to the scan legs, about 0.8 s (i.e., 16″) prior to each scan leg and about 1.5 s (i.e., 30″) after the official scan leg has finished. During these times the scan speed is already/still very close to the requested value.

Figure 1 summarises the recommendations for mini scan-map implementation for point-sources. Figure 2 shows the simulated movement of the source for the recommended 10-leg mini scan-map on the array and the corresponding coverage map as produced by HSpot.

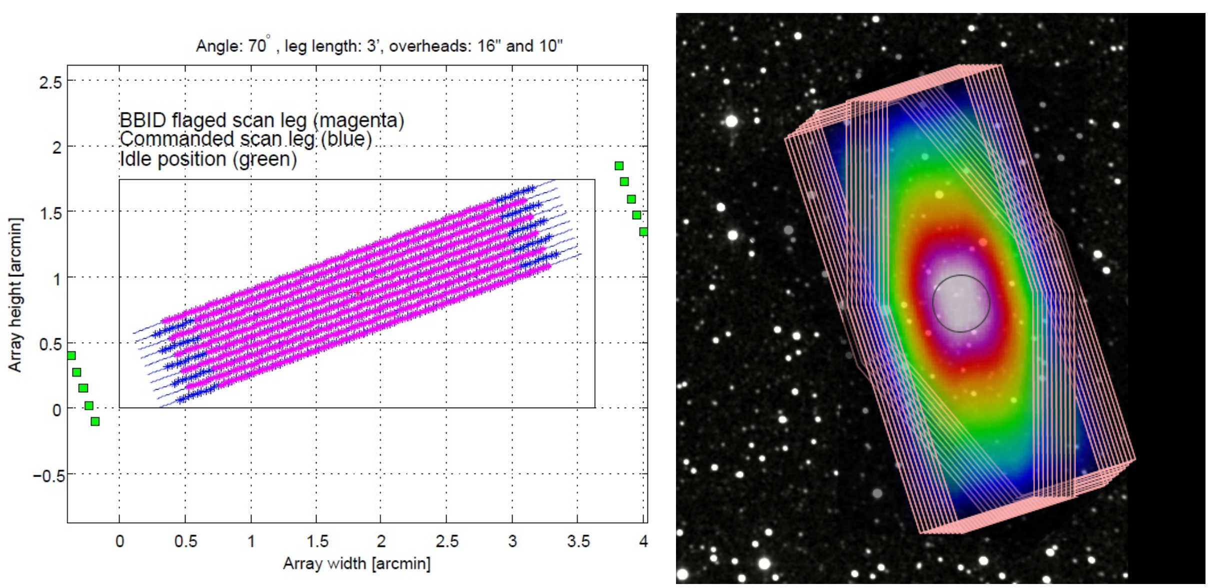

Figure 2: Left: simulated source movement on-array for 3.0 arcmin scan leg length, including the useful leg extensions which are still at constant speed (and idle-positions). Right: Coverage map for 2 mini scan-maps at array angles of 70 and 110 deg. The homogeneous, high-coverage area (circle) is about 50″ in diameter.

1.2 Performance

- homogeneous high coverage area of ∼50 arcsec diameter (10 scan legs, 4″ leg separation)

- on-source leg times (useful times at ∼20″/s speed):
  2.0 arcmin: (6.0 -1.0)+0.8+1.5 s = 7.3 s
  2.5 arcmin: (7.5 -1.0)+0.8+1.5 s = 8.8 s
  3.0 arcmin: (9.0 -1.0)+0.8+1.5 s = 10.3 s
  Note, that due to commanding time-constraints the BBID-labeled scan legs are about 1 s shorter than the HSPOT-specified leg lengths. Example: a scan-leg with a HSPOT-specified length of 3.0 arcmin will contain BBID-labeled data for 3 arcmin/(20″/s) - 1 s= 8 s. In addition to the labeled data there might be a few frames more where the satellite speed is still close to 20″/s speed, typically 0.8 s on one side and 1.5 s on the other side.

- On-source time, AOR execution time, efficiency (2 AORs, 2-band photometry):

	2.5 arcmin			3.0 arcmin		
	OST	concat. AORs	Eff.	OST	concat. AORs	Eff.
1 rep	176 s	446+ 325 s	0.23	206 s	456+ 335 s	0.26
2 rep	352 s	718+ 597 s	0.27	412 s	738+ 617 s	0.30
3 rep	528 s	990+ 869 s	0.28	618 s	1020+ 899 s	0.32
5 rep	880 s	1534+1413 s	0.30	1030 s	1584+1463 s	0.34
6 rep	1056 s	1806+1685 s	0.30	1236 s	1866+1745 s	0.34

- Instrumental central area point-source 1-σ rms-noise (blue/green/red): 30.6/36.0/68.5 mJy / $\sqrt{t_{total}}$ (values have been confirmed by GT KPs)

	2.5 arcmin	3.0 arcmin
1 rep	2.5/2.9/5.6 mJy	2.3/2.7/5.1 mJy
2 rep	1.8/2.1/4.0 mJy	1.6/1.9/3.6 mJy
3 rep	1.4/1.7/3.2 mJy	1.3/1.6/3.0 mJy
5 rep	1.1/1.3/2.5 mJy	1.0/1.2/2.3 mJy
6 rep	1.0/1.2/2.3 mJy	0.9/1.1/2.1 mJy

  Note, that the 3.0 arcmin leg length is in general more sensitive, but the source is outside the bolometer array during the satellite turnarounds. For the 2.0/2.5 arcmin leg length the souce is on-array all the time. Depending on the science case this might be an advantage.

- 1-σ confusion noise levels for PACS point-sources
  in blue/green/red: ≥ 0.01 mJy, ≥ 0.3 mJy & ≥ 0.9 mJy (based on clean regions from GT KPs)

- derived/measured 5-σ/1 h noise for PACS (3.0 arcmin legs, 10 legs, 4 arcsec separation, 6 repetitions, 70/100° cross-scan maps):

	instrumental 1-σ-noise	bgr. conf. 1-σ-noise		total 5-σ noise	Note
blue	0.93 mJy	≥ 0.01 mJy	×5	**≥4.7 mJy**	instr. limited
green	1.10 mJy	≥ 0.3 mJy	×5	**≥5.7 mJy**	instr./confN limited
red	2.08 mJy	≥ 0.9 mJy	×5	**≥11.4 mJy**	confN limited

- The above presented noise values are in agreement with the values from the current HSpot (5.1.1) when using the "Central area point-source 1-σ values"

- small aperture are sometimes problematic (slightly deformed PSFs) 10-15″ in blue/green and 20″ in red work nicely
- sky should be taken at least 30-35″ distance from source (in blue/green) and 40-50″ distance from source in red

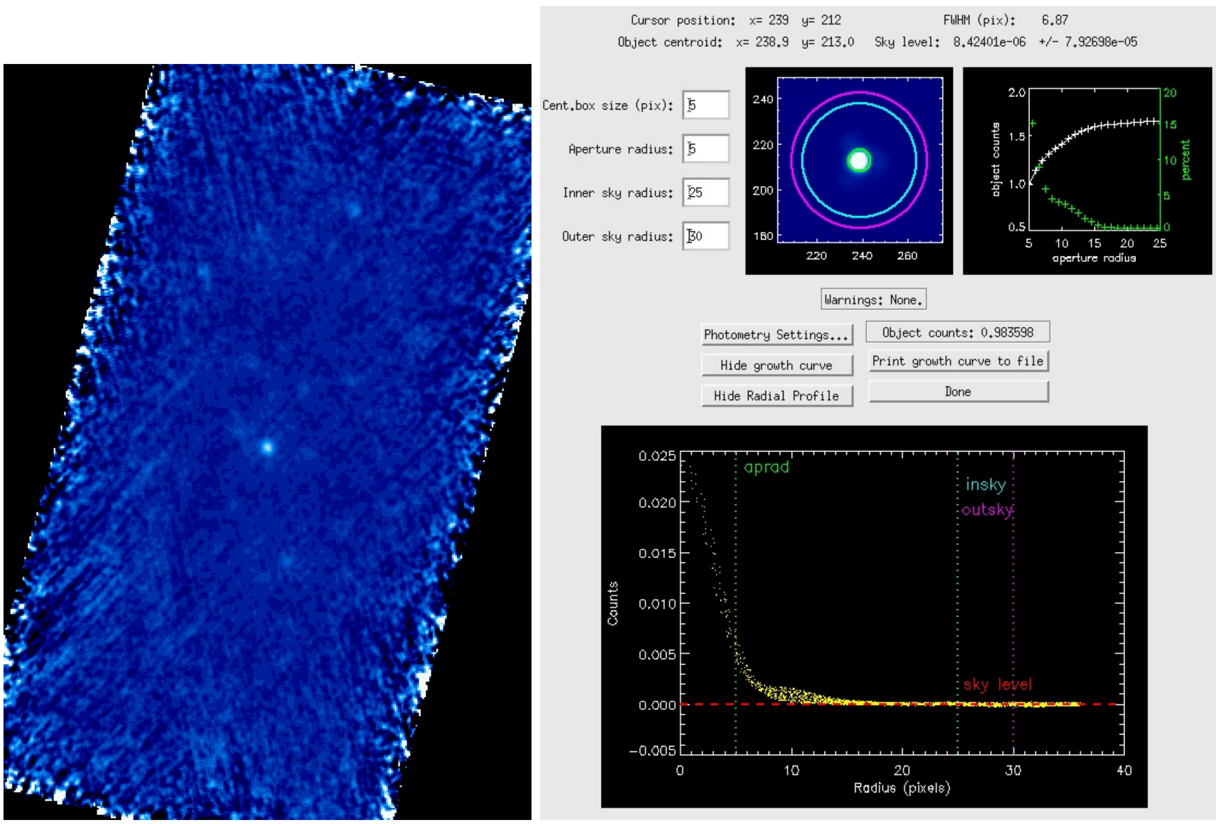

Figure 3: Left: combined cross-scan mini-maps for HD 159330 (∼30 mJy at 100 μm.) Right: Growth curve and radial profile for a combined cross-scan mini-map on γ Dra.

1.3 Advantages of scan maps for point-sources

The advantages for the scan map mode are:

- it provides a better characterisation of the close vicinity of the target and larger scale structures in the background
- also targets with positional uncertainties of 10″ or more are still perfectly covered
- the final map has a much larger area of homogeneous coverage (about 50″ in diameter) depending on observation configuration, see Fig. 2)
- more pixels see the target, the impact of noisy, variable and dead pixels is less problematic
- better point-source sensitivity in all bands as a high-pass filter can be used to remove 1/f noise up to higher frequencies.
- no negative beam in final map (as compared to the chop-nod technique in section 2).

1.4 Caveats of scan maps for point-sources

The small array size requires the implementation of short scan legs of 2 to 4′ only. Combined with the optimum scan speed of $20''/s$ this leads to short on-scan times of about 10 s. The corresponding satellite turnarounds between these scan legs take currently almost 20 s. The ratio between useful on-array time and satellite manoeuvre times is therefore very low.

The PSF-shape in the 20″/s scan speed has also one component related to the scan-angle and might not perfectly match the standard PSF-products obtained as part of the calibration programme (see Sect. 6.1).

2 Point-source chopped-nodded observations

The PACS photometer point-source mode uses the PACS chopper to move the source by about 50″, corresponding to the size of about 1 blue/green bolometer matrix or the size of about half a red matrix, with a chopper frequency of 1.25 Hz. The nodding is performed by a satellite movement of the same amplitude but perpendicular to the chopping direction. On each nod-position the chopper executes 3×25 chopper cycles. The 3 sets of chopper patterns are either on the same array positions (no dithering) or on 3 different array positions (dither option). In the dither-option the chopper pattern is displaced in ±Y-direction (along the chopper direction) by about 8.5″ (2 2/3 blue pixels or 1 1/3 red pixels). Each chopper plateau lasts for 0.4 s (16 readouts on-board) producing 4 frames per plateau in the down-link. The full 3×25 chopper cycles per nod-position are completed in less than 1 minute. The pattern is repeated on the second nod-position. In case of repetition factors larger than 1, the nod-cycles are repeated in the following way (example for 4 repetitions): nodA-nodB-nodB-nodA-nodA-nodB-nodB-nodA to minimise satellite slew times.

Note: The longest possible duration of a point-source AOR in chopping-nodding techniques is 5.55 h in case of the maximum allowed repetition factor of 120.

2.1 Chop-nod mode implementation for point-sources

If the the chop-nod point-source mode is used, it is recommended to use the dither-option to improve the PSF-sampling for fainter targets. However it is reminded that the mini scan map mode is superior in terms of sensitivity for the faintest sources.

Due to symmetry reasons in the analysis of the nod-positions we recommend to use either a repetition factor of 1 (nodA - nodB) or a multiple of 2 for the repetition factor (example for a repetition factor of 4: nodA-nodB-nodB-nodA - nodA-nodB-nodB-nodA). In the analysis, the data are sliced by nod-blocks consisting of ”nodA-nodB-nodB-nodA” and later a recombination of these slices images is performed.

2.2 Performance

The current HSpot (v5.1.1) predictions in chop-nod technique are 7.5/8.8/16.7 mJy in blue/green/red for the instrumental 5-σ/1 h noise. The true achieved sensitivities are slightly better than the HSpot prediction, but clearly worse than the values from mini scan-maps of similar AOR duration.

The most likely causes for the lower sensitivities in the chop-nod technique (compared to the mini scan-map mode) are:

1. a too simple approach in the sensitivity estimate to take into account $1/f$ noise: the effective actual noise level with 1.25 Hz chopper frequency and 4 readouts per chopper plateau is higher than the adopted 3 Hz value of the 1/f noise spectrum assumed in HSpot predictions.
2. the actual optical coupling of the instrument to the sky,
3. the detector time constants which affect the first frame after each chopper transition and hence the detector responsivity. Currently, 25% of the data are discarded for that reason,
4. combination of all effects.

5. the low number of pixels which actually see the source

The noise spectrum is such that higher sensitivities would be reached for faster chopper frequencies, but due to the detector time constants the signal losses increase in a way that for a given AOR execution time the sensitivity would not improve.

2.3 Advantages of chop-nod Point-Source mode

One advantage of the chop-nod technique is the stability of the reconstructed PSF due to the small RPE of 0.3″ and the fixed chopper and satellite patterns with respect to the array orientation.

The chop-nod technique (in combination with the dither-option) provides good quality photometry for isolated sources. The data-reduction procedures are consolidated and produces photometrically reliable maps.

The chop-nod mode allows to obtain very high spatial resolution which might be needed for resolving small-scale structures. But since there is no ”cluster pointing-mode” available, such a sub-pixel (satellite) dithering is only possible by entering serveral concatenated/grouped AORs with slightly shifted target positions.

Many celestial calibration sources (stars, asteroids, planets) have meanwhile been observed in the described chopping-nodding technique, allowing to reduce and calibrate the science target observations in a very controlled and reliable way. The photometric monitoring and related calibration tasks will be performed in this mode throughout the Herschel mission.

2.4 Caveats of chop-nod Point-Source mode

The biggest caveat on the chop-nod technique is the sensitivity. For a given AOR-execution time the mini scan-map technique reaches significantly better sensitivities. All science programmes originally set up in chop-nod mode should consider to switch to the mini scan-map mode (Sect. 1).

The implemented chop-nod technique has also limitations in case of nearby sources (all 3 bands) and confusing background structures (mainly in the red band). In these cases the various chopped-nodded beams might overlap in the final map and accurate photometry is more difficult (see Fig. 4, left side).

The area of homogeneous coverage in the final image is limited to a region of side length 8-10 blue pixels (about 25-30″) around the source. Outside this region the noise properties are different due to a lower pixel coverage (see Fig. 4, right side).

The chop-nod technique relies strongly on the performance of very few pixels. Some of these key pixels are meanwhile known to show intermittent variability (column 11 in blue matrix 6), i.e. with potentially higher noise levels. It is not possible to completely avoid the bad pixels due to array size constraints, possible astrometric uncertainties for the science targets and the APE of the satellite.

The PACS chop-nod technique is not suitable for the follow-on option which was foreseen for moving solar system targets to catch the object a second time after it has moved by about 3 FWHM. The final map is too much disturbed by the various beams and the poorer pixel coverage at these distances from the map centre does not allow to fully characterise the background as it was planned via the follow-on option.

There are also intrinsic limitation of the point-source mode at removing 1/f noise at the largest frequencies, see : SAp-PACS-MS-0711-09 contrary to the highpass filtering in scan map mode.

The better sensitivity in scan mapping mode is also due to the better spatial sampling.

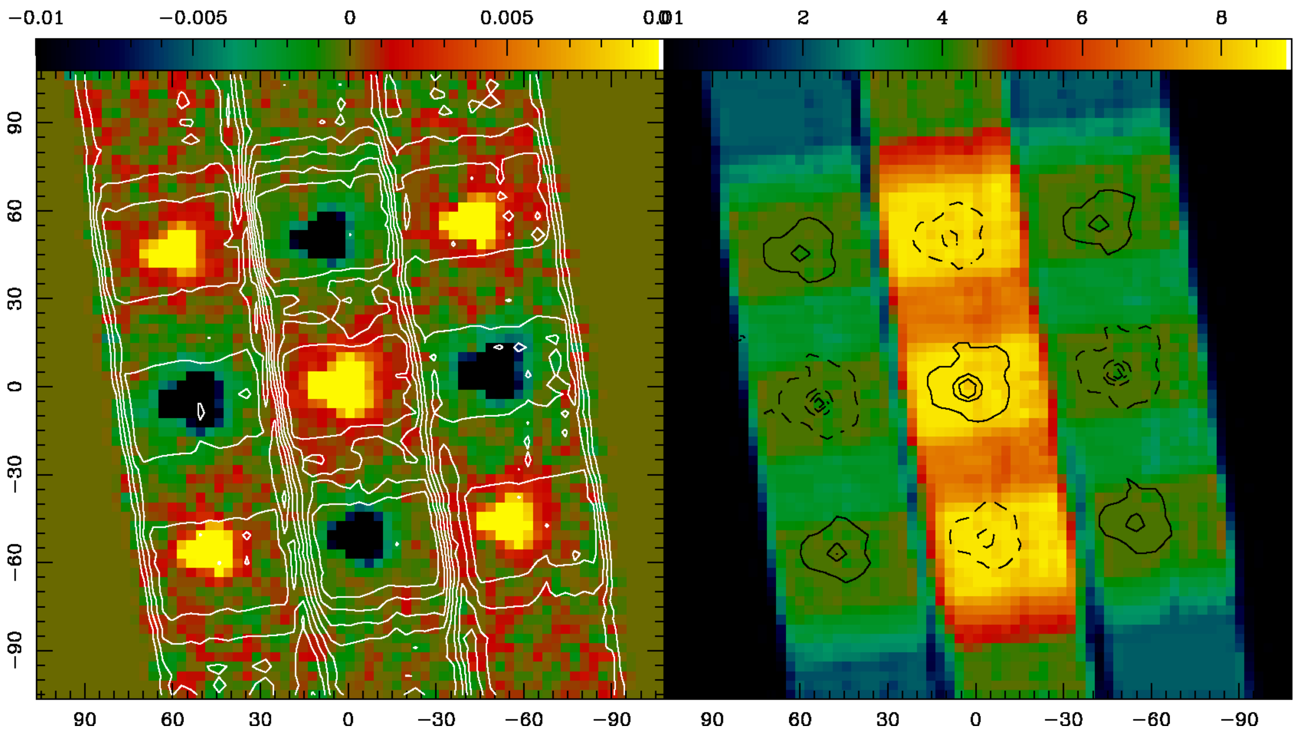

Figure 4: Synopsis of the final map (left) and the pixel coverage (right) after the final processing step with all chop/dither/nod positions projected onto the sky for a bright target with several Jansky. It demonstrates the limitation in aperture photometry to find clean background regions due to the various positive and negative beams. The coverage map illustrates that only a fraction of the central image of the target has the full pixel coverage.

3 Direct comparision of both modes

The chop-nod point-source mode work well operationally. It is the prime mode through which the PACS photometer has been calibrated. The calibration on point sources is very consistent with the models, as well as with the scanning mode.

In the chop-nod technique the source is on-array all the time, but the derived differential signal corresponds to only half of the total time. The elimination of the chopper transitions cost another 25% of the time. Another 3 min are going into the calibration block and another few minutes into the satellite movements for the nodding. For a 1 hour chop-nod AOR the effectively used time is therefore roughly 20 min (although the on-source is more than 45 min) which is comparable to the efficiency reached in the mini scan-map mode (see Section 1).

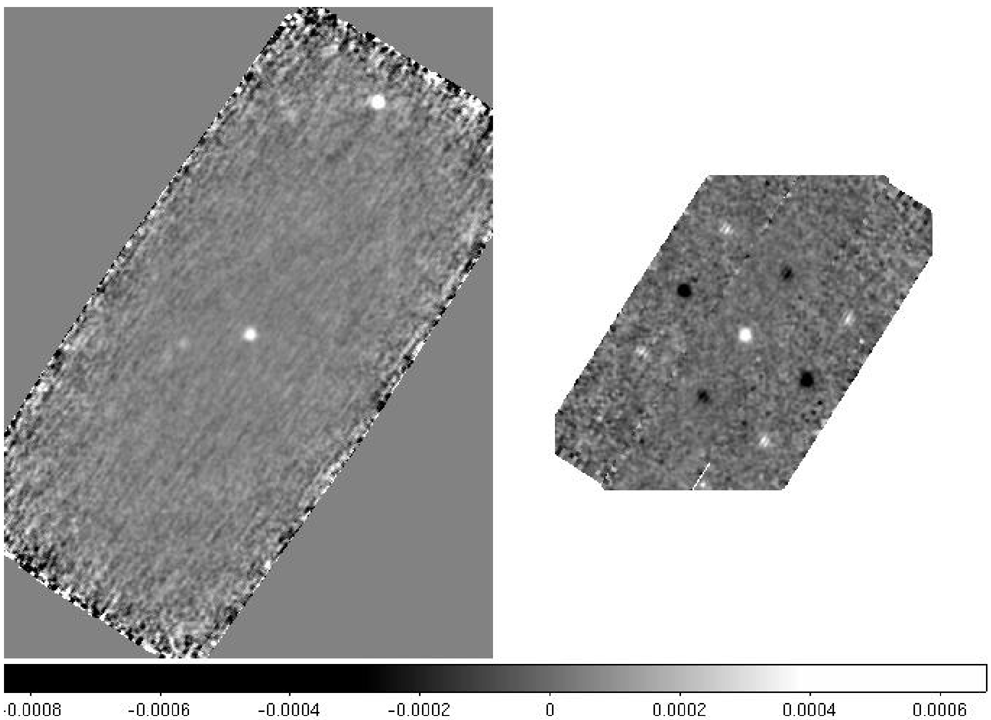

Figure 5: HD 1382865 (OD132) observed in scan-map mode (left) and chop-nod (right) for a similar AOR execution time in the blue band (70 μm), displayed with the same image cut levels.

But with the present performance of the instrument and of the telescope pointing this mode is scientifically less efficient than the mini-scan mode. The mini scan-map has strong advantages in terms of map quality and sensitivity for point- and compact sources as well as for the detection of faint extended emission. We therefore recommend the mini scan-map technique for all science observations with the above recommended implementation (see Fig. 1) or with similar settings. We also recommend that if the science objective is something else than making the photometry of a point source (e.g. searching for faint extended structure near the source) a cross-scan is absolutely mandatory.

It is also important to mention that the gyro propagation mode (dedicated pilot studies are performed in late 2010) could benefit the mini scan-maps, rendering it more efficient again for science project focused on point sources (better stability of the pointing, i.e. better PSF).

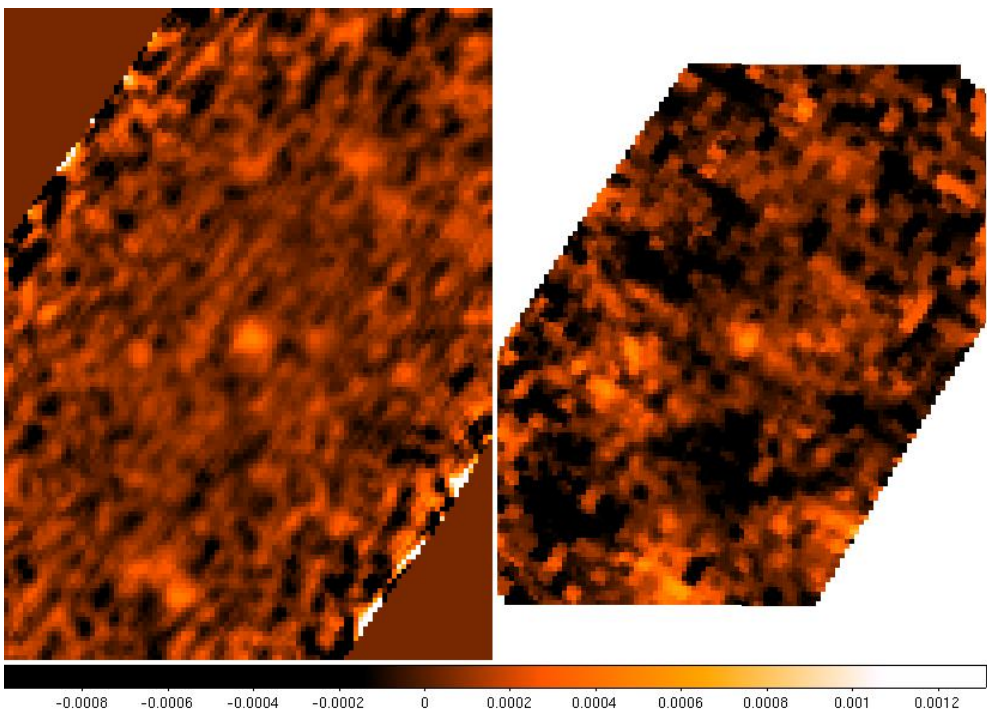

Figure 6: HD 1382865 (OD132) observed in scan-map mode (left) and chop-nod (right) for a similar AOR execution time in the red band (160 μm), displayed with the same image cut levels.

4 Small-source Mode and Large Raster Mode

Both modes have been replaced by the Scan Map Mode implementation without loosing sensitivity performance. Already implemented observations should be moved to the Scan Map Mode following the implementation recommendations in Section 1. Nevertheless, several reference measurements in this 2×2 raster fields with off-array chopping and nodding are available as part of the photometer validation programme.

The Large Raster Mode, with the availability of a large range of possible steps and step sizes, has been executed during performance verification phase in different flavours. But in all considered cases the repetition of these fields in Scan Map Mode provided more reliable products and better sensitivity. This mode was therefore never commissioned.

5 The Calibration Block

There is always one calibration block at the beginning of each PACS photometer AOR (also in cases of grouped/concatenated observations). The calibration block is executed during the target acquisition phase and lasts for about 30 s. The chopper moves with a frequency of 0.625 Hz between the two PACS internal calibration sources. 19 chopper cycles are executed, each chopper plateau lasts for 0.8 s (32 readouts on-board) producing 8 frames in the down-link.

Up to ∼ OD 545 the calibration block was always executed towards the end of the target acquisition phase (slew) and the science part was separated from the calibration block by only 5 s delay time. But the bolometer signals show a noticeable drift after the calibration block for about 30 s. Depending on the reduction technique it might therefore be needed to eliminate or correct the first seconds of data inside the map (typically the first scan-leg of a mini scan-map).

In more recent observations (starting with OD 546) the calibration block was executed at the earliest possible moment during the slew to allow for a longer signal stabilisation before the science observations start. In case of concatenated observations and for very short slews the calibration block is separated from the science data by the minimum separation time of 5 sec.

The calibration blocks allow to follow the evolution of the bolometer response during the day and during the mission lifetime. The main causes for response changes are the bolometer temperature (which increases slowly during the 2.5 days of the cooler hold time) and the primary mirror temperature (which changes due to changing Sun-Earth-Herschel constellations). Part of the second effect is also seen in the calibration block signals via straylight onto the PACS internal calibration sources. The overall absolute response change, as determined via the cleaned and averaged differential calibration block signal, is about ±0.5% in the blue and green channel and about ±0.8% in the red channel. These numbers are based on the evaluation of all photometer calibration blocks during the first 500 ODs. The effects are so small that the calibration blocks are currently not used in the processing of the science data. Due to the very high response stability of the bolometers there is no need to interrupt long measurements for additional calibration blocks.

6 General photometer aspects

6.1 Point spread function

The photometer PSF 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.

An illustration of the PSF is shown in Figure 7.

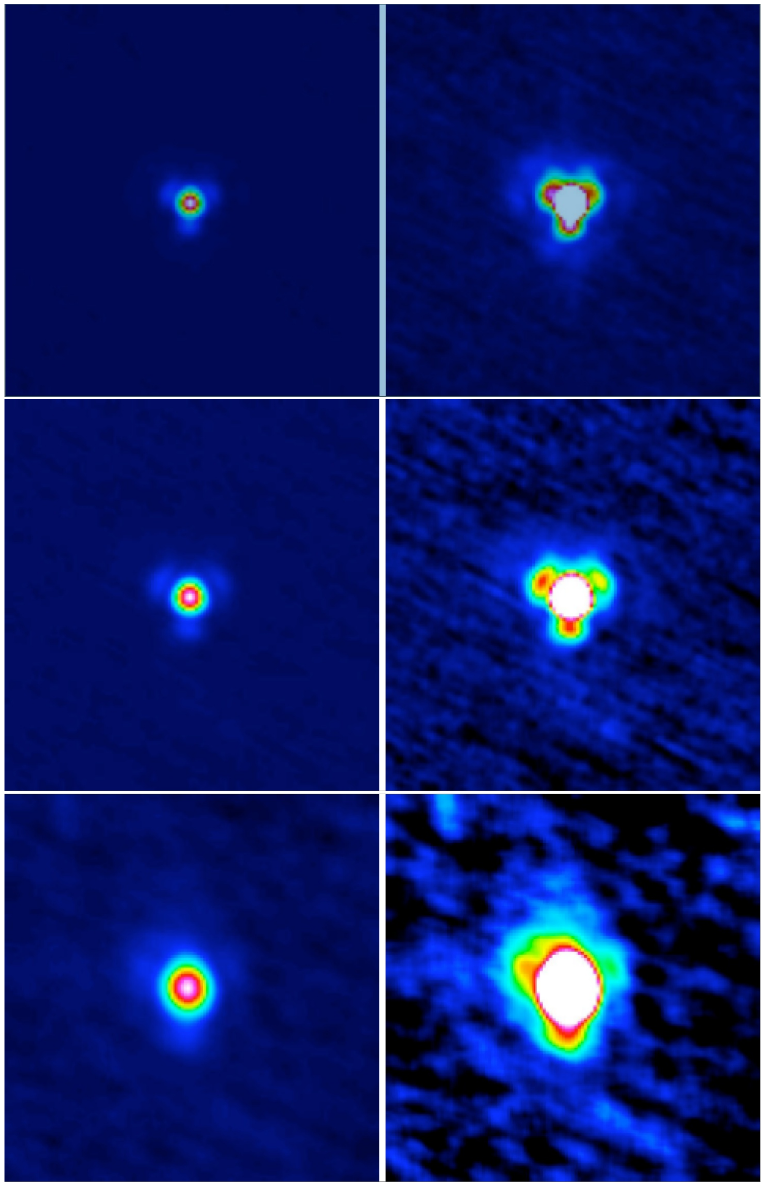

Figure 7: The photometer PSF in blue, green and red (top to bottom) derived from scans performed at 10″/s. Left-hand panels display the image with a linear scale up to the peak, while right-hand panels show up to 10% of the peak.

These PSFs and derived quantities reflect the intrinsic optical quality of Herschel+PACS. In the chop-nod point-source reduction they will be slightly smeared, in particular at short wavelengths, according to telescope pointing jitter and drifts (note that for the PSFs presented in Fig. 7 a re-centering technique was used to eliminate pointing influences). The latest information about PACS photometer PSFs can be found in the PACS document "PACS photometer PSF", PICC-ME-TN-033, version 1.0, available on the HSC web-site. The PACS library of modelled PSFs is available from `http://pacs.ster.kuleuven.ac.be/pubtool/PSF/`.

6.2 Flux calibration

The flux calibration of the 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). These gain-drifts with time are usually not relevant for the mini scan-map mode (see also Section 5).

Based on a large set of celestial flux calibrators (stars, asteroids, Uranus & Neptune) ranging from fluxes below 20 mJy to several hundred Jansky, the flux calibration for point-sources is very reliable (at least up to 100 Jy, above 100 Jy the bolometers start to show a non-linear behaviour). The estimated **absolute flux accuracy** is better than 5% in the blue and green bands and better than 10% in the red band.

The aperture correction factors can be taken from Fig. 8 (PICC-ME-TN-033, Version 1.0) or from the tables in Sect. A.

The flux calibration of the PACS photometer rests on:

1. a spectral convention of $\nu \times f_\nu$ = constant and reference filter wavelengths at 70, 100 and 160 μm.
2. a set of celestial flux calibrators that are mostly stars and asteroids for which model spectra are available that allow either color-correction of the measured spectral densities in order to compare them with the predicted monochromatic model fluxes or computation of the expected measured spectral densities.

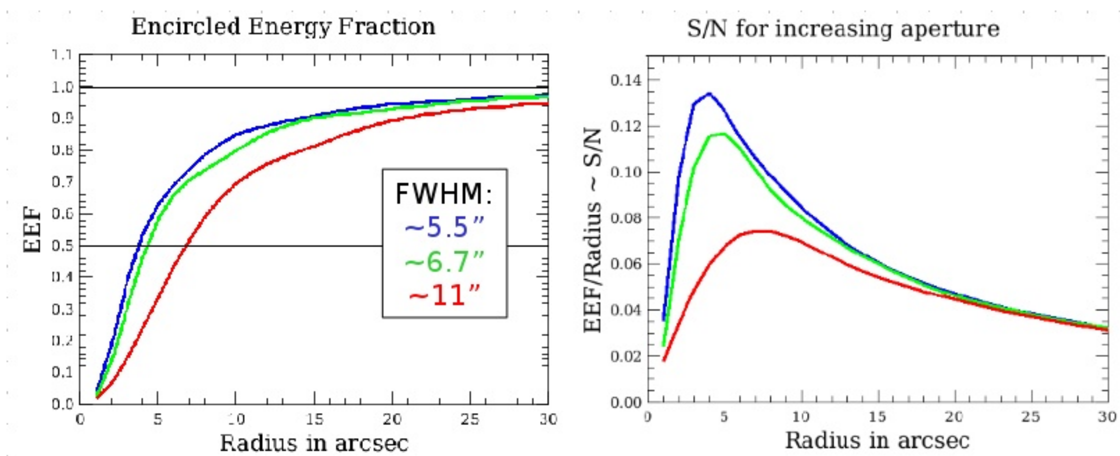

Figure 8: Left: Encircled energy fraction as a function of circular aperture radius for the three bands. Derived from slow scan (20″/s) OD160 Vesta data. The EEF fraction shown is normalized to the signal in aperture radius 60arcsec, with background subtraction done in an annulus between radius 61 and 70 arcsec. The right panel shows the corresponding S/N curve under the assumption that noise scales linearly with aperture radius. Note that this assumption is not met for scanmaps with 1/f noise.

6.3 Non-linearity of the bolometer

The non-linear regime of the PACS bolometers starts for point-sources above ∼100 Jy (in all 3 bands). The brightest flux calibrators Uranus (∼880/880/630 Jy), Neptune (∼370/370/270 Jy) and Ceres (∼260/140/60 Jy) are already falling into this non-linear range. The observed fluxes are about 5-20% lower than the model fluxes, depending on the band and the target. Below ∼100 Jy the bolometer response is linear and perfectly calibrated.

6.4 Pointing

The Relative Pointing Error (RPE) is about 0.3″ implying a high stability for the chopping phases. Due to the Spatial Relative Pointing Error (SRPE) of about 1.5″ a slight broadening of the PACS PSF is expected when combining the images of the two nods, in particular in the blue/green bands where the PSF is sharper. The Absolute Pointing Error (APE), which affects the complete chop-nod pattern, is better than 2″.

6.5 Digitization

Because of satellite data-rate issues, we have had to add a supplementary compression stage called bit-rounding before the data is down-linked. This means that while we average 4 images on board, we also round the last n bits of the result. The default value for n was 2 during the Performance Validation campaign (high-gain observations performed with bit-rounding of 2 are effectively digitized with a step of $2\,10^{-5}$ V, or 4 ADU), now released to 1 bit only since the Nov. 2, 2009. The PACS ICC was experimenting with dispensing with this compression step in some observing modes, e.g. using no bit rounding during scan-map mode. But this option was rejected in spring 2010 due to the very small improvement in noise performance accompanied by a significantly increased datarate which could cause problems in long ODs where also the entire Daily Tele-Communications Periods (DTCP) is used for science observations.

A Tables for the encircled energy function

Table 1: Encircled energy fraction as a function of circular aperture radius for the three bands. Derived from slow scan (20″/s) OD160 Vesta data.The EEF fraction shown is normalized to the signal in aperture radius 60 arcsec, with background subtraction done in an annulus between radius 61 and 70 arcsec.

	encircled energy fraction			Radius	encircled energy fraction		
Radius [″]	blue	green	red	[″]	blue	green	red
1	0.047	0.032	0.018	31	0.978	0.978	0.956
2	0.214	0.156	0.069	32	0.979	0.980	0.959
3	0.402	0.318	0.146	33	0.981	0.981	0.963
4	0.548	0.474	0.241	34	0.982	0.983	0.966
5	0.642	0.595	0.341	35	0.983	0.984	0.969
6	0.701	0.672	0.438	36	0.984	0.985	0.972
7	0.750	0.718	0.524	37	0.985	0.986	0.975
8	0.794	0.749	0.597	38	0.986	0.987	0.977
9	0.830	0.778	0.656	39	0.987	0.988	0.980
10	0.856	0.809	0.700	40	0.988	0.989	0.982
11	0.873	0.840	0.734	41	0.989	0.990	0.983
12	0.886	0.866	0.759	42	0.989	0.991	0.985
13	0.895	0.885	0.781	43	0.990	0.992	0.987
14	0.904	0.900	0.801	44	0.991	0.993	0.988
15	0.913	0.910	0.820	45	0.992	0.994	0.990
16	0.922	0.917	0.838	46	0.992	0.994	0.991
17	0.931	0.923	0.855	47	0.993	0.995	0.992
18	0.938	0.928	0.871	48	0.993	0.996	0.993
19	0.945	0.932	0.885	49	0.994	0.996	0.994
20	0.949	0.938	0.897	50	0.995	0.997	0.995
21	0.953	0.943	0.907	51	0.995	0.997	0.996
22	0.957	0.948	0.916	52	0.996	0.997	0.997
23	0.960	0.954	0.923	53	0.997	0.998	0.998
24	0.963	0.958	0.929	54	0.997	0.998	0.998
25	0.966	0.963	0.934	55	0.998	0.998	0.999
26	0.968	0.966	0.938	56	0.998	0.999	0.999
27	0.970	0.970	0.942	57	0.999	0.999	0.999
28	0.973	0.972	0.946	58	0.999	0.999	0.999
29	0.974	0.975	0.949	59	1.000	1.000	1.000
30	0.976	0.977	0.953	60	1.000	1.000	1.000

B Tables for the colour corrections

Table 2: Photometric colour corrections for a range of black-body temperatures and different power-laws. Photometric reference spectrum: $\nu F_\nu = \lambda F_\lambda = \text{const.}$. PACS bolometer reference wavelengths: 70.0, 100.0, 160.0 μm. In order to obtain a monochromatic flux density one has to divide the measured and calibrated band flux by the below tabulated values. *: Colour corrections for sources with temperatures below 20 K can become quite significant, in particular at 70 μm.

BB temp.	CC_70	CC_100	CC_160
BB (10 000 K)	1.02	1.03	1.07
BB (5000 K)	1.02	1.03	1.07
BB (1000 K)	1.01	1.03	1.07
BB (500 K)	1.01	1.03	1.07
BB (250 K)	1.01	1.02	1.06
BB (100 K)	0.99	1.01	1.04
BB (50 K)	0.98	0.99	1.01
BB (20 K)*	1.22	1.04	0.96
BB (15 K)*	1.61	1.16	0.99
BB (10 K)*	3.65	1.71	1.18
Power law (ν^β)	CC_70	CC_100	CC_160
$\beta = -3.0$	1.04	1.04	1.06
$\beta = -2.0$	1.02	1.01	1.02
$\beta = -1.0$	1.00	1.00	1.00
$\beta = 0.0$	1.00	1.00	1.00
$\beta = 1.0$	1.00	1.01	1.03
$\beta = 2.0$	1.02	1.03	1.08
$\beta = 3.0$	1.04	1.07	1.14