User Provided Data Products: Herschel/PACS photometer observations of main-belt asteroids (release note)

Small Bodies: Near and Far; 687378 – SBNAF – RIA

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Abstract

In this release note we describe User Provided Data Products of selected Herschel/PACS main belt asteroid measurements of 4 Vesta, 8 Flora, 18 Melpomene and 2867 Šteins. In all these cases the standard products in the Herschel Science Archive appeared to be problematic, and we were able to improve the quality of the final, science ready data products by applying special processing steps. This delivery is part of 'Small Bodies: Near and Far', a Horizon 2020 project that addresses critical points in reconstructing physical and thermal properties of near-Earth, main-Belt, and trans-Neptunian objects (see the project webpage for details:http://www.mpe.mpg.de/tmueller/sbnaf/).

Contents

1 Introduction

SMALL BODIES: NEAR AND FAR (SBNAF) is a Horizon 2020 project (project number: 687378) that addresses critical points in reconstructing physical and thermal properties of near-Earth, main-belt, and trans-Neptunian objects (see the project webpage for details: http://www.mpe.mpg.de/~tmueller/sbnaf/).

One of the goals of the SBNAF project is to produce a set of high-quality data products for Herschel observations of Solar System objects for an upload to the Herschel Science Archive (HSA). These new products will then be available for the entire scientific community, in parallel to the standard pipeline-processed Herschel archive data.

In this release note we describe User Provided Data Products (UPDPs) of a few Herschel/PACS photometer *main-belt asteroid* measurements. For these measurements the Standard Product Generation of the Herschel Science Archive did not provide suitable final images, as special processing was required to reach scientifically valuable data products. These UPDPs include measurements of 4 Vesta, 8 Flora, 18 Melpomene and 2867 Šteins.

2 New data products

2.1 Data reduction

The PACS photometer data reduction optimized for moving Solar System objects is described in Kiss, Müller, Vilenius et al. 2014, ExpAstron 37, 161: "Optimized Herschel/PACS photometer observing and data reduction strategies for moving solar system targets" (https://arxiv.org/abs/1309.4212), and also in the UPDP release note of near-Earth asteroid observations (http://www.mpe.mpg.de/~tmueller/sbnaf/doc/nea_hsa_upload_release_note_v1.pdf).

For targets whose data can be reduced in a fixed frame and have overlapping backgrounds at different epochs differential and double-differential products can be produced (DIFF and DDIFF, see the documentation cited above). However, for MBAs the apparent velocities are typically to high for these kind of products and for most targets the reduction had to be performed in the co-moving frame using a specific motion correction (dubbed as 'SSO'). In addition, selection of repetitions and/or scan legs and stacking of multiple images were necessary in most cases as described in the target-specific subsections below, and also in the summary tables in the Appendix. A special case was the measurements of 4 Vesta during a close αTau encounter which was not taken in the standard SSO tracking mode, but in the fixed celestial frame. More details on these specific measurements can be found in Müller et al. 2014, ExpAstron 37, 253., and also below.

2.2 αTau-Vesta measurements

The measurements on αTau-Vesta were taken in a fixed sky position which was pre-calculated and located in the middle between both objects at the given epoch of the Herschel observations. The default archive products show images with αTau being perfectly point-like, but Vesta is elongated, i.e. reduced in the fixed celestial frame. For producing reliable products also for Vesta, the processing was repeated, but now in Vesta's co-moving reference system (see Fig. 1). Now, Vesta looks perfectly point-like (and can be used for standard aperture photometry) while αTau is elongated. More details on these specific measurements can be found in Müller et al. 2014, ExpAstron 37, 253. The new FITS files (1 blue, 1 green, 2 reds) and the corresponding stamp images are provided as UPDP to the HSA.

A similar set of products was produced for measurements on the close encounter between Callisto and Ganymede (see Müller et al. 2016, A&A 588, 109) where both targets were moving with different apparent motions and in different directions.

2.3 Multi-repetition chop-nod measurements

Modifications in the standard chop-nod script were necessary to process the multi-repetition measurements of 8 Flora (OD 101) and 18 Melpomene (OD 41). The automatic pipeline processing did not work here.

8 Flora: The Flora measurement from OD101 was conducted with 30 repetition in chop-nod mode (low gain, blue/red filter combination, dithering). The total integration time was about 1.4 hours (rotation period is about 12.5 hours). During the processing, the measurement was split into 15 blocks, each including a full nodA-nodB-nodB-nodA sequence. Each block resulted then in a pair of 70 & 160 μm images which can be used for extracting the photometry. Fig. 2 shows the final images of the first block.

The 30 new FITS files (15 for the blue channel, 15 for the red) are delivered as UPDP to the HSA.

18 Melpomene: The Melpomene measurement from OD41 was conducted with 20 repetition in chop-nod mode (low gain, blue/red filter combination, dithering). The total integration time was about 1.0 hour (rotation period is about 11.6 hours). During the processing, the measurement was split into 10 blocks, each including a full nodA-nodB-nodB-nodA sequence. Each block resulted then in a pair of 70 & 160 μm images which can be used for extracting the photometry. Fig. 3 shows the final images of the first block.

The 20 new FITS files (10 for the blue channel, 10 for the red) are delivered as UPDP to the HSA.

2.4 Faint MBA 2867 Šteins

The Rosetta fly-by target and MBA 2867 Šteins was part of the science programme GT1_lorourke_9 "Herschel In-situ Asteroid & Comet Observation programme" (PI: L. O'Rourke). The minor planet Šteins was too faint for photometry using the standard maps. The new data products are based on optimized SSO reduction procedures for SSOs (Kiss et al. 2014) and uses stacking of scan and cross-scan images in the 70 and 100 μm bands and all possible (four) maps / OBSIDs in the 160 μm band. The background has a very high level of confusion noise (see Fig. 4) and influences severely the final photometry.

The 3 new FITS files (1 for the blue channel, 1 for green, and 1 for the red) are delivered as UPDP to the HSA.

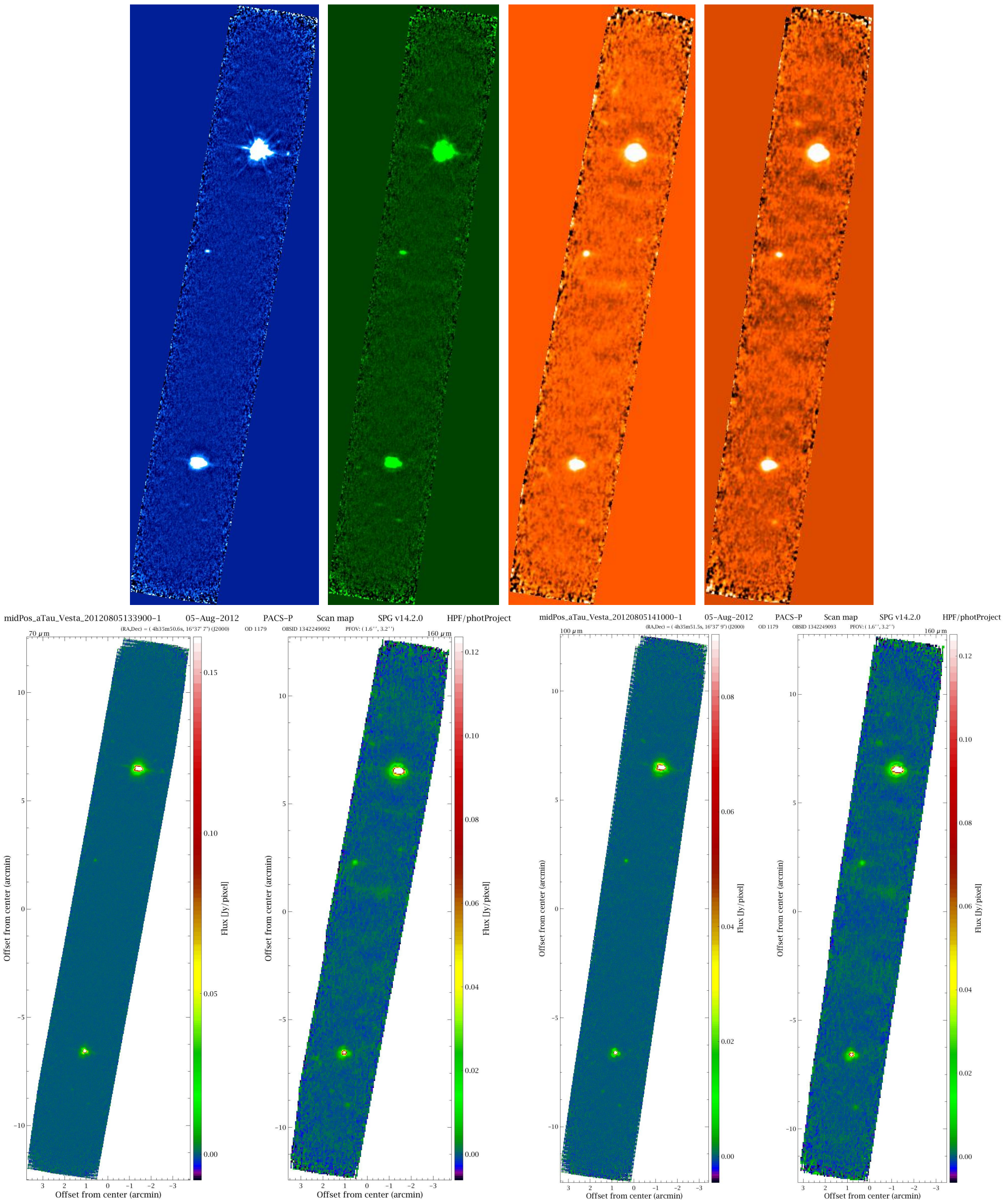

Figure 1: Top: Image stamps of the newly processed observations of αTau-Vesta at 70 μm (blue), 100 μm (green), and twice 160 μm (red). Images are centered on Vesta (upper bright source). Bottom: Postcards from the HSA: 70/160 μm & 100/160 μm. Images are centered on αTau (lower bright source). The middle source in all images is the galaxy SSTSL2 J043553.24+163919.8.

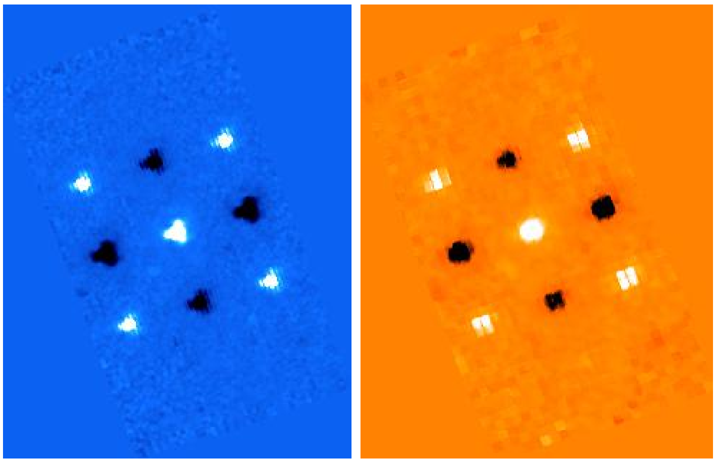

Figure 2: Image stamps of the newly processed observations of 8 Flora at 70 μm (blue) and 160 μm (red). Only the first block with about 0.1 h integration time is shown.

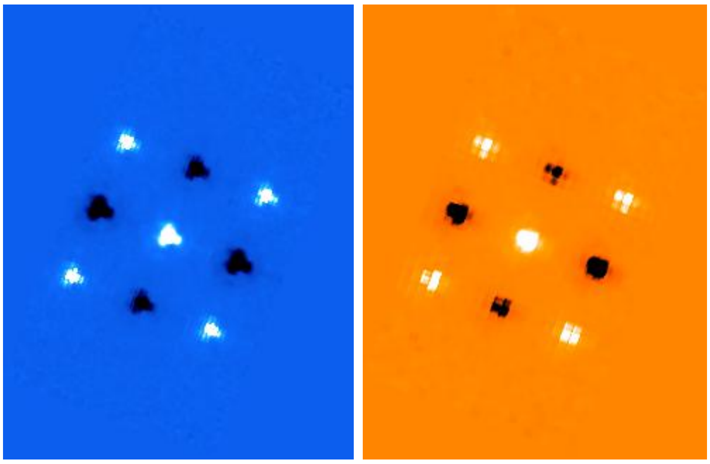

Figure 3: Image stamps of the newly processed observations of 18 Melpomene at 70 μm (blue) and 160 μm (red). Only the first block with about 0.1 h integration time is shown.

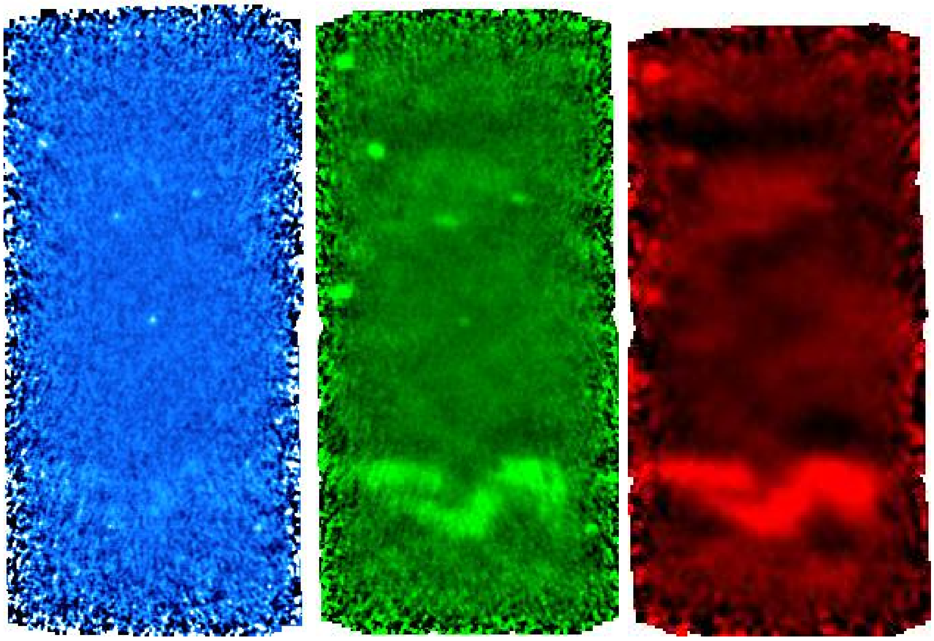

Figure 4: Image stamps of the newly processed observations of 2867 Šteins at 70 μm (blue), 100 μm (green), and 160 μm (red). The asteroid can be seen at 70 and 100 μm in the center of the fields.

References

- Kiss, C.; Müller, T. G.; Vilenius, E.; et al., 2014, Experimental Astronomy, 37, 161
- Kiss, C.; Müller, T. G.; and the SBNAF team: "User Provided Data Product upload of Herschel/PACS near-Earth asteroid observations", UPDP release note, December 30, 2016 (Herschel Science Archive)
- Müller, T.G.; Balog, Z., Nielbock, M., et al., 2014, Experimental Astronomy, 37, 253
- Müller, T.G., Balog, Z., Nielbock, M., et al., 2016, A&A, 588, A109

Appendix

Summary of additional FITS keywords

OBS_ID	Herschel observation identifier number / single observation used for data product
OBSID001, OBSID002, ... OBSIDnnn	Herschel observation identifier number / multiple observations used for data product
OBSDAY	Herschel operational day / single observation used for data product
OBSDAY01, OBSDAY02, ... OBSDAYnn	Herschel operational day / multiple observations used for data product
PROPOSAL	Herschel proposal ID of the observations used
LAYER0, LAYER1	Type of data in a specific data layer of the FITS cube ("image" or "coverage")
EQLEVEL	Equivalent level of SPG processing
TARGET	Name or designation of the target
INSTRUME	Main Herschel instrument
SUBINSTR	Subinstrument
FILTER	Nominal wavelength of the filter used (mircometer)
DATAPRID	Type of data product
PROJECT	Project identifier
LEGS	Legs used for data product generation
REPETIT1, REPETIT2, ..., REPETITn	Repetition(s) used from the respective OBSID(s)

Table 1: List of keywords added to the header of the data product FITS files. Note that not all keywords apply to a specific data product type.

Summary of new data products

Target		Band	Filename	OBSID(s)	Type
4	Vesta	70	map_4_Vesta_sso_1342249092_70	1342249092	SSO /Stacked
4	Vesta	100	map_4_Vesta_sso_1342249093_100	1342249093	SSO /Stacked
4	Vesta	160	map_4_Vesta_sso_1342249092_160	1342249092	SSO /Stacked
4	Vesta	160	map_4_Vesta_sso_1342249093_160	1342249093	SSO /Stacked
8	Flora	70	map_8_Flora_sso_1342182740_70_rep0	1342182740	SSO rep 0
8	Flora	70	map_8_Flora_sso_1342182740_70_rep1	1342182740	SSO rep 1
8	Flora	70	map_8_Flora_sso_1342182740_70_rep2	1342182740	SSO rep 2
8	Flora	70	map_8_Flora_sso_1342182740_70_rep3	1342182740	SSO rep 3
8	Flora	70	map_8_Flora_sso_1342182740_70_rep4	1342182740	SSO rep 4
8	Flora	70	map_8_Flora_sso_1342182740_70_rep5	1342182740	SSO rep 5
8	Flora	70	map_8_Flora_sso_1342182740_70_rep6	1342182740	SSO rep 6
8	Flora	70	map_8_Flora_sso_1342182740_70_rep7	1342182740	SSO rep 7
8	Flora	70	map_8_Flora_sso_1342182740_70_rep8	1342182740	SSO rep 8
8	Flora	70	map_8_Flora_sso_1342182740_70_rep9	1342182740	SSO rep 9
8	Flora	70	map_8_Flora_sso_1342182740_70_rep10	1342182740	SSO rep 10
8	Flora	70	map_8_Flora_sso_1342182740_70_rep11	1342182740	SSO rep 11
8	Flora	70	map_8_Flora_sso_1342182740_70_rep12	1342182740	SSO rep 12
8	Flora	70	map_8_Flora_sso_1342182740_70_rep13	1342182740	SSO rep 13
8	Flora	70	map_8_Flora_sso_1342182740_70_rep14	1342182740	SSO rep 14
8	Flora	160	map_8_Flora_sso_1342182740_160_rep0	1342182740	SSO rep 0
8	Flora	160	map_8_Flora_sso_1342182740_160_rep1	1342182740	SSO rep 1
8	Flora	160	map_8_Flora_sso_1342182740_160_rep2	1342182740	SSO rep 2
8	Flora	160	map_8_Flora_sso_1342182740_160_rep3	1342182740	SSO rep 3
8	Flora	160	map_8_Flora_sso_1342182740_160_rep4	1342182740	SSO rep 4
8	Flora	160	map_8_Flora_sso_1342182740_160_rep5	1342182740	SSO rep 5
8	Flora	160	map_8_Flora_sso_1342182740_160_rep6	1342182740	SSO rep 6
8	Flora	160	map_8_Flora_sso_1342182740_160_rep7	1342182740	SSO rep 7
8	Flora	160	map_8_Flora_sso_1342182740_160_rep8	1342182740	SSO rep 8
8	Flora	160	map_8_Flora_sso_1342182740_160_rep9	1342182740	SSO rep 9
8	Flora	160	map_8_Flora_sso_1342182740_160_rep10	1342182740	SSO rep 10
8	Flora	160	map_8_Flora_sso_1342182740_160_rep11	1342182740	SSO rep 11
8	Flora	160	map_8_Flora_sso_1342182740_160_rep12	1342182740	SSO rep 12
8	Flora	160	map_8_Flora_sso_1342182740_160_rep13	1342182740	SSO rep 13
8	Flora	160	map_8_Flora_sso_1342182740_160_rep14	1342182740	SSO rep 14
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep0	1342179011	SSO rep 0
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep1	1342179011	SSO rep 1
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep2	1342179011	SSO rep 2
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep3	1342179011	SSO rep 3
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep4	1342179011	SSO rep 4
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep5	1342179011	SSO rep 5
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep6	1342179011	SSO rep 6
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep7	1342179011	SSO rep 7
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep8	1342179011	SSO rep 8
18	Melpomene	70	map_18_Melpomene_sso_1342179011_70_rep9	1342179011	SSO rep 9
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep0	1342179011	SSO rep 0
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep1	1342179011	SSO rep 1
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep2	1342179011	SSO rep 2
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep3	1342179011	SSO rep 3
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep4	1342179011	SSO rep 4
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep5	1342179011	SSO rep 5
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep6	1342179011	SSO rep 6
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep7	1342179011	SSO rep 7
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep8	1342179011	SSO rep 8
18	Melpomene	160	map_18_Melpomene_sso_1342179011_160_rep9	1342179011	SSO rep 9
2867	Steins	70	map_2867_Steins_sso_70	1342250354/55	SSO /Stacked
2867	Steins	100	map_2867_Steins_sso_100	1342250356/57	SSO /Stacked
2867	Steins	160	map_2867_Steins_sso_160	1342250354/55/56/57	SSO /Stacked

Table 2: List of new data products for the asteroids 4 Vesta, 8 Flora, 18 Melpomene, and 2867 Šteins, prepared for an uploaded to the Herschel Science Archive. The columns of the table are (1) Target; (2) wavelength (μm); (3) file name; (4) OBSID(s) used; (5) product type. See the main text for a detailed description of the data products.

Observational details

OD	OBSID	Target	SAA [°]	UTC Start time yyyy mon dd	hh:mm:ss	dur. [s]	fil	D	G	R
41	1342179011	18 Melpomene	1.1	2009 Jun 24	04:03:11	3338	B/R	Y	L	20
101	1342182740	8 Flora	24.4	2009 Aug 23	11:11:23	4979	B/R	Y	L	30

Table 3: Problematic Herschel-PACS photometer **chop-nod observations of main-belt asteroids** (proposals Calibration_coppacs_12, Calibration_pvpacs_18), taken in point-source observing mode, and solar system object (SSO) tracking mode. SAA: solar aspect angle; dur.: duration of observation in seconds; fil: filter/band combination (B/R: 70/160 μm; G/R: 100/160 μm); D: dither yes(Y)/no(N); G: low (L) or high (H) gain; R: repetition of entire chop-nod pattern.

OD	OBSID	Target	SAA [°]	UTC Start time yyyy mon dd	hh:mm:ss	Dur [s]	Fil	G	R	S $''$/s	Len×n×sep $' \times \# \times ''$	ang. [°]
1179	1342249092	αTau-Vesta	26.6	2012 Aug 05	13:20:51	1620	B/R	H	1	20	20.0×20× 5	170(s)
1179	1342249093	αTau-Vesta	26.6	2012 Aug 05	13:48:10	1620	G/R	H	1	20	20.0×20× 5	172(s)
1201	1342250354	2867 Steins	-20.3	2012 Aug 27	14:35:35	398	B/R	H	1	20	3.0×10× 4	70(i)
1201	1342250355	2867 Steins	-20.3	2012 Aug 27	14:42:03	321	B/R	H	1	20	3.0×10× 4	110(i)
1201	1342250356	2867 Steins	-20.3	2012 Aug 27	14:54:55	1167	G/R	H	4	20	3.0×10× 4	70(i)
1201	1342250357	2867 Steins	-20.4	2012 Aug 27	15:14:50	1167	G/R	H	4	20	3.0×10× 4	110(i)

Table 4: Problematic Herschel-PACS photometer **scan-map observations of main-belt asteroids** (proposals Calibration_rppacs_149 and GT1_lorourke_9), taken in scan-map observing mode, and solar system object (SSO) tracking mode (Šteins) and in fixed observing mode (αTau-Vesta). SAA: solar aspect angle; dur.: duration of observation in seconds; fil: filter/band combination (B/R: 70/160 μm; G/R: 100/160 μm); G: low (L) or high (H) gain; R: repetition of entire scan map; S: scan-speed in $''$/s, scan-map parameters: Len: scan-leg length (in arc min) × n: number of scan legs × sep: scan-leg separation (in arc sec); ang.: satellite scan angle in degrees with respect to instrument reference frame (i) or the sky reference frame (s).