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Herschel-PACS high-precision FIR fluxes of NEAs and MBAs

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Abstract

We present Herschel-PACS photometer observations of near-Earth and main-belt asteroids. All measurements were carefully inspected for quality problems, were reduced and calibrated in a (semi-)standard way. The derived flux densities are tied to the standard PACS photometer response calibration, which is based on repeated measurements of five fiducial stars. Most of the measurements have signal-to-noise ratios well above 100, but the overall absolute flux uncertainty is dominated by the estimated 5% model uncertainty of the stellar models in the PACS wavelength range between 60 and 210 μm. The relative PACS photometric accuracy is related to the stability of about 1% of the bolometer detector over the entire *Herschel* lifetime. The high scientific potential of these measurements is shown via radiometric studies of selected objects: the determination of the objects' sizes, albedos, and thermal properties. At the same time, the PACS results will lead to improved asteroid model solutions for future calibration applications for far-IR, submm, and mm-projects.

1. Targets

The Herschel Space Observatory [1] was operational from 2009 to 2013. One of the three instruments on board was the Photodetecting Array Camera and Spectrometer (PACS) [2] which covered the wavelength range between 55 and 210 μm. The reference wavelengths of the three photometer filters are 70.0, 100.0, and 160.0 μm. Most of the on-sky calibration work for Herschel's photometric observations was done on bright point-like sources like Uranus, Neptune [3], a selection of fiducial stars [4, 5], and a sample of well-known large main-belt asteroid [6]. In addition to the asteroid calibration observations there were several smaller scientific project on near-Earth (NEAs) and prominent main-belt asteroids (MBAs). The full list of dedicated small-body observations comprises: NEAs: 101955 Bennu, 433 Eros, 308635 (2005 YU_{55}), 175706 (1999 FG_3), 162173 Ryugu, 99942 Apophis. MBAs: 1 Ceres, 2 Pallas, 3 Juno, 4 Vesta, 6 Hebe, 8 Flora, 10 Hygiea, 18 Melpomene, 19 Fortuna, 20 Massalia, 21 Lutetia, 29 Amphitrite, 47 Aglaja, 52 Europa, 54 Alexandra, 65 Cybele, 88 Thisbe, 93 Minerva, 253 Mathilde, 360 Carlova, 423 Diotima, 511 Davida, 704 Interamnia, 2000 Herschel, and 2867 Šteins.

2. Data reduction, calibration & flux extraction

For the bright main-belt asteroids the standard data reduction and calibration schemes worked fine, for the fainter objects we followed the optimized Herschel/PACS photometer observing and data reduction strategies for moving solar system targets [7]. The absolute flux calibration of 5% (relevant for radiometric size determinations) is based on repeated measurements of five fiducial stars [4, 5], the relative photometric error is typically below 1% and allows to characterize thermal surface properties with unprecedented accuracy. Flux densities were derived from aperture photometry and are currently prepared for a catalogue publication [15] with about 40 far-Infrared (FIR) fluxes for the six NEAs, and more than 1060 FIR fluxes for MBAs.

3. Scientific results

The NEA observations were all part of small dedicated science projects and the corresponding results were presented in a list of publications [8, 9, 10, 11, 12, 13]. A small fraction of the MBA fluxes has also been used in the scientific context [6, 14]. Our new asteroid flux catalogue allows to study the all objects in great detail: We will be able to determine the thermal inertia for all objects with high precision. For objects with significant orbit eccentricities we can also study if the object's thermal inertia changes with heliocentric distance, similar to our findings for Hebe [14]. Specific cases where the observations were taken very close to a pole-on situation will help us to test the reliability of thermophysical models concepts. With our high-quality fluxes we will also make a first study on surface roughness variations for the different MBAs.

Many more scientific applications will be possible when combining these measurements with auxiliary thermal data from IRAS, MSX, AKARI, WISE, or ALMA. New shape and spin solutions for our prominent objects (from AO imaging, non-convex lightcurve inversion techniques, occultations, or interplanetary missions) will help us to disentangle shape, thermal, surface roughness, albedo or emissivity effects. Dedicated studies of some NEAs and MBAs with ground-truth information will be used for benchmarking radiometric and lightcurve inversion techniques as part of our EU-funded "Small Bodies Near and Far (SBNAF)" project.

Acknowledgements

Figure 1: Left: The SBNAF project logo: `http://www.mpe.mpg.de/~tmueller/sbnaf/`. Right: The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 687378.

References

[1] Pilbratt, G. L., Riedinger, J. R., Passvogel, T. et al.: Herschel Space Observatory. An ESA facility for far-infrared and submillimetre astronomy, A&A, 518, L1, 2010.

[2] Poglitsch, A., Waelkens, C., Geis, N. et al: The Photodetector Array Camera and Spectrometer (PACS) on the Herschel Space Observatory, A&A, 518, L2, 2010.

[3] Müller, T. G., Balog, Z., Nielbock, M. et al.: Far-infrared photometric observations of the outer planets and satellites with Herschel-PACS A&A 588, 109, 2016.

[4] Balog, Z., Müller, T. G., Nielbock, M., et al.: The Herschel-PACS photometer calibration. Point-source flux calibration for scan maps, Experimental Astronomy, 37, 129, 2014.

[5] Nielbock, M., Müller, T. G., Klaas, U. et al.: The Herschel PACS photometer calibration. A time dependent flux calibration for the PACS chopped point-source photometry AOT mode, Experimental Astronomy, 36, 631, 2013.

[6] Müller, T. G., Balog, Z., Nielbock, M. et al.: Herschel celestial calibration sources. Four large main-belt asteroids as prime flux calibrators for the far-IR/sub-mm range, Exp. Astronomy, 27, 253, 2014.

[7] Kiss, C., Müller, T. G., Vilenius, E. et al.: Optimized Herschel/PACS Photometer observing and data reduction strategies for moving solar system targets, Exp. Astronomy, 37, 161, 2014.

[8] Müller, T. G., O'Rourke, L., Barucci, A. M. et al.: Physical properties of OSIRIS-REx target asteroid (101955) 1999 RQ_{36}. Derived from Herschel, VLT/ VISIR, and Spitzer observations, A&A 548, 36, 2012.

[9] Müller, T. G., Miyata, T., Kiss, C. et al.: Physical properties of asteroid 308635 (2005 YU_{55}) derived from multi-instrument infrared observations during a very close Earth approach, A&A 558, 97, 2013.

[10] Müller, T. G. & Vilenius, E.: Main results on asteroids and comets returned from the Herschel mission, 40th COSPAR Scientific Assembly, 2-10 August 2014, Moscow, Russia, Abstract B0.4-29-14, 2014.

[11] Müller, T. G., Ďurech, J., Ishiguro, M. et al.: Hayabusa-2 mission target asteroid 162173 Ryugu (1999 JU_3): Searching for the object's spin-axis orientation, A&A 599, 103, 2017.

[12] O'Rourke, L., Müller, T. G., Altieri, B. et al.: Herschel observations of near-Earth objects: Encounters with the spacecraft and with the Earth, Asteroids, Comets, Meteors 2014, Proceedings, K. Muinonen et al. (eds.), 400, 2014.

[13] O'Rourke, L., Müller, T. G., Barucci, A. et al.: Herschel observations of the Marco Polo-R asteroid 175706 (1996 FG_3), European Planetary Science Congress 2012, EPSC2012-789, 2012.

[14] Marsset, M., Carry, B., Dumas, C. et al.: 3-D shape of asteroid (6) Hebe from VLT/SPHERE imaging: Implication for the origin of ordinary H chondrites, A&A, submitted.

[15] Müller, T. G., Kiss, C., Farkas-Takács, A. et al.: Far-infrared photometry of main belt and near-Earth asteroids from Herschel-PACS measurements, A&A, in preparation.