EPSC Abstracts
Vol. 6, EPSC-DPS2011-1299, 2011
EPSC-DPS Joint Meeting 2011


# TNOs are Cool: Thermophysical modeling of a sample of 20 classical KBOs using Herschel/PACS

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## Abstract

We determine the sizes and albedos of 20 classical Kuiper belt objects. Our observations with the PACS instrument on-board *Herschel* Space Observatory cover the wavelength range where the thermal emission from trans-Neptunian objects has its maximum. We use a consistent method for data reduction and aperture photometry of this sample, and determine sizes and albedos using thermophysical models. We compare the results to previous ground- and space-based estimates. Our new results confirm the recent findings that there are very diverse albedos among the classical KBOs, which has important implications to their global properties, such as size distribution and the total mass of the belt. An increased average albedo would mean a decreased total mass of these targets. Almost all of the 20 targets have higher albedos than assumed. There are variations between the different groups within our sample: the cold classicals together with the two inner hot classicals have higher albedos than the hot classicals. Our refined sizes and albedos make an important contribution to the estimates of the fundamental properties of these objects.

## 1. Introduction

The size distribution of TNOs and their various dynamical classes holds clues to the process of giant-planet and small-body formation and the collisional evolution of small bodies. The total mass can be estimated from the size distribution and its shape describes accretion vs. collisional erosion; for large bodies accretion processes are dominant (slope of the size distribution steeper), and bodies smaller than 50-100 km in diameter result from collisional evolution [1]. Within the classical TNOs the cold classicals have a steeper size distribution than hot classicals.

The combination of optical and thermal infrared observations gives both sizes and albedos. For binaries the effective radiometric size of the system is acquired making it possible to infer densities.

In the planning of the observations and their durations we assumed a geometric albedo of 8% (except for 2002 $UX_{25}$ 12%) and used the Near-Earth Asteroid Thermal Model NEATM [2] with beaming factor $\eta = 1.2$. The corresponding flux estimates are in Table 1, where cold classicals (inclination $< 5°$) are above the horizontal line. 2002 $KX_{14}$, 2004 $UX_{10}$ and 2004 $PF_{115}$ are further classified as inner KBOs.

## 2. Observations

Our 20 targets have been selected from the classicals sample of the open time key programme "TNOs are Cool" [3] for which we have three-band photometric observations with *Herschel* PACS [4]. Our sample includes nine cold classicals and 11 hot classicals. We used the mini-scan map mode for point-sources of the PACS instrument, and observed all three bands (reference wavelengths 70.0, 100.0 and 160.0 $\mu$m) with cross scans. We used the follow-on strategy: the observations were repeated after the target had moved by a distance of 25″ to 50″. This allows us to characterize the sky background.

### 2.1. Preliminary observational results

The difference of our flux estimates (Table 1) compared to the observed fluxes are significant implying higher albedos than the 8% used in calculating the flux estimates: the observed fluxes are on the average 46%

less than estimates for the whole sample, however for cold classicals together with inner hot classicals the observed fluxes are as much as 50-70% less than the estimates. For hot classicals excluding inner classicals the observed fluxes are 20-30% less.

Table 1: Flux estimates at PACS channels 70.0, 100.0 and $160.0\,\mu\mathrm{m}$ for 20 classical KBOs used in observation planning. Known binaries [5] are marked by *.

| Target | Flux **estimates** [mJy] |
|---|---|
| 119951 (2002 $KX_{14}$) | 19.0 / 21.0 / 16.0 |
| (2001 $XR_{254}$)* | 4.0 / 5.0 / 4.0 |
| (2001 $QY_{297}$)* | 4.0 / 5.0 / 4.0 |
| (2001 $RZ_{143}$)* | 3.0 / 3.0 / 2.0 |
| (2002 $GV_{31}$) | 8.0 / 9.0 / 7.0 |
| 79360 (1997 $CS_{29}$)* | 7.0 / 8.0 / 6.0 |
| 88611 Teharonhiawako* | 4.0 / 5.0 / 4.0 |
| (2005 $EF_{298}$) | 5.0 / 5.0 / 4.0 |
| 138537 (2000 $OK_{67}$) | 6.0 / 6.0 / 5.0 |
| 148780 Altjira* | 3.0 / 4.0 / 3.0 |
| 144897 (2004 $UX_{10}$) | 20.0 / 22.0 / 16.0 |
| (2002 $KW_{14}$) | 9.0 / 10.0 / 7.0 |
| (2001 $KA_{77}$) | 4.0 / 5.0 / 4.0 |
| 19521 Chaos | 10.0 / 12.0 / 9.0 |
| 175113 (2004 $PF_{115}$) | 13.0 / 15.0 / 12.0 |
| (2002 $MS_4$) | 18.0 / 22.0 / 18.0 |
| 145452 (2005 $RN_{43}$) | 29.0 / 32.0 / 25.0 |
| 55637 (2002 $UX_{25}$)* | 23.0 / 27.0 / 21.0 |
| 90568 (2004 $GV_9$) | 34.0 / 38.0 / 29.0 |
| 120347 (2004 $SB_{60}$)* | 16.0 / 19.0 / 15.0 |

## 3. Thermophysical modeling

In order to derive diameters and albedos from thermal-IR observations a thermal model is used. This requires assumptions on the temperature distribution on the surface and the emissivity. We use the NEATM with a fitted beaming parameter $\eta$. As an example we show 2002 $KX_{14}$ (Fig. 1). The reflected light gives one constraint in this diameter vs albedo plot (non-linear dotted curve) and thermally emitted light gives another one (straight lines in Fig. 1).

## Acknowledgements

*Herschel* is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA.

Part of this work was supported by the German *Deutsches Zentrum für Luft- und Raumfahrt*, DLR project numbers 50 OR 0903, 50 OFO 0903 and 50 OR 0904.

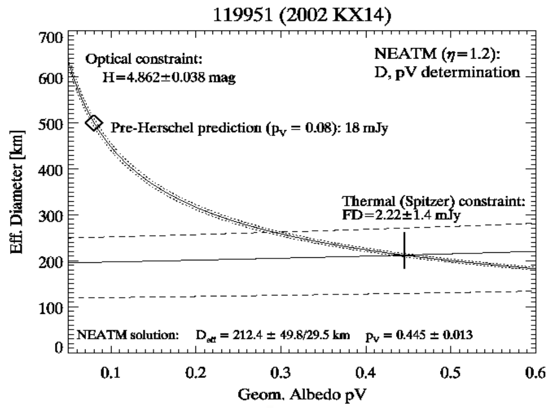


Figure 1: Combining visible and far-IR data to determine both the size and the albedo. The absolute visual magnitude is from [6] and the Spitzer flux from [7].

## References

[1] Petit, J-M., Kavelaars, J.J., Gladman, B., Loredo, T.: Size Distribution of Multikilometer Transneptunian Objects, in The Solar System Beyond Neptune, eds. Barucci, M.A., Boehnhardt, H., Cruikshank, D.P., Morbidelli, A., The University of Arizona Press, ISBN 978-0-8165-2755-7, pp. 71-87, 2008.

[2] Harris, A.W.: A Thermal Model for Near-Earth Asteroids, Icarus, 131, pp. 291, 1998.

[3] Müller, T.G., Lellouch, E., Böhnhardt, H. et al.: "TNOs are Cool": A Survey of the Transneptunian Region, Earth, Moon and Planets, 105, 209-219, 2009.

[4] 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.

[5] Noll, K.S., Grundy, W.M., Stephens, D.C., et al.: Evidence for two populations of classical transneptunian objects: The strong inclination dependence of classical binaries, Icarus 194, 758-768, 2008.

[6] Rabinowitz, D.L., Schaefer, B.E., Tourtellotte, S.W.: The diverse solar phase curves of distant icy bodies I, AJ, 133, 26-43, 2007.

[7] Brucker, M.J., Grundy, W.M., Stansberry, J.A., et al.: High albedos of low inclination Classical Kuiper belt objects, Icarus, 201, 284-294, 2009.