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Studies of Trans-Neptunian objects with Herschel

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Abstract

Determining basic properties of remote solar system bodies is challenging due to their large distances and small angular sizes. Interpreting thermal observations -obtained by infrared space observatories like Spitzer and Herschel- is currently the best method to characterize large samples of trans-Neptunian objects. We observed more than 130 TNOs and Centaurs with the PACS photometer and the brightest ones also with the SPIRE photometer onboard Herschel. Combining data from optical wavelengths to thermal emission data, which for TNOs peak at far-infrared, allows us to determine size and albedo simultaneously (instead of assuming an albedo) and to infer thermal and surface properties (radiometric technique). The TNOs in our sample are between 100 and 2400 km in diameter, and Centaurs down to 30 km. We find diversity in albedos of individual targets as well as between different dynamical classes. We search for correlations between physical and orbital parameters and present the latest results on basic physical properties as well as sample properties of the different dynamical classes.

1. Introduction

Trans-Neptunian objects (TNO) represent the leftovers of the formation of the Solar System [1] and they are analogues to the parent bodies of dust in debris disks around other stars [2, 3]. In addition to Pluto more than 1500 TNOs/Centaurs have been discovered since the first Kuiper belt object in 1992 [4]. Their physical properties (size, albedo, density, shape, spin-properties, thermal properties) provide constraints to the models of formation and evolution of the various dynamical classes of objects in the outer Solar System. The knowledge of albedo is also important in constraining surface composition via spectroscopy (see [5] for an example).

2. Observations

Almost 10% of the known TNOs/Centaurs are included in our Herschel Open Time Key Programme (OT KP) “TNOs are Cool: A survey of the Transneptunian region" [6] and related Science Demonstration Phase, Open Time and Director’s Discretionary Time Programmes. More than 130 TNOs have been observed in PACS photometry mode and part of the sample also in SPIRE photometry mode. The results presented here are mostly based on three-band, multi-epoch photometric observations with Herschel/PACS. We use a consistent method for data reduction, background elimination, calibration and aperture photometry for the entire sample to obtain monochromatic flux densities at 70.0, 100.0 and 160.0 μm for each source. Additionally, we use Herschel/SPIRE flux densities at 250, 350, and 500 μm and Spitzer/MIPS flux densities at 23.68 and 71.42 μm when available [7, 8], and in very few cases also WISE data at 11.6 and 22.1 μm [9]. For a few targets we also obtained full thermal lightcurves in two bands close to the thermal emission peak. As auxiliary data we use reexamined absolute visual magnitudes from the literature and data bases, part of which have been obtained by ground based programmes in support of our Herschel key programme.

3. Results

We derived diameters and albedos via radiometric modeling techniques. However, the thermal emission of an airless body depends not only on size and albedo, but also the object's shape and spin-properties, the surface emissivity, roughness and porosity influence the thermal spectral energy distribution. The different model concepts, as well as the observations taken in early mission phases of Herschel have been presented in a series of papers [10, 11, 12].

As a next step, we focused on samples of three different dynamic classes (we use the Gladman-classification [13], based on 10 Myr time-scale orbit calculations, to distinguish between dynamically hot and cold classicals, Resonants, Plutinos, Scattered-disk and Detached objects): (i) the size/albedo characterization of 15 scattered disk and detached object [14]; (ii) physical characterization of 18 Plutinos [15]; (iii) Herschel/PACS observations and thermal modeling of 19 classical Kuiper belt objects, including new or updated density estimates for six classical binaries [16].

The Herschel measurements also played a key role for the detailed description of large and prominent TNOs: (90377) Sedna and 2010 EK_{139} [17], (136472) Makemake [12, 18], 2012 DR_{30} [19], and (136199) Eris [14, 20].

The interpretation of dedicated PACS and SPIRE multiband observations of the dwarf planet Haumea, 6 TNOs (Huya, Orcus, Quaoar, Salacia, 2002 UX_{25}, and 2002 TC_{302}), and two Centaurs (Chiron and Chariklo) is presented in a very recent work [8]. We derived the size, albedo, and thermal properties, including thermal inertia and surface emissivity. Several targets show a significant decrease of their spectral emissivity longward of 300 μm and especially at 500 μm. In this work we derived updated densities for the binaries Quaoar/Weywot, Orcus/Vanth, and Salacia/Actea.

We will also include currently ongoing studies of the full Spitzer/Herschel samples of classical Kuiper belt objects [21] and Centaurs [22], and an overview of the general thermal properties of Kuiper Belt objects and Centaurs [23]. Also densities will be given for most of the 25 binaries in our sample.

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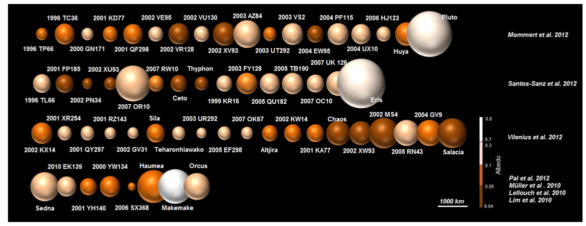

Figure 1: This figure summarizes an intermediate stage of the published diameter and albedo results for 60 objects observed with Herschel. Credit: M. Rengel, MPS.

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