Herschel Open Time Key Programme: TNOs are Cool: A Survey of the Transneptunian Region

Thomas G. Müller (PI), Emmanuel Lellouch (Co-PI), Hermann Böhnhardt (Co-PI), John Stansberry (NASA-PI), Antonella Barucci, Jacques Crovisier, Audrey Delanloup, Alain Deroszewski, Elisabetta Dotto, Rémi Duffard, Sonia Fornasier, Olivier Groussin, Pedro J. Gutiérrez, Olivier Haurnaut, Alan Harris, Paul Hartogh, Daniel Hestroffer, Jonathan Homer, Dave Jewitt, Mark Kidger, Csaba Kiss, Pedro Lacerda, Luna Lara, Tanya Lim, Michael Mauller, Raphael Moreno, Jose Luis Ortiz, Miriam Rengel, Pablo Santos-Sanz, Bruce Swinyard, Thomas Zeller, David Trilling.

MPE Garching, Germany (Instituut voor Sterrenkunde). Observatoire de Paris-Meudon, France. MPS Rotterdam, Lindau, Germany. Univ. of Arizona, USA. Observatorio Astronómico de Roque de los Muchachos, Spain. UKA-CAO, Granada, Spain. Lick, Univ. de California, Berkeley, USA. INAF-CNR, Milan, Italy. INAF-CNR, Palermo, Italy. Laboratoire d’Astrophysique de Marseille, France. ESO, Chile. DLR Berlin, Germany. Observatoire de Paris, France. Open University, Milton Keynes, UK. Univ. of Hawaii, USA. ESEAC, Villanueva del Castillejo, Spain. Konkoly Observatory, Hungary. RAL, Didcot, UK. UB, Birken, CH

Over one thousand objects have been discovered orbiting beyond Neptune. These trans-Neptunian objects (TNOs), represent the primitive remnants of the solar system disk from which the other planets formed, and are an analog for unseen dust parent-bodies in debris disks observed around other main-sequence stars.

The dynamical and physical properties of these bodies provide unique and important constraints on formation and evolution models of the outer Solar System. While the dynamical architecture in this region (also known as the Kuiper Belt) is becoming relatively clear, the physical properties of the objects are only beginning to be revealed. In particular, fundamental parameters such as size, albedo, density and thermal properties are difficult to measure. Measurements of their thermal emission, which peaks at far-IR wavelengths, offers the best means available to determine these physical properties. While Spitzer has provided the first results, notably resulting a large albedo diversity in this population, the increased sensitivity and high-precision measurements of the Herschel instrument will permit profound advances in this field.

Within our accepted project we propose to perform radiometric measurements of 139 objects, including 25 known multiple systems. When combined with measurements of the dust population beyond Neptune (e.g. from the New Horizons mission to Pluto), our results will provide a benchmark for understanding the Solar System debris disk, and extra-solar ones as well.

Sizes and Albedos

- Binary systems are common among TNOs; they are of particular interest.
- Best (nearby) system (Triton’s mean-bulk-density ρ)
- Size and albedo can be measured for both the main and largest TNOs (Pluto, Triton)
- Albedo should not be inferred from photometric brightness comparisons, especially for objects at high inclination.
- Albedo does not work for the faintest objects in the sample.
- Thermal modeling will be used to determine the SED and therefore to infer the albedo-density relation.
- With Herschel, 3.5 μm photometry is different per object, and will help to constrain the composition and size of the debris.
- Herschel will not perform any calibration of the dust colors.
- Thermal properties are based on Spitzer data (Stansberry et al. 2006).

Main goals

(i) A determination of the size distribution of the large (> 200 km) objects, thought to have remained unchanged from their formation phase.
(ii) Systematic searches for correlations between size, albedo, and other physical and orbital parameters, in order to constrain the formation and evolution processes.
(iii) Determination of mass-density for at least 20 binary TNOs, diagnostic of nebular chemistry and interior structure.

The first study of their thermophysical properties, including thermal inertia and surface emissivity.

--- "colors" the picture of the outer regions of our solar system.

Herschel Observations/Modes/AORs

- PACS (all Targets)
  - Chopped/switched photometry (17.7–123 μm) for 14 TNOs.
  - Slitless spectra (41–1000 μm) for 13 TNOs.
  - 80 km and 100 km line spectroscopy.
  - 80 and 160 km line spectroscopy.

- SPIRE (15 bright targets)
  - Large map photometry at 250, 350 and 500 mμm.

- Kinematical constraints on orbital elements.
- Thermal properties are inferred from Spitzer data (Stansberry et al. 2006).

Thermal Lightcurves

- About 20 TNOs exhibit measurable lightcurves, or evident periodicities of their visible magnitude with rotation phases.
- With the exception of Pholus, which is spherical and has a lightcurve due to shape effects, and a couple of bodies believed to be elongating lightcurves from tidal interactions are not expected to observe any deviations from a simple geometric albedo.
- This may influence the determination of the size and allows for any non-axisymmetric features in the rotation period.
- This may impact the determination of the axis ratio and any non-axisymmetric features in the rotation period.
- Thermal lightcurves will provide in addition to determining shape to objects, albedo, constraints on thermal inertia.

Thermal Modeling

- STMs and TPIs provide a map of size, distance, and thermal properties, model debris clouds are based on the best fit to all Spitzer TNO results. The thermal inertia comes mainly from shape modeling, but for the similar small objects the influence of the surface roughness is included in the best-fit model.
- Emission from TNOs as a function of heliocentric distance, as measured by Spitzer.
- The dotted curves are model calculations for 2003 EL61, using the information from Barucci et al. (2006). The best-fit TNO model is based on a model thermal inertia for 2003 EL61: a) the origin of surface emissivity, surface roughness, emissivity, and therefore provide reliable albedo and size solutions.

Herschel TNO/ Centaur Map

- 25 Centaurus (a = 31 AU)
- 29 TNOs (Chambers, Kowal, Weidenschilling, 1998)
- 2 planetary satellites (captured TNOs)

- Colors of TNOs and Centaurs (more than 10 objects) in the infrared: size and albedo variations (Kowal, 1996).
- The size of the objects is proportional to the corresponding object’s distance from the Sun (Kowal, 1996).
- Colors (H, H + 2.5 μm, and H + 5 μm) for 29 TNOs.
- The size distribution of TNOs (Mitton et al. 2013).
- The dot sizes are proportional to the corresponding object’s distance from the Sun.
- Size and albedo comparison (Kowal, 1996).
- Colors (H, H + 2.5 μm, and H + 5 μm) for 29 TNOs.

- Thermal properties are based on Spitzer data (Stansberry et al. 2006).
- Thermal lightcurves at 250, 350 and 500 mμm for 13 TNOs.
- Expected S/N values for 5 objects in all 3 bands (targets have between 15 and 300 mJy at 250 mμm).
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