'Eyes' of Herschel survey enigmatic region beyond Neptune

How trans-Neptunian objects can help us understand our Solar System and its formation

Since its discovery in 1930, Pluto had a special place as one of the planets of the Solar System… until 2006. In August that year, Pluto and other similar objects were the subject of controversy because the term 'planet' was redefined: from then on, only celestial bodies that dynamically dominate their orbital region (among other criteria) would be considered planets. Pluto, in part because of the many small bodies – more than 1,500 were discovered so far – that inhabit the region beyond the orbit of Neptune, lost its planet status. It is now a dwarf planet, part of a group of remote and very cold objects beyond Neptune called trans-Neptunian objects (TNOs).

But these objects also have a special place in the Solar System. They represent the primitive remnants of the disk from which the planets formed, and they inhabit the region where terrestrial water might have originated from. Researchers from the Max Planck Institute for Solar System Research in Germany have recently confirmed that the water of a comet originating in the TNO region has the same composition as the water in our oceans. Scientists are trying to learn about the formation and evolution of the Earth and the Solar System, and TNOs offer several clues.

The physical properties of these TNOs are largely unexplored and the thermal properties are difficult to measure, mainly because these objects are far away. But recent studies, combining new observations carried out with the Herschel Space Observatory and sophisticated models to interpret the data, reported physical and thermal properties of a sample of TNOs. These findings are of significance because they provide unique and important constraints on the almost unprocessed material coming from the frontiers of the Solar System, and on the formation and evolution of the Solar System itself. TNOs represent a fingerprint of the planet-formation era.

Difficulties in determining TNOs thermal properties

The dynamical characteristics of TNOs, such as velocity and orbit, are relatively easy to determine with visible-light telescopes on Earth – and have allowed astronomers to divide TNOs into clubs or dynamic groups. These observations revealed a variety of inclinations of TNOs' orbital planes resulting in a complex orbital architecture, which astronomers cannot yet fully explain. To find out why different groups of TNOs have distinct dynamical properties, scientists need to measure other characteristics of these objects.

Further, measuring physical properties such as size and albedo (percentage of reflected light: low albedo is indicative of a dark surface material like tholin, and high albedo of pure ices) is particularly significant in identifying candidate dwarf planets like Pluto. These Sun-orbiting objects are large enough for their self-gravity to crush them into a nearly round shape but, unlike planets, dwarf planets do not dynamically dominate their orbital region. Objects with more ice (high albedo) become round at smaller sizes than those with more rock – a high-albedo TNO with a diameter larger than about 400 km is considered a strong dwarf planet candidate.

However, estimating physical properties of TNOs is considerably harder than measuring their velocities and orbits, since it requires observations in wavelengths other than the visible. Measurements of thermal emissions, which peak at far-infrared wavelengths, offer the best available means to determine those physical properties. But these wavelengths are mostly absorbed by water vapour in the Earth's atmosphere; therefore, they can be best detected from space.

Herschel comes to help

The Herschel Space Observatory, one of the cornerstone missions of the European Space Agency (ESA) with participation from NASA, is delivering a wealth of observations of celestial targets in the far-infrared and sub-millimetre wavelength range, including objects in the region beyond Neptune. Herschel, with its 3.5-m-diameter telescope (the largest infrared telescope in space) and three scientific instruments onboard, is the only space facility ever developed to fully cover these parts of the electromagnetic spectrum.

In the framework of the Herschel Open Time Key Programme *TNOs are cool: A survey of the trans-Neptunian region*, led by Thomas Müller of the Max Planck Institute for Extraterrestrial Physics in Germany, measurements of around 130 TNOs are being obtained. The team recently reported fundamental properties of TNOs in various studies published in the journal *Astronomy & Astrophysics*. Astronomers believe different TNO groups are the outcome of the various evolutionary processes that sculpted the Solar System. Therefore, it is crucial to investigate the physical properties of TNOs in the different clubs to grasp these various processes.

Pluto-like bodies

Some TNOs show dynamic behaviour similar to that of the dwarf planet Pluto (i.e., with an orbital velocity 2/3 of Neptune), being called Plutinos. Recently, Mommert and collaborators published sizes and albedos of 18 Plutinos – the largest sample to date – based on dedicated Herschel observations. The sample comprises objects which, with the exception of Pluto, range from 150 to 730 km in diameter and between 0.04 and 0.28 in albedo. Some models predict Pluto-sized objects (~2,000 km in diameter) in this club, but future surveys are needed to discover if such objects do exist or if models need to be revised.

Scattered and detached objects

Other TNOs have highly elliptical orbits and sometimes high orbit inclinations: they are members of the 'scattered disk objects' or SDOs club, and their formation is still poorly understood. Another group of TNOs are well outside Neptune's orbit – beyond 50 times the Earth-Sun distance – and are named detached objects.

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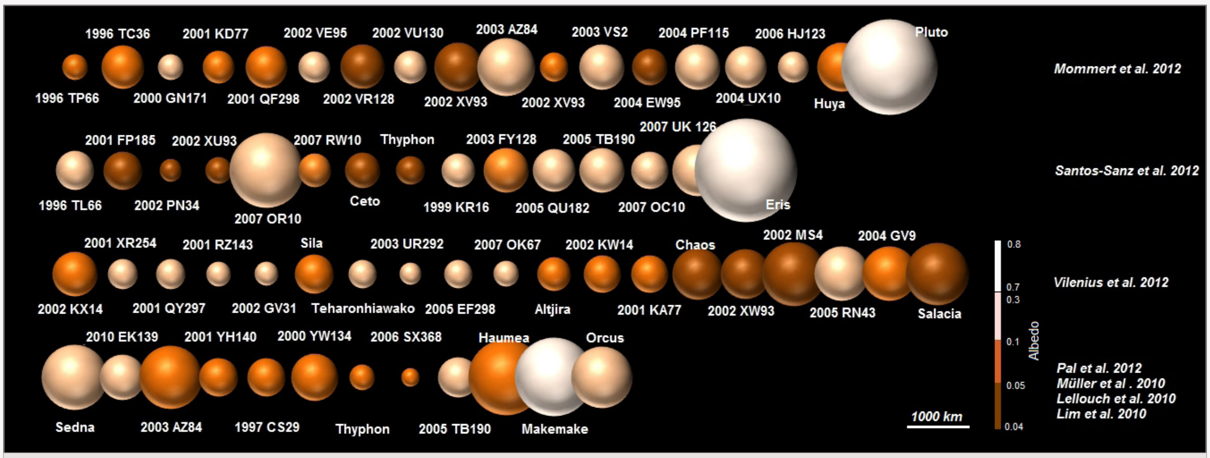

Diagram showing relative sizes of the population of TNOs already published, based on Herschel data (Credit: Miriam Rengel)

From Herschel observations, Santos-Sanz and colleagues have recently characterized 15 SDOs and detached objects, measuring their size, albedo, and other properties. Aside from Eris – a large dwarf planet, – diameters of the sample ranged from 100 to 1,280 km, and low albedos (from 0.04 to 0.09).

Interesting objects in this group include 2010 EK_{139}, and Sedna. As reported by Pál and collaborators, 2010 EK_{139} turned out to have more than a quarter of Pluto's diameter and an albedo higher than previously believed, indicating that the surface might be covered by a large fraction of ice making the object a plausible candidate for a dwarf planet. Sedna is peculiar because of its orbit: it is the most distant detached TNO known, and is therefore important in determining the edge of the Solar System population with perturbed orbits.

Left out: The classicals

Another study, focusing on TNOs that do not belong to any other club and have nearly circular orbits, found yet other large objects. Vilenius and colleagues measured the diameters and albedos of 19 of these so-called classicals and found large objects, such as 2002 MS_4 and 120347 Salacia, among them. They also found the sample to be diverse in terms of albedo. Curiously, these members represent the superposition of two different subclasses, the cold and hot populations, which have high or low inclinations, respectively. Their study found that these TNOs with high inclinations have higher albedos than the TNOs with low inclinations. Most scenarios suggest that the cold and hot populations may have originally formed in different regions, and migrated during early Solar System evolution.

When size matters: Is Pluto the largest TNO?

Previous direct imaging suggested that Pluto's 'twin' Eris was about 5% larger than Pluto, which itself has a diameter of about 2,000 km. More recently, Eris occulted a faint star and astronomers measured a smaller Eris size than previous measurements, but still in the size-range of Pluto. Since the atmosphere of Pluto prevents accurate measurements of the location of its surface, researchers have not yet been able to confirm whether Eris is larger than Pluto. In the old nomenclature, Eris would clearly be a planet.

Herschel is helping to determine if Pluto is indeed the largest object beyond the orbit of Neptune and find more about Eris and other large TNOs. Further, the growing samples of the various clubs observed with Herschel, and the detailed characterization of these objects, will provide information on the present and the original size distribution of these bodies, remnants of the formation of the Solar System. Herschel results will now be fed into formation and evolution models, which will help scientists draw a more accurate picture of our Solar System, our immense home.

Many large TNOs are worlds of their own. With moons, icy surfaces, and (very likely thin) atmospheres, they would likely have been called planets in former times. They can tell us many things about the early stages of the Solar System, and maybe even about how Earth formed and gained its water and organic materials.

One thing is clear: there is still much to find out about the intriguing, distant, icy bodies beyond Neptune.

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