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A compositional study of trans-Neptunian objects using photometric data beyond 2.2 μm

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Abstract

This is a work focus on the study of the surface composition of TNOs using photometric measurements beyond 2.2 μm. We used the Spitzer Space Telescope which has to broad-band filters centered at 3.6 and 4.5 μm. Combining these data with ground-based observations, we studied the surface composition of a sample of 141 objects. Around 80% of our sample has water ice detected on their surfaces.

1. Introduction

Trans-Neptunian objects (TNOs) form the most pristine population in the solar system and yield important information on the composition of the proto-planetary disk from which the solar system was assembled. These objects were formed beyond the "frost lines" of many volatile molecules (H_2O, CO_2, NH_3, N_2...) that may have been directly accreted into them. As a consequence, and akin to comets, TNOs are expected to be mainly composed of a mixture of silicates (derived from dust grains in the nebula) and these molecular ices, with water dominating the ice component; later, irradiation processing of those ices creates heavier organic and hydrocarbon compounds ranging from, e.g., CH_4 to mixtures of high molecular mass substances commonly referred to as "tholins" (e.g., [1, 2]).

2 Data sample

We have observed 141 TNOs during different Spitzer observational cycles, from 2005 to 2016. Our sample is composed of classical objects (those with stable and relatively low eccentricity and inclination orbits), resonant objects (those in mean-motion resonance with Neptune), and detached objects (those with perihelia well outside the orbit of Neptune), see [3].

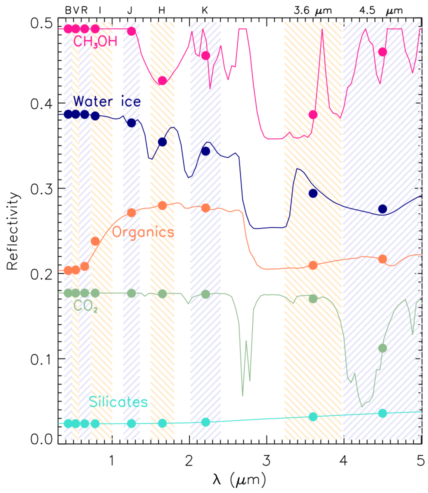

Figure 1: Synthetic reflectance of pure materials typically found on the surfaces of TNOs. The particle size used to build these models is 10 μm. Vertical violet and brown shaded bars indicate VNIR and IRAC/Spitzer filter bands, as labeled on the top x axis. Each material displays a different behavior as a function of the wavelengths in which it is observed. Dots represent the spectrophotometric measurements as given by the convolution of each synthetic material with the set of filters.

3. Methods

We have carried out photometric observations beyond 2.2 μm (where the above-mentioned materials have their fundamental absorption bands, see figure 1) on a sample of 141 objects. We have used the Near Infrared Camera at Spitzer Space Telescope to obtain photometric measurements at 3.6 and 4.5 um. Combining these measurements with ground-based observations, we have built different color-color diagrams in order to study their capacity of diagnosing the surface composition of TNOs. The one that produces the lowest degeneracy is the $K - 3.6$ μm versus $3.6 - 4.5$ μm diagram (see figure 2), which is especially suitable to detect dust mantles, small amounts of water ice not detectable using NIR classical spectroscopy or photometry, and to show surfaces candidate to contain methanol ice such as 2014 MU_{69} [4, 5].

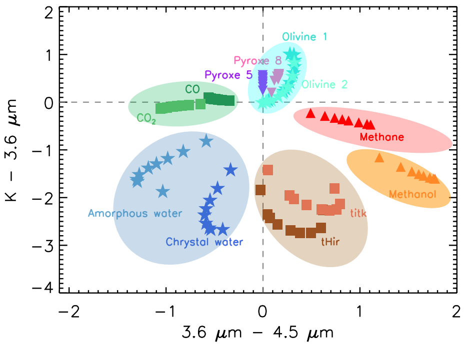

Figure 2: Color-color diagram for $K - 3.6\,\mu$m versus $3.6 - 4.5\,\mu$m. Different colors and shape points show different pure materials of synthetic models. Each material is represented using different particle sizes (10, 20, 30, 40, 50, 70, 90 and 100 μm), being the smallest size the closest one to the center of the diagram. As it can be seen, materials are spread out over the diagram, filling each of them a different region.

4. Results

We have found that $\sim 80\%$ of our sample is composed with a certain amount of water ice, being the most common composition a mixture of water ice, amorphous silicates, and complex organics. Only $\sim 15\%$ could include other ices such as carbon monoxide, carbon dioxide, methane or methanol and only small objects seem to have surfaces dominated by silicates. We will discuss these results and also how, using new technology, as the James Webb Space Telescope, we will be able to incorporate to our sample extremely faint objects ($>$ 23 mag in V-band), thus increasing our knowledge about this primitive population.

Acknowledgements

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