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# Ices in Centaurs and Transneptunians

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## Abstract

An analysis of all the near-infrared spectroscopic data on transneptunian objects (TNOs), and Centaurs, from the complete ESO-VLT Large Program and the literature, has been performed. An overview of the ice content for a total sample of 75 objects with respect to the physical and dynamical characteristics has been carried out.

## 1. Introduction

The small bodies that orbit the Sun beyond Neptune, the Transneptunian objects (TNOs) have very different surface characteristics, with few links between their orbital and surface properties (Doressoundiram et al. 2008).

We have analyzed all the available data from the ESO Large Program (Barucci et al. 2011) and the literature which covered the near-infrared spectral range to detect possible relationships between spectral characteristics and other properties. The data for 75 objects were collected, including 2 satellites (Charon and Hi'iaka). A statistical analysis of the ice content with respect to the physical and dynamical characteristics has been carried out.

## 2. Results

To investigate the ice abundance on surfaces of TNOs and Centaurs we have divided all the available objects into three groups. The first group represents objects for which ice spectral features are statistically significant ($>3\sigma_D$). This sample contains 30 objects for which the presence of ices in the topmost surface layer is confirmed by detection of absorption bands (depth D>3%). 14 of these objects have abundant ice content (D>20%). This group also includes the three objects (Pluto, Eris and Makemake) rich in methane ice. For 18 objects the water ice band at 2.0 μm was not detected within the accuracy of observations, i.e. $<3\sigma_D$. This second group includes objects with clear evidence of the 2.0 μm band, but have been classified as "tentative" as they do not follow the strictly defined statistical criteria, even if the $H_2O$ band is clearly visible on the spectra. The third group consists of objects for which the measured band depth is small ($D \leq 3\%$) or the band was not found within the accuracy of observations (error larger than the band depth D). We define this group as no ice (present on the surface), but higher quality data would be required to be sure that no ice is present.

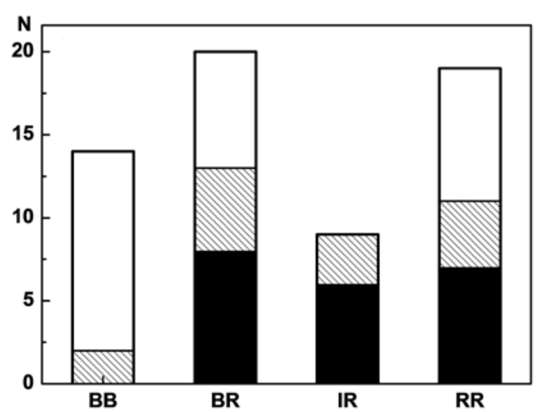


Figure 1: Number of icy (white) and non-icy (black) bodies as a function of their taxonomical class. The hatched areas contain objects with tentative ice detection.

The distribution of ice has been analyzed as a function of their absolute magnitude, taxonomy and dynamical classes. The ratio of icy bodies to all considered objects as a function of their taxonomy is shown in Fig.1. The BB class, containing objects with neutral spectra, is mainly dominated by bodies with abundant water ice content. Figure 2 illustrates a distribution of the depth of the 2 micron band as a function of the spectral slope for the different dynamical types. The depths of the water ice band appear ramdomly distributed with respect to the visible spectral slope. Centaurs have no abundant surface ice content (D<20%).

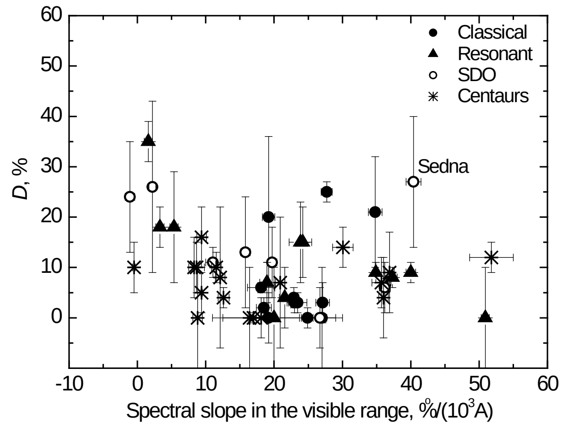


Figure 2: The depth of the 2 µm water band *D* versus the spectral slope in the 0.5-0.8 µm range for objects of different dynamical classes. Haumea's family is not included.

# 4. Conclusions

The major results, from our analysis on 75 objects, are :

1) all objects classified as BB class, containing objects with neutral spectra, have icy surfaces. The objects of the IR class, present only among classical and resonant populations, do not contain any body with "sure" water ice determination;
2) the possible presence of $CH_3OH$ has been mainly detected on objects following the RR class (very red surfaces);
3) no Centaur is found with an abundant surface ice content. The majority of Centaurs seems to have a heterogeneous composition. This could be due not only to the presence of some "fresh" areas resurfaced by impacts, but also to temporal/sporadic activity;
4) objects with abundant water ice content tend to have a smaller absolute magnitude which corresponds in general to a larger size;
5) both icy bodies and bodies with no ice content are abundant among classical objects.

All the objects classified in the group defined as "no detectable ice" could contain small amounts of ice that can be detected in the future when the quality of the spectra is improved by using larger telescopes. Other ices could also exist (DeMeo et al., 2010), but their signatures are hidden inside the S/N ratio of our data and their amount could be up to a few %.

The discovery of transneptunian objects has completely changed our view of the formation and evolution of our planetary system, but it is still difficult to draw a compositional formation and evolution scenario for the TNO population because we are far from having a sufficient knowledge of their surface properties. The faintness of these objects does not currently permit us to improve the observational knowledge of these objects. Moreover, few theoretical models or laboratory simulations (formation processes models, internal evolution models, space weathering effects, etc.) are available.

This population contains objects which are all supposed (on the basis of the available estimation of their densities) to be formed of ices (mainly $H_2O$) and rock in the interior with different surface compositions and properties connected with their evolution history. Irradiation is an important process that can alter the TNO surfaces, but ice grains could also already be irradiated before they accreted into planetesimals.

Our present knowledge of these objects will improve in a substantial way when new sky surveys and new technologies become available and space missions, like Herschel and New Horizons, provide more precise data.

# References


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