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The reddest transneptunian objects

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Abstract

We analysed the reddest objects of the transneptunian and centaur populations, following the taxonomical class RR. The RR class of objects among the studied objects contains more than ¼ of the whole populations, including Centaurs, detached, classical, plutinos and scattered objects, and contains objects with all classes of ice content with a slight majority of sure ice content.

1. Introduction

The last 20 years of studies of transneptunian objects changed completely our view on the formation and evolution of the Solar System. Nevertheless their physical properties remain still unexplained. Barucci et al. [1] characterized the physical properties and the surface composition of these objects, obtaining high quality data for about 40 objects using the most powerful telescopes and instruments at VLT-ESO. A statistical analysis of all existing data including those available in the literature, covering the visible and near-infrared spectral range, was carried out studying all the possible relations between spectral characteristics and other physical and dynamical parameters. The data for 76 objects were collected including two TNOs' satellites (Charon and Hi'iaka) [1] and 2007 OR10 [10] .

The distribution of ices has been analyzed as a function of the object absolute magnitude, taxonomy (Fig. 1) [2] and dynamical classes. The main results are: i) all objects belonging to the BB class have icy surfaces, while none of the objects of the IR class shows "sure" water ice detection; ii) the possible presence of methanol has been detected on very red objects (following the RR class). The distribution of ice content vs. dynamical parameters (semimajor axis, inclination and eccentricity) is almost random, except in the Centaur population, where no high ice content is present on the surface. These results together with the fact that all colors are also randomly distributed, strongly argue in favor of the important mixing that occurred during the solar system formation [3, 4].

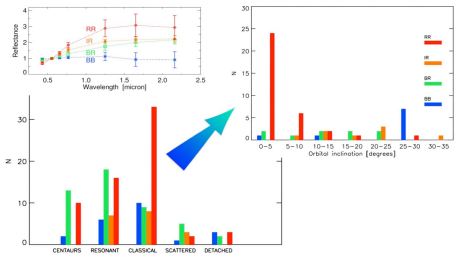

Fig 1: *The lower left panel shows the distribution of the four TNO taxonomic groups (whose average photometric colors are represented in the upper left panel as reflectance values normalized to the Sun in the V-band) within each dynamical class. The right panel shows the distribution of the taxonomical groups, with respect to the orbital inclination relative to the ecliptic plane, for the "classical" TNOs*

2. The extra-red objects

In the complete sample of 76 objects, the CH_3OH ice seems mainly present on RR class objects. This could indicate a chemically primitive nature for these objects. We obtained new observations of the extra red plutino (55638) 2002 VE95 [5]. They show a clear heterogeneity on its surface covered by different ice compounds, such as water ice (4-19%) and methanol (10-12%) and different organic compounds. This object is among the reddest ones with spectral characteristics very similar to (5145) Pholus [6] and (90377) Sedna [7]. These three very red objects (see Fig. 2) belong to different dynamical classes, but have a similar composition, even if Sedna has a more significant variation on the surface with different hydrocarbon ices. The dimensions of the three objects seem also different: about 150 km for Pholus, 250 km for 2002 VE95 and higher than

1000 km for Sedna In this work we concentrate our analysis on the reddest objects of the transneptunian and centaur populations (Table 1). The RR class of objects contains more than ¼ of the whole populations and contains objects with all three classes of ice content (sure, no ices and tentative ice detection) with a slight majority of sure ice content. The dynamical classes include Centaurs, detached, classical, plutinos and scattered objects.

Table 1: *List of the RR objects for which near-infrared spectral observations are available with their dynamical class and H magnitude (see [1] & [10]).*

Object	***Type***	***H***
5145 Pholus	Cen	7.1
15789 1993 SC	3:2	7.0
15875 1996 TP_{66}	3:2	6.9
26181 1996 GQ_{21}	11:2	5.2
31824 Elatus	Cen	10.1
42301 2001 UR_{163}	9:4	4.2
44594 1999 OX_3	SDO	7.4
47171 1999 TC_{36}	3:2	4.9
50000 Quaoar	Cl	2.5
55576 Amycus	Cen	7.8
55638 2002 VE_{95}	3:2	5.3
66652 1999 RZ_{253}	Cl	5.9
79360 1997 CS_{29}	Cl	5.2
83982 Crantor	Cen	9.1
90377 Sedna	Det	1.6
250112 2002 KY_{14}	Cen	9.5
307616 2003 QW_{90}	Cl	5.3
281371 2008 FC_{76}	Cen	9.1
309737 2008 SJ_{236}	Cen	12.2
119951 2002 KX_{14}	Cl	4.4
145452 2005 RN_{43}	Cl	3.9
2007 OR10	SDO	2.0

3. Conclusions

Methanol has been detected mainly on very red objects of the RR taxonomical class (Pholus, Sedna & 2002 VE95). These three red objects have different dimensions and belong to completely different dynamical classes. This could imply that these objects exhibit an almost primordial surface. This is in agreement with laboratory irradiation experiments [8] showing a strong reddening of the spectra composed of methanol. The effect of reddening depends on the composition of the object and on the irradiation history while the thickness of the organic crust depends on the irradiation dose. Brown et al [9], looking at the color diversity on the TNO population, proposed a chemical and dynamical plausible hypothesis where the surface composition and colors are set by formation-location-dependent volatile loss in the early solar system. They concluded that objects formed further in the disk could retain methanol. These results are in agreement with the hypothesis that a substantial mixing has occurred after the TNOs formation but cannot exclude the hypothesis of initial heterogeneity.

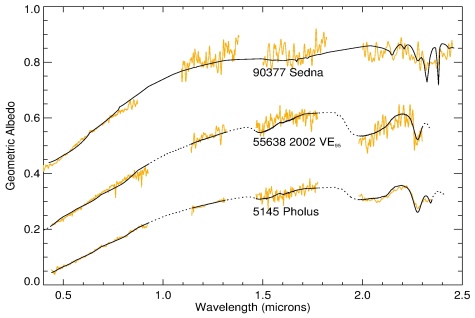

Fig 2: *Among the reddest TNOs, 2002VE95, Sedna and Pholus are probably the most interesting minor icy bodies of the solar system. Despite different physical and dynamical properties, these 3 objects exhibit the presence of mixtures of different ices on their surface. The models are superimposed to the spectra of the objects and suggest the presence of water ice mixed with methanol ice for 2002VE95 and Pholus, and water, nitrogen and methane ices for Sedna. Production of organic material from these probable primordial compounds is highly supported by the extra-red color of their surface and laboratory works [6].*

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