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NEW INSIGHTS ON ICES IN CENTAUR AND TRANSNEPTUNIAN POPULATIONS*

M.A. Barucci¹, A. Alvarez-Candal², F. Merlin^{1,3}, I. N. Belskaya^{1,4}, C. de Bergh¹, D. Perna⁵, F. DeMeo⁶, and S. Fornasier^{1,3}

¹LESIA, Observatoire de Paris, 5, place Jules Janssen, 92195 Meudon Principal Cedex, France

²ESO, Alonso de Córdova 3107, Vitacura Casilla 19001, Santiago 19, Chile

³Université de Paris Diderot-Paris VII, Paris

⁴Institute of Astronomy, Kharkiv National University, 35 Sumska str., 61022 Kharkiv, Ukraine

⁵INAF-Osservatorio Astronomico Capodimonte, Salita Moiariello 16, 80131 Napoli, Italy

⁶MIT, 77 Massachusetts Avenue 54-416, Cambridge, MA 02139, USA

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Editorial correspondence to:

Dr. M.A. Barucci

Observatoire de Paris

F-92195 Meudon Cedex

Phone: +33 14 507 77 75

Fax: +33 14 507 71 44

E-mail: Antonella.Barucci@obspm.fr

Abstract

A Large Program (LP) has been carried out at ESO-VLT using almost simultaneously the UT1, UT2 and UT4 telescopes (Cerro Paranal, Chile). The aim of this Large Program was to obtain simultaneous visible and near-IR spectroscopic measurements (using FORS, ISAAC and SINFONI instruments) with a S/N ratio as high as possible for almost all objects among different dynamical groups observable within the VLT capability.

In this paper we present results on the second half of the Large Program which includes new near-infrared spectroscopy data of 20 objects. For 12 of them for which we had obtained the complete spectral range (V+J+H+K bands), we apply a radiative transfer model to the entire spectral range to constrain their surface composition.

We also present an analysis of all near-IR spectral data available on TNOs and Centaurs from both the complete LP and the literature. An overview for a total sample of 75 objects is thus carried out analyzing the ice content with respect to the physical and dynamical characteristics. The major new results are: i) all objects classified as BB class seem to have icy surfaces; ii) the possible presence of CH_3OH has primarily been detected on very red surfaces (RR class objects) and iii) the majority of Centaurs observed multiple times have an heterogeneous composition.

Key Words: Transneptunian objects, Centaurs, spectroscopy.

1. Introduction

The study of the small bodies that orbit the Sun beyond Neptune, the Transneptunian Objects (TNOs), has completely changed our view of the formation and evolution of the Solar System. It has shown that this region of the Solar System, although very far from the Sun, has been heavily perturbed, as indicated by the presence of bodies with highly inclined and/or very eccentric orbits and the existence of widely different dynamical classes. It has also shown that, although these objects reside in more or less the same region of the Solar System, they can have very different surface characteristics, with few apparent links between their orbital and surface properties (Doressoundiram et al., 2008).

Given the faintness of TNOs, spectroscopic observations of these objects can only be carried out at a limited number of places around the world, since they require large telescopes and well-adapted instruments. Furthermore, they are very time demanding. This is why the number of objects for which high quality spectroscopy was possible, and particularly in the near-infrared range which is essential for surface composition studies, concerned only a small fraction of the objects discovered thus far (about 40 objects out of more than 1200).

The near-infrared spectroscopic observations have been obtained essentially with the ESO-VLT in Chile, the Keck, Gemini and Subaru telescopes in Hawaii and the TNG telescope in the Canary Islands. A few other telescopes have been used to get visible spectra, and some very limited observations have been made in the far-IR with the Spitzer (see Barucci et al., 2008) and Herschel (Mueller et al. 2010) Space telescopes. Various surface compounds have been detected, including ices of water, methane, nitrogen, carbon monoxide, methanol, ethane and ammonia. Some silicates are also present, as well as complex refractory carbonaceous compounds. The largest objects, such as Pluto, Eris, Haumea and Makemake have unique surface properties (see review by Brown 2008) as they have retained the most volatile species. Surfaces of smaller objects are less well known but the existing observations raise many questions. It is very difficult at this point to make the link between their current surface characteristics and all possible processes that could have modified them: different regions of formation for the objects, differences in orbital evolution, solar and cosmic ray irradiation, destructive and non-destructive collisions, etc. In particular, the very red colors of some of them, the existence or absence of water ice signatures in their spectra, the two classes of Centaurs (which are escapees from the Transneptunian region), are some of the main puzzles that remain to be solved. For that, it is essential to increase the sample of objects for which high quality data are available in each of the currently defined dynamical classes (dynamically hot and dynamically cold classical objects, resonant objects, scattered disk objects, detached objects, Centaurs).

The ESO-Very Large Telescope in Chile has played an important role in the spectroscopy of TNOs over the past years. A Large Program (LP) has been carried out at ESO-VLT mainly during 2007-2008 using almost simultaneously the UT1, UT2 and UT4 telescopes (Cerro Paranal, Chile). The aim of this large program was to obtain simultaneous visible and near-IR spectroscopy (using FORS, ISAAC and SINFONI instruments) with as high S/N ratio as possible for almost all objects observable within the VLT capability. The program focused on high quality spectroscopy for objects selected among different dynamical groups.

Results of visible spectral measurements for 43 TNOs and Centaurs obtained in the framework of this Large Program were presented and discussed in Alvarez-Candal et al. (2008) and Fornasier et al. (2009). The near-infrared observations in the range of 1.49-2.4 microns of 21 objects were presented in Guilbert et al. (2009a). Data on a few more objects were published by Protopapa et al. (2009), Alvarez-Candal et al. (2010), DeMeo et al. (2010), Merlin et al. (2009 and 2010a,b), Guilbert et al. (2009b) and Barucci et al. (2008 and 2010). Here we present results on the second half of the LP which includes new data on near-infrared spectroscopy of 20 objects. We also present an analysis of all spectral data available both from the complete LP and the literature, covering the near-infrared spectral range. An overview for a total sample of 75 objects is thus carried out.

2. Observation and Data Reduction

The near-infrared spectroscopy has been performed in the J band with ISAAC and in H+K with SINFONI. In this paper, we present the J spectra for four objects and H+K spectra for 20 objects observed in the framework of the Large Program.

Observational conditions of objects spectroscopically investigated during the second part of the LP are reported in Table 1. For each object we report the observational date and universal time (UT of the beginning of the exposure), the median seeing during the observation, the visible magnitude, the total exposure time in seconds, the airmass value at the beginning and at the end of observation, the observed solar analog stars with their airmass used to remove the solar and telluric contributions, and the instrument used. The V magnitudes are given as measured by Perna et al. (2010) which were generally obtained simultaneously with the SINFONI observations. In a few cases when the object's magnitude was not measured by Perna et al. (2010) we give a catalogue value of the V magnitude, as reported in the ephemerides. Below we briefly describe the specifics of observations and data reduction for each instrument.

2.1 SINFONI observations

SINFONI is an integral field unit spectrograph on Unit 4 (Yepun) of the VLT. It has been used to observe the H and K bands simultaneously with the same grism and a spectral resolution of 1500. The spatial resolution was 0.25 arcsec/spaxels, with corresponding FoVs of 8.0 arcsec.

The instrument was used in the no-AO mode, except during the nights of 2007 December, for which a Laser Guide Star (LGS) was used.

All data were reduced using the SINFONI pipeline versions 1.9.4 and 2.0.0, released by ESO. The reduction followed that described in Guilbert et al. (2009a) until the buildup of the science cubes, but without proceeding with the sky-subtraction. This last step was performed using a more thorough procedure (Davies, 2007) to improve the sky-subtraction and to obtain higher quality data.

Once the cubes are sky-subtracted they are combined to obtain the final science cube. The spectra are then extracted using a cylindrical aperture of 5 spaxels (see below) with QFitsView, developed by the Max Planck Institute (Garching bei München). The spectra of the science objects were then divided by that of a solar analogue star observed the same night, with the same setup and an airmass matching as close as possible that of the science object. The spectra of the analogue star were extracted using the same aperture as the science object to minimize possible systematic geometric effects. The related observational circumstances are reported in Table 1.

One crucial part of the extraction of the reduced spectra was to decide the optimal aperture size to be used. The spectra obtained with SINFONI are not perfectly aligned with the z-axis (wavelength axis), therefore using too small of an aperture could cause an off-center extraction of the spectra at some wavelengths, depending on where we center the cylinder for the extraction. Using an aperture too large to gather all the flux will include places with negative flux (results of the sky subtraction) and will decrease the S/N ratio due to the inclusion of large residuals from the background.

To choose the “optimal” aperture we extracted the spectra of an object using different aperture sizes (from 1 to 14 spaxels, corresponding to 0.25 up to 3.5 arcsec on the sky), and performed two tests. First, we studied the change of the S/N ratio (measured at 1.6 and 2.2 μm) against the aperture size. Second, we computed the slope introduced in the spectra while varying the aperture size. For this test we used an aperture size of 5 spaxels as a reference which our previous experience, based on a trial-and-error approach, indicated as a good first guess. We found that aperture sizes between 5 and 7 spaxels provide a good balance between S/N and spurious spectral slope in the extracted spectra. So we decided to stick to our choice of 5 spaxels to extract the spectra.

The spectra obtained with SINFONI are shown in Fig. 1. All spectra are normalized to 1.55 microns and are shifted vertically by a constant for clarity.

2.2. ISAAC observations

Near-infrared spectroscopy in the J band (1.1–1.4 μm) has been obtained using the SW mode of the ISAAC instrument (equipped with a Rockwell Hawaii 1024 $\times$ 1024 pixel Hg:Cd:Te array), mounted at the VLT–UT1 (Antu). The spectral resolution is about 500 with a 1" slit. The observations were executed by nodding the object along the slit by 10" between two positions A and B. First steps of the reduction procedure were performed using the ESO ISAAC pipeline (which runs through EsoRex, the "ESO Recipe Execution Tool"): flat-fielding, wavelength calibration (through atmospheric OH lines or Xe-Ar lamp lines), A-B (or B-A) subtraction for each pair of frames, correction for spatial and spectral axis distortion, and shifting and adding of the frames. The resulting combined spectrum of the object was then extracted using ESO-MIDAS.

The TNOs reflectivities were obtained by dividing the spectra by that of the solar analog star closest in time and airmass, as reported in Table 1. The spectra were finally smoothed with a median filter technique (e.g., Barucci et al. 2000), with a box of 10 $\text{\AA}$ in the spectral direction and a threshold around 10-25%. Due to the time constraints and priority given to the photometry in this wavelength range we obtained J spectra for only four objects. The obtained spectra are reported in Fig. 3 and 4.

3. Results

In what follows we combine the spectroscopic and photometric data that were obtained from nearly simultaneous visible and near-infrared observations carried out at UT1, UT2 and UT4 VLT–ESO telescopes (Cerro Paranal, Chile) in the framework of the LP. For the H and K bands, we analyzed the spectral behavior measuring the depth of the possible water ice band absorption (at 2.0 μm), and the slope in the K band as described below. Finally for the objects for which we obtained higher quality spectra and a complete range of observations, a surface model has been investigated.

3.1 SINFONI spectral analysis

In order to obtain some quantitative information from the spectra, we computed a set of values to help us characterize a priori the spectra. The parameters we used are the depth D , calculated as the fractional difference in flux at 2.0 μm with respect to that at 1.75 μm , and the slope of the K part of the spectra (S_k), computed between 2.05 and 2.3 microns. The first parameter, defined as

$$D (\%) = (1 - \text{flux}_{2.0\mu\text{m}}/\text{flux}_{1.75\mu\text{m}}) \times 100 \quad (1)$$

gives us an idea of the possible amount of water ice present on the objects' surfaces. It was computed as the median value of the flux between 1.71-1.79 μm and 2.0-2.1 μm . The error assigned to each value of flux was the standard deviation in each interval. The error in D was obtained by error propagation.

The second parameter S_k was computed by a linear fit in the range of 2.05-2.3 μm . It could point to the presence of methanol-like compounds that might affect the slope of the spectra at these large wavelengths.

The results are reported in Table 2. The analysis of these 2 parameters demonstrates the level of diversity in the measured spectra. Given the way the K slope has been defined, it is positive only for objects for which the spectral behavior is red, or for those with a significant H_2O ice content.

3.2 Spectral combination

To interpret the surface composition and apply the best fit model we used the visible spectroscopic data obtained almost simultaneously using FORS2 and presented in Fornasier et al. (2009). We also used the V, J, H and K photometry to calibrate and align the different spectroscopic ranges, as reported and discussed in Perna et al. (2010). The already published V spectra, together with the new J and H + K spectra, calibrated with the simultaneous photometry, are reported in Fig. 2-4.

3.3 Model fits

In order to investigate the surface properties of these objects, we use the spectral model developed by Hapke (1981, 1993). The composition and physical parameters are obtained following the work described in Merlin et al. (2010a). In that work, neglecting the interferences and simplifying the computation at zero phase angle, the geometric albedo is defined as:

$$\text{Alb} = r_0(0.5 + r_0/6) + (w/8) ((1 + B_0) P(0) - 1)$$

where w is the single-scattering albedo and r_0 is the bihemispherical reflectance. The w parameter depends on the optical constants of the material and is described in Hapke (1981). B_0 is the ratio of the near-surface contribution to the total particle scattering at zero phase and $P(0)$ is the phase function, approximated by a single Henyey-Greenstein function. See Merlin et al. (2010a) for a complete explanation.

To investigate the surface composition, we used a set of identified or possible compounds for which optical constants are available. The general approach is to use the chemical compounds that can account for the present signatures, or plausible compounds for these distant objects that can reproduce the general spectral behavior. The code allows iterating with varying albedo, components, quantities and grain sizes with a minimization of the chi square between the model and the observed data. For each object we ran models considering amorphous and crystalline water ice, olivine, Triton, Titan and ice tholins, kerogen, pyroxene, methanol, methane, amorphous carbon and kaolinite.

Results of the best fit models for 12 objects are reported in Table 3 which contains the percentage of the different components and particle size in microns. The results were obtained with albedos in the V band given in Table 3 for which the model gives the best χ^2 . Lykawka and Mukai (2005) found a correlation between the albedo and the object size when $H < 5.5$, suggesting that objects with brighter absolute magnitude should have higher albedo and this is in agreement with our results. For the resonant object 2003 AZ₈₄ the albedo has been derived from Spitzer observations by Stansberry et al. (2008).

The best model fits are reported in Fig. 2-3-4. For two of them (2004 UX₁₀ and 2008 SJ₂₃₆) we present two models as we do not find a single best fit for the entire spectral range. For 10 of the analyzed objects, we needed H₂O (in crystalline or amorphous or both states) to model their surface composition while for four of them (2004 TY₃₆₄, 2004 UX₁₀, 2008 FC₇₆, and 2008 SJ₂₃₆) CH₃OH is necessary to fit the general spectral behaviors. For two objects, we use a blue component like kaolinite, using the method described by Merlin et al. (2010b) to extract optical constants.

3.4 Overview of the spectral behavior

We obtained near-infrared spectra for 12 TNOs and 8 Centaurs, including 11 objects (2003 CO₁, 2004 UX₁₀, 2005 RM₄₃, 2003 MW₁₂, 2007 UK₁₂₆, 2002 KY₁₄, 2003 UZ₄₁₃, 2007 UM₁₂₆,

2007 VH₃₀₅, 2008 FC₇₆, and 2008 SJ₂₃₆) which had not previously been observed in the near-infrared range. Several objects have spectra showing the 2 and 1.5/1.65 μm bands associated to water ices (amorphous/crystalline state) and a few of them also show features at around 2.27 μm due probably to methanol. The deepest spectral band at 2 μm and the largest slope were measured for (145453) 2005 RR₄₃. This object belongs to the Haumea family which is known to have a water ice rich surface (e.g. Barkume et al. 2008). Our spectrum shows the presence of crystalline water ice because of a strong absorption feature at 1.65 μm (see Fig. 4), as reported by previous authors (Pinilla-Alonso et al. 2007, Barkume et al. 2008). The depth of this band seems slightly different between the three different spectra even if the signal to noise ratio is more limited for the data of Barkume et al. (2008) and Pinilla-Alonso et al. (2007). The slope in the near infrared is similar in the three cases as well as the slope observed in the visible spectra. The rotational period ($P=5.08\pm0.04$ h) determined by Perna et al. (2009), in the framework of this LP, is not precise enough to confirm or not the homogeneity of the surface.

Four objects, (145451) 2005 RM₄₃, (15874) 1996 TL₆₆, (208996) 2003 AZ₈₄, and 2003 UZ₄₁₃, also show rather deep water ice bands. All these objects have a neutral color in the visible and belong to the BB taxonomic group (Barucci et al. 2005b). The near infrared spectra of the detached object (145451) 2005 RM₄₃ and the 3:2 resonant object 2003 UZ₄₁₃ (Fig.4) were measured for the first time. The modelling of these spectra implies the presence of crystalline water ice (see Table 3). The spectra of another 3:2 resonant object, (208996) 2003 AZ₈₄, were previously reported by Guilbert et al. (2009) within the first part of the LP and Barkume et al. (2008). The observations performed by Barkume et al. (2008) are not compatible with the presence of crystalline water ice, contrary to the spectrum obtained in this paper (see Fig. 4), where the absorption feature reported at 1.65 μm is compatible with the signature of crystalline water ice. Merlin et al. (2010a) gave more details on modelling and suggested a heterogeneous surface composition of this object. The infrared spectrum of SDO (15874) 1996 TL₆₆ was first presented by Luu and Jewitt (1998). They did not find evidence for absorption features. This object was observed twice within the LP in 2007 (Guilbert et al. 2009) and 2008 (this work). Although the spectra are rather noisy (Fig. 1), the presence of water ice is suggested with around 20% deep absorption band present at 2 μm .

The largest negative slope in the range 2.05-2.3 microns was measured for the classical object (144897) 2004 UX₁₀ in December 2007, however, the spectrum was noisy. Better quality observations in November 2008 showed a smaller but still negative spectral slope. Three more objects, classical (55637) 2002 UX₂₅, and Centaurs 2007 VH₃₀₅ and 2008 SJ₂₃₆, also revealed noticeable negative spectral slopes in the 2.05-2.3 μm range. These objects can be considered as

possible candidates to have methanol-like compounds in their surfaces. New observations are needed for confirmation.

The spectra of the 3:2 resonant object 2003 UZ₄₁₃ (Fig.4), Centaur 2007 UM₁₂₆ (Fig.2), and the classical object (174567) 2003 MW₁₂ show the largest positive slope in the range 2.05-2.3 microns. The best model fitting the spectra of two of them was obtained assuming the presence of ice tholin on their surfaces (see Table 3).

Other measured objects show less pronounced spectral features. For some of them a 2 μm band has been marginally detected while for others, the estimated band depth at 2 μm is within the uncertainties of measurements (see Table 2).

Comparing the new data with previously published data we found two objects with a possible heterogeneous surface composition. These objects are the 3:2 resonant object (208996) 2003 AZ₈₄ (see discussion above), and the classical object (120348) 2004 TY₃₆₄. Barkume et al. (2008) obtained a spectrum of 2004 TY₃₆₄ from 1.4 to 2.4 μm . Their spectrum is mainly flat in this wavelength range and the depth of the absorption band at 2.0 μm is near 4%, which is very close to that measured on our spectrum. However, there is significant variation around 2.25 μm , with a deep absorption band present on our spectrum (see Fig. 2), that we interpret as the presence of CH₃OH, not reported on the previous spectrum. This suggests a heterogeneous surface that should be confirmed in the near infrared and also verified from the visible range.

Looking at the spectral K region for the other objects, some signatures (with different shape and centers) also seem to be present for 2005 RR₄₃ at 2.23 μm and for 2007 VH₃₀₅ at 2.24 μm . For the first object, the only component able to create a feature at 2.23 μm is NH₃ in its pure state but a large band at 2.0 μm is needed. A band at 2.0 μm is indeed visible in the spectrum, but it is already well reproduced by water ice in the models. For 2007 VH₃₀₅, the only possible compound to interpret the absorption band centred at 2.24 microns, could be diluted ammonia in water ice but there is no clear evidence of water ice on its spectrum. Except for these objects for which absorption bands are questionable, we do not report any other absorption features for other objects. For 2003AZ₈₄ and 2005RM₄₃, there is a small feature close to 2.29 microns possibly due to noise. No components available in our data base are able to fit a feature located at this wavelength.

4. Discussion on global analysis

We have analyzed all the available data from both the LP and the literature which covered the near-infrared spectral range to detect possible relationships between spectral characteristics and other properties. Table 4 presents objects for which near-infrared data are available. It

contains the dynamical type of the object, as defined by Gladman et al. (2008), its taxonomic class according to Barucci et al. (2005b), the absolute magnitude H , information on the ice detection, an estimation of the depth of the water ice band at $2.0\ \mu\text{m}$ D , its uncertainty σ_D , as published in the related papers, and their references. In the last column the ice detection criteria have been also added: Y for “sure detection”, T for “tentative detection” and N for “no detection”. The data for 75 objects were collected, including 2 satellites (Charon and Hi'iaka), among which 33 objects were observed during several observing runs.

To investigate the presence of ice on surfaces of TNOs and Centaurs we have divided the objects from Table 4 into three groups (Y, T, and N). The first group (labeled Y) represents objects for which ice spectral features has $D > 3\%$ and are statistically significant ($> 3\sigma_D$). This group also includes 5 objects (2060 Chiron, 10199 Chariklo, 31824 Elatus, 54598 Bienor and 90377 Sedna) for which water ice has been clearly previously detected (see Table 4 for references). This sample contains 30 objects for which the presence of ices in the topmost surface layer is confirmed by detection of absorption bands and classified as “sure”. 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 (see Table 4). For 18 objects the water ice band at $2.0\ \mu\text{m}$ was not detected within the accuracy of observations (i.e. $3\sigma_D$), and are labeled T. This second group includes objects with clear evidence of the $2.0\ \mu\text{m}$ band, but have been classified as “tentative” as they do not follow the strictly defined statistical criteria, even if the H_2O band can be clearly visible on the spectra. The third group (labeled N) 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.

The distribution of ice has been analyzed as a function of their absolute magnitude (Fig.5), taxonomy (Fig. 6) and as a function of their dynamical classes (Fig. 7).

In Fig. 5 all analyzed objects for which D is available have been plotted versus absolute magnitude H . If several measurements of the same object are available, we use the largest value of the measured depth D for further analysis. The most abundant ice content corresponds to the brightest objects (smaller absolute magnitude H), which correspond in general to objects with larger diameter.

The ratio of icy bodies (sure, tentative and no ice) to all considered objects as a function of their taxonomy is shown in Fig.6. The BB class, which contains objects with neutral visible spectra, is mainly dominated by bodies with “sure” and abundant water ice content (see Table 4). The IR class does not contain any object with sure water ice. Centaurs are mainly distributed in the BR and RR classes, with similar H_2O ice content distribution.

In the complete sample of 75 objects, the CH₃OH ice seems mainly present on RR class objects (very red surfaces). This detection could indicate a chemically primitive nature for these objects.

Figure 7 illustrates a distribution of the depth of the 2 micron band as a function of the orbital type. The depths of the water ice band are typically distributed in the same way, excluding the satellite Charon and the objects from the Haumea family for which the depth at 2 μ m is greater. There is no Centaurs found with an abundant surface ice content ($D > 20\%$). In our sample we have only three objects belonging to the cold classical population and all of them have no ice detection on their surface.

The behavior of the presence of ice content and dynamical parameters (semimajor axis, inclination and eccentricity) is shown in Fig.8. The distribution of ice content is almost random and slightly different from that presented by Brown et al. (2007). All classes are distributed randomly, except in the Centaur population, for which no high ice content on the surface is present.

5. Conclusions

In this paper we report the new near-IR observations obtained during the second period of the Large Program performed at VLT-ESO, Chile. New spectra have been obtained in the H+K band with SINFONI for twenty objects and also in the J band with ISAAC for four of them. For 12 of these objects with higher quality data and with complete spectra available from the visible to near-infrared, and the photometric data to properly adjust the different bands, a radiative transfer model has been used to interpret the observed spectra and investigate the surface composition. As described by Barucci et al. (2008) much of the information obtained from spectral modeling is nonunique, especially if the albedo is not available, the S/N is not very high and/or there are no specific features of particular components. Nevertheless, this is the best way we have to investigate the surface compositions of TNOs. For all the objects observed during the LP, the presence of ices has been quantified with the measurements of the D and S_k parameters. All the H & K band spectra of TNOs available in the literature have been collected and analyzed to find correlations with ice abundance, dynamical classes and taxonomical classes.

On the analysis of 75 objects, the major results are :

- 1) all objects classified as BB class objects seem to 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 have been mainly detected on very red surfaces (objects following the RR class);
- 3) the majority of Centaurs observed multiple times have an heterogeneous composition. This seems to indicate a major characteristics of the Centaur population for which the variation affecting the surface could be due not only to the presence of some “fresh” areas resurfaced by impacts, but also to a temporal/sporadic activity. No Centaur is found with an abundant surface ice content;
- 4) objects with abundant water ice content ($D > 20\%$) tend to have a smaller absolute magnitude which corresponds in general to a larger size;
- 5) The classical objects are abundant both among icy bodies and bodies with no ice content. All dynamically cold objects of the classical population in our sample (3 bodies) have no ice.

The surface properties of Centaurs and TNOs are in general different due essentially to their different dynamical evolution. It is important to underline that Centaurs are small but still visible because they are not too far. The surface of these objects should be compared with those of TNOs in the same diameter range. In this last case, we are limited to the brighter ones implying a bias due to the fact that icy objects are usually brighter and easier to be observed.

All the objects classified in the group “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 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 expected presence of more volatile ices (CH_4 , N_2 , CO and CO_2) has been well described (e.g. Levi and Podolak, 2009) for TNOs and depends on their density, radius, and surface temperature.

It is difficult to draw a compositional formation and evolution scenario for the TNO population because we are still far from having a sufficient knowledge of their surface properties. The limits of the available ground-based telescopes 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 (Hudson et al. 2008), but ice grains could also already be irradiated before they accreted into planetesimals.

It is clear that the color of TNOs and Centaurs depends on many parameters, as for example the amount of ice present on their surface and their heliocentric distance. The facts that i) CH_3OH ice seems to be mainly present on very red surface objects, and ii) all neutral surface objects have H_2O ice (at high content) on their surface, provide important constraints to the global scenario. The presence of CH_3OH ice on the reddest objects is in favor of the hypothesis that those surfaces are more primordial. New and well determined albedos, thanks to the Herschel mission (Müller et al. 2010), will allow us to better characterize the surface properties of these populations.

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

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Table 1. Observational circumstances of the new observed objects

Object	Date	Seeing ^b	V ^c	UT start	T _{exp}	Air- mass	Analog (airmass)	Instrument
5145 Pholus	12 Apr 2008	0.40	21.3	7:55	5400	1.140- 1.170	SA110-361s (1.102)	SINFONI
15874 1996 TL66	23 Nov 2008	1.20	20.9*	3:59	9000	1.232- 1.549	Hyades 142 (1.425)	SINFONI
44594 1999 OX3	22 Sep 2008	0.85	21.3	1:21	9600	1.128- 1.034	SA115 271 (1.107)	SINFONI
55576 Amycus	12 Apr 2008	0.95	20.4	3:09	7800	1.350- 1.020	SA102 1081 (1.120)	SINFONI
55637 2002 UX25	04 Dec 2007 ^a	1.05	19.9*	0:45	4200	1.206- 1.249	LD 93 101 (1.219)	SINFONI
	05 Dec 2007 ^a	1.10	---	0:51	1800	1.206- 1.235	HD 1368 (1.241)	SINFONI
95626 2002 GZ32	13 Apr 2008	0.63	19.7*	5:16	3600	1.140- 1.180	HD147935 (1.160)	SINFONI
120061 2003 CO1	12 Apr 2008	0.50	19.6	5:32	7800	1.110- 1.240	SA102 1081 (1.120)	SINFONI
120348 2004 TY364	21 Nov 2008	0.85	20.6	1:34	7800	1.025- 1.076	SA98 978 (1.134)	SINFONI
144897 2004 UX10	06 Dec 2007 ^a	1.05	20.6	0:31	5400	1.121- 1.175	HD 1368 (1.104)	SINFONI
	22 Nov 2008	0.90	---	2:25	8400	1.126- 1.391	SA93 101 (1.335)	SINFONI
145451 2005 RM43	05 Dec 2007 ^a	1.10	20.1	2:17	5400	1.124- 1.198	LD 93 101 (1.190)	SINFONI
	07 Dec 2007 ^a	0.80	20.1	3:54	2160	1.141- 1.194	HD2966 (1.174)	ISAAC
145453 2005 RR43	07 Dec 2007 ^a	1.45	20.1	3:21	6600	1.115- 1.301	Hyades 143 (1.385)	SINFONI
174567 2003 MW12	13 Apr 2008	0.70	20.6	6:24	6600	1.180- 1.090	HD147935 (1.160)	SINFONI
208996 2003 AZ84	22 Nov 2008	0.90	20.5	7:20	5400	1.249- 1.287	SA115 271 (1.109)	SINFONI
229762 2007 UK126	21 Sep 2008	1.05	20.4	7:24	8400	1.139- 1.078	SA93 101 (1.115)	SINFONI
	22 Sep 2008	1.49	20.4	8:37	2520	1.078- 1.099	Hip018768 (1.054)	ISAAC
2002 KY14	21 Sep 2008	0.85	19.9	23:30	5400	1.660- 1.272	SA112 1333 (1.275)	SINFONI
	22 Sep 2008	1.42	19.9	3:00	2880	1.224- 1.319	Hip092515 (1.261)	ISAAC

Object	Date	Seeing ^b	V ^c	UT start	T _{exp}	Air- mass	Analog (airmass)	Instrument
2003 UZ413	21 Nov 2008	1.25	20.6	4:16	7200	1.157- 1.555	SA93 101 (1.183)	SINFONI
2007 UM126	21 Sep 2008	1.05	20.9	3:25	3000	1.216- 1.092	SA115 271 (1.175)	SINFONI
	22 Sep 2008	0.85	20.9	4:27	4200	1.144- 1.087	SA93 101 (1.122)	SINFONI
2007 VH305	23 Nov 2008	1.20	21.4	0:36	4200	1.140- 1.263	SA93 101 (1.167)	SINFONI
2008 FC76	20 Sep 2008	1.05	20.4	23:40	7200	1.440- 1.248	SA112 1333 (1.201)	SINFONI
	22 Sep 2008	1.14	20.4	0:37	3240	1.285- 1.249	Hip092515 (1.261)	ISAAC
2008 SJ236	22 Nov 2008	0.90	20.8	0:30	5400	1.257- 1.398	SA93 101 (1.335)	SINFONI

^aObservations performed in AO mode with LGS

^bSeeing = the median seeing during the observation

^cVisible magnitude from Perna et al. 2010 (except * = reported from the ephemeris).

Table 2. Spectral parameters on observed objects

Number	Name	Date	D (%)	σ D (%)	S _k	σ S _k	Class
5145	Pholus	13 Apr 2008	13.2	11.8	-0.3	0.3	Cen
15874	1996 TL ₆₆	23 Nov 2008	19.5	18.6	-0.6	0.5	SDO
44594	1999 OX ₃	22 Sep 2008	6	5.4	0	0.2	SDO
55576	Amycus	13 Apr 2008	7.4	5.3	-0.4	0.2	Cen
55637	2002 UX ₂₅	04 Dec 2007	11.9	14.3	-1.1	0.2	Cl
55637	2002 UX ₂₅	05 Dec 2007	-	-	-	-	Cl
95626	2002 GZ ₃₂	14 Apr 2008	9.6	5.7	0.1	0.2	Cen
120061	2003 CO ₁	13 Apr 2008	4.6	3.5	0.4	0.1	Cen
120348	2004 TY ₃₆₄	21 Nov 2008	5.8	5.4	-0.6	0.1	Cl
144897	2004 UX ₁₀	06 Dec 2007	20.1	15.5	-1.8	0.3	Cl
144897	2004 UX ₁₀	22 Nov 2008	5.6	9.7	-0.7	0.2	Cl
145451	2005 RM ₄₃	05 Dec 2007	25.5	16.9	0.1	0.4	Det
145453	2005 RR ₄₃	07 Dec 2007	74.5	13.1	7.1	0.7	Cl
174567	2003 MW ₁₂	14 Apr 2008	-4.5	5.3	0.7	0.1	Cl
208996	2003 AZ ₈₄	22 Nov 2008	16.5	12.8	-0.4	0.5	3:2
229762	2007 UK ₁₂₆	21 Sep 2008	11	7.2	-0.5	0.2	Det
250112	2002 KY ₁₄	22 Sep 2008	8.8	8.0	-0.2	0.1	Cen
	2003 UZ ₄₁₃	21 Nov 2008	17.7	10.7	0.8	0.3	3:2
	2007 UM ₁₂₆	21 Sep 2008	-5.1	9.5	1.2	0.3	Cen
	2007 UM ₁₂₆	22 Sep 2008	-	-	-	-	Cen
	2007 VH ₃₀₅	23 Nov 2008	7.5	13.6	-1.0	0.4	Cen
	2008 FC ₇₆	21 Sep 2008	4.1	8.0	-0.2	0.2	Cen
	2008 SJ ₂₃₆	22 Nov 2008	6.9	13	-1.5	0.4	Cen

Table 3. Results on the surface composition with the different components (in %) and particle size (in microns). The particles sizes are given in parentheses. H₂Ocr is for H₂O ice in crystalline state, while H₂Oam is for amorphous state.

Object	Alb	H ₂ Ocr	H ₂ Oam	CH ₃ OH	Olivine	Ice T.	Titan T.	Triton T.	Kero-gen	Carbon
44594 1999 OX ₃	0.05	-	5(30)	-	34(45)	-	24(2)	20(3)	17(30)	-
120348 2004 TY ₃₆₄	0.10	-	14(5)	37(20)	-	-	8(1)	28(3)	-	13(10)
144897 2004 UX ₁₀	0.10	-	-	-	54(12)	-	15(1)	18(1)	13(70)	-
144897 2004 UX ₁₀	0.10	-	-	59(50)	-	-	10(1)	13(3)	18(5)	-
145451 2005 RM ₄₃	0.20	28(20)	14(200)	-	4(5)	-	2(1)	6(1)	-	46(10)
145453 2005 RR ₄₃	0.30	66(20)	21(200)	-	7(75)	-	-	2(1)	-	4(10)
208996 2003 AZ ₈₄	0.12*	13(20)	31(30)	-	-	-	-	10(1)	-	46(10)
229762 2007 UK ₁₂₆ ¹	0.20	-	12(50)	-	-	-	17(1)	32(1)	4(20)	15(10)
2002 KY ₁₄	0.06	-	9(45)	-	-	-	30(1)	33(2)	28(20)	10(10)
2003 UZ ₄₁₃	0.10	17(20)	-	-	-	38(15)	19(60)	3(200)	-	23(10)
2007 UM ₁₂₆	0.14	-	30(10)	-	-	10(5)	-	40(20)	-	20(10)
2008 FC ₇₆	0.05	-	-	26(20)	5(200)	-	16(2)	24(1)	-	29(10)
2008 SJ ₂₃₆ ²	0.07	-	-	-	25(33)	-	2(5)	23(6)	12(20)	-
2008 SJ ₂₃₆	0.07	-	3(200)	26(200)	7(1)	-	7(80)	43(2)	14(20)	-

^{1&2}The models also include 20 and 38%, respectively, of a component with a general spectral behavior close to the kaolinite in the near infrared (see text) and with a particle size of 15 μ m.

Synthetic models of 144897 2004 UX₁₀ and 2008 SJ₂₃₆ including methanol are also presented to have a better fit on the K region and are reported in dashed lines on Figure 2.

* For 2003 AZ₈₄, the used albedo has been derived by Stansberry et al. 2008.

Table 4. List of the objects for which near-infrared spectral observations are available. In the last column the ice detection is reported (Y for “sure detection”, T for “tentative detection” and N for “no detection”)

N	Object	Type	Class	H	Ices	D (%)	σ_D	Reference	Ice detection
1	2060 Chiron	Cen	BB	6.5	H ₂ Ovar	~5 10 +		Fos99 Lu00 Br00a Ro03	Y
2	5145 Pholus	Cen	RR	7.1	H ₂ O, CH ₃ OH	12 13 13	3 12	Cr98 Br00a LP-this paper	Y
3	8405 Asbolus	Cen	BR	9.0	None	0 0 <0	1	Ba00 Br00a, Ro02 Bark08	N
4	10199 Chariklo	Cen	BR	6.4	H ₂ Ovar	~10 + 7-14 <0		BrK98 Br00a Dot03b LP-Gu09b	Y
5	15789 1993 SC	3:2	RR	7.0	None?	0	10	Je01	N
6	15874 1996 TL ₆₆	SDO	BB	5.4	H ₂ O	<20 24 20	11 19	Lu98 LP-Gu09a LP-this paper	T
7	15875 1996 TP ₆₆	3:2	RR	6.9	None	<0	4	Bark08	N
8	19308 1996 TO ₆₆ *	Cl	BB	4.5	H ₂ O	65	5	Br99	Y
9	19521 Chaos	Cl	IR	4.8	None	<0	4	Bark08	N
10	20000 Varuna	Cl	IR	3.6	None?	+		Li01	N
						<0	2	Bark08	
11	24835 1995 SM ₅₅ *	Cl	BB	4.8	H ₂ O	56	6	Bark08	Y

12	26181 1996 GQ ₂₁	11:2	RR	5.2	H ₂ O, CH ₃ OH?	9	2	Bark08	Y
13	26375 1999 DE ₉	5:2	IR	4.7	H ₂ Ovar?	~10 15 <0 <0 +	8 2	Je01 Alv07 Bark08 LP-Gu09a LP-Me10a	T
14	28978 Ixion	3:2	IR	3.2	H ₂ O	6 7	4 4	Bark08 LP-Gu09a	T
15	29981 1999 TD ₁₀	SDO	BR	8.8	None	<0	0	Bark08	N
16	31824 Elatus	Cen	RR	10. 1	H ₂ Ovar	+		Bau02	Y
17	32532 Thereus	Cen	BR	9.0	H ₂ Ovar	+		Ba02, Me05 Li05	Y
18	33340 1998 VG ₄₄	3:2	IR	6.5	None?	<0	10	LP-Gu09a Bark08	N
19	38628 Huyba (2000 EB ₁₇₃)	3:2	IR	4.7	H ₂ Ovar	+		Li01	T
20	42301 2001 UR ₁₆₃	9:4	RR	4.2	None?	<7 +	7	Br00c dB04 Alv07 Bark08	N
21	42355 Typhon	SDO	BR	7.2	H ₂ O	14 11	10 3	Bark08	Y
22	44594 1999 OX ₃	SDO	RR	7.4	H ₂ O?	6	5	Alv10 LP-Gu09a	T
23	47171 1999 TC ₃₆	3:2	RR	4.9	H ₂ Ovar	+		LP-this paper	Y
24	47932 2000 GN ₁₇₁	3:2	IR	6.0	None?	8 4	2 3	Dot03a, Me05 Bark08 LP-Gu09a, LP- Pr09	N
25	50000 Quaoar	Cl	RR	2.5	H ₂ O, CH ₄ , NH ₃ , C ₂ H ₆ ?	<0 <0 4	16 6	dB04, Alv07 Bark08 LP-Gu09a	Y
26	52872 Okyrhoe (1998 SG35)	JC	BR	11. 0	None?	22 25	1 2	Je04 LP-Gu09a Sch07, Da09	T
27	54598 Bienor (2000 QC ₂₄₃)	Cen	BR	7.6	H ₂ O	+		Dot03a	Y
28	55565 2002 AW ₁₉₇	Cl	IR	3.4	None?	4 2	2 2	Bark08 LP-DM10a	N
29	55576 Amycus (2002 GB ₁₀)	Cen	RR	7.8	H ₂ O	+		Dot03a	Y
30	55636 2002 TX ₃₀₀ *	Cl	BB	3.3	H ₂ O	4 16	2 6	Bark08 LP-Gu09a	N
31	55637 2002 UX ₂₅	Cl	IR	3.6	None?	+		Dor05	T
32	55638 2002 VE ₉₅	3:2	RR	5.3	H ₂ O CH ₃ OH?	3 3	2 7	Bark08 LP-Gu09a	Y
33	60558 Echeclus	JC	BR	9.0	None	+		Dor05	T
34	63252 2001 BL ₄₁	Cen	BR	11. 7	None?	7 64	10 1	Li06b Bark08	Y
35	65489 Ceto (2003 FX ₁₂₈)	SDO	--	6.3	H ₂ O	67 64	10 1	Bark08	N
36	66652 1999 RZ ₂₅₃	Cl	RR	5.9	None?	2 12	2 14	Bark08 LP-this paper	N
37	73480 2002 PN ₃₄	SDO	BR	8.2	H ₂ O	5 9 11	4 2 6	Ba06 Bark08 LP-Ba11	Y
38	79360 1997 CS ₂₉	Cl	RR	5.2	None?	<0		LP-Gu09a	N

39	83982 Crantor	Cen	RR	9.1	H ₂ O	13 14 11 6	4 1 4	Dor05 Alv07 Bark08 LP-Gu09a	Y
40	84522 2002 TC ₃₀₂	5:2	--	3.8	H ₂ O	9	4	Bark08	T
41	84922 2003 VS ₂	3:2	--	4.2	H ₂ O	7	2	Bark08	Y
42	90377 Sedna	Det	RR	1.6	H ₂ O CH ₄ , N ₂	+ 27	13	Ba05a, Tr05 LP-Ba10	Y
43	90482 Orcus (2004 DW)	3:2	BB	2.3	H ₂ O, NH ₃ ?	30 + 30 25 35	3 5 4	Fo04 Tr05, dB05 LP-Gu09a, LP- Ba08 Del10 LP-DM10a	Y
44	90568 2004 GV ₉	Cl	BR	4.0	None	0	3	LP-Gu09a	N
45	95626 2002 GZ ₃₂	Cen	BR	6.8	H ₂ Ovar?	<0 10	2 6	Bark08 LP-this paper	T
46	119951 2002 KX ₁₄	Cl	RR- IR ⁺	4.4	None	<0 3	12 4	Bark08 LP-Gu09a	N
47	120061 2003 CO ₁	Cen	BR ⁺	8.9	None?	5	4	LP-this paper	T
48	120132 2003 FY ₁₂₈	Det	BR	5.0	None?	7 -<0	16	Bark08 LP-Gu09a	N
49	120178 2003 OP ₃₂ *	Cl	BB ⁺	4.1	H ₂ O	74	0	Bark08	Y
50	120348 2004 TY ₃₆₄	Cl	--	4.5	H ₂ O	4 6	2 5	Bark08 LP-this paper	T
51	127546 2002 XU ₉₃	SDO		8.0	None?	3	8	Bark08	N
52	134340 Pluto	3:2	BR	- 0.7	CH ₄ , CO, N ₂ , C ₂ H ₆ ?			Ow93, DM10b, Me10b	Y
53	136108 Haumea*	Cl	BB	0.2	H ₂ O	+ 48	0	Tr07, Me07 Bark08	Y
54	136199 Eris	Det	BB	- 1.2	CH ₄ , N ₂			Br05, Me09	Y
55	136472 Makemake	Cl	BR ⁺	- 0.3	CH ₄			Li06a, Br07, Bark08	Y
56	144897 2004 UX ₁₀	Cl	BR	4.5	H ₂ O?	6 20	10 16	LP-this paper	T
57	145451 2005 RM ₄₃	Det	BB	4.4	H ₂ O	26	17	LP-this paper	T
58	145452 2005 RN ₄₃	Cl	RR- IR ⁺	3.9	None?	3 1	2 3	Bark08 LP-Gu09a	N
59	145453 2005 RR ₄₃ *	Cl	BB	4.0	H ₂ O	83 65 74	5 2 13	PA07 Bark08 LP-this paper	Y
60	174567 2003 MW ₁₂	Cl	--	3.6	None?	<0	5	LP-this paper	N
61	202421 2005 UQ ₅₁₃		--	3.4	H ₂ O	6	1	Bark08	Y
62	208996 2003 AZ ₈₄	3:2	BB	3.6	H ₂ O	18 17 17	4 6 13	Bark08 LP-Gu09a LP-this paper	Y
63	229762 2007 UK ₁₂₆	Det	--	3.4	H ₂ O	11	7	LP-this paper	T
64	250112 2002 KY ₁₄	Cen	RR	9.5	H ₂ O	9	8	LP-this paper	T
65	2003 QW ₉₀	Cl	RR ⁺	5.3	H ₂ O	21	11	LP-Gu09a	T
66	2003 UZ ₄₁₃	3:2	BB	4.3	H ₂ O	18	11	LP-this paper	T
67	2004 NT ₃₃	Cl	--	4.4	None?	3	1	Bark08	N
68	2004 PG ₁₁₅	SDO	--	5.0	H ₂ O	10	2	Bark08	Y
69	2005 QU ₁₈₂	SDO	--	3.4	None	<0	2	Bark08	N
70	2007 UM ₁₂₆	Cen	BR	10. 1	None?	<0	10	LP-this paper	N
71	2007 VH ₃₀₅	Cen	BR	11. 5	None?	8	14	LP-this paper	N
72	2008 FC ₇₆	Cen	RR	9.1	None?	4	8	LP-this paper	N
73	2008 SJ ₂₃₆	Cen	RR	12. 2	None?	7	13	LP-this paper	N

74	Charon	3:2		0.9	H ₂ O, NH ₃	58	3	Br00b Me10a	Y
75	Hi'iaka*	Cl			H ₂ O	87	11	Bark06	Y

*Haumea's family, ** new determination of taxonomy class, + the presence of the band was reported in the corresponding paper but its depth was not calculated

References: Alv07 = *Alvarez-Candal et al. (2007)*; Alv10 = *Alvarez-Candal et al. (2010)*; Ba00 = *Barucci et al. (2000)*; Ba02 = *Barucci et al. (2002a)*; Ba05a = *Barucci et al. (2005a)*; Ba06 = *Barucci et al. (2006)*; Ba10 = *Barucci et al. (2010)*; Ba11 = *Barucci et al. (2011)*; Bark06 = *Barkume et al. (2006)*; Bark08 = *Barkume et al. (2008)*; Bau02 = *Bauer et al. (2002)*; Br99 = *Brown et al. (1999)*; Br00a = *Brown (2000)*; Br00b = *Brown and Calvin (2000)*; Br00c = *Brown et al. (2000)*; Br05 = *Brown et al. (2005)*; Br07 = *Brown et al. (2007)*; BrK98 = *Brown and Koresko (1998)*; Cr98 = *Cruikshank et al. (1998)*; Da09 = *Dalle Ore et al. (2009)*; dB04 = *de Bergh et al. (2004)*; dB05 = *de Bergh et al. (2005)*; DM10a = *DeMeo et al. (2010a)*; DM10b = *DeMeo et al. (2010b)*; Del10 = *Delsanti et al. (2010)*; Dor03 = *Doressoundiram et al. (2003)*; Dor05 = *Doressoundiram et al. (2005)*; Dot03a = *Dotto et al. (2003a)*; Dot03b = *Dotto et al. (2003b)*; Fo04a = *Fornasier et al. (2004a)*; Fos99 = *Foster et al. (1999)*; Gr05 = *Grundy et al. (2005)*; Gu09a = *Guilbert et al. (2009a)*; Gu09b = *Guilbert et al. (2009b)*; Je01 = *Jewitt and Luu (2001)*; Je04 = *Jewitt and Luu (2004)*; Li01 = *Licandro et al. (2001)*; Li05 = *Licandro and Pinilla-Alonso (2005)*; Li06a = *Licandro et al. (2006a)*; Li06b = *Licandro et al. (2006b)*; Lu00 = *Luu et al. (2000)*; Lu98 = *Luu and Jewitt (1998)*; Me05 = *Merlin et al. (2005)*; Me07 = *Merlin et al. (2007)*; Me09 = *Merlin et al. (2009)*; Me10a = *Merlin et al. (2010a)*; Me10b = *Merlin et al. (2010b)*; Ow93 = *Owen et al. (1993)*; PA07 = *Pinilla-Alonso et al. (2007)*; Pr09 = *Protopapa et al. (2009)*; Ro02 = *Romon-Martin et al. (2002)*; Ro03 = *Romon et al. (2003)*; Sch07 = *Schaller and Brown (2007)*; Tr05 = *Trujillo et al. (2005)*; Tr07 = *Trujillo et al. (2007)*.

Figure captions

Figure 1ab. Spectra of Centaurs (a) and TNOs (b) obtained with SINFONI and smoothed at a resolution of 250. They are normalized to 1.55 microns and shifted by 1 unit for clarity except 2005 RR₄₃ shifted by 1.5. For 2004 UX₁₀ spectra correspond to Dec 2007 (1) and Nov 2008 (2).

Figure 2. Spectrum of 2008SJ₂₃₆, 2004UX₁₀, 2004 TY₃₆₄ and 2007 UM₁₂₆. Continuous, dashed and dotted black lines represent the synthetic spectrum obtained with Hapke model. The continuous or dashed lines of the model represent the ranges where the model has been computed. Visible and near-infrared photometry data have been converted in reflectance (circles with errors) and used to connect the different part of the spectra. For the objects 2004 UX₁₀ and 2008 SJ₂₃₆, two models have been presented. Reflectance spectra of the last three objects have been shifted by +1.5, +2.5, and +3.5 units for clarity.

Figure 3. Spectrum of 2007 UK₁₂₆, 1999OX₃, 2002KY₁₄ and 2008 FC₇₆. Reflectance spectra of the three last objects have been shifted by +1, +2.5, and +3.5 units for clarity. See caption of Fig.2 for details.

Figure 4. Spectrum of 2005 RR₄₃, 2005 RM₄₃, 2003 AZ₈₄ and 2003 UZ₄₁₃. Reflectance spectra of the three last objects have been shifted by +1, +2, and +3 units for clarity. See caption of Fig.2 for details.

Figure 5. Depth of the 2 μ m water band D versus the absolute magnitude H for objects of different dynamical classes. Haumea's family is not included in the graph.

Figure 6. Number of icy (white) and non-icy (black) bodies as a function of their taxonomical class. Objects for which ice determination is considered as tentative, are shown by hatched areas.

Figure 7. The depth of the 2 micron band as a function of dynamical classes. The members of Haumea's family are shown as open circles. The three cold classical objects of our sample did not show the 2 μ m water ice band in their spectra.

Figures 8ab. Eccentricity and inclination of transneptunian objects vs. semimajor axis for icy (open circles) and non-icy (black circles) bodies. Objects for which ice determination is considered as tentative are shown by grey circles. The three objects with methane ice are included. Haumea's family members are shown by crossed circles. Sedna has been excluded as its semimajor axis is out of the plot.

Figures 1a, 1b.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figures 8a, 8b.

We present an analysis of all near-IR spectral data available on TNOs and Centaurs both from new data from an ESO-Large Program and the literature.

On the analysis of 75 objects, the major results are :

- 1) all objects classified as BB class objects 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 have been mainly detected on very red surfaces (objects following the RR class);
- 3) the majority of Centaurs observed multiple times have an heterogeneous composition. This seems to indicate a major characteristics of the Centaur population for which the variation affecting the surface could be due not only to the presence of some “fresh” areas resurfaced by impacts, but also to a temporal/sporadic activity. No Centaur is found with an abundant surface ice content;
- 4) objects with abundant water ice content tend to have a smaller absolute magnitude which corresponds in general to a larger size;
- 5) the classical objects are abundant both among icy bodies and bodies with no ice content. All dynamically cold objects of the classical population in our sample (3 bodies) have no ice.

The new results provide important constraints to the global formation and evolution scenario for the TNO population.