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Infrared spectroscopy of the largest known trans-Neptunian object 2001 KX_{76}

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Abstract. We report complete near-infrared (0.9–2.4 μm) spectral observations of the largest know trans-Neptunian objects (TNO) 28976 = 2001 KX_{76} taken in two different nights using the new Near Infrared Camera Spectrometer (NICS) attached to the 3.56 m Telescopio Nazionale Galileo (TNG). The spectra are featureless and correspond to a neutral colored object. Our observations indicate that the surface of 2001 KX_{76} is probably highly evolved due to long term irradiation, and that collisional resurfacing processes have not played an important role in its evolution.

Key words. minor planets – comets – infrared – trans-Neptunian objects

1. Introduction

The trans-Neptunian object (TNO) 28976 = 2001 KX_{76} was discovered in May 2001, and it is the largest known TNO (Millis et al. 2001). Assuming a geometric albedo of 4% its diameter is ∼1100 km. TNOs are remnant planetesimals from the early solar system formation stages, populating a region just beyond the orbit of Neptune (Edgeworth 1949; Kuiper 1951), called the Edgeworth-Kuiper belt (EKb). They comprises three dynamical classes: objects in the 3:2 mean motion resonance with Neptune have been described as "Plutinos" (Jewitt & Luu 1996), those beyond about 41 AU as "Classical EKb Objects", and those with a much larger semi-major axis and higher eccentricity than the previous classes are known as "Scattered Disk Objects" (Luu et al. 1997). 2001 KX_{76} has orbital elements that fit with those of the Classical EKb Objects.

The low temperature in the EKb and the low density of TNOs imply they are probably the most pristine objects in the Solar System. So they can provide key information on the composition and early conditions of the pre-solar nebula. Though the study of their surface properties is very important from a cosmogonical point of view, as it could provide important clues to understand the conditions existing at the beginning of the solar system.

A powerful method for remote determination of the composition of volatile surface component of the outer solar system objects is the Near-infrared spectroscopy (Brown & Cruikshank 1997). Due to the small size and large distance of this objects, this technique is actually limited to the largest members of the EKb. Very few near-infrared spectra of TNOs have been already published: Brown et al. (1997) present the spectrum of 1993 SC; Luu & Jewitt (1998) the spectrum of 1996 TL_{66}; Brown et al. (1999) the spectrum of 1996 TO_{66}; Brown et al. (2000) the spectrum of 2000 EB_{173}; Licandro et al. (2001) the spectra of (20000) Varuna (= 2000 WR_{106}) and 2000 EB_{173}; and Jewitt & Luu (2001) the spectra of 2000 EB_{173}, 1999 DE_9, 1996 TS_{66}, and 1993 SC. Even the number of published spectra of TNOs is very low, large different surface properties have been inferred among them. Strong color variations, from neutral to very red objects, have been also reported photometrically by several authors (e.g. Jewitt & Luu 2001; Gil-Hutton & Licandro 2001; Davies et al. 2000; Barucci et al. 2000). This color diversity is confirmed in the reported infrared spectra. But also some absorption bands possibly due to hydrocarbons and/or water ice were observed in the infrared spectrum of some objects (1993 SC, 1999 DE_9, 1996 TO_{66}, 20000 Varuna), while the spectra of other TNOs (1996 TL_{66}, 1996 TS_{66}, 2000 EB_{173}) are featureless in the observed range. This diversity of surface compositions has been observed also in similar objects like Centaurs and irregular satellites (Brown 2000). The observed surface diversity can be attributed to intrinsically different compositions among TNOs and/or to some resurfacing processes (Jewitt & Luu 2001; Gil-Hutton 2002).

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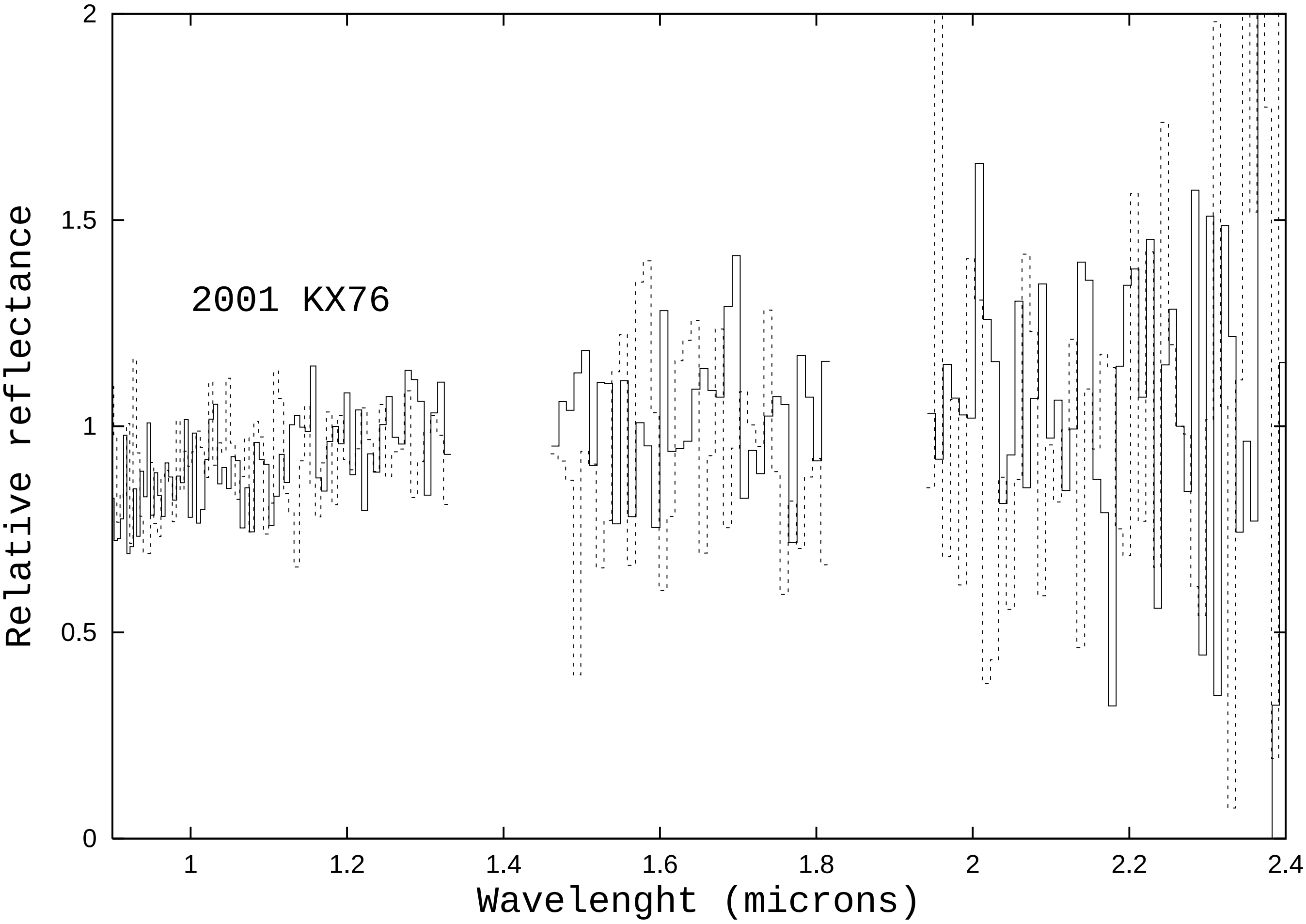

Fig. 1. Reflectance spectra of 2000 KX$_{76}$ obtained in two different nights. Full line correspond to the spectrum obtained on July 6.0 UT, and dashed line to the one taken on July 12.0 UT, 2001. The spectra has been normalized around 1.6 μm. Note that both spectra are identical withing the noise, featureles, and correspond to an object with neutral color.

2. Observations

We have obtained low resolution spectra of 2001 KX$_{76}$ on July 6.0 UT and July 12.0 UT, 2001, with the 3.6 m Telescopio Nazionale Galileo (TNG), using NICS, the near-infrared camera and spectrometer (see Baffa et al. 2001). Among the many imaging and spectroscopic observing modes, NICS offers a unique, high throughput, low resolution spectroscopic mode with an Amici prism disperser (Oliva 2001), which yields a complete 0.9–2.4 μm spectrum. A 1.5$''$ width slit corresponding to a spectral resolving power $R \simeq 34$ and quasi-constant along the spectrum, has been used. The low resolution together with the high efficiency of the Amici prism (about 90% across the useful wavelength range) allowed us to obtain spectra of faint objects like TNOs with a four meter class telescope for the first time (Licandro et al. 2001), and with the advantage of having the whole infrared range measured simultaneously.

The identification of the TNO was done by taking series of images through the J_s filter separated by one our, and by comparing them. The object was identified as a moving object at the predicted position and with the predicted proper motion. The slit was oriented in the paralactic angle, and the tracking was at the TNO proper motion. The acquisition consisted of a series of 5 images of 60 s exposure time in one position (position A) of the slit and then offsetting the telescope by 30$''$ in the direction of the slit (position B). This process was repeated and a number of $ABBA$ cycles were acquired. The total exposure time was 3600 s each night. The reduction and calibration of the spectra was done as in Licandro et al. (2001).

To correct for telluric absorption and to obtain the relative reflectance, the G star Land (SA) 110–361 (Landolt 1992), which has visible colors very similar to that of the Sun, was observed during the same night just after 2001 KX$_{76}$, and at a similar airmass. Land (SA) 110-361 was observed also in previous nights together with the solar analogue star P330E (Colina & Bohlin 1997). Both stars present similar spectra in the infrared region, so we used Land (SA) 110-361 as a solar analogue. The spectrum of the TNO was divided by the spectrum of the solar analogue star, and then normalized to unity around 1.6 μm, thus obtaining the relative reflectance plotted in Fig. 1. Around the telluric water band absorptions the

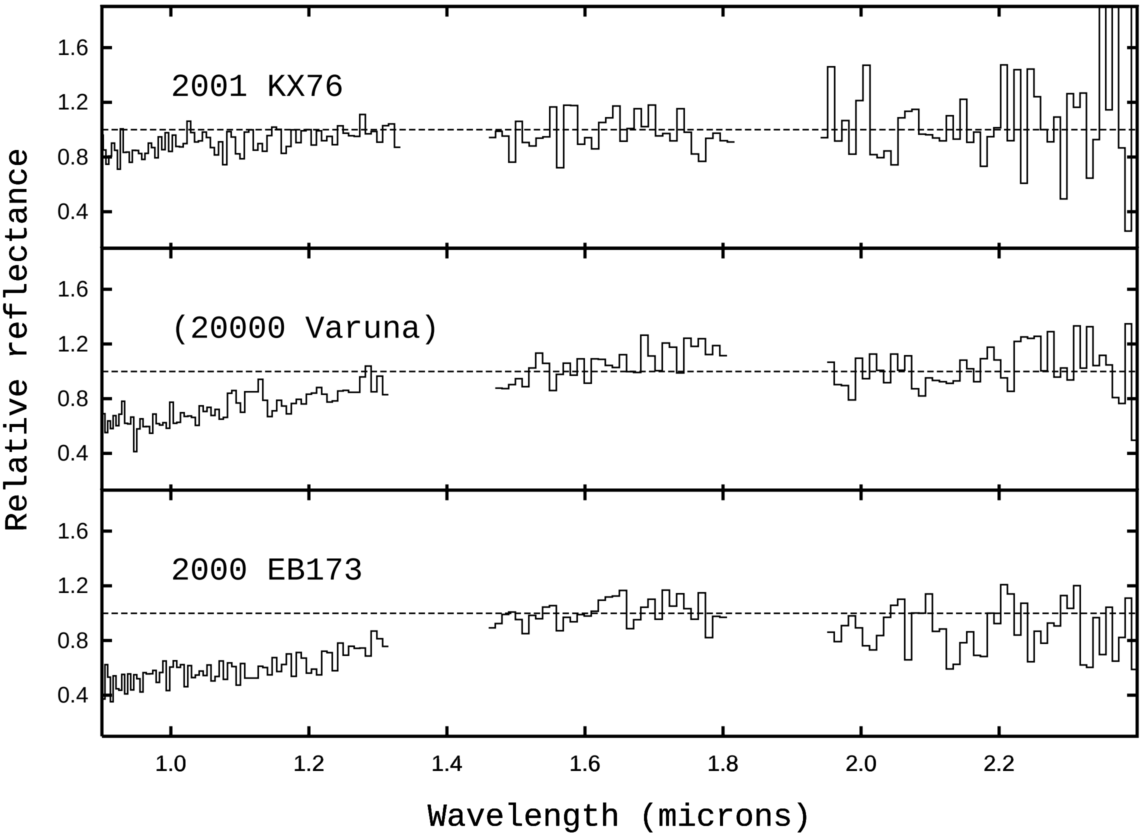

Fig. 2. The reflectance spectrum of 2001 KX_{76} is ploted together with the spectra of Varuna and 2000 EB_{173} taken from Licandro et al. (2001). The spectrum of 2001 KX_{76} is the mean of the spectra presented in Fig. 1. Note that the spectrum of 2001 KX_{76} do not present the strong water ice absorption bands observed in the spectrum of Varuna.

S/N of the spectrum is very low, additionally, the telluric absorption varies between the TNO spectra and the standard stars spectra introducing false spectral features. Therefore, these parts are not included in the final spectra.

3. Discussion

The spectra of 2001 KX_{76} are shown in Fig. 1. Both are identical withing the noise. This means that the object was observed at a very similar rotational phase or that the composition of its surface is very homogeneous. The spectrum of 2001 KX_{76} is featureless and, compared with the very red slope spectra of Varuna and 2000 EB_{173} (Licandro et al. 2001), is almost neutral (see Fig. 2).

The spectrum of 2001 KX_{76} do not show the water ice absorption features at 1.5 and 2.0 μmin observed in Varuna. Similar objects with neutral colors present a large variation in the detected amount of water ice in the surface. Brown et al. (1999) detected water ice in 1996 TO_{66} while Luu & Jewitt (1998) did not in 1996 TL_{66}. Also red TNOs presents this variation in the detected amount of water ice in their surfaces (see Licandro et al. 2001). Though it seems that the diversity between red and neutral TNOs has no relation with the presence of water ice in the surface.

The observed very red color of some TNOs is probably due to an evolved surface which is the result of long term irradiation by solar radiation, solar wind, and galactic cosmic-rays. This results in the selective loss of hydrogen and the formation of an "irradiation mantle" of carbon residues (Moore et al. 1983; Johnson et al. 1984; Strazzulla & Johnson 1991). This process makes that an initially neutral color and high albedo ice becomes redish. But further irradiation gradually reduces the albedo at all wavelengths, and the material becomes very dark, neutral in color, and spectrally featureless (Andronico et al. 1987; Thompson et al. 1987). Gil-Hutton (2002) shows that the total amount of radiation received by TNOs during the age of the solar system can produce very dark, neutral surfaces. The neutral color and the lack of ice features in the spectrum of 2001 KX_{76} suggest that the surface of this object has a very evolved irradiation mantle, that has not suffered from a strong collisional resurfacing process. In contrary, the presence of water ice in the surface of Varuna suggest that it has undergone a strong resurfacing due to collisions, capable of retrieve "fresh" material from below the irradiation mantle. Even if the collisional resurfacing process were not the primary cause of the observed color dispersion of the TNOs according to Jewitt & Luu (2001), it could be the reason to explain why water ice is observed in the very evolved surface of these objects. Thus, more infrared spectroscopy of a large number of TNOs is needed.

4. Conclusions

Two spectra of 2001 KX_{76}, obtained in different nights, are presented. Both are almost identical withing the noise, suggesting that the TNO was observed at a very similar rotational phase or that the composition of its surface is very homogeneous. The spectra are featureless and correspond to a neutral colored object. This suggest that the surface of 2001 KX_{76} is probably highly evolved by long term radiation and that any possible collisional resurfacing process did not erode significantly its irradiation mantle.

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