X-shooter Science Verification Proposal

Title: Surface composition of TNO and Centaurs to investigate the structure and the evolution of the primordial solar nebula.

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Abstract:

The bodies beyond the orbit of Neptune are among the most primitive objects of the Solar System. They are considered the remnants of the external planetesimals swarm and they can provide essential information on the processes that dominated the evolution of the early solar nebula. The knowledge of the physical properties and the composition of these objects is essential to investigate the nature and structure of the protoplanetary nebula at large heliocentric distances.

The aim of this proposal is to carry out simultaneous visible and near–infrared spectroscopic observations of Centaurs and Trans-Neptunian Objects (TNOs) to look for spectral features diagnostic of ices, mineral compounds (as silicates and/or organics), and products of aqueous alteration processes. Their identification will allow us to retrieve the surface composition of the observed objects investigating their history and thermal evolution.

Scientific Case:

The Edgeworth-Kuiper Belt (EKB) is believed to contain remnant material from the formation of the outer planets. In this region, icy planetesimals have formed and have grown to larger bodies such as Trans-Neptunian Objects (TNOs). Centaurs, whose orbits are between Jupiter and Neptune and are chaotic with very short lifetimes ($\sim 10^6$ years), are believed to have escaped from the EKB. Due to their common origin, TNOs and Centaurs contain the most primordial material that we can observe today.

Up to now, more than 1200 TNOs and about 90 Centaurs are known: however, their physical and dynamical properties are far from being understood. A huge variety of spectral behaviors has been found, suggesting a great diversity of surface composition. A new taxonomy has been obtained which identified four groups on the basis of the their colors (neutral/flat to red, see Barucci et al. 2005, AJ 130, 1291). This diversity has often been attributed to different collisional evolution states and different levels of surface alteration due to space weathering produced by high-energy radiation. The very red surface colors may be due to long term irradiation by cosmic rays. High-energy radiation bombardment of mixtures of CH_3OH, CH_4, H_2O, CO_2, CO and NH_3 ices, produces a "radiation mantle" which is hydrogen-poor, carbon-rich and therefore dark (Strazzulla, 1997, Adv. Space Res. 19 n7, 1077; Strazzulla 1998, In "Solar System Ices", Astrophys. Space Sci Lib. 281). The neutral color could be produced by deposits of fresh icy material from the body interior or from an impactor after major collisions, or by re-condensation of a temporary atmosphere produced by intrinsic gas and dust activity. A possible cometary-like activity has been suggested too, but further observations are needed to confirm this hypothesis.

The stony ingredients of the original EKB objects should be primarily of silicate nature. Their detection is extremely difficult, since they may be covered by ice and/or organic mantles. However absorption features detected between 600 and 1600 nm in the Centaur Pholus have been attributed to such (Cruikshank et al., 1998, Icarus 135, 389).

NIR spectroscopic observations are useful to detect the presence of organic materials on the surface of

TNOs and Centaurs. Absorption bands typical of water ice, solid N_2 and methane ice, too, have been identified in the reflectance spectra of several Centaurs and TNOs observed in the NIR range (Brown et al. 1998, Science 280, 1430; Brown et al. 1999, ApJ 519L, 101; Brown et al. 2005, ApJ, 635, L97; Barucci et al. 2005, AA 439, L1; Barucci et al. 2006, AA 455, 725; De Bergh et al. 2005, AA, 437, 1115; Licandro et al. 2006 AA 447 329; Guilbert et al. 2009, Icarus 201, 272).

Spectroscopic observations in the optical range have revealed the presence of features at 600, 745 nm (2000 GN171, Lazzarin et al. 2003, AJ, 125, 1554), and at ∼700 nm (2000 EB173, Lazzarin et al. 2003) which are very similar to those found in several main belt asteroids believed to have undergone aqueous alteration. Aqueous alteration is a low temperature chemical alteration of materials which takes place in presence of liquid water. Its detection might indicate the presence of water ice in the original bodies, that were heated sufficiently during their early evolutionary phases to develop the alteration at their surface. As hydrous altered materials seem to be present in comets and hydrous silicates have been detected in Interplanetary Dust Particles and micrometeorites and have been probably originated in the solar Nebula, it would not be surprising to find aqueous altered materials in TNOs. As suggested by Jarvis and Vilas (2000, BAAS 32, 65.11), if the presence of spectral characteristics usually related to aqueous alteration processes will be confirmed on the surface of TNOs and/or Centaurs, a mechanism to produce them even at large heliocentric distances must be defined.

We are applying for UT2+xshooter time to carry out simultaneous optical and NIR spectroscopic observations of TNOs and Centaurs thus to investigate their surface composition. In particular we want to look for:
i) ices: signatures of hydrocarbon ices (e.g. CH_4, C_2H_2, C_2H_4, C_2H_6) could be observed in the K band at 2200-2300 nm, and in the H band at 1660, 1720 and 1729 nm (CH_4). While absorption features due to water ice would be observable at 1520 and 2030 nm. Reaching a relatively high SNR (≥30) we could distinguish between the presence of crystalline (through the 1650 nm signature) or amorphous H_2O ice. Taking into account that TNOs and Centaurs distances from the Sun are such that the water ice should be amorphous, the presence of crystalline water ice on their surface could be due to continued outgassing as a result of cryovolcanism (Jewitt and Luu, 2004, Nature 432, 731) or continuous micrometeorite impact leading to vaporization and subsequent re-condensation of crystalline water (Brown and Calvin, 2000, Nature, 287, 107).

ii) other mineral compounds: the presence of organic compounds (tholins, kerogen, carbons) and silicates (olivines, silicates,...) can be investigated in the optical range. In addition, spectral signatures at 430, 500, 550, 600-650, 700 and 800-900 nm could indicate the presence of hydrated silicates. These spectral features are related to charge transfer transitions which are usually forbidden and possible only in the presence of liquid water. The detection of these features together with those at 1400 and 2200 nm, would imply the presence of liquid water on the surface of TNOs and a temperature near the melting point for at least a short period of time in the past. It is extremely important to confirm the detection of these features which have been reported just for a few objects and to search for them on the whole TNO and Centaurus population.

A radiative transfer model, already applied to several TNOs and Centaurs, will be used to model the surface of the observed objects, including the presence of several possible materials. Moreover, laboratory spectra of minerals, meteorites and ices will be compared with the acquired spectra.

We note that the use of xshooter in place of 2 or 3 different spectrographs which are not capable of simultaneous observations, is critical to be able to carry out visible and near-infrared spectroscopy of each object in the same viewing geometry. In order to properly model the surface composion of a TNO or a Centaur it is fundamental to make sure that the multi waveband spectra refer to the same rotational phase.

Calibration strategy:

We will need to observe a minimum of 2 solar analog for each observed target. In particular we will need to bracket the target observation with that of two different solar analog at similar airmass. No telluric observation is necessary. Both the science target and the solar analogs will be observed using the

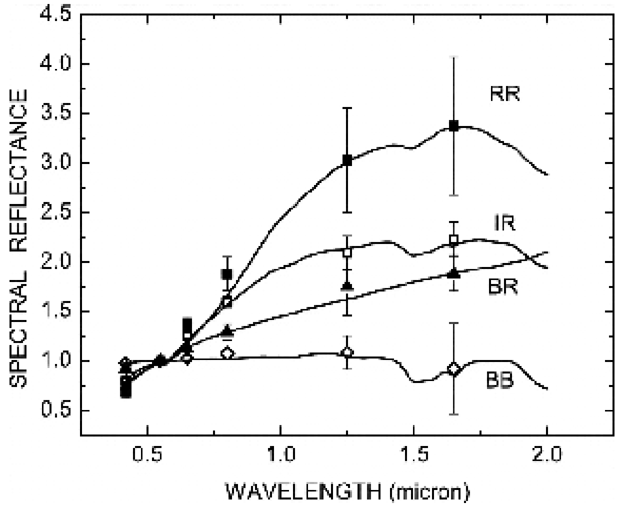

Figure 1: Average values of the reflectance of the broadband colours obtained for each taxonomic class, normalized to the Sun and to the V colour (Figure from Barucci et al. 2005). For each group the compositional model of the spectrum of one of the members of the group is superposed. For RR the spectral model of 47171 1999 TC36 (Dotto et al. 2003, Icarus 162, 408) is superposed; for BB the spectrum of 90482 Orcus (Fornasier et al. 2004, AA 422, L43); for IR the spectrum of 26375 1999 DE9 (Doressoundiram et al. 2003, AJ 125, 2721); and for BR the spectrum of 63252 2001 BL41 (Doressoundiram et al. 2003, AJ 125, 2721)

AutoNod on slit template to facilitate the removal of the sky background in the NIR.

Targets and number of visibility measurements

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
60558 Echeclus	14 26 05	-10 51 17	19.9	SLT	approx. coords at Jul 15 2009
47932 2000 GN171	14 17 36	-16 29 51	20.8	SLT	approx. coords at Jul 15 2009
28978 Ixion	16 49 34	-23 50 01	19.5	SLT	approx. coords at Jul 15 2009
50000 Quaoar	17 12 43	-15 17 18	19.1	SLT	approx. coords at Jul 15 2009
120178 2003 OP32	21 42 03	+03 50 02	20.4	SLT	approx. coords at Jul 15 2009
136199 Eris	01 41 22	-04 16 06	18.8	SLT	approx. coords at Jul 15 2009
47171 1999 TC36	01 28 01	+00 19 54	19.8	STL	approx. coords at Jul 15 2009

Time Justification:

We propose to observe three targets among those listed in the above section; the actual choice depending on the SV slot which will be devoted to the program observation. We are applying for 1.5 hr integration time for the V$\sim$19 mag targets, 2hr integration time for the V$\sim$20 mag targets, and 3hr integration time for the fainter targets at V$\sim$21 mag. For the V$\sim$19 and V$\sim$20 mag targets we add 15 more minutes of telescope time to include the acquisition and readout overheads and 30 more minutes for the observation of the two solar analogs. The target which require an integration time of 3 hr will need two acquisitions. Asking for the observation of 3 objects and needing a total time of 2:15-4:00 hr per target (again depending on the magnitude), we ask for a total telescope time of 1 night. However, even the observation of a single TNO or Centaur would be useful to test our science case.