New results of NEO-SURFACE: Near Earth Objects - SURvey oF Asteroids Close to the Earth

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Introduction

There is a high degree of diversity in terms of physical properties among the Near Earth Object (NEO) population: some objects have very elongated shapes, others are tumbling asteroids, very long and very short rotational periods are observed, and even binary and ternary systems are known. A great diversity is also seen among the distribution of taxonomy classes, which reflect to some extents the chemical and mineralogical surface composition: among the main belt Q and S-type objects are mostly located in the inner asteroid belt, C-types are distributed from the mid to the outer belt, and D-types are in the outer belt.

The study of the physical nature of NEOs is compelling in view of the potential hazard posed to our planet. Physical characterization of NEOs is essential to define successful mitigation strategies in case of possible impacts. In fact, whatever the scenario, it is clear that the technology needed to set up a realistic mitigation strategy strongly depends upon the knowledge of the physical properties of the impacting object.

NEOs can also be suitable targets for space missions, but in order to guarantee both the technical feasibility and the high scientific return of the mission, physical characterization is needed. Unfortunately, our knowledge of the structure and composition of NEOs is still rather limited, since less than 10% of the known NEOs have spectral types determined from observations.

In order to increase the present knowledge of the physical properties of NEOs future targets of mitigation, rendez-vous and sample-return missions we are carrying out a survey called NEO-SURFACE: Near Earth Objects - SURvey oF Asteroids Close to the Earth (www.oa-roma.inaf.it/planet/NEOSurface.html).

The survey

We focused our effort on:

i) The so-called Potentially Hazardous Asteroids (PHAs), having close approaches with the Earth in the near future;
ii) NEOs accessible for a rendez-vous space mission characterized by a total delta-V lower than 10.5 km/s. The delta- V is in this case the velocity change needed to be applied to an already free flying spacecraft to reach a target asteroid at a given semi-major axis *a* (as a reference the Solar System escape velocity is 12.3 km/s).

For PHAs, the derived physical parameters are fundamental to estimate the response to non-gravitational forces (mainly to the Yarkovsky effect), model the future dynamical evolution, and assess the mitigation technologies to be used in case of impact with the Earth.

For NEOs suitable targets of a rendez-vous space mission, the knowledge of the physical properties is needed to guarantee both the technical feasibility and the high scientific return of the mission. Ground-based physical characterization is crucial to the choice of the target for a sample return mission, since for this kind of mission the cost is extremely elevated and it depends on the orbit of the chosen object.

In our survey are presently included data for 40 objects (27 PHAs and 13 low delta-V NEOs) observed in the 0.4 - 2.5 μm spectral range.

Observations

Data here presented have been collected in three different runs (December 2012, July and August 2014) at the the Telescopio Nazionale Galileo (TNG) located at the Roque de los Muchachos Observatory in La Palma, Canary islands.

During the runs of December 2012 and August 2014 visible spectra were acquired using the DOLORES detector (Device Optimised for the LOw RESolution), with the low resolution blue (LR-B) grism, and a 2 arcsec slit width, oriented along the parallactic angle to reduce the effects of atmospheric differential refraction. Visible photometry was performed with the DOLORES instrument during the observational run of July 2014, using the broadband B, V, R and I filters.

Calibration and extraction of the spectra were done using MIDAS and following standard procedures. The different spectra of the same asteroid take at subsequent time are summed. For the visible photometry images were reduced using standard procedures with the MIDAS and IRAF software packages. The absolute calibration of the magnitudes was obtained by means of the observation of several Landolt (1992) standard fields.

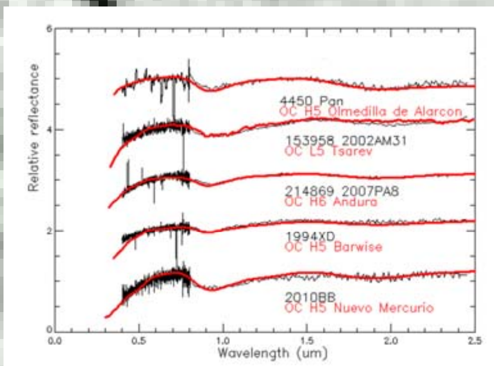

Fig.1 Visible spectra for five Potentially Hazardous Asteroids together with their meteorite analogues, combined with the NIR spectra made available by the MIT-UH-IRTF Joint campaign for NEO Reconnaissance. The spectra are normalized at 0.55 μm and shifted by 1 in reflectance for clarity.

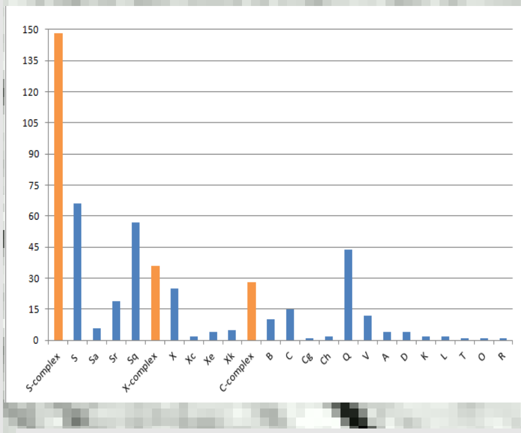

Fig. 2 The distribution of taxonomic classes for our sample of 21 objects, together with PHAs with spectral types determined from observations. Notice the prevalence of S-complex asteroids, which account for more than half of the total sample of 255 PHAs with physical characterization. This is probably due to the high efficiency of the transport mechanisms from the inner main belt, where S-types are more common, into near-Earth orbits. However an observational bias, since C-type asteroids are generally darker, could not be excluded.

Results

During the three runs we observed a global sample of 21 PHA and 2 low delta-V NEOs. For a detailed analysis of the low delta-V asteroids, see Ieva et al. (2014, A&A 569, 59).

To better constrain taxonomic classification we combined visible spectra with infrared data, when available, from the MIT spectral catalog (http://smass.mit.edu/catalog.php). Five objects are shown for comparison in Fig. 1.

To assess the taxonomic class of the PHAs we performed a χ^2 best-fit method between the collected spectra and the most representative one of each class of the Bus-DeMeo taxonomy (DeMeo et al. 2009, Icarus 202, 160). For 9 asteroids color indexes were computed and they are reported in Tab.1.

Sixteen asteroids were classified as belonging to the S-complex, three were classified as belonging to the C-complex, one belong to X-complex and one is a D-type. Nineteen of these objects were taxonomically classified for the first time.

Using the M4AST online tool (Popescu et al. 2012, A&A 544, 130), we compared through a χ^2 method our observed spectra and the whole sample of meteorite spectra included in the RELAB database. To identify the suitable meteorite analogue class for each observed PHA, we checked the presence and position of diagnostic spectral features, taking into account also the meteorite and NEA albedo and considering the overall spectral match. We also compared the spectral parameters of the observed bodies with meteorite spectral parameter ranges (see e.g. Clark et al. 2011, Icarus 216, 462 and Dunn et al. 2013, Icarus 222, 273), ending up with a few meteorites belonging to the same group, which can be considered as suitable spectral analogues. We confirmed a general good match between S-complex asteroids and ordinary chondrite meteorites.

Object	B	R	I	V	B-V	V-R	V-I
1994 CJ1	19.37	17.93	17.79	18.62	0.75	0.69	0.83
1995 SA	19.10	17.87	17.53	18.22	0.88	0.35	0.69
2002 SR41	19.60	18.36	17.91	18.54	0.06	1.18	0.63
2004 LJ1	19.24	17.98	17.69	18.55	0.69	0.57	0.86
2005 UK1	19.82	18.38	18.17	18.93	0.89	0.55	0.76
2008 LV16	19.41	18.05	17.80	18.52	0.89	0.47	0.72
2010 LE15	20.09	18.55	18.37	19.16	0.93	0.61	0.79
2010 NY65	19.45	18.12	17.60	18.62	0.83	0.50	1.02
2014 ER49	19.52	18.08	17.66	18.56	0.96	0.48	0.90

Tab. 1 Magnitudes and color indexes for 9 PHAs observed at TNG during the July 2014 run.

Conclusion

Our analysis points to a prevalence of silicate S-types, over more porous carbonaceous C-types among PHAs and low delta-V asteroids. Several studies suggest that this is probably due to dynamical effects, since S-types are more common in the inner main belt and they are closer to the 3:1 resonance, which pump their eccentricity and push them into near-Earth orbits. However a observational bias, due to the fact that S-types are brighter, cannot be excluded.

The NEOWISE infrared survey (Masiero et al. 2011) suggests that there are lots of low albedo C-types among the NEA population, which are probably not seen due to a selection effect. C-types are the most promising and interesting targets for an astrobiological mission, since they contain pristine material and probably organic, prebiotic compounds. For this reason in the next observational campaigns we will focus mainly on small, faint NEAs, in order to look for more primitive objects.

Our data also enlarged by 8% the global sample of 255 PHAs with some physical characterization (Fig. 2). The physical characterization of a potential impactor represents the first step toward designing a space mission devoted to either mitigation or direct exploration by spacecraft. Objects of different composition tend to respond in different ways to mitigation techniques. Therefore ground-based spectroscopic surveys, like NEO-SURFACE, are likely to provide fundamental contribution to this purpose.