VISIBLE SPECTROSCOPIC SURVEY OF POTENTIALLY HAZARDOUS ASTEROIDS FROM THE ASIAGO OBSERVATORY IN THE FRAMEWORK OF THE NEOROCKS PROJECT

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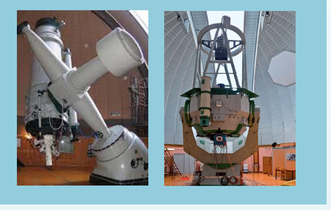

Abstract: We present an update of our ongoing spectroscopic survey of Near Earth Objects (NEOs), performed with the Asiago Telescopes. The program is part of the EU-funded NEO Rapid Observation, Characterization and Key Simulations (NEOROCKS) project, of the call SU-SPACE-23-SEC-2019 from the Horizon 2020 (grant agreement n. 870403) https://www.neorocks.eu/ focused on the acquisition and analysis of data of new discovered small size objects.
The importance of NEOs is widely recognized as they can help to investigate the origin and evolution of the Solar System, in particular the origin of life and water on Earth. They are possible future mining resources, and they are also possible threatening objects to our planet. This is particularly true for the Potentially Hazardous Asteroids, a subgroup of NEOs characterized by orbits that can make close approaches to the Earth and large enough to cause significant regional damage in the event of an impact. So, it is important and urgent to know in detail their dynamical, physical, and compositional properties in order to have more information to establish mitigation strategies.

Observational Data: The observational program started in January 2020 and is performed with the 1.22m Galileo Telescope and at the 1.80m Copernico Telescope at the Asiago Observatory, Italy. The first one is equipped with a Boller & Chivens spectrograph, a long-slit (250 micron aperture, corresponding to 3 arcsec) and a grating of 300 lines/mm in the spectral range 0.45-0.9 micron. The detector is an Andor iDus DU440 camera with EMCCD (2048x512 pixel) and provides a spatial scale of 1 arcsec/pixel. The second one is equipped with AFOSC (Asiago Faint Object Spectrograph and Camera), a long-slit (134 micron aperture, corresponding to 1.69 arcsec) and a Volume Phase Holographic Grisms (VPH6) of 285 lines/mm that yields a dispersion of 3.5 A/pixel with low resolution, R = 500, in the spectral range 0.4-1 micron. The detector is a an Andor DW436BV camera which use an E2V CCD4240 AIMO back illuminated CCD (2048X2048 pixels).

Asteroid	Type	Size (m)	Tax	Meteorite
1990UQ	PHA	900	Sq	Ordinary Chondrite
1991 DG	PHA	500	Xe	Carb. Chondrite
1991 VH	NEO	500	?	Ordinary Chondrite
1997GL3	PHA	200	V	Achondrite
1998 OR2	NEO	2100	Xk	Carb. Chondrite
1999 AP10	NEO	1200	S	Ordinary Chondrite
1999 HF1	NEO	4400	Cb	Carb. Chondrite
1999 HL49	NEO	1300	R	Ordinary Chondrite
1999TC5	NEO	700	L	Achondrite
1999YK5	NEO	3879	B	Carb. Chondrite
2000 YH4	NEO	700	A?	Achondrite
2001 WS1	PHA	1400	D?	Carb. Chondrite
2002 AU5	NEO	1100	C ?	Carb. Chondrite
2002 PZ39	PHA	900	?	Carb. Chondrite
2003 AF23	PHA	240	C	Carb. Chondrite
2003 SW222	NEO	1300	A	Achondrite
2003 WR21	PHA	482	Sq	Ordinary Chondrite
2005 WJ56	PHA	710	Xc	Enstatite Chondrite
2008 AF4	PHA	400	O	Ordinary Chondrite
2008 TZ3	PHA	270	Cb	Carb. Chondrite
2010 DF1	NEO	159	L	Achondrite
2011YQ10	NEO	500	V	Achondrite
2012 BC20	NEO	600	Sq	Ordinary Chondrite
2013PY6	NEO	500	D?	
2015NU13	PHA	400	O	Ordinary Chondrite
2017 HW1	NEO	900	Cb	Carb. Chondrite
2019 WO2	PHA	30	Sq	Ordinary Chondrite
2019 WR3	PHA	90	K	Carb. Chondrite
2020 RF	NEO	120	K	Carb. Chondrite
2020 ST1	PHA	140	Xc	Carb. Chondrite
2020 WU5	PHA	600	Cgh	Carb. Chondrite
2020 XU6	PHA	220	?	Unusual CI
2021 LQ24	NEO	300	Sa	Ordinary Chondrite
APOPHIS	PHA	375	Sq	Ordinary Chondrite

TABLE 1: The analyzed asteroids are reported. For each object the type, size (m), taxonomy and meteorite analogous are shown. The colored ones correspond to the spectra shown in Figure 1 (green) and Figure 3 (yellow).

Data reduction and analysis: The spectra have been reduced using the standard Image Reduction and Analysis Facility (IRAF) routine and normalized at 0.55 micron. After the usual procedures for spectra reduction (bias subtraction, flat field division etc…), each spectrum is then divided by the appropriate solar analogue taken during the same night with similar airmass.
We perform the taxonomic classification through a comparison with spectral types from the Bus & Binzel Taxonomy (2002) and with laboratory meteorites spectra from the Relab database. In Table 1 the analyzed asteroids and their taxonomic classification are reported.

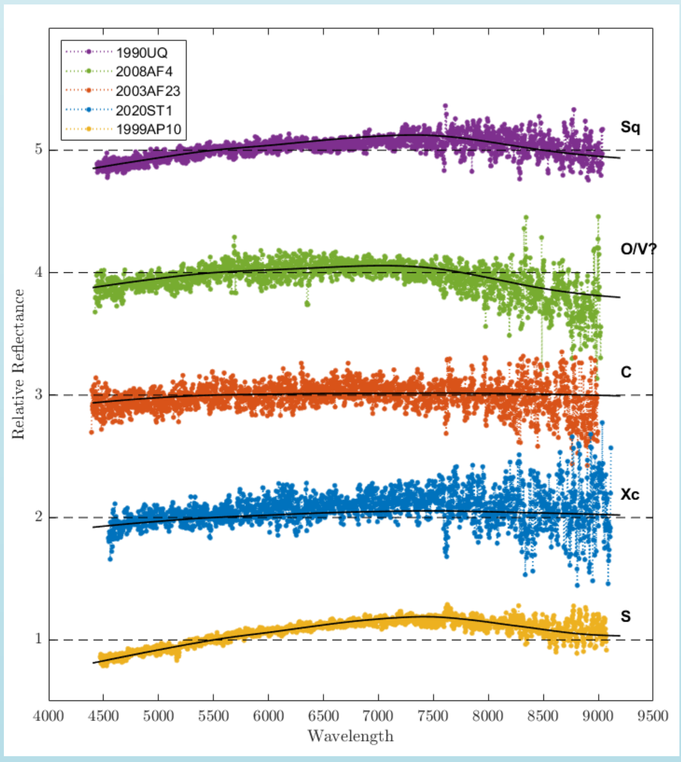

FIGURE 1: Spectra of five objects and their mean spectral type. The spectra have been taken at the Galileo Telescope, normalized at 5500 Å and shifted for clarity.

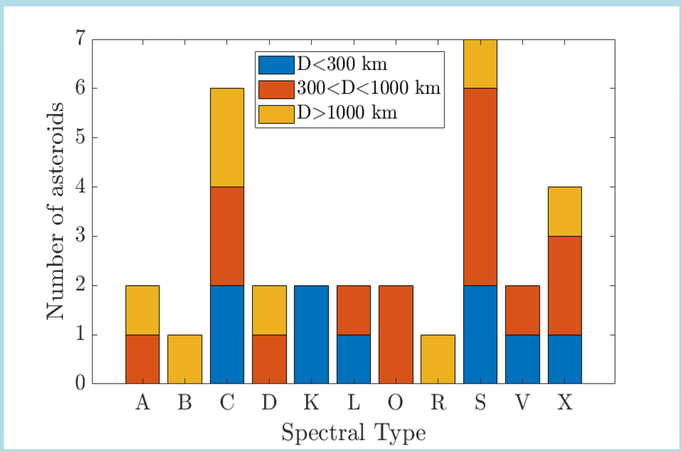

FIGURE 2: Distribution of the analyzed NEOs within the different taxonomic classes. Each color refers to the size of the objects.

Results: We have observed about 70 NEOs, 28 of which are PHAs, with a size range that span from 30 m to more than 1 km. Some of them are newly discovered, and most of them have an unknown taxonomic classification or not a clear one yet. Figure 1 shows the spectra of five asteroids taken with the Galileo Telescope with their mean spectral type.
Up to now we have found different types of asteroids, spanning from the more common silicate S to carbonaceous C, and also some rare types as O or B. Figure 2 shows the taxonomic types distribution of the analyzed objects with the size.
We study the correspondence between asteroids spectral type and meteorites spectra taken from the Relab database.
Figure 3 shows the spectra of five asteroids obtained with the Copernico Telescope and their meteorite analogous. It is interesting to notice the good link between the spectra of peculiar types, such as 1999TC5 (L type) and 1997GL3 (V type) and their analogous Urelite and Diogenite.
Some asteroids (e.g., 1988OR2 and Didymos) have been observed during their rotational periods, allowing the study of their surface variegation. In particular, we are performing a systematic follow up of the PHA Didymos since the impact of the DART spacecraft on 26th September 2022 on its moon Dimorphos with spectroscopic observations started in October 2022 as soon as the object was observable in the north hemisphere and that we will carry on until it remains visible, in spring 2023.

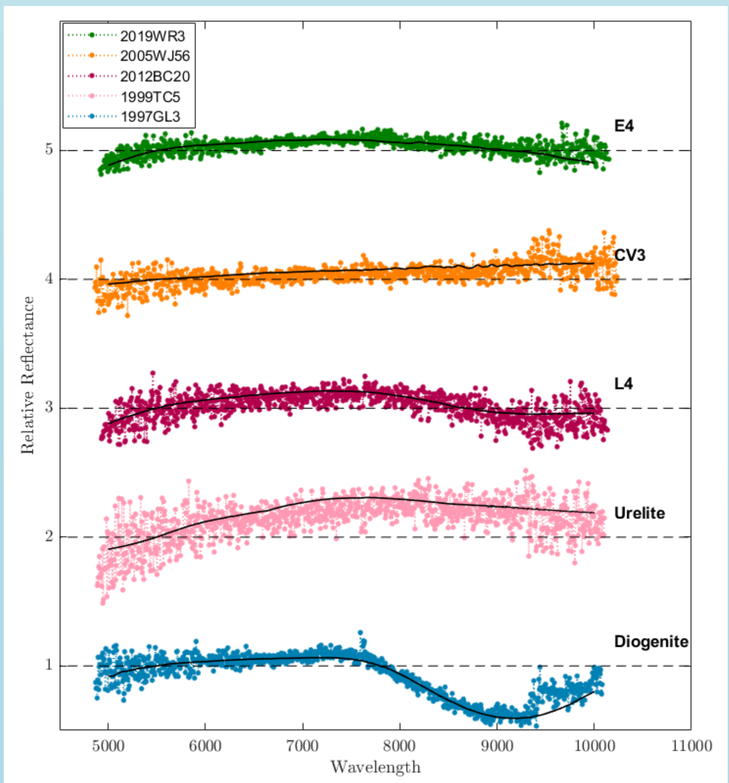

FIGURE 3: Spectra of five objects together with their meteorite analoguos. The spectra have been taken at the Copernico Telescope, normalized at 5500 Å and shifted for clarity.

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