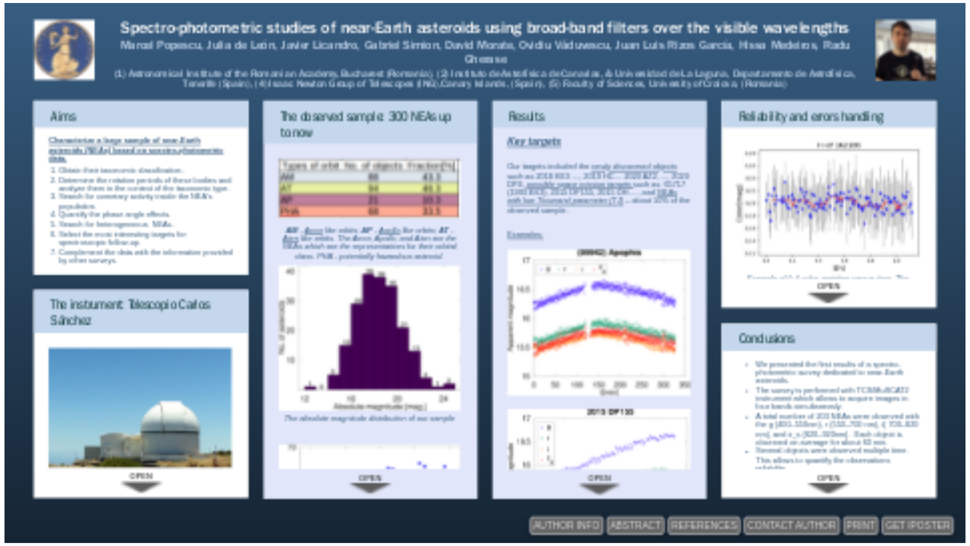
Spectro-photometric studies of near-Earth asteroids using broad-band filters over the visible wavelengths



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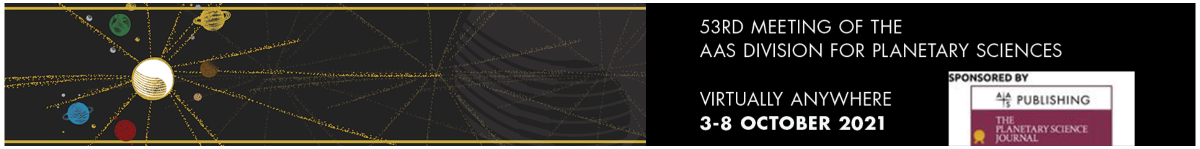
PRESENTED AT:



AIMS

Characterize a large sample of near-Earth asteroids (NEAs) based on spectro-photometric data.

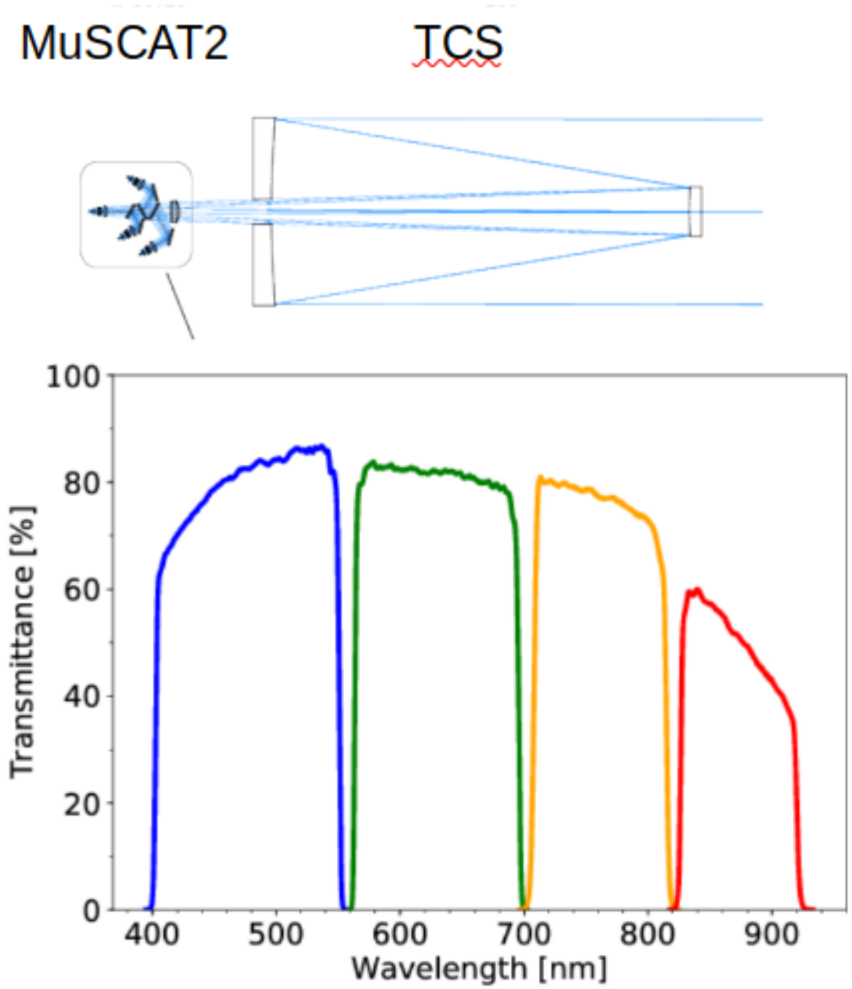
1. Obtain their taxonomic classification.
2. Determine the rotation periods of these bodies and analyze them in the context of the taxonomic type.
3. Search for cometary activity inside the NEA's population.
4. Quantify the phase angle effects.
5. Search for heterogeneous NEAs.
6. Select the most interesting targets for spectroscopic follow-up.
7. Complement the data with the information provided by other surveys.

THE INSTRUMENT: TELESCOPIO CARLOS SÁNCHEZ

Telescopio Carlos Sánchez (TCS) is a 1.52 m telescope located on Teide Observatory, Izaña (Tenerife, Canary Islands, Spain) at 2390 m altitude.


Telescopio
Carlos Sánchez

MuSCAT2 instrument mounted on TCS. The four cameras provide images obtained simultaneously with four different filters.

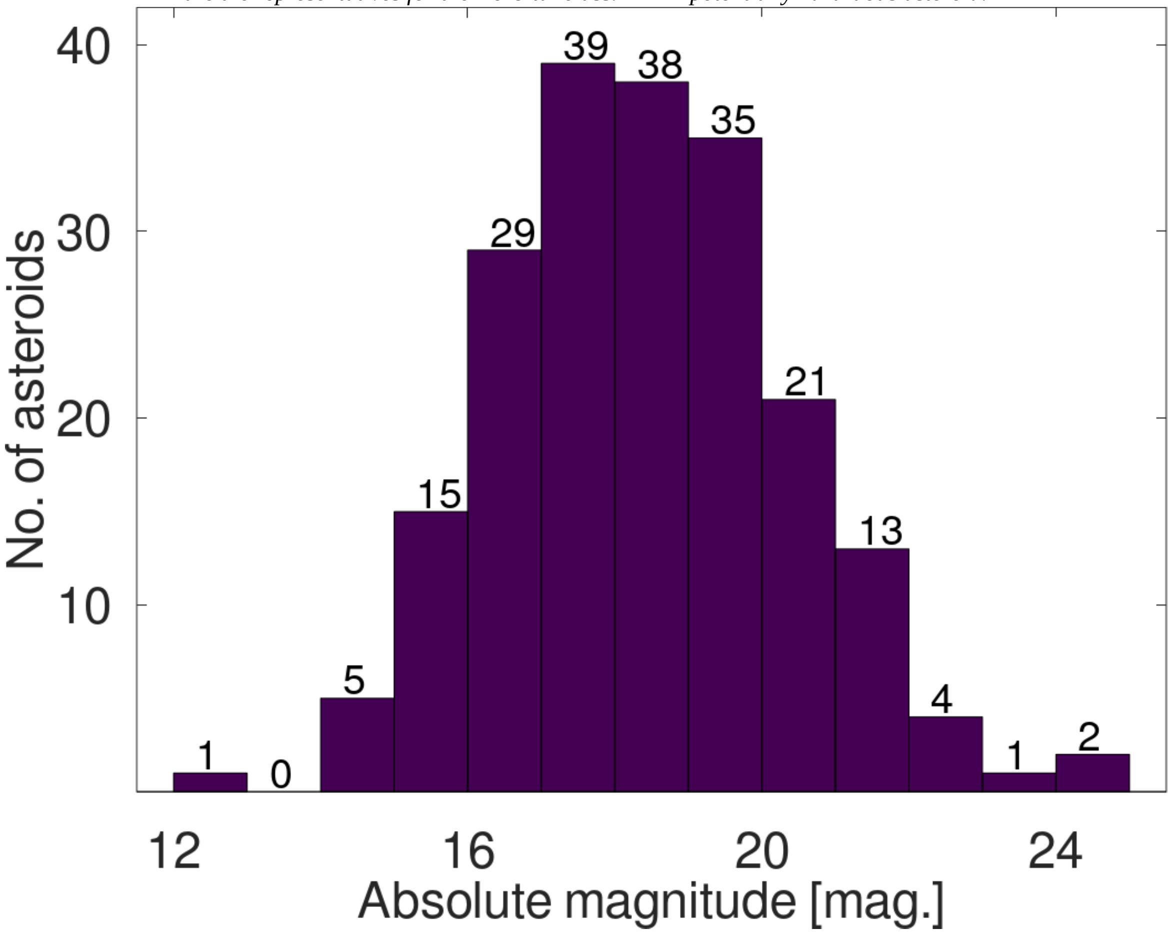


*Total transmittance of the MuSCAT2 instrument in **g** (400–550nm), **r** (550–700 nm), **i**(700–820 nm), and $\mathbf{z_s}$ (820–920nm) bands (Narita et al. 2019).*

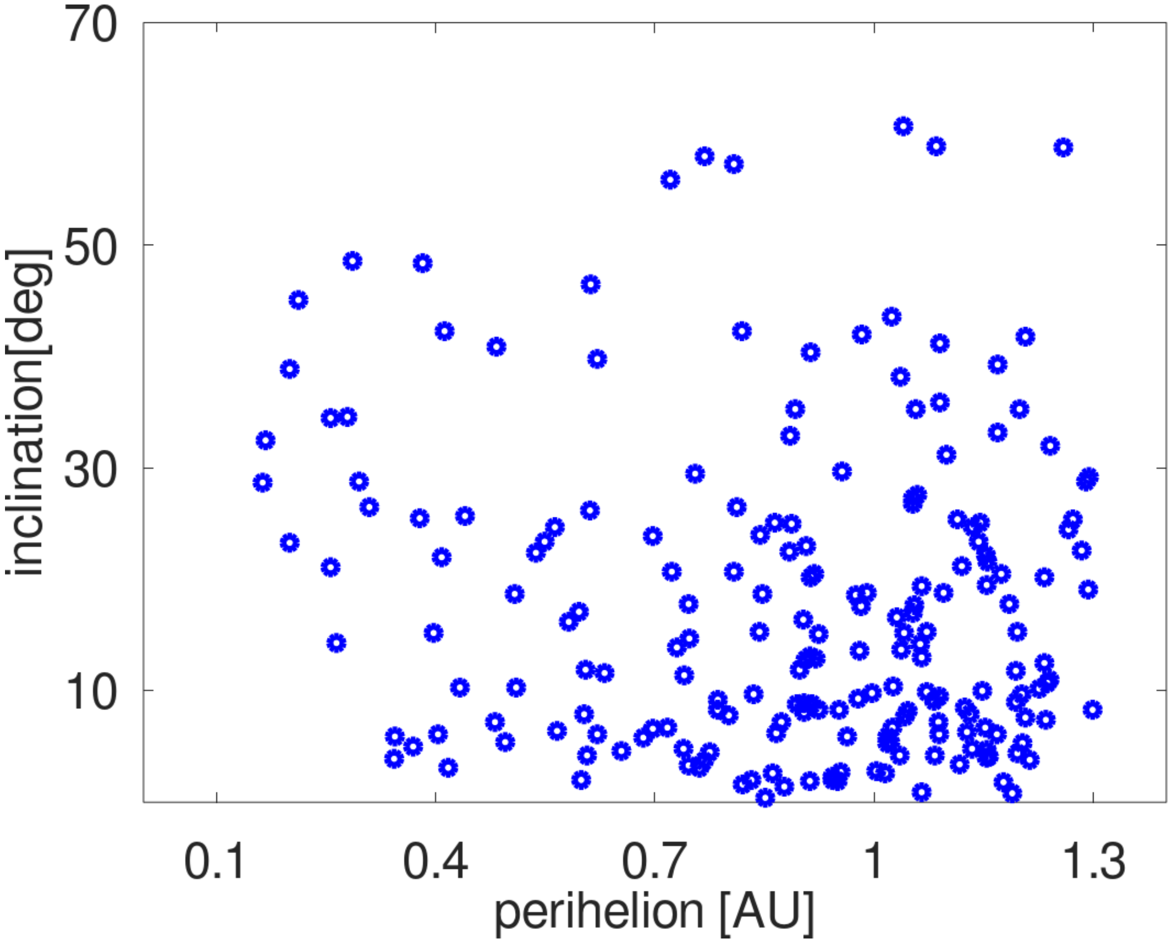
THE OBSERVED SAMPLE: 300 NEAS UP TO NOW

Types of orbit	No. of objects	Fraction[%]
AM	88	43.3
AT	94	46.3
AP	21	10.3
PHA	68	33.5

AM *- Amor like orbits;* ***AP*** *- Apollo like orbits;* ***AT*** *- Aten like orbits. The Amor, Apollo, and Aten are the NEAs which are the representatives for their orbital class. PHA - potentially hazardous asteroid.*

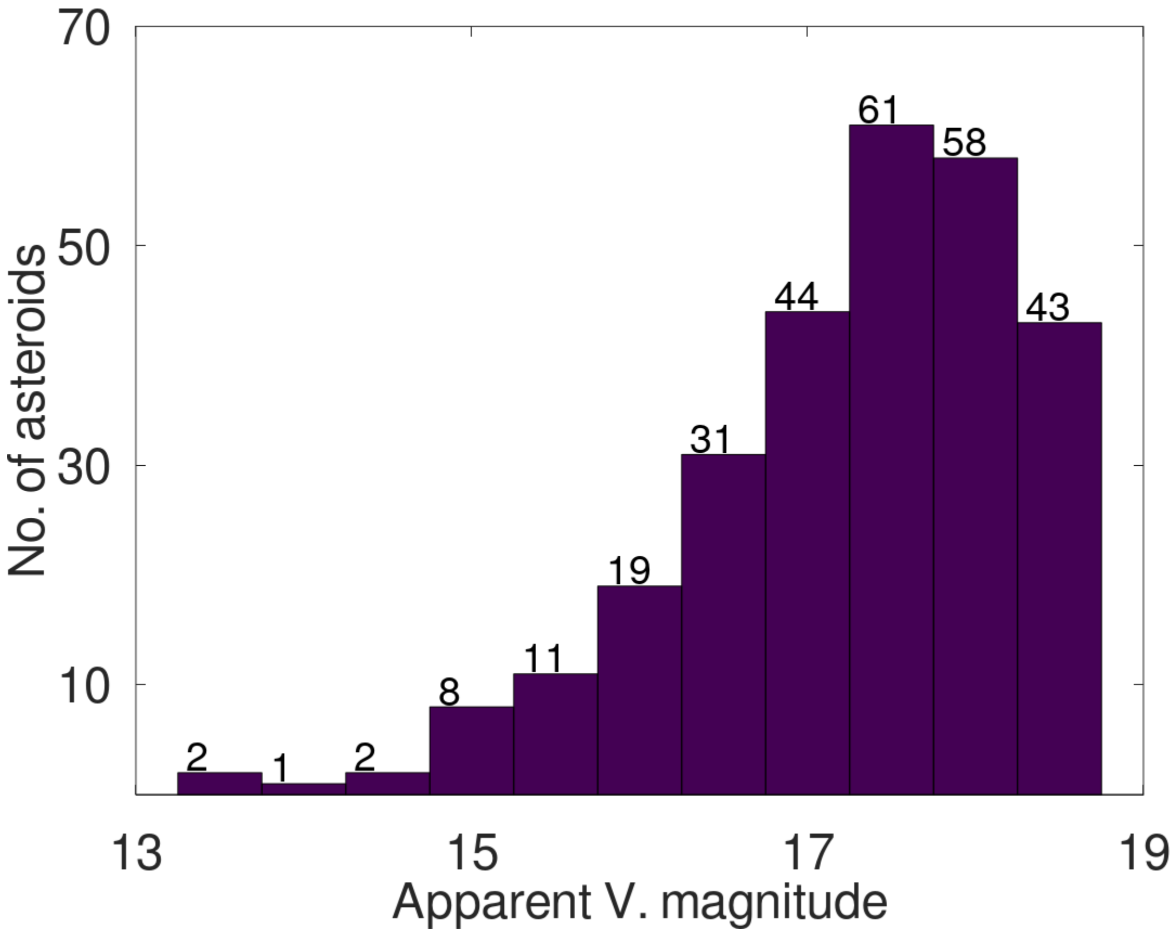


The absolute magnitude distribution of our sample

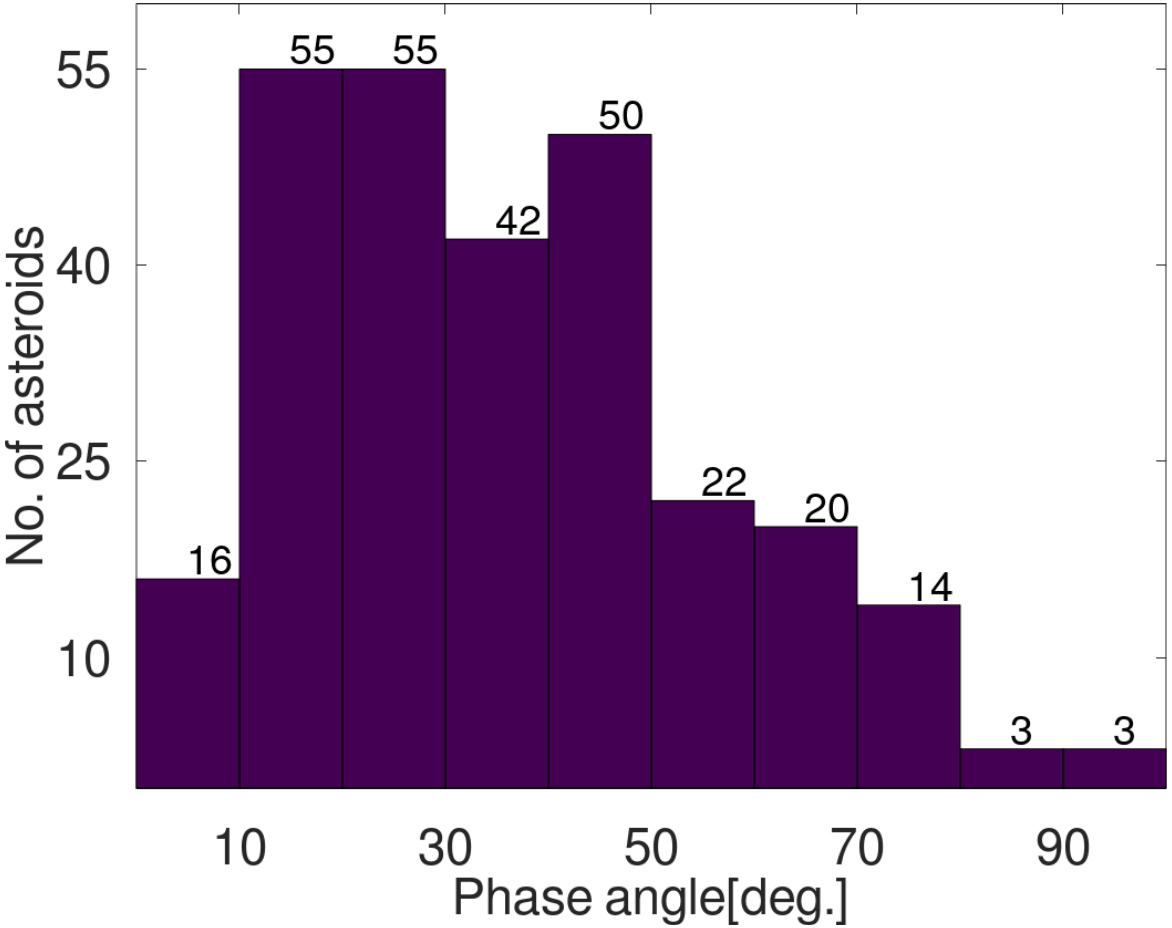


The perihelion distance vs orbital inclination of the observed NEAs

Observational circumstances



We observed objects brighter than 18.5 magnitudes in order to obtain colors with photometric erros less than 0.1 mag



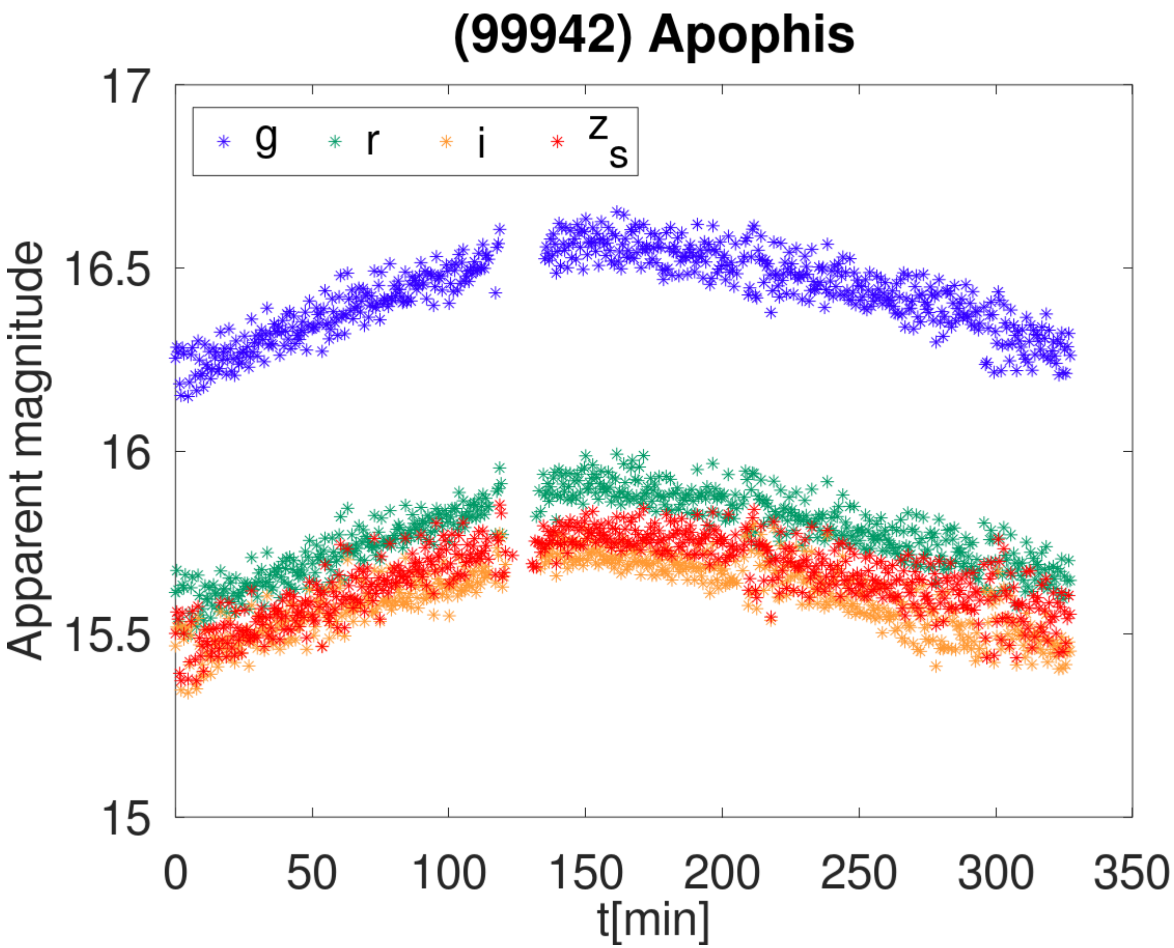
We observed objects on a wide interval of phase angles. Some of the objects were imaged on multiple nights at various phase angles.

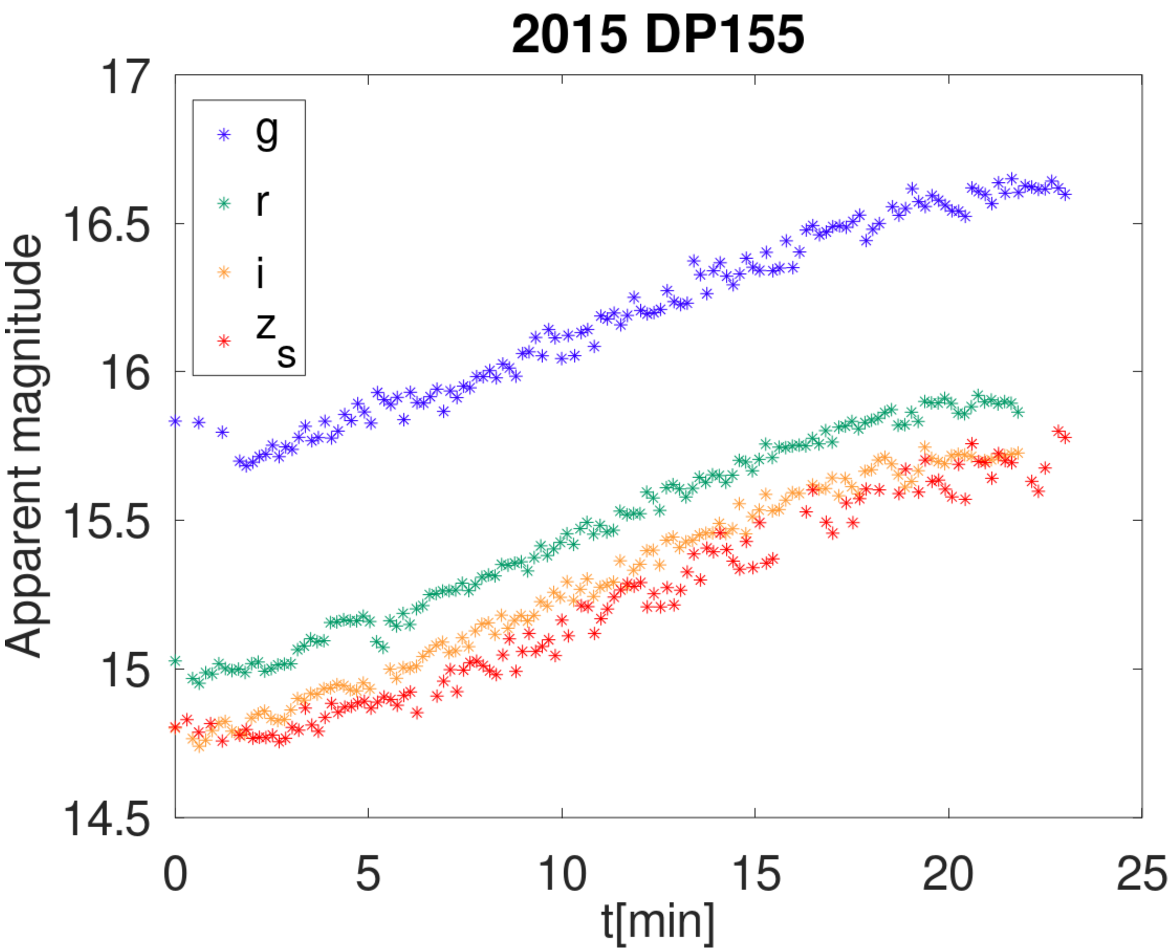
RESULTS

Key targets

Our targets included the *newly discovered objects* such as 2018 KE3 …, 2019 HC… 2020 AZ2, ..., 2020 DP4, *possible space mission targets* such as 65717 (1993 BX3), 2015 DP155, 2015 OH…., and *NEAs with low Tisserand parameter (TJ)* – about 10% of the observed sample.

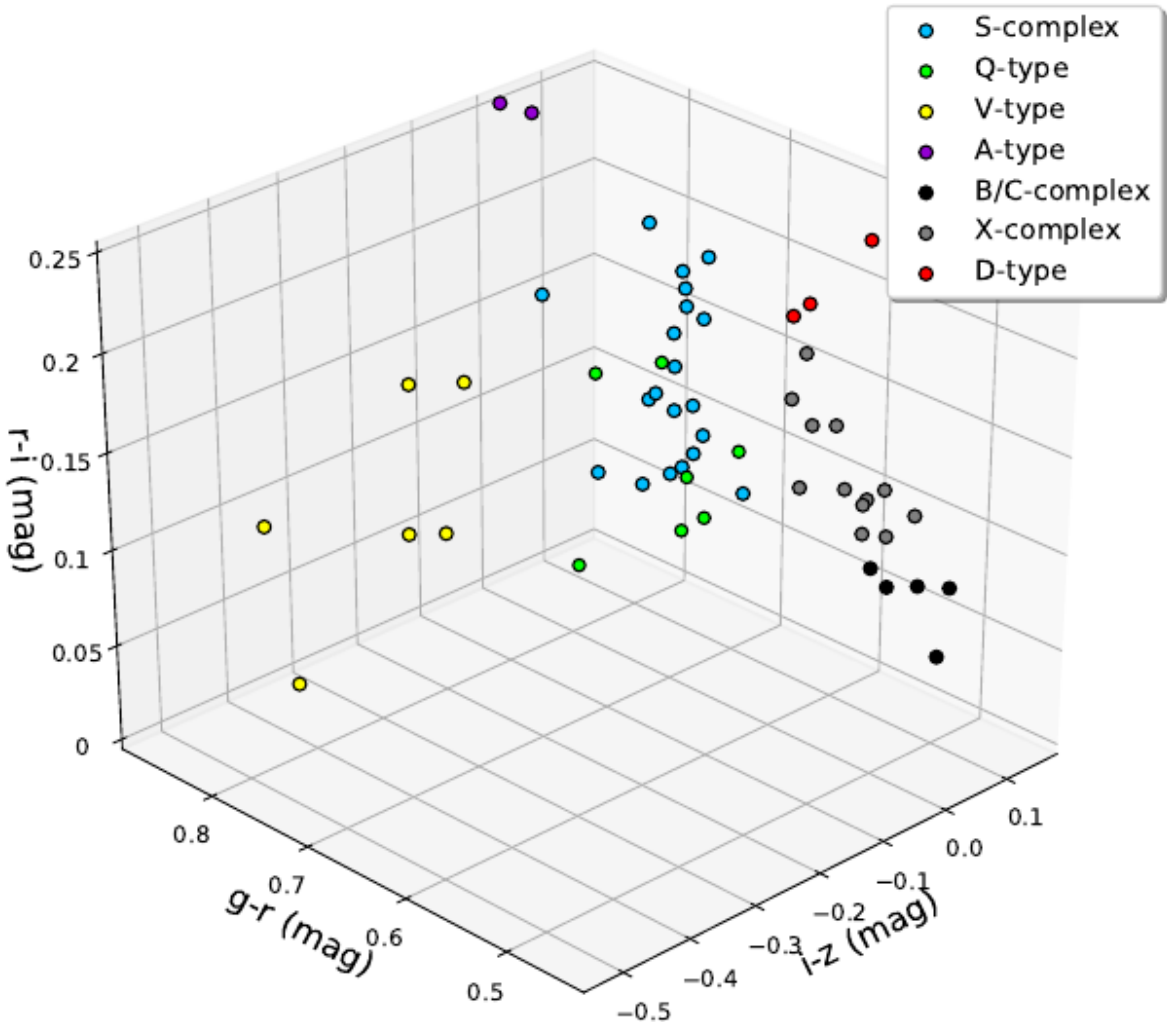
Examples:


(99942) Apophis
g
r
i
z
s
Apparent magnitude
17
16.5
16
15.5
15
0
50
100
150
200
250
300
350
t[min]



Classification

The reference set: for 86 asteroids observed by us there is published spectral data (e.g. Lazzarin et al. 2005, 2008; de León et al.2010; Perna et al. 2018; Popescu et al. 2019; Binzel et al. 2019 …)



The 3D color diagram of asteroids observed by our program and for which the taxonomic type was previously known based on spectral data

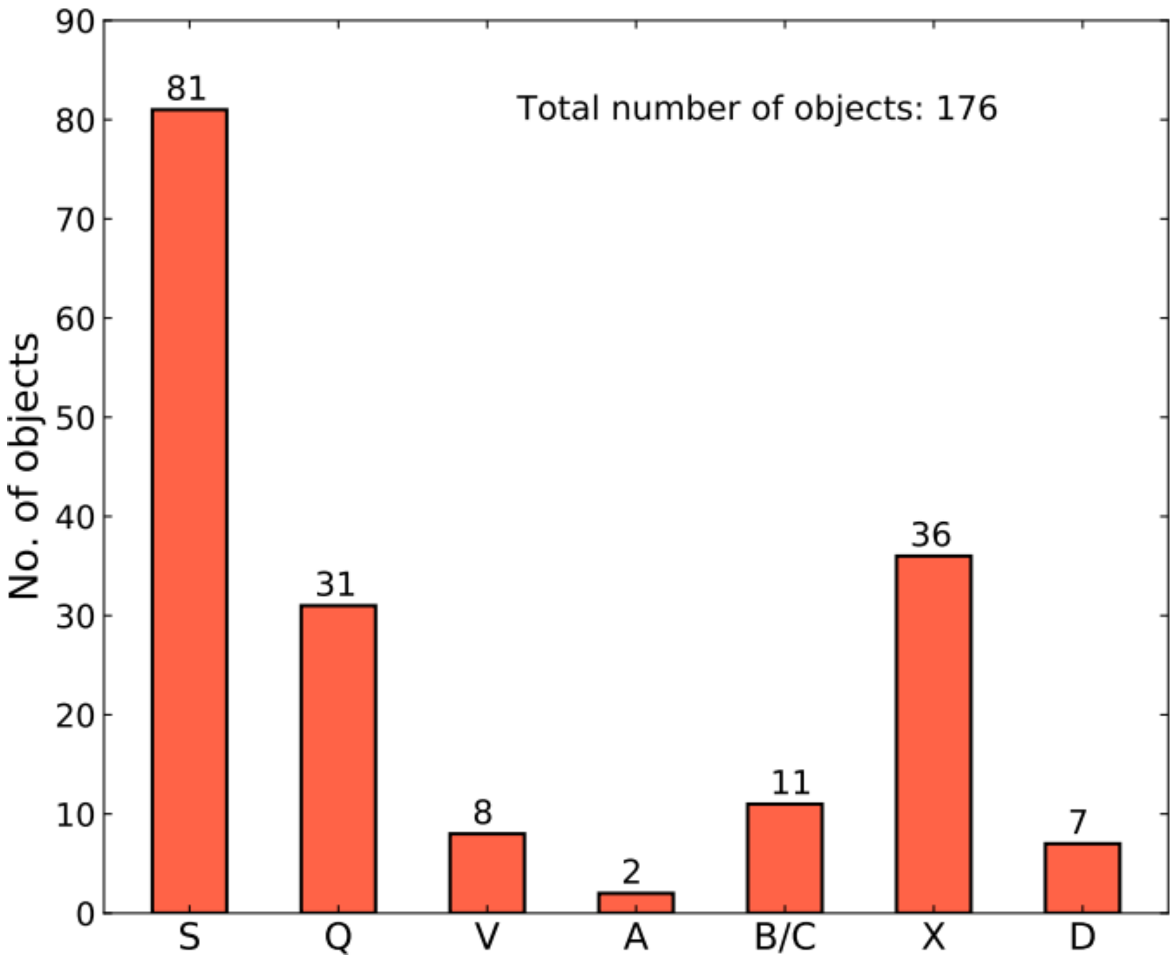
The taxonomic types defined in DeMeo et al. (2009) system have been divided in three major groups, namely the Q / S-complex (green and blue dots), C-complex (black dots) and X-complex (grey dots). Besides them, the end-member types A-, D- and V-types.

- Each taxonomic group (C-complex, D, Q, S-complex, V, X) occupies a specific region in the color-color space, as a consequence of their different spectral properties.

- The *RF (random decision forests)* and the *KNN (k-nearest neighbors)* algorithms attribute a class for a new object, based on a reference set.
- We assigned a probability for each classification in order to quantify the effect of color errors.

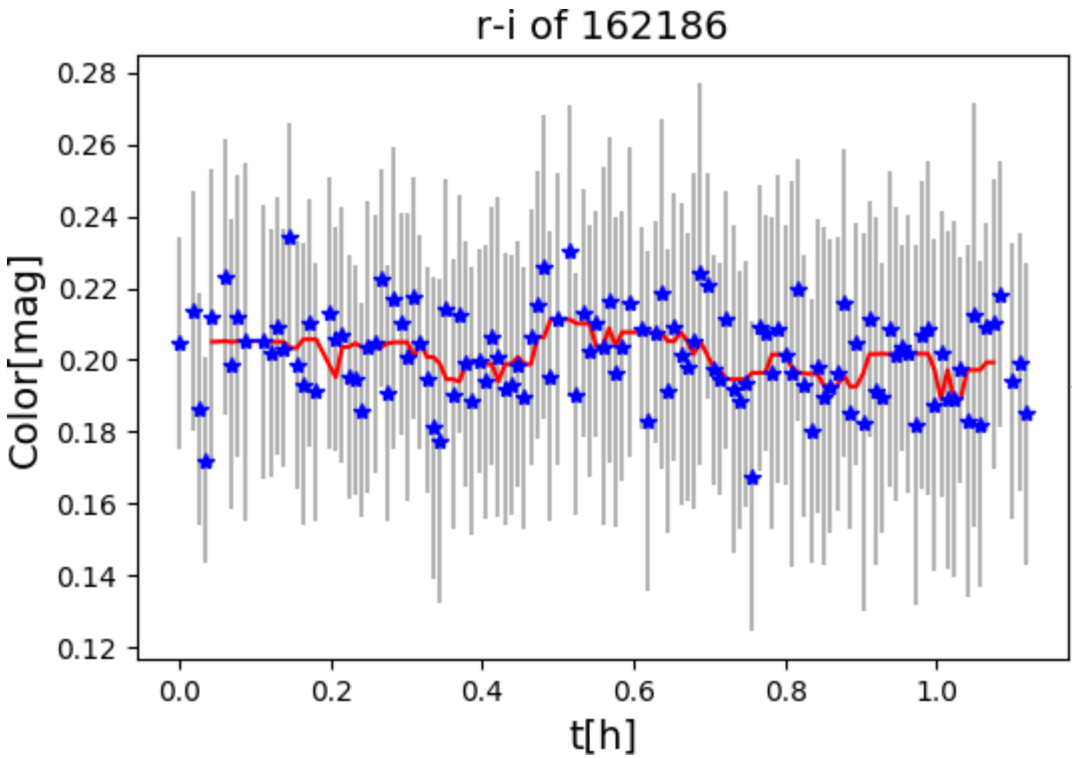
		K-Nearest Neighbors		Random Forest Classifier		
Designation	**No. of colors**	Predicted tax.	Probability	Predicted tax.	Probability	Final taxonomy
2059	3	S	1	Q	0.518	S
5879	3	S	1	S	0.999	S
6478	2	Q	0.901	Q	0.956	Q
6945	3	S	1	S	1	S
8730	2	S	1	S	1	S
18109	3	X	0.999	C	0.831	X
36236	3	S	1	Q	1	S
65717	3	C	1	C	1	C
105140	3	S	1	S	0.909	S
111253	3	S	0.613	Q	0.63	S-comp
136874	3	X	0.992	D	0.994	D
138095	3	Q	0.978	Q	0.995	Q
138127	3	S	0.984	S	1	S

Sample of the table summarizing the assigned taxonomic types. The classification was performed based on both, K-Nearest Neighbors (K = 3) and Random Forest algorithms. On the second column, the number of available color features for each object is given. Then, on the following four columns are the spectral types and the corresponding prediction probabilities returned by each algorithm. Finally, the last column contains the final attributed spectral type.

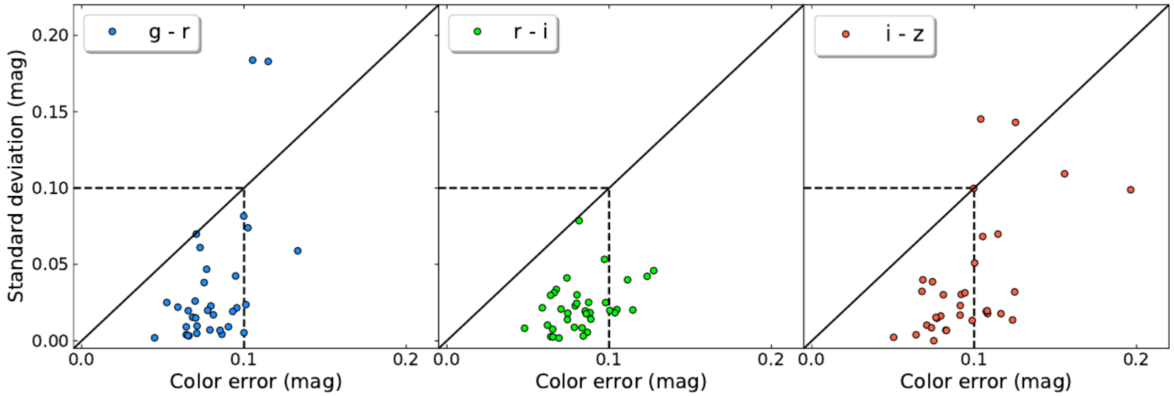


The distribution of taxonomic groups for the observed sample.

RELIABILITY AND ERRORS HANDLING



Example of (r-i) color variation versus time. The values are computed using individual exposures of 30 sec each. The photometric errors are reported by the Photometry Pipeline (Mommert 2017)



Comparison between the spread of values for each color of an object which was observed on multiple nights (measured by standard deviation) and the individual photometric errors of these values.

CONCLUSIONS

- We presented the first results of a spectro-photometric survey dedicated to near-Earth asteroids.
- The survey is performed with TCS/MuSCAT2 instrument which allows to acquire images in four bands simultaneosly.
- A total number of 203 NEAs were observed with the g (400–550nm), r (550–700 nm), i(700–820 nm), and z_s (820–920nm). Each object is observed on average for about 60 min.
- Several objects were observed multiple time. This allows to quantify the observations reliability
- We developed an algorithm for performing the taxonomic classification.
- This is an ongoing survey, with observing time allocated on every month since 2018.

Acknowledgments

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AUTHOR INFO

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ABSTRACT

The spectro-photometric observations of asteroids provide the first information regarding their composition. They allow to classify the observed objects in given taxonomic types which are associated with compositional groups. This technique has been successfully applied both for the data retried from all-sky surveys and for studies of individual minor planets. The main advantage of it is that the measurements are obtained with much less effort compared to the spectral ones, and it allows to characterize targets having faint magnitudes. The draw-back is the accuracy of the results. Our project aims to characterize a large sample of near-Earth asteroids (NEAs) using the observations obtained with four broad-band filters g (400-550), r (550-700), i (700-820) and z_s (820-920) nm. They are performed with the MUSCAT-2 instrument which is mounted on the 1.52-m Carlos Sanchez Telescope, located on Teide Observatory, Canary Islands. The images corresponding to the four bands are acquired simultaneously. We used the Photometry Pipeline (PP) software and several Python scripts for reducing the data. We applied several pattern recognition algorithms for determining the class of each object. The NEAs observed within our project and for which the spectral data is available were used as a training set. We present the results of this program and the applicability of spectro-photometry in the visible region for studying the near-Earth asteroids. The various inaccuracies and the method limitations are constrained. The possibility to detect objects with a heterogeneous composition trough this technique is also discussed. The observations with the MUSCAT-2 instrument are performed regularly (1-2 nights every month). The project started in 2018 and up to now we were able to obtain the spectro-photometric classification for 191 NEAs (107 were classified for the first time) with the absolute magnitudes distributed in the range of 12 -24. A number of 44 objects were observed multiple times in various conditions. This allowed us to assess the reliability of the method.

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[4] Binzel R. P., et al. 2019, Icarus, 324, 41