Simultaneous observations in four optical bands of near-Earth asteroids using TCS/MuSCAT2 instrument

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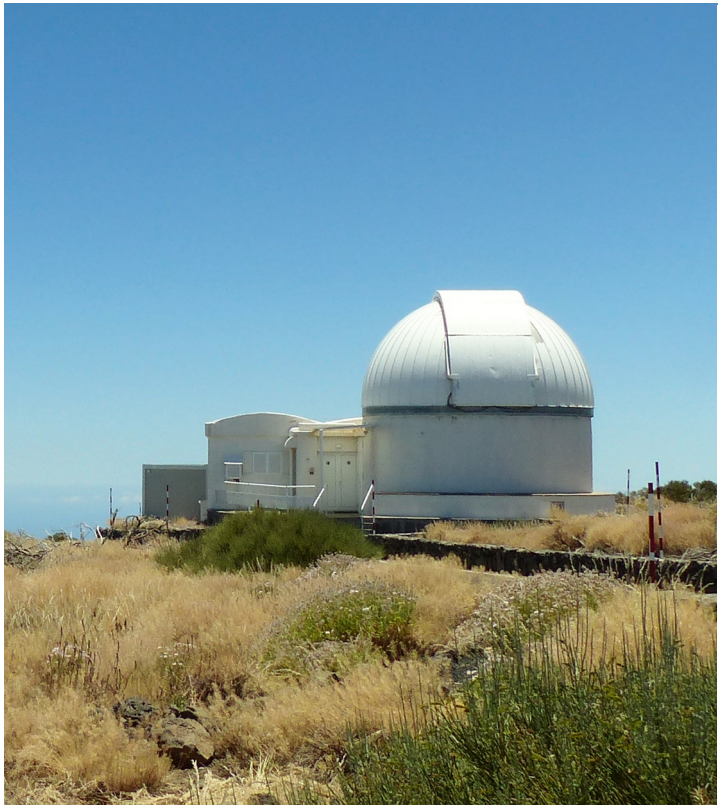
The program

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

- 1) obtain the taxonomic classification;
- 2) search for heterogeneous asteroids;
- 3) search for cometary activity inside the NEA's population;
- 4) quantify the phase angle effects;
- 5) determine the rotational periods and discuss them in the context of compositional types;
- 6) select the most interesting targets for a spectroscopic follow-up
- 7) complement the data with the information provided by other surveys;

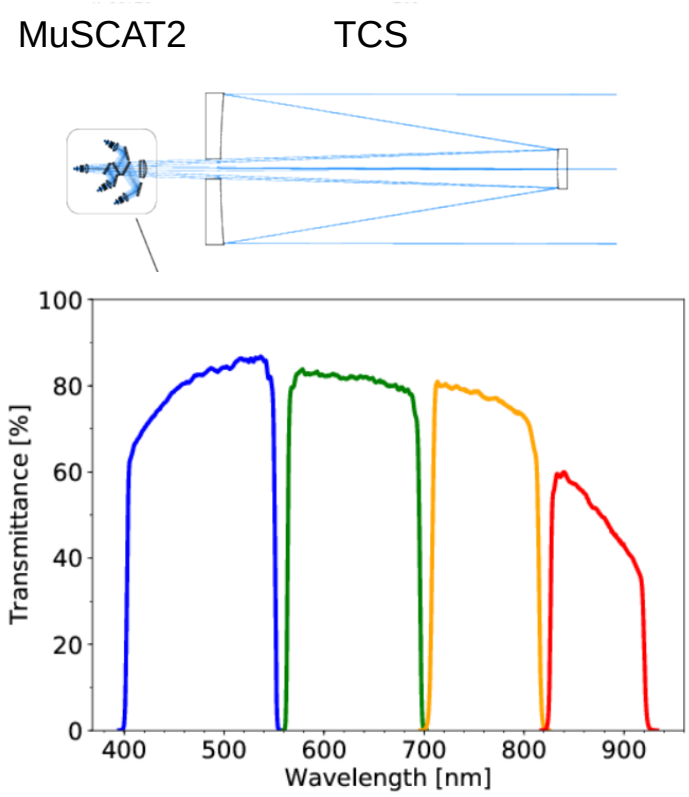
Strategy: Observe during two nights on every month to obtain data for 10 – 18 NEAs on each session.

The instrument



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

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



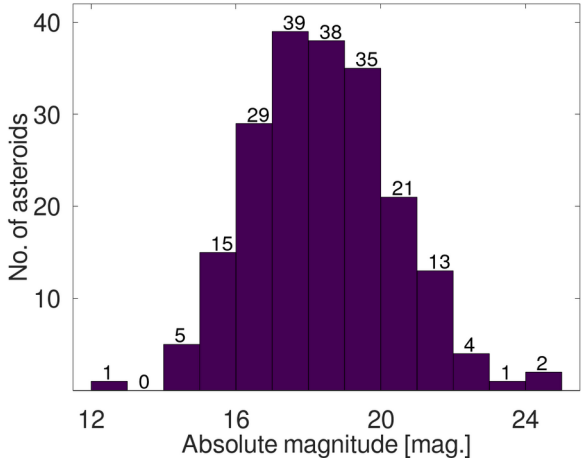
Total transmittance of the MuSCAT2 instrument in g (400–550nm), r (550–700 nm), i(700–820 nm), and zs (820–920nm) bands (Narita et al. 2019).

The observed sample: 283 observations for 203 NEAs

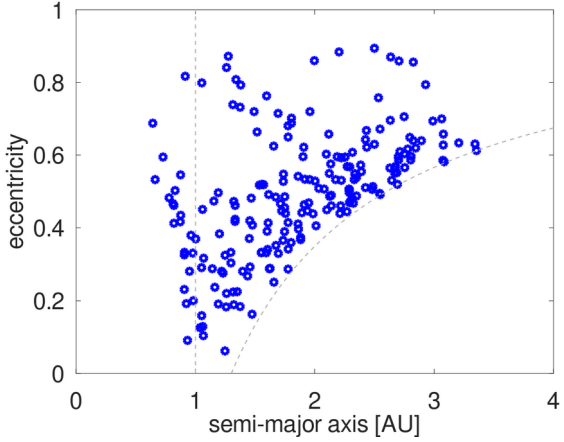
Sample statistics

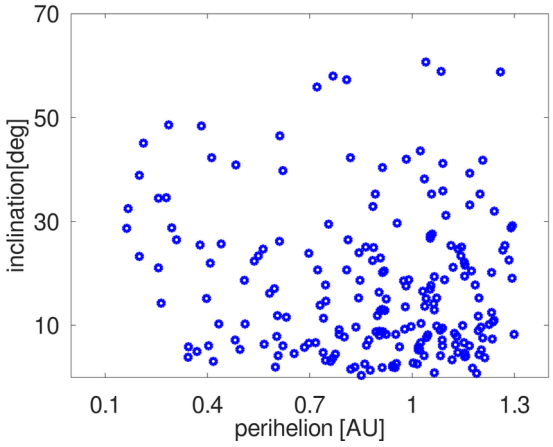
Types of orbit	No. of objects	Fraction[%]
AM	88	43.3
AT	94	46.3
AP	21	10.3
PHA	68	33.5

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.

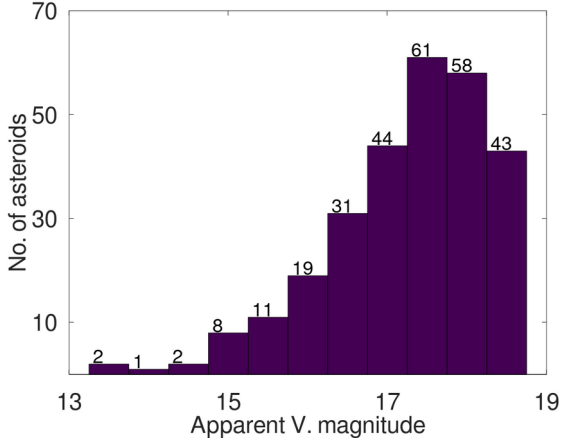


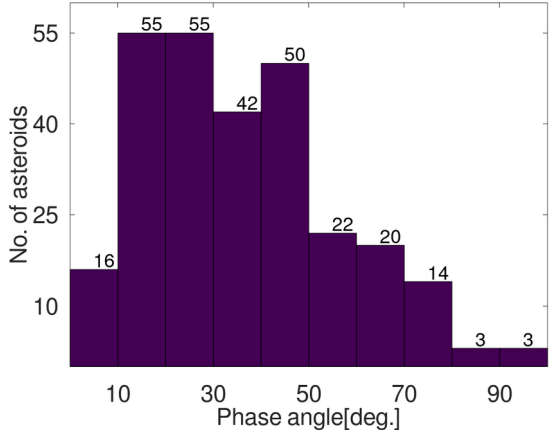
Orbital elements





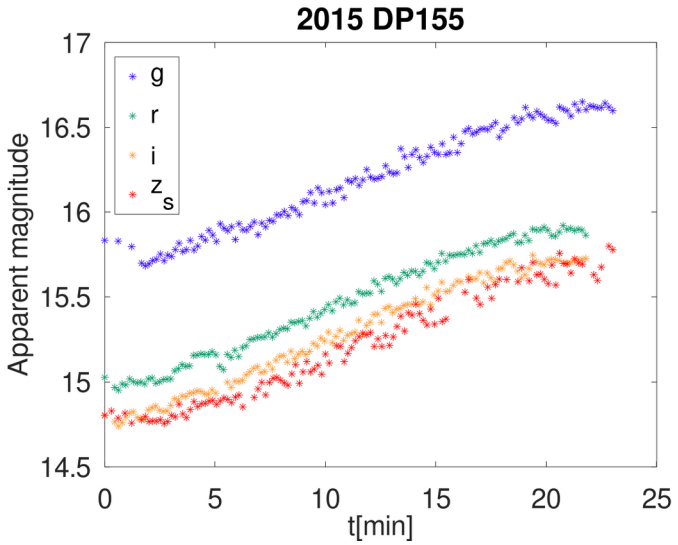
Observational circumstances



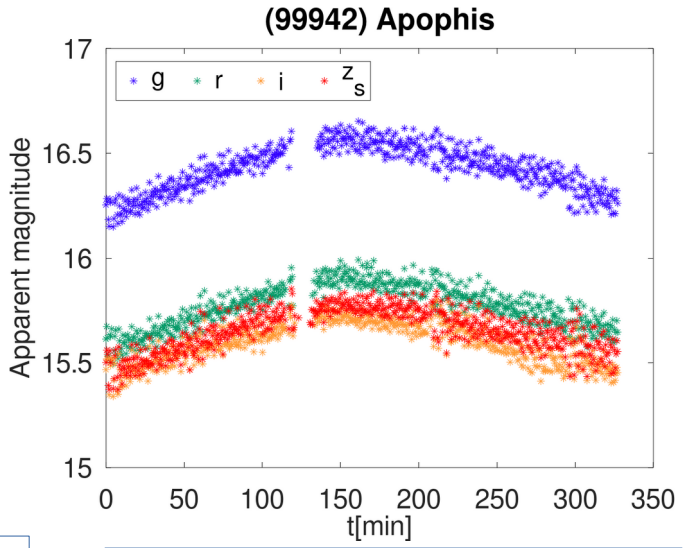


Key targets

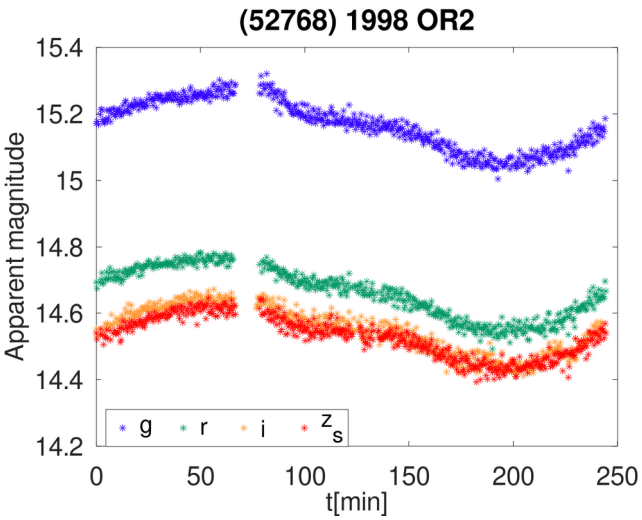
- Our targets included the ***newly discovered objects*** such as 2018 KE3 …, 2019 HC… 2020 AZ2, ..., 2020 DP4, and the ***space-mission candidates*** such as 65717 (1993 BX3), 2015 DP155, 2015 OH…., ***NEAs with low Tisserand parameter (T_J)*** – about 10% of the observed sample.



2015 DP155, an example of NHATS target (Near-Earth Object Human Space Flight Accessible Targets Study - CNEOS website https://cneos.jpl.nasa.gov/)



The PHA (99942) Apophis.



The PHA (52768) 1998 OR2, a target observed also by Arecibo radar.

What are we searching for?

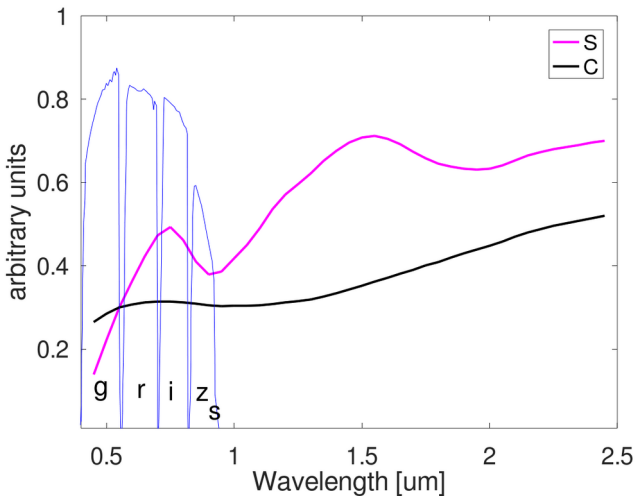
- To find information about asteroids composition, without using spectral observations, but imaging with broad-band filters

Why?

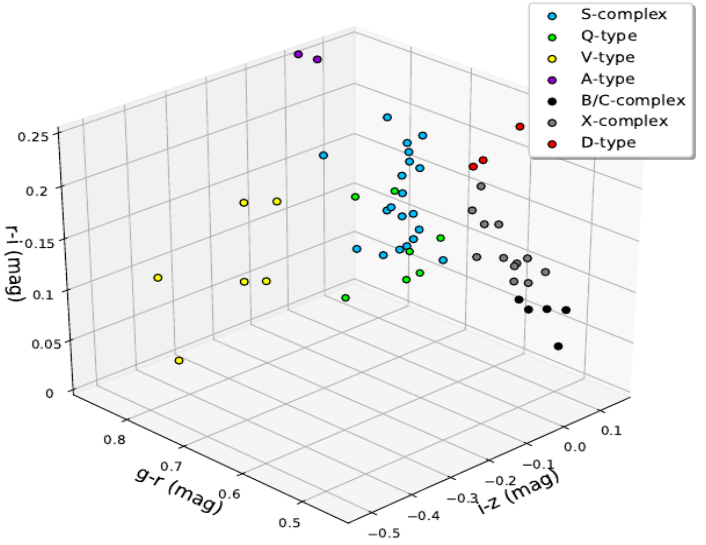
- Because these kind of observations require less exposure time and they can be done for very faint targets.

Classification

- The filters sample relevant spectral features for asteroids.
- 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 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.



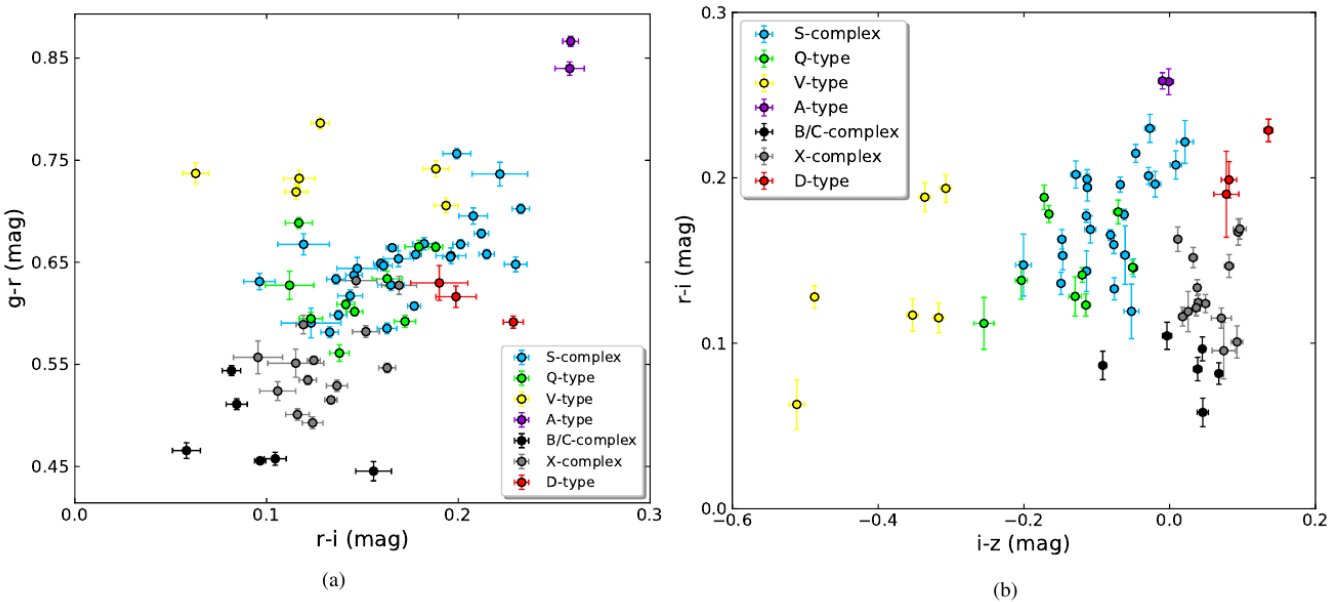
The filters profile compared with the main taxonomic classes (S-complex, C-complex) from Bus-DeMeo taxonomy.



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

Taxonomic classification

- 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.



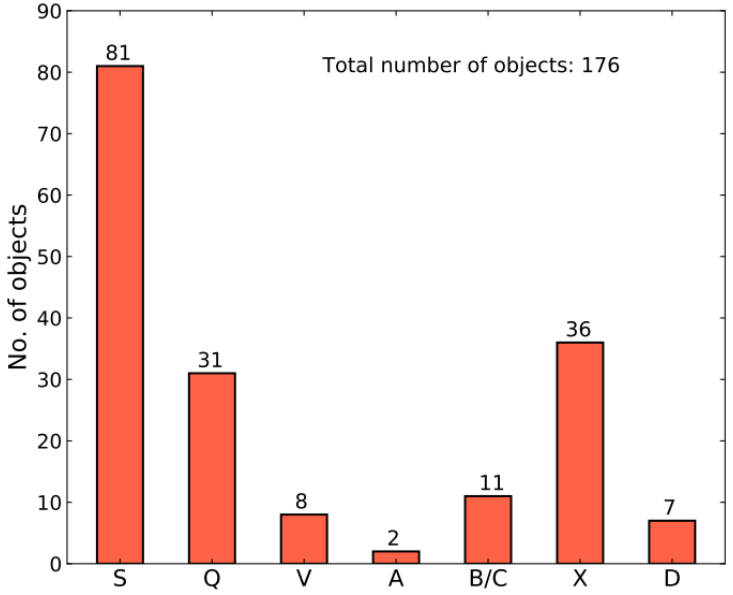
Reference set: *color-color diagrams of asteroids with already assigned taxonomic type based on the existing spectral data (e.g. Lazzarin et al. 2005, 2008; de León et al.2010; Perna et al. 2018; Popescu et al. 2019; Binzel et al. 2019 ...)*

Classification results

- **176 NEAs** were classified following this schema.
- The classification accuracy is about ~80 %.
- The taxonomic distribution is dominated by the Q/S-complex group.
- The end members are identified with very high accuracy.

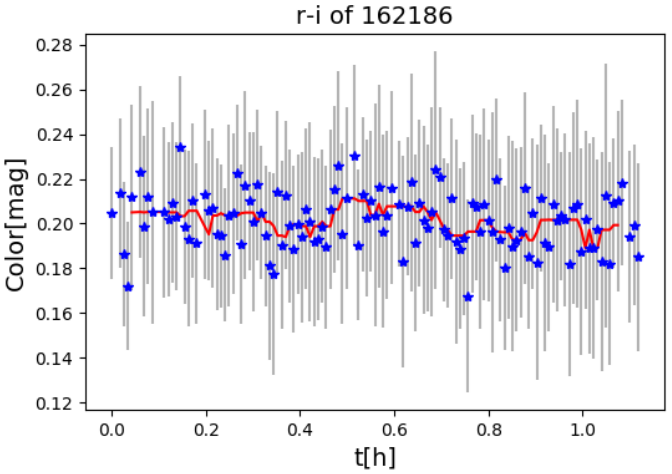
		K-Nearest Neighbors		Random Forest Classifier		
Designation	**No. of colors**	Predicted tax.	Probability	Predicted tax.	Probability	Final taxonomy
2059	3	S	1	Q	0.518	S
5879	3	S	1	S	0.999	S
6478	2	Q	0.901	Q	0.956	Q
6945	3	S	1	S	1	S
8730	2	S	1	S	1	S
18109	3	X	0.999	C	0.831	X
36236	3	S	1	Q	1	S
65717	3	C	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

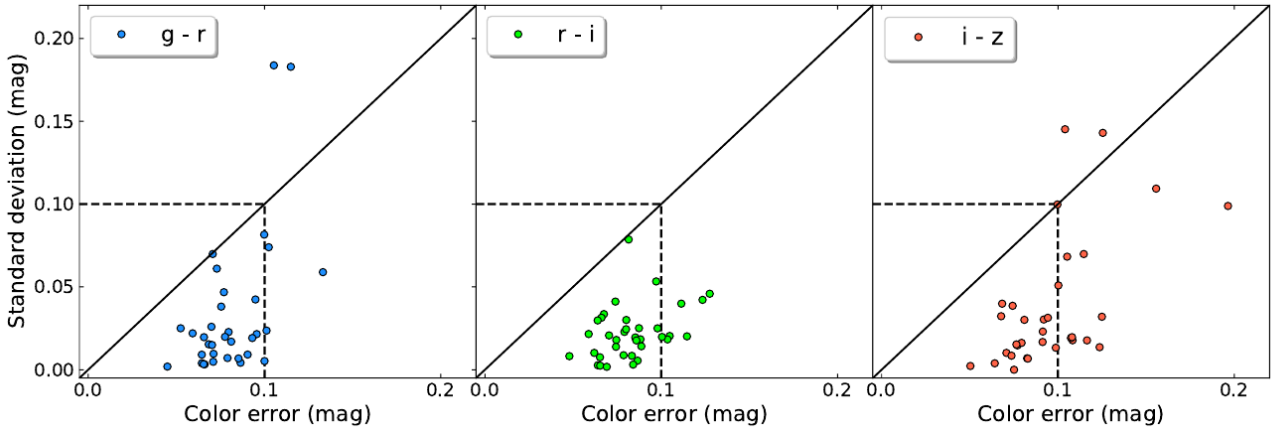


Result: *The distribution of taxonomic groups for the observed sample*

Reliability and errors handling



Example of (r-i) color variation versus time. The values are computded using individual exposures of 30 sec each.



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.

**** Yo may also like other presentations which include TCS/MuSCAT2 data: de León et al. (EPSC2021-221), Medeiros et al. (EPSC2021-783), Prodan et al. (EPSC2021-477) ****

Acknowledgments

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NEO ROCKS
Near Earth Object Rapid Observation, Characterization and Key Simulations