EPSC Abstracts
Vol. 13, EPSC-DPS2019-694-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The Mission Accessible Near-Earth Objects Survey (MANOS): taxonomic distribution of sub-kilometer NEOs

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Abstract

The Mission Accessible Near-Earth Objects Survey (MANOS) is a new generation of surveys aiming to observe and characterize sub-kilometer ($H > 24$ mag), low Δ_v (< 7.5 km/s), newly discovered Near-Earth Objects (NEOs) with Minimum Orbital Intersection Distance (MOID) < 0.01 AU. This survey began in August 2013 and has been collecting astrometry, photometry, and reflectance spectra of this understudied category of the NEO population. We present results from the visible reflectance spectroscopy portion of the survey obtained with the 8.1-meter Gemini North and South telescopes, the 4.3-meter Lowell's Discovery Channel Telescope and the 4.1-meter SOAR telescope.

1. Introduction

Near-Earth objects (perihelia q<1.3 AU) are small objects in the Solar System which regularly make close approaches with the Earth. Observation of these objects in photometry, spectroscopy, and radar have provided valuable information about their physical and rotational characterization.

The characterization of NEOs is fundamental to understand the origin and formation of our Solar System. Their study allow for the observation of objects up to 3 orders of magnitude smaller than the smallest observable in the Main Belt of asteroids (MBA). Their full characterization (composition, size, density, rotation) is of great importance in assessing defense strategies and damage previsions on the ground in the event of a potential impact. Lastly, NEOs are potential targets for in-situ resource utilization either for mining or life support for manned mission. They will be the subject of several spacecraft missions in the next decades (OSIRIS-REx, Hayabusa2, DART, DESTINY+).

To date, the physical properties of only the largest NEOs (D>1 km) have been obtained and a representative census of the physical properties of sub-km NEOs does not exist yet. However, sub-kilometer NEOs represent more than 95% of the currently known population.

The physical properties of NEOs appear to be size dependent. The surface properties (i.e. fine grain regolith or bare rock) of these objects remains an open question. Laboratory measurement have proven that regolith grain size is an important parameter and could be partially responsible for spectral variations across the NEO population [4, 3]. Compositional discrepancy is also observed between large NEOs (>1km) and meteorites [9, 12].

2. What is MANOS ?

The Mission Accessible Near-Earth Objects Survey (MANOS) is a multi-year survey supported by the National Optical Astronomy Observatory (NOAO) and Lowell Observatory, and funded by the NASA NEOO (Near-Earth Object Observations) office. The MANOS program consists of a physical characterization survey at visible and near-infrared wavelengths which is providing light-curves, astrometry, and reflectance spectra of sub-km, low Δ_v (typically <7.5 km/s) NEOs. MANOS often targets newly discovered objects, which typically do not have a brighter apparition for the next several years or even decades. MANOS results can be found in [10, 11, 5].

3. Data reduction

All spectroscopic data have been reduced using a new python based pipeline for long-slit spectroscopy reduction developed specifically for this project [5]. This pipeline is intended to be easily portable to any visible spectrograph and is optimized for asteroid spectral reduction. The use of the same pipeline for all data obtained by this survey allows us to obtain a consistent data set of spectral properties of small NEOs.

This pipeline will be released as an open source package in the near future.

4. Spectroscopic survey

We report here the first results of the visible spectroscopic survey of small NEOs. We have determined the taxonomic type of 210 asteroids with a mean size around 60 meters ($H \sim 25$ mag) and as small as a few meters ($H \sim 30$ mag). Fig. 1 shows the distribution of H magnitude of the NEOs observed by MANOS compared to the NEOSHIELD2 sample [8], and the visible spectra from the MITHNEOS [1] sample. This is the first comprehensive dataset for spectroscopically classified NEOs smaller than 100 meters. In the MANOS dataset, we find a net increase in the fraction of X-complex objects and a decrease in the fraction of S-type asteroids. These variations are associated with variation of the taxonomic distribution of NEOs as a function of size. We believed this variation is due to the fact that NEOs originate from different source regions in the Main Belt. Each of these source regions have a different delivery rate efficiency as a function of object size [7]. We also observed a variation of the Q/S ratio. We found that the Q/S ratio is dependent on the perihelion distance of the object with discontinuities around perihelion distances equals to the semi-major axis of Venus (a=0.72 AU) and the Earth (a=1 AU). [2] already suggested that Earth encounter is responsible for the refreshing of a space-weathered S-type to a fresh Q-type surface. We found here that Venus should also be considered. The general trend with q is also suggestive that other mechanisms such as thermal fatigue [6] should also be considered as a surface refreshing mechanism.

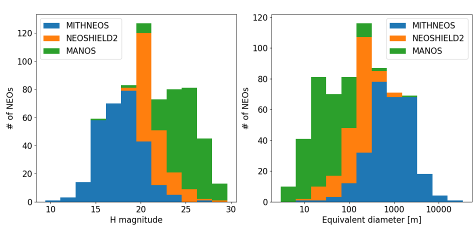

Figure 1: Stacked histogram of the distribution of H magnitude (left) and diameter (right) of the MANOS (blue), NEOSHIELD2, and MITHNEOS surveys.

Acknowledgements

MANOS is funded by the NASA Near-Earth Object Observations program, grant number NNX17AH06G.

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