EPSC Abstracts
Vol. 11, EPSC2017-537-1, 2017
European Planetary Science Congress 2017

Spectral properties of near-Earth asteroids on cometary orbits

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Abstract

A fraction of near-Earth asteroids has orbital characteristics similar to comets. In a first approximation based on dynamical models, the near-Earth asteroids on cometary orbits (NEACOs) can be defined as NEAs with Jovian Tisserand parameter $T_J < 3$. Up to now (April 21, 2017), about 956 objects (6%) out of 16030 NEAs are in this category.

We aim to study the spectral distributions of NEACOs and to identify those with cometary origin. We present the spectral observations for 19 NEACOs consisting of 16 visible spectra obtained with the 2.5m Isaac Newton Telescope and 9 near-infrared (NIR) spectra obtained with the NASA Infrared Telescope Facility (IRTF). Although initially classified as asteroid, one of our targets - 2007 VA85 was confirmed to be active comet 333P/LINEAR on its 2016 appearance.

To complement our dataset we retrieved taxonomic classification for another 57 objects from EARN - DLR database. Therefore, we studied the taxonomic distribution of 76 asteroids, out of which 49 are numbered asteroids. This sample represents about 8 $\%$ of the known NEACOS and it is four time larger compared to previous works [1, 2].

We found that the NEACOs population is a mixing of different spectral types and their taxonomic distribution varies significantly with the value of T_J. The Q,S-complex,taxonomical types associated to olivine-pyroxene compositions are about $\sim 70\%$ for the objects satisfying $2.9 < T_J < 3$ in our sample, while the objects classified as B,C,X and D types - which can be associated with cometary nuclei, are dominant (21 out of 29 objects) for $T_J < 2.7$. A particular interesting case is that of (466130) 2012 FZ23 which has a $T_J = 2.367$ and exhibits a R/Sr type spectrum.

1. Introduction

Asteroids and comets have been considered as a two distinct types of objects. They formed at different distances of the young Sun, thus, their composition is characteristic of the region where they formed. The first distinction is that the comet nuclei are surrounded by a coma produced by the outgasing of volatiles when approaching the Sun. The discovery of extinct or dormant comets which show asteroidal appearance as well as the asteroid outburst required to review the definition of these objects (e.g. [3]).

In most of the cases, the cometary orbits have $T_J < 3$, while the majority of asteroids have $T_J > 3$. From physical point of view, the active, dormant and dead comets are very dark, often reddish, objects , with spectra similar to D, P, and C-type asteroids and with albedos and color probably controlled by carbonaceous dust containing reddish organic compounds (e.g. [4]). Their spectra describe objects that are the most pristine observable Solar System objects.

In this work we discuss the spectral properties of 76 NEACOs. We show new visible and NIR spectra for 19 objects observed with the INT and with the IRTF telescopes. Our set was complemented with another 57 objects classified taxonomically in order to derive a taxonomical distribution relative to T_J parameter.

2. Spectral data

We obtained new spectra of 19 NEACOs using the 2.54 m INT (16 observations), and the 3m IRTF (9 observations) telescopes. For two objects we joined our visible part with near-infrared information available at MIT-UH-IRTF database.

We used the IDS longslit spectrograph (INT) with the R150V diffraction element and the RED2+ camera in order to cover the spectral interval 0.4-0.92 μm. We used the SpeX instrument, with the 0.8x15" slit, in the low resolution mode to obtain spectra over 0.8-2.5 μm interval.

We classified each spectrum in the Bus-DeMeo taxonomic system by using the MIT-SMASS on-line tool (for vnir spectra) and by performing curve matching with the 25 classes defined by this taxonomy (using M4AST website). The results are summarized in Table 1.

Table 1: The asteroids observed with the INT and the IRTF telescope. The '*' shows data from MIT-UH-IRTF database.

Desig.	Tj	Taxon.	Spec. interval
2007 VA85	0.418	D	nir
466130	2.367	R/Sr	nir
248590	2.441	T/D	nir
433992	2.566	D	vis+nir
414287	2.619	Xk/B	vis+nir*
450160	2.689	S	nir
413192	2.779	X	vis
1998 GL10	2.788	X	vis
442037	2.816	Cg/K	vis+nir*
2015 XB379	2.82	L	vis+nir
214088	2.845	Sq	vis+nir
2015 WH9	2.88	Xk	vis
430439	2.929	T /D	vis
9400	2.94	Sq	vis
293054	2.945	S	vis
2015 CA1	2.96	T	vis
2011 YB40	2.985	Q	vis
416071	2.993	Sr	vis+nir
417264	2.997	Xc	vis+nir

3. Results

We complemented our sample using data existing in the EARN-DLR database. We searched for asteroids unambiguously classified and found information for other 56 NEACOs. Therefore, the total data set includes 76 objects which include 49 numbered asteroids. Except 2007 VA85 ($T_J = 0.418$) which was confirmed as an active comet, all of them have orbits similar to Jupiter Family Comets ($2 < T_J < 3$).

For a statistical analysis we divided the data in two groups: Q/S group (silicate-like) - objects classified as Q or S-complex and which are associated with olivine-pyroxene compositions, and B/C/X/D group (cometary-like) - objects classified as B,C,X,T and D types - which are featureless spectra and may represent a carbonaceous chondrite composition and organic compounds, similar to a cometary nuclei. We note that X class represents three distinct types (E - enstatite, M-metallic, and P-primitive) which can be differentiated by their albedo and only the P class may represent an extinct or dormant comet.

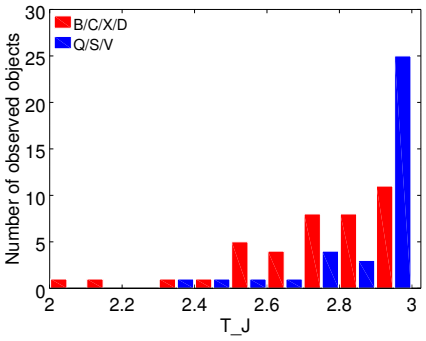

Figure 1: The taxonomic distribution relative to the T_J parameter. A 0.1 width bin on Ox axe was used.

The histogram plotted in Fig.1 shows that the ratio of silicate-like versus cometary-like objects varies significantly with the value of T_J. The Q,S-complex taxonomical types are about $\sim 70\%$ (25 out of 36) for the objects satisfying $2.9 < T_J < 3$ in our sample. The objects classified as B,C,X and D types represent the majority - 21 out of 29 objects, for $T_J < 2.7$. Although subject to different biases (including observational and discovery biases), this distribution shows that there is no strict correlation between the T_J factor and the object composition. Two particular cases within this distribution are those of (466130) 2012 FZ23 which has a $T_J = 2.367$ and exhibits a spectrum similar to R/Sr type and of (455426) 2003 MT9, $T_J = 2.591$ which has an S/Sr spectrum.

Although on its discovery 2007 VA85 was classified as asteroid, on its close approach from 2016 a cometary activity was detected, thus receiving the designation 333P/LINEAR. The observation performed with IRTF/SPEX on March 09, 2016 shows a very red spectrum compatible with a D-type object [5].

Acknowledgements

This research use the data provided by E.A.R.N. - The Near-Earth Asteroids Data Base ($http://earn.dlr.de/nea/$), MIT-UH-IRTF Joint Campaign for NEO Reconnaissance ($http://smass.mit.edu/$) and JPL Small-Body Database Browser ($https://ssd.jpl.nasa.gov/sbdb.cgi$). We thank to INT/ING students R. Ashley, M. Diaz Alfaro, R. Errmann, F. Lopez, I. Ordonez, H.F. Stevance for their support with INT/IDS observations. The work of M. Popescu, I. L. Boaca, R.M. Gherase and D.A. Nedelcu was supported by a grant of the Romanian National Authority for Scientific Research – UEFISCDI, project number PN-II-RU-TE-2014-4-2199.

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