Asteroids: New Observations, New Models
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The IMPACTON Project: Pole and Shape of Eight Near-Earth Asteroids†

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Abstract. The formation and evolution of Solar System small bodies, in particular those in near-Earth orbits, is a complex problem which solution strongly depends on a better knowledge of their physical properties. To contribute to the international efforts in this direction the IMPACTON project (www.on.br/IMPACTON) set up a dedicated facility denominated Observatório Astronômico do Sertão de Itaparica (OASI). Using the 1-m telescope several dozens of NEAs were observed between March 2012 and October 2014. Here we will present the results obtained for 8 objects. Relative magnitudes were used to obtain lightcurves and derive rotational periods. Applying the inversion method developed by Kaasalainen and Torppa (2001) and Kaasalainen *et al.* (2001), along with lightcurves from literature, allowed to refine the rotational period of these asteroids as well as to derive their pole direction and shape. The obtained results confirm a lack of poles toward the ecliptic and with a majority of retrograde rotators. A more representative sample, however, is needed in order to drive robust conclusions.

Keywords. Minor planets, asteroids: general - techniques: photometry - methods: numerical

1. Introduction

The IMPACTON project, which in Portuguese stands for "Enterprise of the National Observatory to Monitor and Study Asteroids in the Neighborhood of the Eart", started back in 2005, with the purpose to install and operate a NEO studies dedicated telescope in Brazil. The main scientific goal of the project being to characterize the physical properties, in particular orbit, spin, shape, and colors, for the largest possible number of NEOs discovered by other search projects.

The new facility Observatório Astronômico do Sertão de Itaparica OASI, is located at Itacuruba (PE), in the Northeastern part of Brazil. Its coordinates are: $08^\circ\ 47'\ 32.1''$ S and $38^\circ\ 41'\ 18.7''$ W. The basic characteristics of the installed equipments are as follows:

- Telescope (Astro Optik, Germany): 1-m primary mirror; AltAz fork mount; pointing precision $< 12''$ RMS; guiding precision $< 0.6''$ RMS; f/3 primary focal ratio; f/8 focal ratio.
- CCD (Apogee Instruments, USA): Model Alta U47, back-illuminated; 1024×1024 pixels; $13\times13\mu$m pixel size; thermoelectric cooling; UBVR and SLOAN filters. (A new CCD with 2048×2048 pixels is presently in use).

† Based on observations obtained at the Observatório Astronômico do Sertão de Itaparica - OASI, Itacuruba, Brazil

Table 1. Rotational period and pole direction of NEAs.

Asteroid	Rotational Period [hr]	Pole Longitude $\lambda[°]$	Pole Latitude $\beta[°]$	Number of lightcurves
(24445) 2000 PM8	6.8123	93	-59	25
(25916) 2001 CP44	4.59827	325	37	14
(85628) 1998 KV2	2.82235	95	48	14
		281*	46*	
(143409) 2003 BQ46	10.5391	172	-72	14
(214088) 2004 JN13	6.33246	268	74	21
(243566) 1995 SA	2.31382	228	-19	18
		35*	-20*	
(251346) 2007 SJ	2.7184	304	-36	12
(312473) 2008 SX245	3.4601	38	22	10
		220*	3*	

* Mirror solution with a worst fit.

The above configuration gives a 5.9x5.9 arcmin field and an image scale of 0.343 arcsec/pix. Moreover, the fully automated telescope and dome, along with an internet dedicated link, a meteorological station, and an all-sky camera allow remote observations to be carried on from the National Observatory, in Rio de Janeiro.

Photometric observations of NEAs are, thus, being carried on in a routinely way since the first light of the telescope, in March 2011. In what follows we will present the observations, the data reduction and the results obtained for 8 of these objects.

2. Observations, Data Reduction & Methodology

Between March 2012 and October 2014, nearly 50 NEA were observed and, in particular: (24445) 2000PM8, (25916) 2001CP44, (85628) 1998KV2, (143409) 2003BQ46, (21408) 2004JN13, (243566) 1995SA, (251346) 2007SJ, and (312473) 2008SX245. The data was acquired using the above described set-up and all the observations were performed in the R band (for a complete list of the obtained data, please refer to Silva 2015).

Data reduction was performed using the MaxIm DL package following the standard procedures of flat-field correction and sky subtraction. Relative magnitudes, between the asteroid and a field star of similar magnitude, were computed to obtain lightcurves.

The methodology used was to first derive a rotational period using a Fourier analysis (e.g. Harris *et al.* 1989) and then compute the pole direction and shape model using the lighcurve inversion method developed by Kaasalainen & Torppa (2001) and Kaasalainen *et al.* (2001).

3. Results and Conclusions

The analysis of the obtained data allowed the determination of rotational period, pole and shape for 8 NEAs as shown in Table 1. To increase the reliability of our results we used additional individual lightcurves obtained from the Minor Planet Center site (Jahn, J. and Kretlow, M. 2014, Warner, B. 2014abcd, Warner, B. 2015).

As can be noted, the obtained rotational periods are in general short, between 2 and 6 hr, which is mainly a selection effect due to the use of relative magnitudes. Just for one asteroid, (143409) 2003BQ46 it was possible to derive a longer rotational period of 10.5 hr. It is noteworthy that for asteroids (85628) 1998KV2, (243566) 1995SA and (312473) 2008SX245 a mirror solution for the pole was obtained and their values are given in the table, although they have a worst fit. The model shape for these objects is shown in

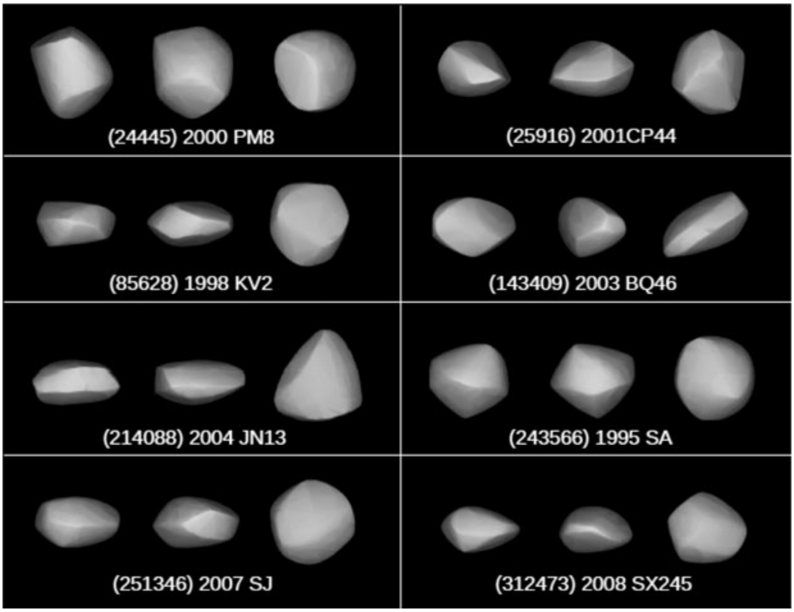

Figure 1. Shape models of 8 NEA

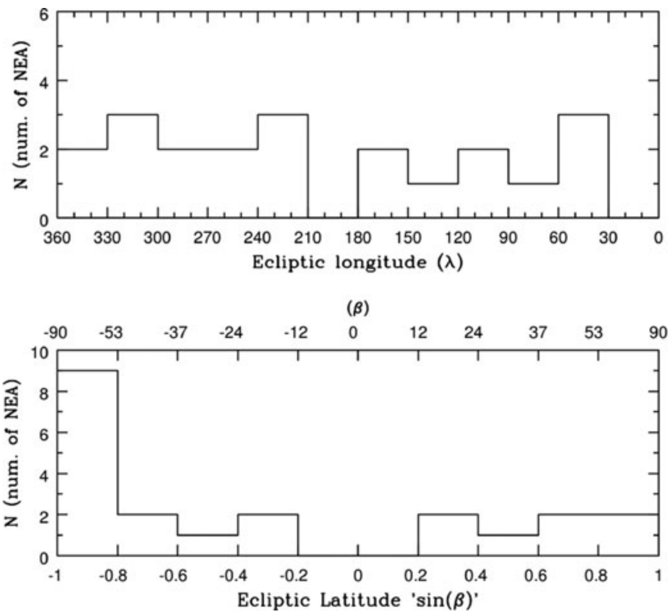

Figure 2. Distribution of ecliptic longitude (upper plot) and latitude (lower plot) of pole directions for 21 NEAs. The width of bins in latitude β corresponds to similar surfaces on the (λ, β)-sphere, so the bins are equidistant in $\sin(\beta)$.

Fig. 1. The shape models are represented by a convex polyhedron with triangular facets in three different positive views in the asteroid's Cartesian frame X, Y, and Z.

Regarding the direction of the pole, several studies have found a lack of pole direction toward the ecliptic plane in the distribution of main-belt asteroids (Hanus *et al.* 2011 and references therein). In order to verify if this is reproduced in the NEAs population

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we added to our data, that of 13 objects from the DAMIT database (Durech *et al.* 2011) which contains pole determined from lightcurve inversion. As is shown in Fig. 2 there seems to be a lack of poles toward the ecliptic and with a majority of retrograde rotators. This seems to be consistent with the Yarkovsky effect which dominates the injection process of NEA by means of orbital drift, and should produce an excess of retrograde rotations (La Spina *et al.* 2004). Obviously, a more representative sample is needed in order to drive robust conclusions.

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