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Photometry and spin rates of 4 NEAs recently observed by the Mexican Asteroid Photometry Campaign

J. C. Saucedo[1], S. A. Ayala-Gómez[2], M. E. Contreras[1], S. A. R. Haro-Corzo[3], P. A. Loera-González[1], L. Olguín[1] and P. A. Valdés-Sada[4]

[1] Departamento de Investigación en Física, Universidad de Sonora
Blvd. Rosales y Colosio, Ed. 3H, 83190 Hermosillo, Sonora, México
email: jsaucedo@cifus.uson.mx

[2]FCFM−Universidad Autónoma de Nuevo León

[3]ENES−Universidad Nacional Autónoma de México

[4]DFM−Universidad de Monterrey

Abstract. We present photometric observations of (4055) Magellan, (143404) 2003 BD_{44}, 2014 JO_{25} and (3122) Florence, four potentially hazardous Near Earth Asteroids (NEAs). The data were taken near their approaches to Earth by 3 observatories participating in the Mexican Asteroid Photometry Campaign (CMFA). The results obtained: light curves, spin rates, amplitudes and errors, are in general agreement with those obtained by others. During the day of a NEAs maximum approach to our planet, its light curve may present significant changes. In the spin rate, however, only minute changes are observed. 2014 JO_{25} is briefly discussed in this regard.

1. Introduction

NEAs have perihelion distances $\leqslant$ 1.3 AU, and if their Earth Minimum Orbit Intersection Distance $\leqslant$0.05 AU and their size are $\geqslant$140 m, they are considered "potentially hazardous". According to their orbits NEAs are divided into 4 classes: the Amors, the Apollos, the Atens and the Atiras/Apohele. Over 18,500 NEAs have been discovered so far and the number keeps growing at a rate unmatched to that at which they are characterized. One way of characterizing asteroids is by obtaining and analyzing their photometric light curves, from which physical properties such as the spin rate can be obtained. According to the Asteroid Lightcurve Photometry Database (ALCDEF) spin rates are known for $\sim$6000 minor planets, roughly representing $\sim$7% of NEAs, and <1% of the general asteroid known population (over 750,000). With this in mind, in 2015 a network was implemented to carry out photometric observations of asteroids: the CMFA (Campaña Mexicana de Fotometría de Asteroides). The CMFA has published spin rates for several main belt asteroids, see Schuster *et al.* in this IAU proceedings. Here we concentrate on the results for NEAs of the CMFA. The spin rate is related to an asteroids cohesion strength. In addition, 3D asteroid shapes can be inferred from light curves obtained at different epochs, since objects are observed from different view angles (Durech *et al.* (2010)). Finally, images used to generate light curves are also used to derive astrometric information that allow us to improve asteroid's orbital parameters.

2. Data and reductions

Consecutive images of the asteroid are taken throughout the night and usually during several nights; to obtain a complete light curve, typically requires from 5 to 10 observing nights for each asteroid. Due to instability issues of telescope mounts, exposure times for individual images are in the range of 30 to 240 seconds. This restriction imposes a severe limitation for the follow-up of interesting faint objects. Filters are not used, to facilitate the observation of fainter objects and to compare and combine the results of the 3 participating observatories: 0.84 m telescope at the Observatorio Astronómico Nacional at Sierra San Pedro Martir (OAN-SPM); 0.40 m telescope at Observatorio Astronómico Carl Sagan (OACS) located in Hermosillo and 0.36 m telescope of the Universidad de Monterrey Astronomical Observatory, Monterrey.

Basic steps of data reduction are performed using IRAF or MaximDL4 software. For light curve extractions and period determinations, MPO Canopus software is used. For crowded stellar fields, first DAOPHOT (Stetson 1987) is used to obtain the light curve and then MPO Canopus is used for the spin rate determination.

Basic information on the 4 NEAs reported here: (4055) Magellan (named in honor of Fernando de Magallanes) is an amor NEA discovered by Eleanor Francis Helin on February 24 1985 at Palomar Observatory. Observations by the Keck Observatory and the NEOWISE mission permit to estimate a diameter of 2.2 - 2.8 km. (143404) 2003 BD_{44} is an Apollo-type NEA discovered by Brian Skiff at Lowell Observatory, Anderson Mesa Station (LONEOS survey). It is considered to be potentially hazardous. Its diameter is estimated to be ~1.3 km. On April 2017 it came within 0.1 AU of the Earth. Radar observations at Arecibo Observatory were carried out during its approach. (3122) Florence (named in honor of Florence Nightingale) is an amor NEA discovered by Schelte John Bus at Siding Spring Observatory in 1981. It is one of the largest NEAs (4.5 km). It had its closest encounter (0.047 AU = 706,106 km) to the Earth (until the year 2500) on September 1 2017. During this flyby, radar observations at Arecibo Observatory and at the Goldstone Deep Space Communications Complex revealed it has two satellites, probably formed due to the YORP effect. The inner moon has a diameter 180 - 240 m, and the outer 300 - 360 m. 2014 JO_{25} is an Apollo NEA discovered by Al Grauer on May 5 2014 at the Mount Lemmon Survey in Arizona, United States, in the NEOS program (NASA and University of Arizona collaboration). Its closest approach on April 19 2017 ($1.8\text{x}10^6$ km) was the closest by any known asteroid of this size, or larger, since asteroid Toutatis in 2004. From NEOWISE spacecraft observations in 2014 Masiero estimated a size of ~650 m. Arecibo and Goldstone radar observations during this approach found an irregular shape with 2 components connected by a narrow neck (it resembles a peanut or perhaps the nucleus of Comet 67P/Churyumov-Gerasimenko). Its long axis is ~1 km, its short axis is ~600 m, and the neck ~200 m). It is potentially hazardous.

3. Results

In Figures 1 and 2 we present the lightcurves obtained. Figure 1 shows 4055 Magellan (left side) and (143404) 2003 BD_{44} (right side) lightcurves; in Figure 2 we show 2014 JO_{25} lightcurve (left side) including the night of the maximum approach, while the right side is also for 2014 JO_{25} where data at the maximum approach were excluded. Notice that the form of the light curves in Figure 2 are very different, but that the amplitudes do not present a significant change. Warner *et al.* 2017b found a similar behavior in the striking difference of the light curves of 2014 JO_{25} during the same approach to Earth. He proposes these abrupt changes are due to this NEAs shape. Table 1 presents a summary of the results, along with comparisons with data for these objects in the literature. Column 1 is the name of the NEA, columns 2 to 4 are the period and error,

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Table 1. NEAs periods and lightcurve amplitudes.

Name		Period (h)	Amp (mag)	N	Literature Period	Reference
4055	Magellan	7.479 ± 0.001[1]	0.50	3	7.4805 ± 0.0013	Waszczak *et al.* 2015
143404	2003 BD$_{44}$	78.617 ± 0.009[2]	0.66	9	78.633 ± 0.004	Warner *et al.* 2017
3122	Florence	2.354 ± 0.003	0.22	4	2.357 ± 0.0002	Franco *et al.* 2018
	2014 JO$_{25}$[3]	4.527 ± 0.0002	0.65	1	…	
	2014 JO$_{25}$	4.527 ± 0.007	0.20	5	4.533 ± 0.02	Warner *et al.* 2017b

Notes:
[1] Sada *et al.* 2016
[2] Sada *et al.* 2017
[3] For day of maximum approach.

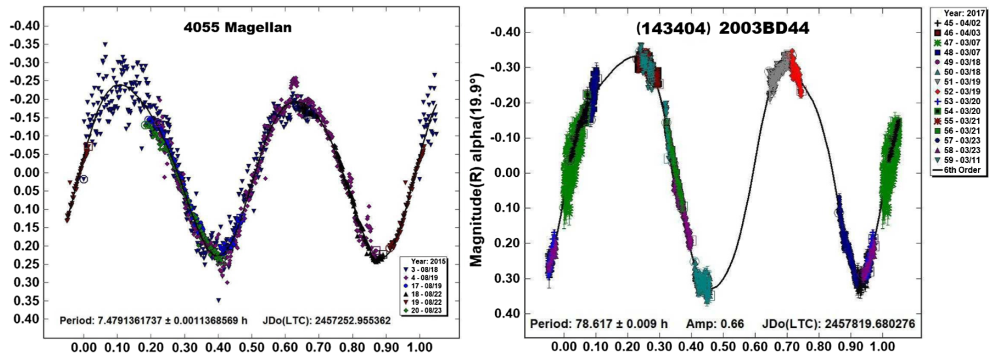

Figure 1. Lightcurves for (4055) Magellan and (143404) 2003 BD$_{44}$.

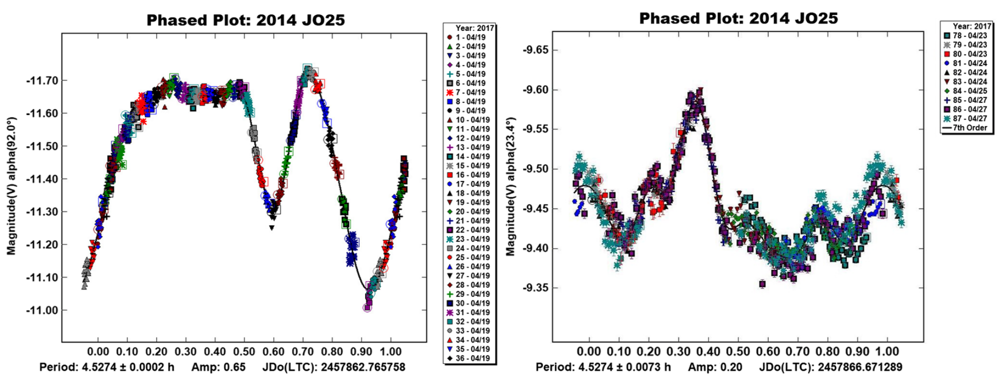

Figure 2. Lightcurves for 2014 JO$_{25}$

amplitude and number of nights measured in this work. Column 5 present the periods and errors observed by authors shown in column 6.

4. Concluding remarks and future work

Relatively small telescopes can contribute to narrow the gap between asteroid discoveries and characterization. Observing networks, both national and international, such as CMFA, EURONEAR (Birlan *et al.* 2010) and others, ought to be encouraged in order to reach a wider range of longitudes and latitudes to allow continuous observations of individual NEAs, while at the same they can be used to train observers throughout the world. From our own perspective, we plan to start taxonomical classification of bright objects (V<15), to obtain astrometry, to carry out infrared observations, to estimate

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more precisely the asteroids' size and albedo, as well as undertake theoretical studies of asteroid.

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