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## ROTATIONAL PERIOD DETERMINATION FOR 12 NEAR-EARTH ASTEROIDS

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Rotational periods for 12 near-Earth asteroids (NEAs) were determined from lightcurves acquired at the Observatório Astronômico do Sertão de Itaparica (MPC Y28, OASI) between May 2016 and 2017 August.

CCD photometric observations of 12 NEAs were made at the Observatório Astronômico do Sertão de Itaparica (code Y28, OASI, Nova Itacuruba) between 2016 May and 2017 August. All images were obtained with the 1.0-m *f*/8 telescope (Astro Optik, Germany) of the IMPACTON project and a CCD Astra Apogee Instruments (2048x2048 pixels) that was binned 2x2. This configuration gave a field-of-view of 11.8x11.8 arcmin and an image scale of 0.343 arcsec/pix. All the observations were performed in the R filter with the exposure time varied depending on the asteroid's brightness and sky motion.

Data reduction was performed using *MaxIm DL* package following the standard procedures of flat-field correction and sky subtraction. Relative magnitudes were computed to obtain the lightcurves and the rotation periods were determined using a Fourier series analysis method (e.g. Harris et al., 1989). The lightcurve for each asteroid includes the best fit line and uses different colors to represent different nights.

The observational circumstances for each of the observed asteroids are given in Table I along with the results, which are discussed individually below. In this table we give for each obtained rotation period a reliability code (Warner et al., 2009).

For some asteroids, the maximum lightcurve amplitude was used to estimate the a/b ratio for a triaxial ellipsoid asteroid shape with a > b > c and rotation about the *c*-axis. This was achieved using the relation  $\Delta m = 2.5\log(a/b)$ , as given by Burns and Tedesco (1970), where  $\Delta m$  is the maximum lightcurve amplitude reached in the equatorial view.

It is worth mentioning that a search of the Asteroid Lightcurve Database (Warner *et al.*, 2009, or other resources) did not find any previously reported results for asteroids–(138404) 2000 HA24, (250620) 2005 GE59, (370702) 2004 NC9, 2001 QE34, 2015 FO124.

<u>3352</u> McAuliffe. This is a suspected binary asteroid (Warner, 2012). It was observed for nearly four hours on two nights during 2017 April. The composite lightcurve fits a synodic period of  $P = 2.205 \pm 0.005$  h with an amplitude of  $A = 0.16 \pm 0.01$  mag. Previous results were reported by Howell (2012) and Warner (2012, 2017a, 2017b), who found rotational periods of 2.207 h, 2.206 h, 2.212 h and 2.2062 h, respectively.



(7888) 1993 UC. Observations of this Amor asteroid were made for about six hours during three nights in 2016 October. The composite lightcurve fits a period of  $P = 2.3374 \pm 0.0009$  h using a 5th-order Fourier fit. It presents a small amplitude of  $0.12 \pm 0.01$ mag and an asymmetric shape. Previous results include Pravec et al. (1996) and Warner (2017a), with rotational periods of 2.34 h and 2.337 h, respectively.



(138404) 2000 HA24. This potentially hazardous asteroid (PHA), member of the Apollo group was observed for nearly six hours on three nights during 2017 April. The composite lightcurve fits a period of  $P = 3.908 \pm 0.001$  h, using a 5th-order Fourier fit, with a small amplitude of 0.19 ± 0.01 mag. It is relatively well-covered and presents a low dispersion of the data.



(153951) 2002 AC3. This NEA was observed for about five hours on two nights in 2017 March. The composite lightcurve with a 4th-order Fourier fit gives a period of  $7.073 \pm 0.001$  h. Although not complete, the lightcurve has two maxima and minima and a high amplitude of  $A = 1.0 \pm 0.01$  mag. From this amplitude, we estimate a lower limit of a/b = 2.51, implying a quite elongated body. Warner (2017c) found a similar rotational period of 7.072 h.



(250620) 2005 GE59. This Apollo class and PHA was observed for almost eight hours on three nights from 2017 February 24 to 26. The composite lightcurve fits a period of  $P = 5.354 \pm 0.002$  h with a small amplitude of  $A = 0.11 \pm 0.02$  mag. It was obtained with a 4th-order Fourier fit and shows some dispersion among the points.



(252091) 2000 UP30. We observed this Apollo asteroid for more than four hours on just one night in 2017 April. The 4th-order Fourier fit to the data revealed a period of  $P = 5.870 \pm 0.002$  h. Although not complete, the lightcurve has two maxima and minima and an amplitude of  $0.43 \pm 0.02$  mag. This suggests an elongated shape with  $a/b \ge 1.49$ . A previous result was reported by Warner (2017c), who found a rotational period of 5.44 h.



(370702) 2004 NC9. We observed this Amor asteroid for almost eight hours on three nights during 2017 March. The composite lightcurve fits a period of  $P = 7.526 \pm 0.002$  h with an amplitude of  $0.52 \pm 0.02$  mag. Since the rotation period is not completely covered, we cannot trust the lightcurve shape around rotational phase 0.1-0.3. The composite lightcurve is asymmetric, with the

primary maximum being much larger than the secondary. The high amplitude implies  $a/b \ge 1.62$ , suggesting an elongated object.



(458198) 2010 RT11. Observations of this Amor asteroid were made for about four hours on two nights on 2016 May 13-14. The composite lightcurve fits a period of  $P = 3.007 \pm 0.001$  h. It has a small dispersion and small amplitude (0.11 ± 0.02 mag), but has an incomplete coverage. A period of 1.75 h was found by Carbognani (2017) using just three hours of observation.



(480004) 2014 KD91. We observed this Amor asteroid for almost eight hours on three nights during 2016 November. The composite lightcurve fits a period of  $P = 2.837 \pm 0.001$  h. It is well-covered and presents a low dispersion of the data. The amplitude of  $0.17 \pm 0.02$  mag may indicate an approximately spherical shape. Previous results were reported by Warner (2017a) and Carbognani (2017) who found 2.829 h and 2.837 h, respectively.



<u>2001 QE34</u>. Observations of this Apollo asteroid were made on January 2017 for about four hours. Since the weather was non-photometric, with occasionally passing clouds, only half of the frames obtained were useful. The derived synodic period is  $P = 3.780 \pm 0.002$  h with a small amplitude of  $A = 0.10 \pm 0.02$  mag.



2015 FO124. This Apollo asteroid is the smallest object studied in our work (D ~ 157 m), assuming the average NEA albedo of 0.14 given by Mainzer et al. (2011). We observed this asteroid from 2016 August 18 to 22 for three hours each night. The composite lightcurve fits a period of  $P = 5.997 \pm 0.002$  h, although some rotational phases are not covered by the observations. This lightcurve is asymmetric and present a high amplitude of 1.54 mag, suggesting a quite elongated shape, with  $a/b \ge 4.17$ .

Number	Name	yyyy mm/dd	Exp	Phase	LPAB	BPAB	Period	P.E	Amp	A.E.	U
3352	McAuliffe	2017 04/22-04/23	90	50.6,50.4	146	6	2.205	0.005	0.16	0.01	3
7888	1993 UC	2016 10/24-10/27	50	65.0,66.5	101	-40	2.337	0.001	0.12	0.01	3
138404	2000 HA24	2017 04/24-04/27	90	18.6,20.0	203	7	3.908	0.001	0.19	0.01	3
153951	2002 AC3	2017 03/01-03/02	70	28.7,29.4	162	-21	7.073	0.001	1.00	0.01	2
250620	2005 GE59	2017 02/24-02/26	30	45.5,42.7	146	-32	5.354	0.002	0.11	0.02	3
252091	2000 UP30	2017 04/28	90	38.7	182	2	5.870	0.002	0.43	0.02	2
370702	2004 NC9	2017 03/03-03/05	80	6.0,7.0	158	-4	7.526	0.002	0.52	0.02	2
458198	2010 RT11	2016 05/13-05/14	80	4.4,4.0	236	1.5	3.007	0.001	0.11	0.02	2
480004	2014 KD91	2016 11/23-11/25	90	44.2,46.2	45	-50	2.837	0.001	0.17	0.02	3
	2001 QE34	2017 01/26	90	10.2	120	-6	3.780	0.002	0.10	0.02	2
	2015 F0124	2017 08/18-08/22	120	17.3,25.0	318	-8	5.997	0.002	1.54	0.01	2
	2016 RP33	2016 09/23-09/25	50	6.0,9.0	358	4	4.707	0.001	0.22	0.02	2

Table I. Observing circumstances. Exp is average exposure time, seconds. The phase angle ( $\alpha$ ) is given at the start and end of each date range, unless it reached a minimum, which is the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L<sub>PAB</sub> and B<sub>PAB</sub> are each the average phase angle bisector longitude and latitude. The U rating is our estimate and not necessarily the one assigned in the asteroid lightcurve database (Warner *et al.*, 2009).



0.0 0.2 0.4 0.6 0.8 1.0 Rotational Phase (Zero phase on 2017/08/21 at 13:21:25 UT)

<u>2016 RP33</u>. This Amor asteroid was observed for nearly six hours on three nights, 2016 September 23 to 25. The derived rotational period is  $P = 4.707 \pm 0.001$  h with a small amplitude of  $A = 0.22 \pm$ 0.02 mag. Since the composite lightcurve presents some rotational phases not covered, the derived period is not conclusive. Warner (2017a) reported a rotational period of 4.682 h.



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