ASTEROIDS LIGHTCURVES ANALYSIS: 2016 NOVEMBER – 2017 JUNE

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Twelve near-Earth asteroids were observed from 2016 November through 2017 June to find the synodic rotation period and lightcurve amplitudes for each asteroid. Results are reported for 2329 Orthos, (138846) 2000 VJ61, (326683) 2002 WP, (489337) 2006 UM, (494706) 2005 GL9, 2005 TF, 2017 BJ30, 2017 BQ6, 2017 CS, 2017 DC36, 2017 GK4, and 2017 JA2.

This paper features the results of photometric observations of near-Earth asteroids (NEAs) made at OAVdA (Carbognani *et al.*, 2007), S. Marcello Pistoiese, and G.V. Schiaparelly from 2016 Nov to 2017 June. Work on NEAs is done when the rotation periods were not known (or at least uncertain) at the time of observations. For some NEAs, photometry has been done on astrometric follow-up images. The observing circumstances and results are given in Table I.

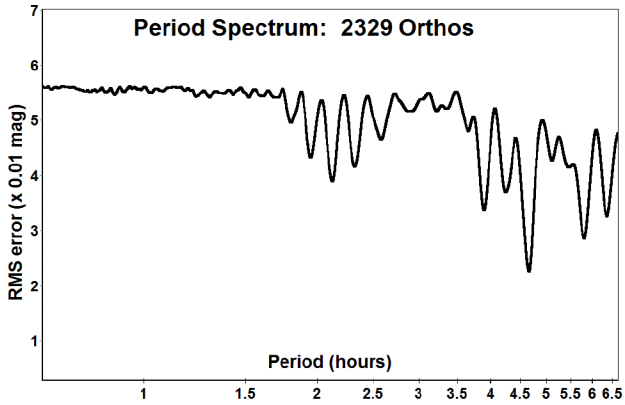
Images at OAVdA were captured with a modified Ritchey-Chrétien *f*/4.7, 0.81-m telescope and FLI-1001E CCD camera with an array of 1024×1024 pixels. The field-of-view was 22.5×22.5 arcmin and the plate scale was 1.32 arcsec/pixel in 1×1 binning mode. Considering that the full-width at half-maximum (FWHM) of the stars 45° above the horizon from OAVdA frequently is about 4.8-5.0 arcsec, 2×2 binning mode appears more useful for photometry.

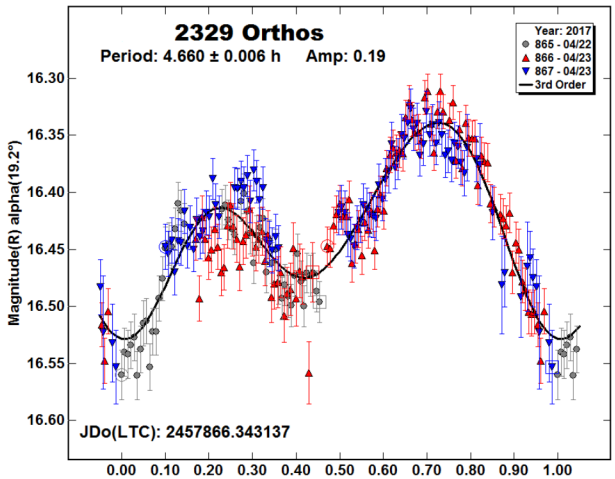
Images at San Marcello were captured with a 0.60-m *f*/4.0 Newtonian and Apogee Alta KAF-1001 CCD camera with an array of 1024×1024 pixels. The field-of-view was 35.2×35.2 arcmin. The plate scale was 2.0 arcsec/pixel in 1×1 binning mode.

Images at G.V. Schiaparelli were obtained with a 0.60-m *f*/4.64 reflector and SBIG ST10-XME (2184×1672 pixels), with a field-of-view of 18.4×12.3 arcmin and a plate scale of 1.51 arcsec/pixel.

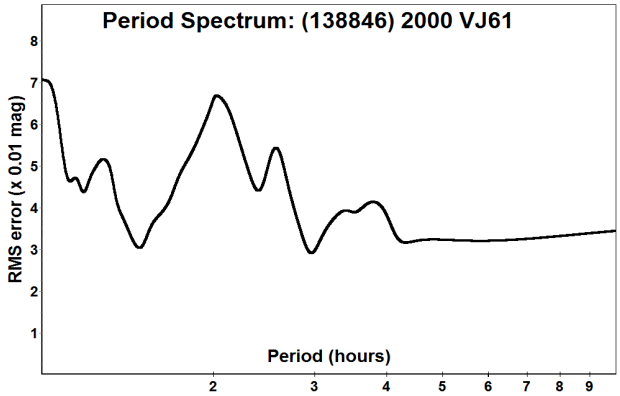
MPO Canopus (Warner, 2009) version 10.7.1.3 was used for photometry and period analysis. For period analysis, *MPO Canopus* implements the Fourier analysis algorithm by Harris (FALC; Harris et al., 1989). When possible, the sessions were calibrated with the *MPO Canopus* Comp Star Selector (CSS), which chooses comparison stars that are similar in color to the target (in general solar-type stars), and the DerivedMags approach.

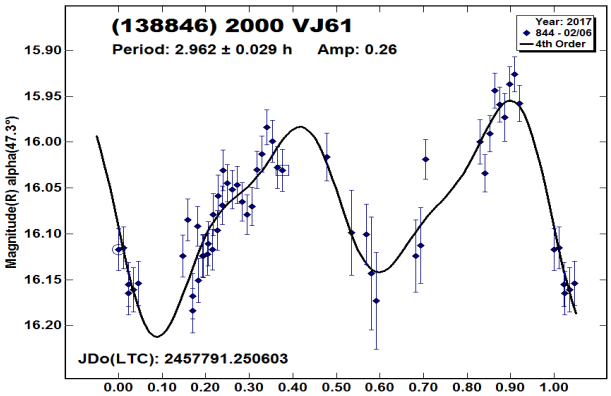
2329 Orthos is an Apollo object. A total of 333 images were taken in OAVdA with a clear filter and 120 s exposures on two nights: 2017 Apr 22 and 23. Magnitudes for the comparison stars were taken from the MPOSC3 catalog (Warner, 2007) rather than the CMC-15 catalog. The data analysis gave a period of 4.660 ± 0.006 h and amplitude of 0.19 mag with good lightcurve coverage. Two more sessions were made a month later, 2017 May 8-9. However the data were affected by moonlight and so very noisy; they were not useful for refining the rotation period value.

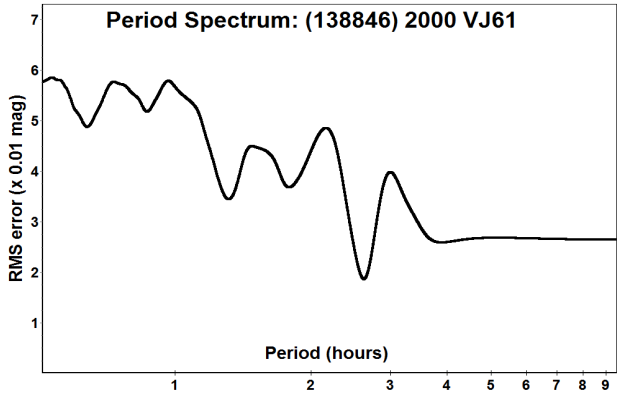


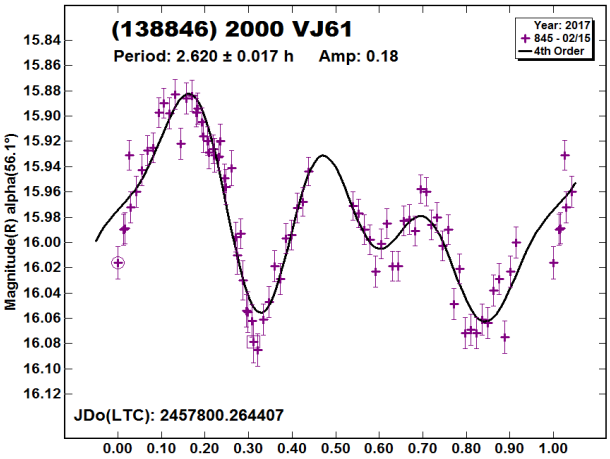


(138846) 2000 VJ61 is an Apollo object. It made an Earth flyby on 2017 May 24 at 0.194 AU. This asteroid was observed from OAVdA in three nights: 2017 Feb 6, 15 and 25. In the first session (104 images with phase-angle α = 47°), there were clouds and the asteroid passed near background stars. For this reason, 23 images were removed from photometry with the CMC-15 catalog. Lightcurve analysis of this first session showed a probable period around 3 hours and amplitude of 0.26 mag. The second session (103 images; α = 56°) was the best of the three: the sky was clear and there were no background stars. Photometry was calibrated using solar-type comparison stars from CMC-15 catalog. The result show a complex lightcurve with a period of 2.620 ± 0.017 h (compatible with the period found in the previous session), and amplitude of 0.18 mag. The last session was short (only 52 images; α = 65°) under cloudy skies. The lightcurve appears different from the previous session (e.g., the amplitude is 0.27 mag). The data were not useful in improving the analysis. The period shown in Table 1 is from the second session only.

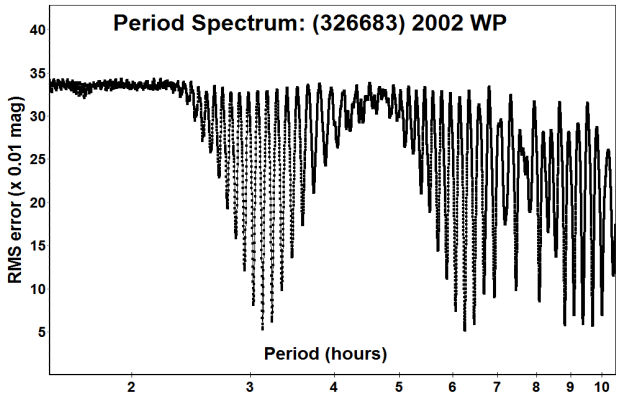


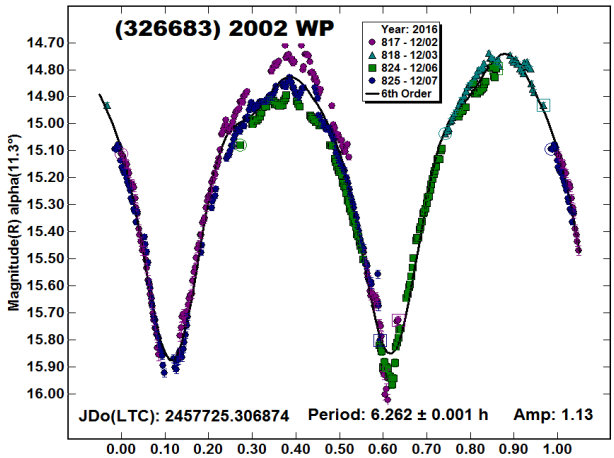




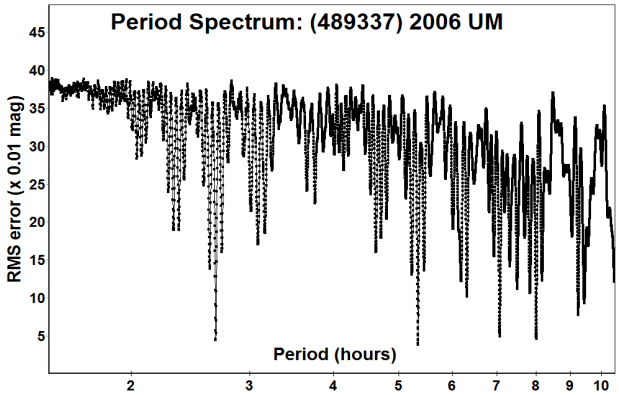


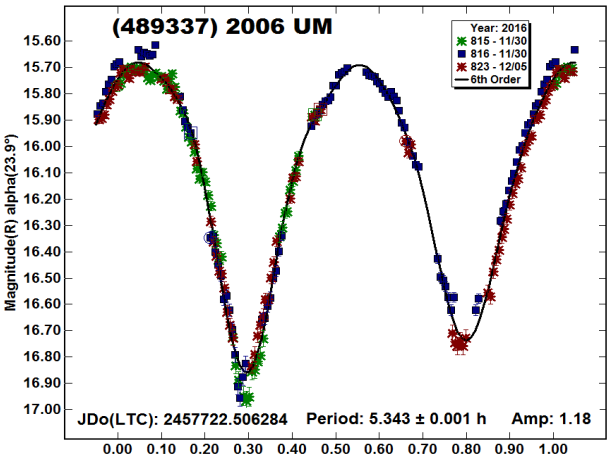
(326683) 2002 WP is an Amor object. It made an Earth flyby on 2016 Dec 07 at 0.152 AU. A total of 778 images were taken in OAVdA with a clear filter and 60 s exposures on two nights: 2016 Dec 2 and 6. Photometry was calibrated using solar-type stars from CMC-15 catalog. The asteroid lightcurve is nearly bimodal and convex with a period of 6.262 ± 0.001 h and amplitude of 1.13 mag. Images with B, V, R, and I filters were also taken in order to determine the color indices. The results will be the subject of a forthcoming paper.



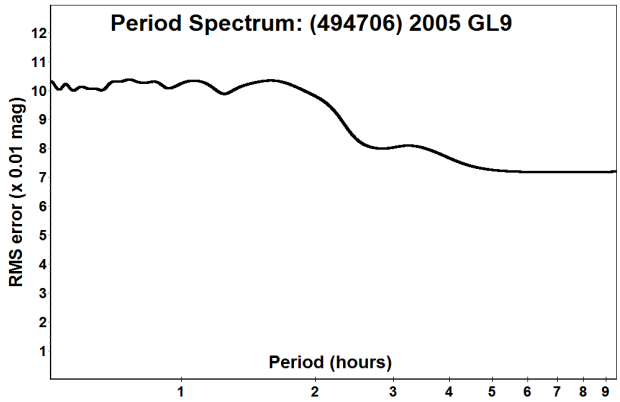


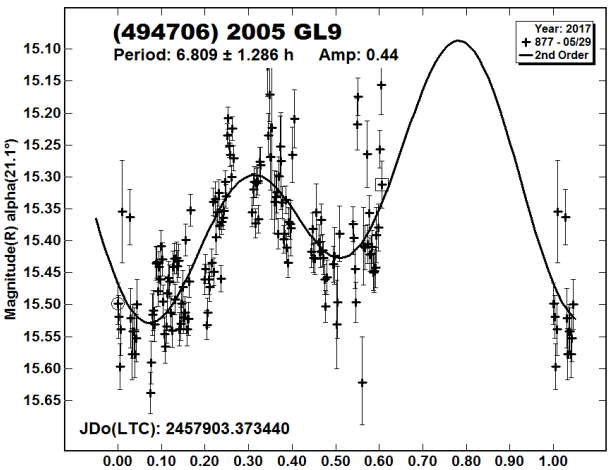
(489337) 2006 UM is an Amor object. It made an Earth flyby on 2016 Dec 13 at 0.178 AU. A total of 355 images were taken in OAVdA using a clear filter and 120 s exposures on three nights: 2016 Nov 29-30 and Dec 5. CMC-15 magnitudes were used for the comparison stars (solar-color only). Analysis found a bimodal lightcurve with P = 5.343 ± 0.001 h and A = 1.18 mag.



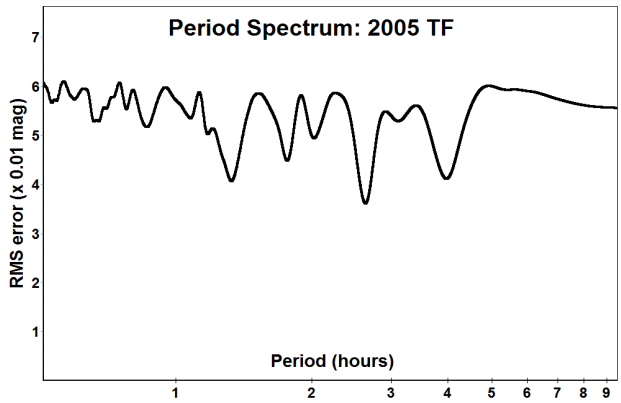


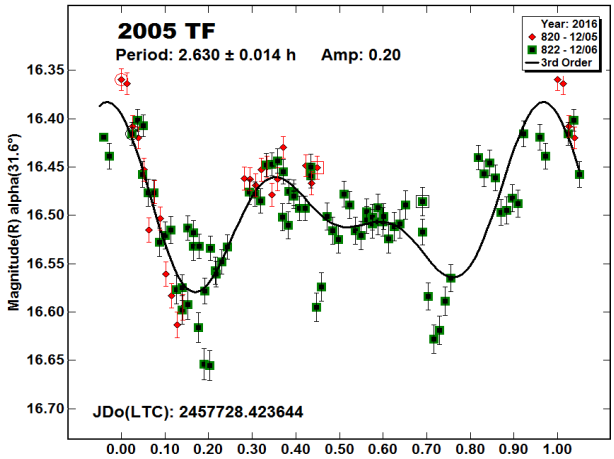
(494706) 2005 GL9 is an Apollo object. It made an Earth flyby on 2017 June 14 at 0.278 AU. A total of 224 images were taken in OAVdA using a clear filter and exposures of 60 s on 2017 May 29 for a total of 4 hours. Photometry was calibrated using solar-type comparison stars from CMC-15 catalog. Unfortunately the sky was cloudy and the photometry was not good. The best bimodal solution shows a period between 6 and 7 hours, but this is not certain.



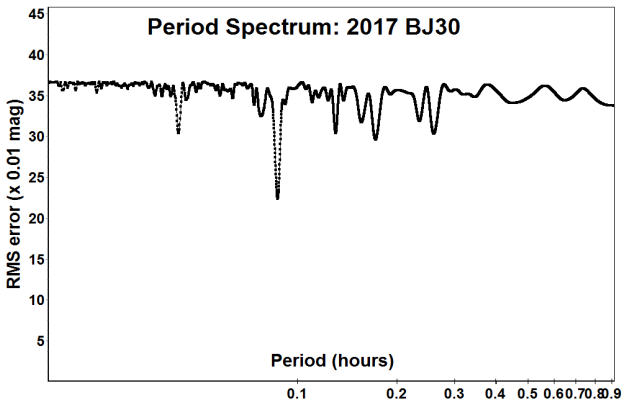


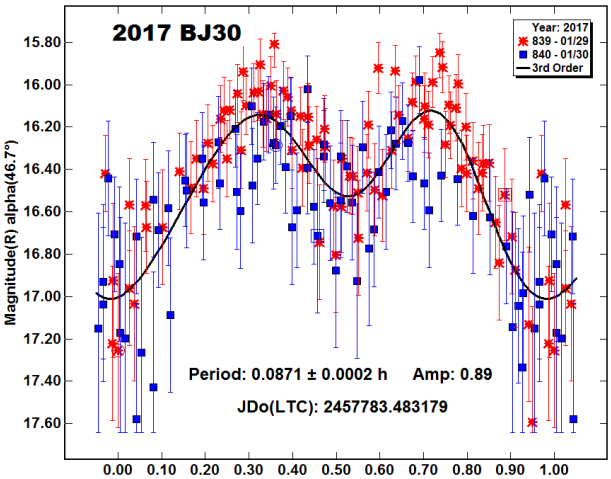
2005 TF is an Amor object. It made an Earth flyby on 2016 Nov 23 at 0.095 AU. A total of 352 images (1×1 binning), were taken in OAVdA using a clear filter and exposures of 120 s on 2016 Nov 30 and Dec 5 for a total of 11.5 hours divided into 4 sessions. Due to crowded fields, photometry was manually calibrated using stars from UCAC4 catalog. The R magnitudes were read with *Aladin 9.0* software. Only the December sessions (180 images) were used to find the period. The result was complex lightcurve with a period of 2.630 ± 0.014 h and amplitude of 0.20 mag.



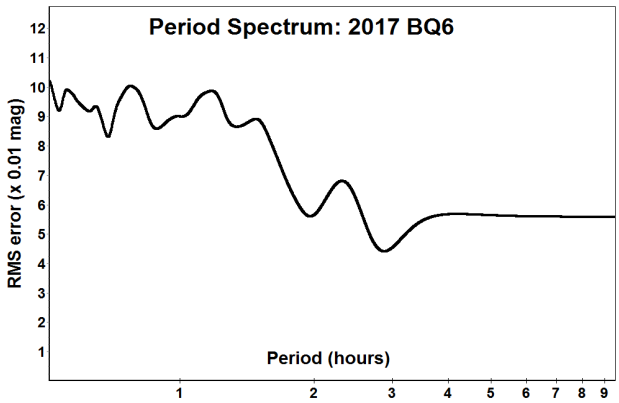


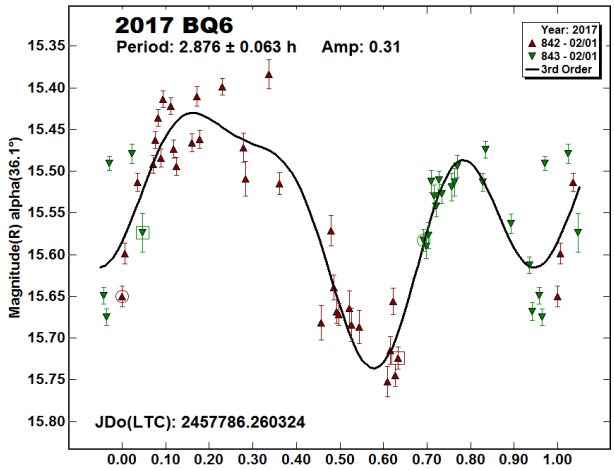
2017 BJ30 is an Apollo object. It made an Earth flyby on 2017 Dec 31 at 0.0026 AU. A total of 415 images in three sessions were taken from San Marcello on 2017 Jan 29. Due to a sky motion of 50″/min, exposures were only 10 seconds. Photometry was done in OAVdA using solar-type comparison stars from CMC-15 catalog. Data analysis found a bimodal lightcurve with a period of 0.0871 ± 0.0002 h and amplitude of 0.89 mag. Considering that this is an object with a diameter of 10-20 meters, the period seems reasonable (Pravec and Harris, 2000).



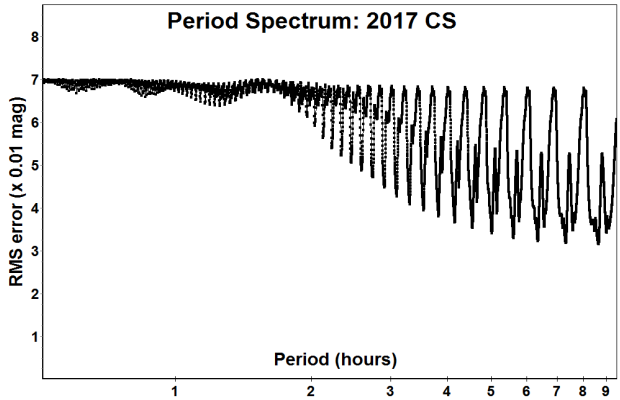


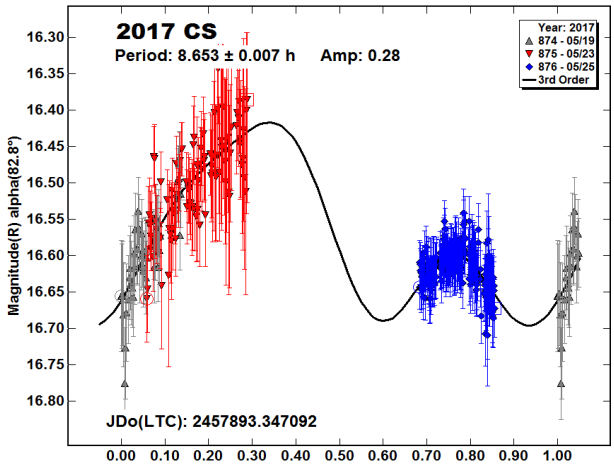
2017 BQ6 is an Apollo object classified as a potentially hazardous asteroid (PHA). It made an Earth flyby on 2017 Feb 7 at 0.017 AU. A total of 177 images were taken in OAVdA on 2017 Feb 1 for about 3 hours using a clear filter and exposures of 60 s in binning 1×1 mode. Images where the asteroid was close to bright stars in the crowded field were eliminated. Photometry was calibrated using solar-type comparison stars from CMC-15 catalog. Data analysis found a bimodal lightcurve with P = 2.876 ± 0.063 h and A = 0.31 mag. The period is compatible with that found by radar observations at Arecibo and Goldstone (*https://www.jpl.nasa.gov/news/news.php?feature=6742*).



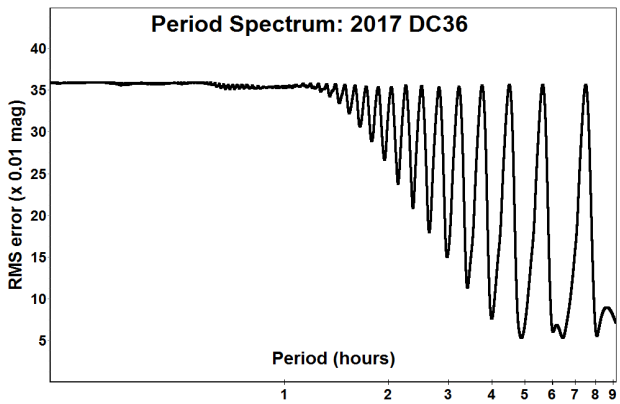


2017 CS is an Apollo classified as a PHA. It made an Earth flyby on 2017 May 29 at 0.020 AU. It was observed from OAVdA on 2017 May 19 and from San Marcello on May 23 and 25. The data were not sufficient to make a reliable determination of the period, which appears to be around 8-9 hours.



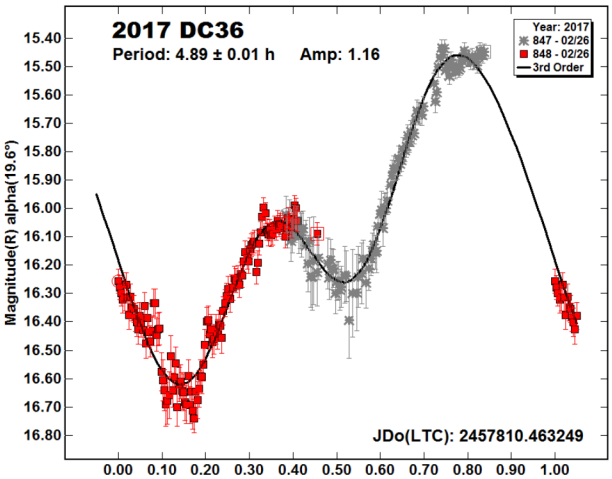


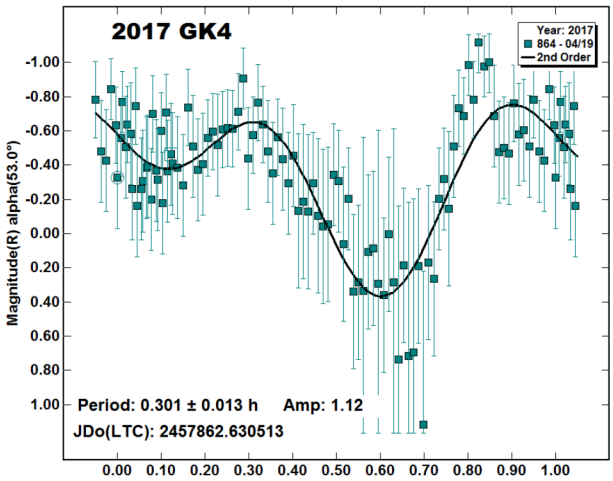
2017 DC36 is an Aten object. It made an Earth flyby on 2017 Feb 18 at 0.011 AU. A total of 260 images were taken from San Marcello using a clear filter and exposures of 60 s on 2017 Feb 25 and 26. Photometry in OAVdA used CMC-15 solar-type comparison stars. Data on the first was affect by bad seeing and the second day by clouds. The only the second day data, divided into two sessions, were used. Analysis found a bimodal lightcurve with a period of 4.89 ± 0.01 h and amplitude of 1.16 mag. Unfortunately, the lightcurve does not appear complete.



Number	Name	2016-2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.
2329	Orthos	04/22-05/09	333	18.6,29.5	192	21	4.660	0.006	0.19	0.04
138846	2000 VJ61	02/06-02/25	103	46.4,63.9	105	-27	2.620	0.017	0.18	0.03
326683	2002 WP	12/02-12/06	778	13.1,5.3	073	-06	6.262	0.001	1.13	0.02
489337	2006 UM	11/29-12/05	355	22.2,32.1	053	09	5.343	0.001	1.18	0.02
494706	2005 GL9	05/29	224	21.1	243	17	6-7	---	>0.4	---
	2005 TF	11/30-12/05	180	29.0,31.3	080	12	2.630	0.014	0.20	0.05
	2017 BJ30	01/29	415	46.7	112	-07	0.0871	0.0002	0.89	0.1
	2017 BQ6	02/01	177	36.1	114	-05	2.876	0.003	0.31	0.03
	2017 CS	05/19-05/25	413	82.5,96.7	197	-04	8-9	---	>0.28	---
	2017 DC36	02/25-02/26	260	19.1,19.2	157	-10	4.89	0.01	1.16	0.03
	2017 GK4	04/19-04/25	336	52.5,76.4	176	10	0.301	0.013	1.12	0.2
	2017 JA2	05/09	300	39.6	216	14	3.20	---	>0.84	---

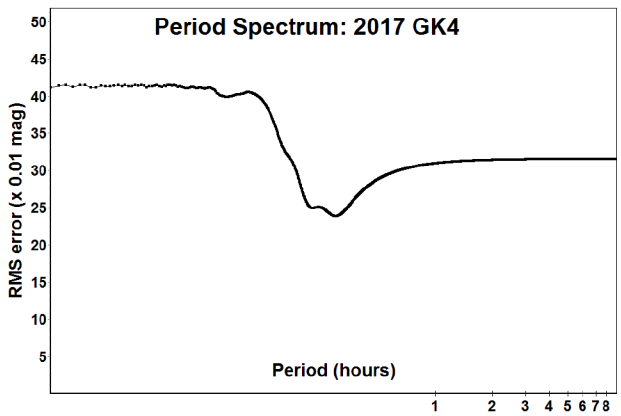
Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The phase angle values are for the first and last date, unless a minimum (second value) was reached. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude(see Harris *et al.*, 1984). Period is in hours. Amp is peak-to-peak amplitude.

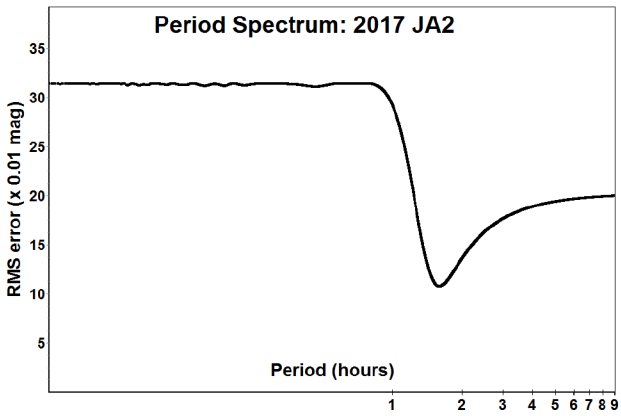


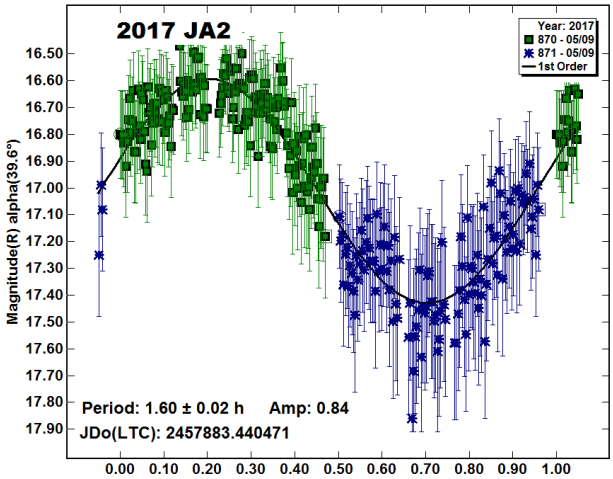


2017 GK4 is an Apollo classified as a PHA. It made an Earth flyby on 2017 Apr 23 at 0.092 AU. A total of 336 astrometric images were taken from G.V. Schiaparelli using a clear filter on 2017 Apr 19, 23 and 25. Only the first session of 122 images was used for analysis. The photometry was done in OAVdA using the few available stars in the field of view for comparisons. Analysis found a bimodal lightcurve with a period of 0.301 ± 0.013 h and amplitude of 1.12 mag. Considering that the diameter is between 100 and 300 meters, this period seems reasonable even though it is well below the "spin-barrier."

2017 JA2 is an Apollo object. It made an Earth flyby on 2017 May 12 at 0.0066 AU. A total of 300 images were taken from OAVdA using a clear filter and exposures of 15 and 20 s on 2017 May 9 for a total of 1.5 hours. The photometry was done using comparison stars from CMC-15 catalog. Analysis found a monomodal lightcurve with a period of 1.60 ± 0.02 h and amplitude of 0.84 mag. Considering the small size (about 20-60 m) and the large amplitude, the bimodal solution appears the most likely, so the real period should be about 3.2 hours.







Acknowledgements

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References

Carbognani, A., Calcidese, P. (2007). "Lightcurve and Rotational Period of Asteroids 1456 Saldanha, 2294 Andronikov and 2006 NM." *Minor Planet Bulletin*, **34**, 18-19.

Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H.J., Debehogne, H., Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Pravec, P., Harris, A.W. (2000). "Fast and Slow Rotation of Asteroids." *Icarus* **148**, 12-20.

Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

Warner, B.D. (2009). MPO Software, *MPO Canopus*. Bdw Publishing. *http://minorplanetobserver.com/*

ROTATIONAL PERIOD DETERMINATION OF TWO MARS CROSSING, A MAIN BELT ASTEROID AND A PHA: (14309) DEFOY, (56116) 1999 CZ7, (5813) EIZABURO AND (3122) FLORENCE

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The main-belt asteroids (5813) Eizaburo and two Mars crossing minor bodies, (14309) Defoy and (56116) 1999 CZ7, have been observed over several nights throughout 2017 March-September in order to determine their synodic rotational period. We also took the opportunity of the (3122) Florence close passage with the Earth in September-October to find its lightcurve.

The observations of the analyzed asteroids were carried out from F. Fuligni Observatory using a 0.35-m f/10 ACF telescope and SBIG ST8-XE CCD camera with Clear filter and from Franceschini's equipment using a 9.25" f/6.3 reflector telescope equipped with Atik 314L- CCD camera with Clear filter. All images were dark and flat-field calibrated with *Maxim DL*. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2012).

3122 Florence. This asteroid, discovered from the Siding Spring observatory at the beginning of the '80s, belongs to the Amor family and is classified as a potentially hazardous asteroid (PHA). A diameter of 4.9 Km makes it one of the biggest PHA known.

Its orbit, resonant with the Earth, brings this big object close to our planet every ~40 years and the 2017 passage is the closest for at least the next 160 years. During this close flyby a radar observation has shown the presence of 2 natural moons with diameters of around 180-240m and 300-360m. Our measurements have been taken since the first days of September (8 sessions in total) but only the last observations have been used for the lightcurve, fitting these data more coherently with the known asteroid properties. We found a synodic period of P = 2.36 ± 0.01 h and an amplitude of A = 0.14 mag (Figure 1).

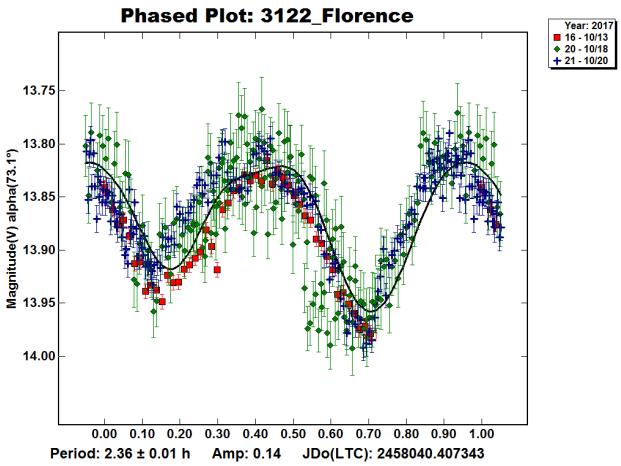

Figure 1. Lightcurve of 3122 Florence. Period P = 2.36h ± 0.01 h.