

LIGHTCURVE ANALYSIS FOR NINE MAIN-BELT ASTEROIDS. ROTATION PERIOD AND PHYSICAL PARAMETERS FROM APT OBSERVATORY GROUP: 2016 OCTOBER-DECEMBER

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Lightcurves of nine main-belt asteroids (MBA) obtained at APT-Observatory Group from 2016 October-December were analyzed for rotation period, amplitude and physical parameters (axis size relationship).

CCD photometric observations of nine main-belt asteroids (MBA) were made from APT Observatory Group during the fourth quarter of 2016. Table I lists the telescope/CCD camera combinations used for the observations. The asteroids were selected from those having a quality rating of $U \geq 2$ in the asteroid lightcurve database (LCDB; Warner *et al.* 2009). Also included were asteroids with no reported period in the LCDB.

Even if an asteroid is rated $U = 3$, it can still be useful to make additional observations. One reason is to see how the lightcurve amplitude changes from one apparition to the next, or how the amplitude changes in a single apparition as the viewing aspect as measured by the phase angle bisector (PAB; Harris *et al.* 1984) changes. Future analysis of changing lightcurve amplitudes from one, usually multiple apparitions, can provide relevant information about the asteroid's shape and spin axis orientation.

The APT Observatory Group consists of two observatories. First is the Isaac Aznar Observatory located in Centro Astronómico del Alto Turia, Aras de los Olmos, Valencia, Spain, at an altitude of 1270 meters and under dark skies ($21.7 \text{ mag/arcsec}^2$ on average). The image scale is $1.44 \text{ arcsec/pixel}$. The second observatory is the POP-Punto de Observación de Puçol, Puçol, Spain. This is in an urban location and is equipped with a 0.25-m telescope, SBIG ST-9 CCD, and adaptive optics. The image scale is $1.56 \text{ arcsec/pixel}$. Details are presented in Table I.

Observatory	Telescope (m)	CCD + Acc.
OIA Obs. Isaac Aznar	0.35m SCT	STL1001E+AO
POP Punto Obser. Puçol	0.25m SCT	ST9XE+AO

Table I. Equipment used for capturing images.

All images were obtained in 1×1 binning mode and were taken without any photometric filter. The SNR for the target assured a lightcurve of sufficient quality and low data dispersion. Dark and bias frames and twilight sky flat-fields were applied to each science image.

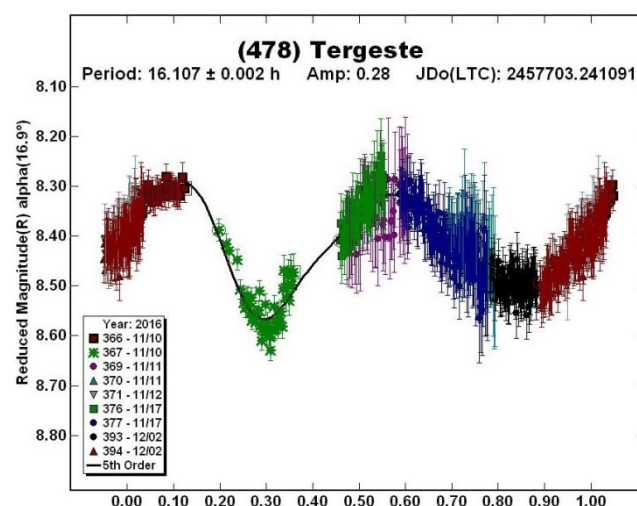
Data reduction was done with *MPO Canopus*. This software implements the FALC period analysis algorithm developed by Harris (Harris *et al.*, 1989). The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. The comp star magnitudes were taken from the APASS (Henden *et al.*, 2009) and MPOSC3 catalogs, depending on availability of comparison stars. The nightly zero points for both catalogs have been found to be

generally consistent to about $\pm 0.05 \text{ mag}$ or better, but on occasion reach 0.1 mag and more.

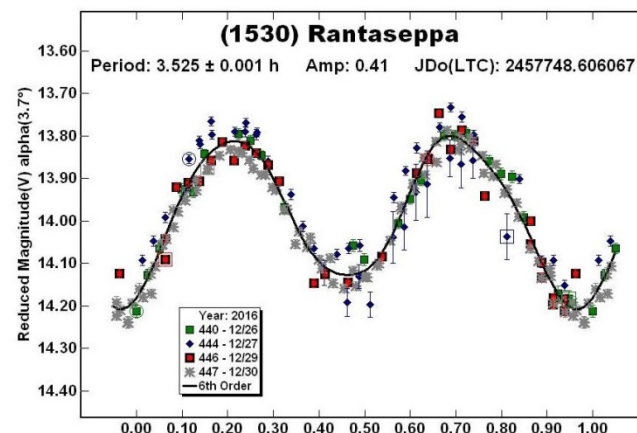
The StarBGone star subtraction algorithm in *MPO Canopus* was used when needed in order to remove the effect of stars located in the asteroid's path. This is most effective when the star's SNR is equal to or lower than asteroid's SNR. (Aznar, 2013).

In Table II, the a/b and b/c columns give the axis ratios for an assumed triaxial ellipsoid where $a > b$ and rotation is about the c -axis (Harris and Lupishko 1989). These were derived after reducing the lightcurve amplitude to zero phase angle (Zappala *et al.* 1980). It should be noted that in finding the ratios, the assumption was an equatorial view of the asteroid. Future analysis will be necessary to confirm this assumption.

478 Tergeste. The period for Tergeste has been reported on many occasions, all being near 16.1 h , e.g., Marciniak *et al.* (2013; 16.105 h). Period analysis based on a data set of 606 data points obtained during nine sessions gave a period of $16.107 \pm 0.002 \text{ h}$.



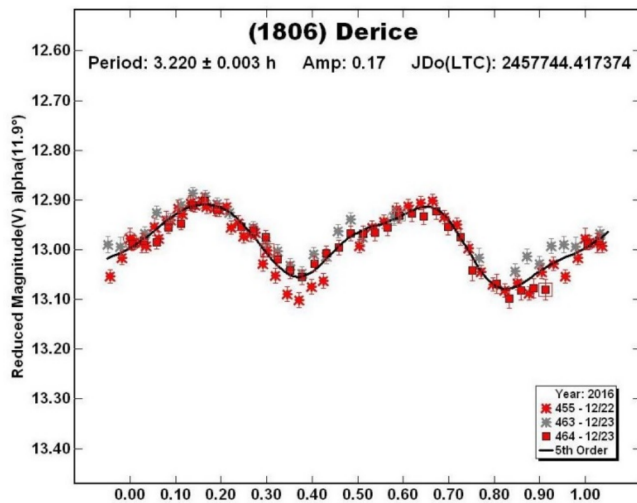
1530 Rantaseppa. Pravec *et al.* (2016) found a period of 3.5258 h for this asteroid. The result here of $3.525 \pm 0.001 \text{ h}$, based on 182 data points over four sessions, is in good agreement. The maximum amplitude of 0.41 mag indicates an elongated body with $a/b = 1.43$, assuming the view was equatorial. If the asteroid was viewed more pole-on, this represents a minimum value.



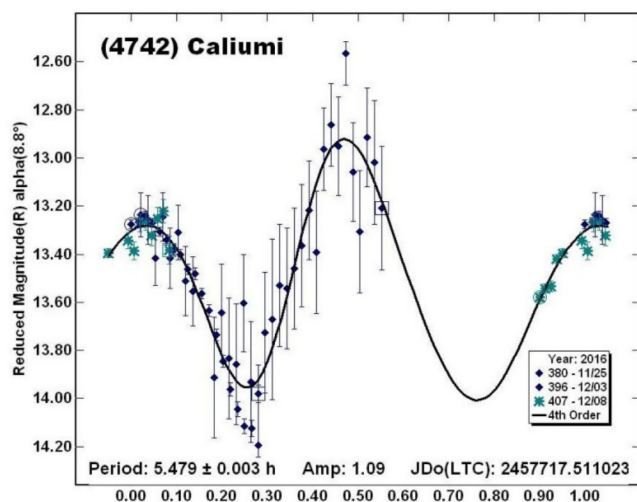
Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	a/b	b/c
478	Tergeste	16/11/10-12/20	606	16.8, 18.4	352	12	16.107	0.002	0.28	0.02	1.87	0.86
1530	Rantaseppa	16/12/26-12/30	182	3.8, 1.4	101	1	3.525	0.003	0.41	0.03	1.43	0.78
1806	Derice	16/12/22-12/23	108	11.9, 11.3	109	-1	3.220	0.003	0.17	0.01	1.47	0.89
4742	Caliumi	16/11/25-12/08	64	8.8, 5.3	76	-6	5.479	0.003	1.09	0.12	2.42	0.49
5112	Kusaji	16/11/07-11/08	54	2.1, 2.3	45	-3	3.336	0.007	0.20	0.02	1.19	0.87
6244	Okamoto	16/12/31-01/03	98	9.5, 7.9	114	-5	2.899	0.003	0.12	0.03	1.12	0.49
7774	1992 UU2	16/12/24-12/26	98	18.8, 19.7	63	0	3.869	0.002	0.46	0.03	1.39	0.81
11087	Yamasakimakoto	16/10/03-11/01	83	5.8, 21.4	3	-2	4.5369	0.0002	0.73	0.05	1.94	0.59
12326	Shirasaki	16/11/10-11/17	117	5.0, 5.7	50	7	3.3383	0.0009	0.20	0.04	1.19	0.88

Table II. 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. Period is in hours. Amp is peak-to-peak amplitude in magnitudes. D is from the JPL Small Bodies Node. The last two columns give the a/b and b/c ratios for an assumed triaxial ellipsoid viewed equatorially based on the amplitude.

(1806) *Derice*. All previous analysis indicates a rotation period of about 3.22 h, e.g., Pravec *et al.* (2016) found 3.2236 h, which is very close to the period reported here.

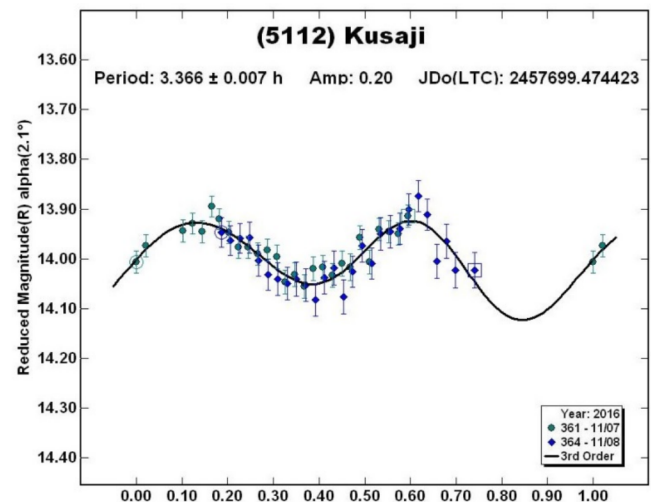


(4742) *Caliumi*. A period of 5.479 h was derived from data obtained on three nights and matches the one found by Pravec *et al.* (2016). The maximum measured amplitude ($\alpha = 8.8^\circ$) was 1.09 mag. Using Zappala *et al.* (1990), the amplitude at $\alpha = 0^\circ$ would be about 0.96 mag, or an a/b ratio of 1.43.

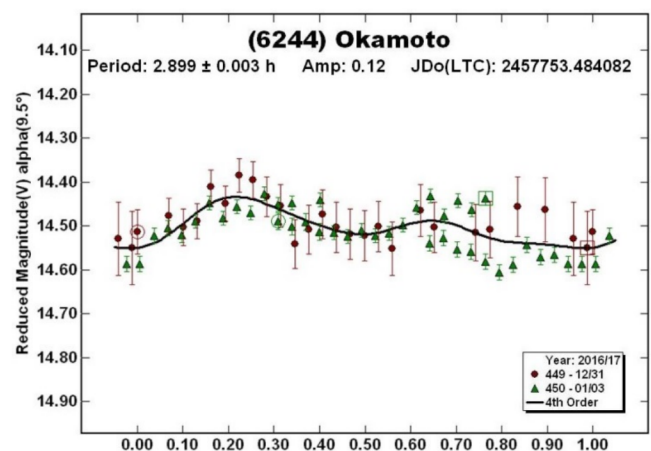


5112 *Kusaji*. Chiorny *et al.* (2016) found 5112 *Kusaji* to be a binary asteroid with a primary rotation period of 2.7995 h and satellite orbital period of 20.74 h. Based on a data set of only two

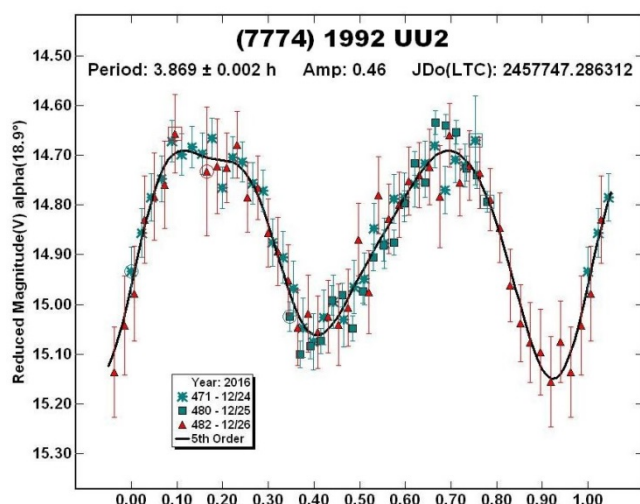
sessions, a period of 3.366 hours was found but this is based on an incomplete lightcurve. Poor weather prevented additional observations.



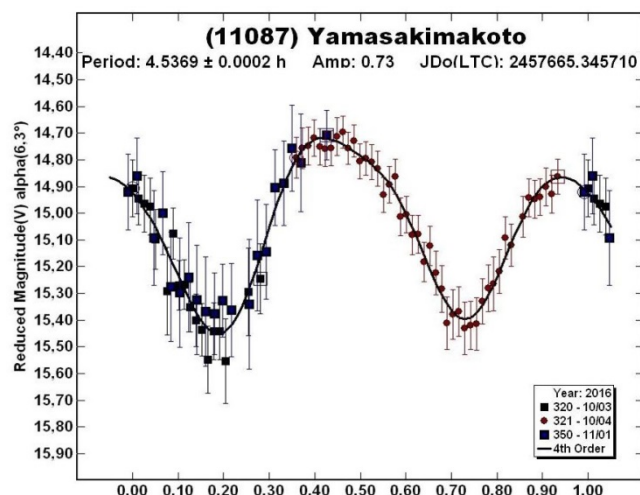
6244 *Okamoto*. Higgins *et al.* (2006) discovered this be a binary asteroid with a primary rotation period of 2.8958 h and satellite orbital period of 20.32 h. Analysis of data obtained from 2016 Dec 31 to 2017 Jan 3 gives a period of 2.8958 ± 0.003 hours.



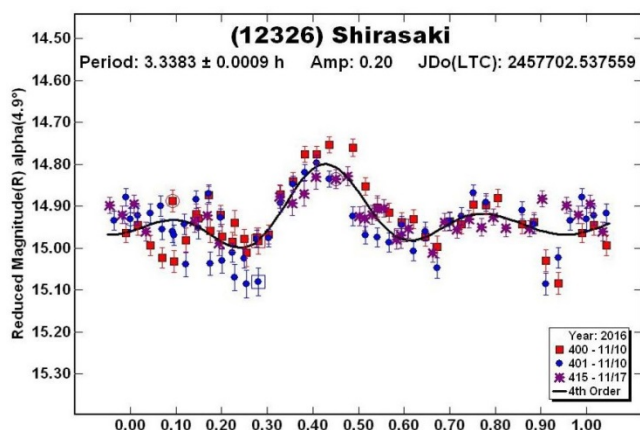
(7774) 1992 UU2. Krotz *et al.* (2010) found a period of 3.87 h. Our analysis on data from 2016 December indicates a similar result: 3.869 ± 0.002 h. Using Zappala *et al.* (1990), the estimated amplitude at $\alpha = 0^\circ$ is 0.35 mag, which leads to a/b = 1.39.



(11087) Yamasakimakoto. There were no entries in LCDB for this asteroid. We have calculated a rotation period of 4.5369 ± 0.0002 h, with an amplitude of 0.73 mag. The lightcurve shows a typical bimodal shape and its amplitude maximum suggests an elongated form with $a/b \sim 1.94$.



(12326) 1998 QF80.



Pray *et al.* (2017) reported this asteroid to be binary. The primary rotation period is 2.7286 h. A secondary period of 12.7 h was found. They suggest it is due to the independent rotation of the

satellite or to a third body. The orbital period of the satellite was found to be 25.06 h. Based on 117 data points obtained on two nights, analysis found a period 3.3383 ± 0.0009 h and amplitude of 0.20 mag

Acknowledgements

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References

- Aznar, A. (2013). "Lightcurve of 3422 Reid Using Star Subtraction Techniques." *Minor Planet Bull.* **40**, 214-215.
- Aznar, A. (2016). "Parameters of Rotation Shapes of Main-belt Asteroids from APT Observatory Group: Second Quarter 2016." *Minor Planet Bull.* **43**, 350-353.
- Harris, A.W., Lupishko, D.F. (1989). "Photometric lightcurve observations and reduction techniques." in *Asteroids II* (R.P. Binzel, T. Gehrels, M.S. Matthews eds.) pp. 39-53. University of Arizona Press. Tucson, AZ.
- Chiorny, V., Pravec, P., Romeuf, D., Montaignut, R., Gillier, C., Benishek, V., Marchini, A., Papini, R., Salvaggio, F., Oey, J. (2016). *CBET* **4336**.
- 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.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.
- Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). <http://www.aavso.org/apass>
- Higgins, D., Pray, D., Kusnirak, P., Pravec, P. (2006). *CBET* **681**.
- Krotz, J., Albers, K., Carbo, L., Kragh, K., Meiers, A., Yim, A., Ditteon, R. (2010). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory." *Minor Planet Bull.* **37**, 99-101.
- Marciniak, A., Pilcher, F., Oszkiewicz, D., Santana-Ros, T., Urakawa, S., Fauvaud, S., Kankiewicz, P., Tychoniec, L., Fauvaud, M., Hirsch, R., and 14 co-authors. (2015). "Against the biases in spins and shapes of asteroids." *Planet. Space Sci.* **118**, 256-266.
- Pravec, P., Wolf, M., Sarounova, L. (2016). <http://www.asu.cas.cz/~ppravec/neo.htm>
- Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2016 Dec 7. <http://www.MinorPlanet.info/lightcurvedatabase.html>
- Zappala, V., Cellini, A., Barucci, A.M., Fulchignoni, M., Lupishko, D.E. (1990). "An analysis of the amplitude-phase relationship among asteroids." *Astron. Astrophys.* **231**, 548-560.