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319 LEONA AND 341 CALIFORNIA – TWO VERY SLOWLY ROTATING ASTEROIDS

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An observing strategy for asteroids suspected of being very slowly rotating is described and recommended to all observers. For 319 Leona the synodic rotation period is 430 ± 2 hours, amplitude 0.7 magnitudes, a second tumbling period is 1084 ± 10 hours, color index V-R = 0.43, H=10.46 ± 0.08 and G=0.11 ± 0.09 at mean light. For 341 California the synodic rotation period is 318 ± 2 hours, amplitude 0.9 magnitudes, a second tumbling period is 250 ± 2 hours, color index V-R = 0.53, H=11.53 ± 0.06 and G=0.18 ± 0.05 at mean light.

For very slowly rotating asteroids the most productive observing strategy is to obtain a short session 15 to 20 minutes every clear night except when the Moon is very close in the sky for several months before and after opposition. Solar colored comparison stars with Sloan r' magnitudes from the CMC15 catalog (VizieR web site) should be used to measure all CCD frames. The internal consistency of the CMC15 catalog is usually within 0.05 magnitudes over the entire sky. The r' magnitudes read off the CMC15 catalog may be converted to the standard Cousins R magnitudes system by R=r'-0.22 (Dymock and Miles, 2009). Lightcurves from all sessions are then composited with no adjustment of instrumental magnitudes. A search should be made for possible tumbling behavior. This is revealed whenever successive rotational cycles show significant variation, and quantified with simultaneous 2 period software. In addition, it is useful to obtain a small number of all-night sessions for each object near opposition to look for possible small amplitude short period variations.

Observations to obtain the data used in this paper were made at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. Exposures were 60 seconds, unguided, with a clear filter. All measurements were calibrated from CMC15 r' values to Cousins R magnitudes for solar colored field stars. Photometric measurement is with MPO Canopus software. To reduce the number of points on the lightcurves and make them easier to read, data points on all lightcurves constructed with MPO Canopus software have been binned in sets of 3 with a maximum time difference of 5 minutes between points in each bin.

Twenty images in both R and V filters were obtained alternately on 2016 September 10 for 319 Leona and 341 California. The same solar colored comparison stars with Sloan r', J, and K magnitudes read from the CMC15 catalog (VizieR web site) were used to measure both image sets. For the R filter images, conversions to Cousins R magnitudes are by R=r'-0.22. For the V filter images conversions to Johnson V magnitudes are by V=0.9947*r'+0.6278*(J-K). Both conversion procedures are from Dymock and Miles (2009). The magnitudes thus converted for each color are shown together. The V magnitude data points can be adjusted upward to obtain the best fit between R magnitude and V magnitude overlapping sessions. The amount of the adjustment is then the color index V-R. For each session R magnitudes were estimated at maximum, mid, and minimum light for the rotational cycle. Each measured R magnitude was converted to its corresponding V magnitude by adding V-R. The H-G calculator function of *MPO Canopus* then drew the phase diagram for H and G at maximum, mid, and minimum light, respectively, in the Johnson V magnitude system.

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.	P2	P.E.
319	Leona	08/04-12/06	3193	17,1,20	4	0	430.	2.	0.5	0.1	1084	10
341	California	06/03-12/07	3793	34,1,26	12	-4	318.	2.	0.5	0.1	250	2

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first date, minimum value, and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). P2 is the second period of tumbling.

<u>319 Leona</u>. Previous published rotation periods and amplitudes are by Behrend (2006), 9.6 hours, 0.03 magnitudes; and by Alkema (2013), 14.9 hours, 0.10 magnitudes. A total of 82 sessions, most of them about 15 minutes, were obtained 2016 Aug. 4 – Dec. 6. A single period lightcurve was constructed with *MPO Canopus* software with best fit to a period 430.66 ± 0.18 hours (Fig. 1). The small formal error is unrealistic because for tumbling asteroids systematic errors are much larger than formal errors. A fit with the 2nd order 2 period Fourier series (Fig. 2) finds a main period 430 ± 2 hours, amplitude 0.7 magnitudes, and candidate second period 1084 ± 10 hours. This fit is done in flux units, not magnitudes. The strongest signals are in the frequencies 2/P_1 and 1/P_2 with their flux amplitude ratio 1:0.22. Use of higher orders is not justified by the data limitations for the very long second period. A raw lightcurve of 319 Leona fitted to the 2 period Fourier model is shown in Fig. 3. Individual rotational cycles and their changes in successive cycles due to tumbling are clearly perceived. Raw lightcurves are also shown for the intervals 2016 Sept. 23-25 on the descending branch of the lightcurve (Fig. 4) and 2016 Sept. 27-29 on the ascending branch (Fig. 5). Within the ± 0.05 magnitude internal consistency of the CMC15 catalog, the all-night lightcurve of the middle night has a slope that fits the slope defined for all three nights. No short period variation is seen. Fig. 6 shows alternating R and V filter magnitudes separated by V-R = 0.43 magnitudes. Fig. 7 shows the V magnitude H-G plot for 319 Leona at maximum light, mid light, and minimum light, respectively.

<u>341 California</u>. Previous published rotation periods and amplitudes are by Behrend (2005), 8.74 hours, 0.07 magnitudes; Behrend (2008), 8.74 hours, 0.02 magnitudes; and Skiff (2014), 317 hours, 0.75 magnitudes. A total of 117 sessions, most of them about 15 minutes, were obtained 2016 June 3 – Dec. 7. A single period lightcurve was constructed with *MPO Canopus* software with best fit to a period of 317.88 ± 0.06 hours (Fig. 8). The small formal error is again unrealistic for a tumbling asteroid. A fit with the 4th order 2 period Fourier series (Fig. 9) finds a main period 318 hours, amplitude 0.9 magnitudes, candidate second period 250 hours, both ± 2 hours. Again in flux units, the strongest signals are in the frequencies 2/P_1 and 2/P_2 with flux amplitude ratio 1:0.21. A raw lightcurve of 341 California fitted to the 2 period Fourier model is shown in Fig. 10. Individual rotational cycles and their changes in successive cycles due to tumbling are clearly perceived. Raw lightcurves are also shown for the intervals 2016 Oct. 3-5 (Fig. 11) and 2016 Oct 9-11 (Fig. 12), both on descending branches of the lightcurve. Within the ± 0.05 magnitude internal consistency of the CMC15 catalog, the all-night lightcurve of the middle night has a slope that fits the slope defined for all three nights. No short period variation is seen. Fig. 13 shows alternating R and V filter magnitudes separated by V-R = 0.53 magnitudes. Fig. 14 shows the V magnitude H-G plot for 341 California at maximum light, mid light, and minimum light, respectively.

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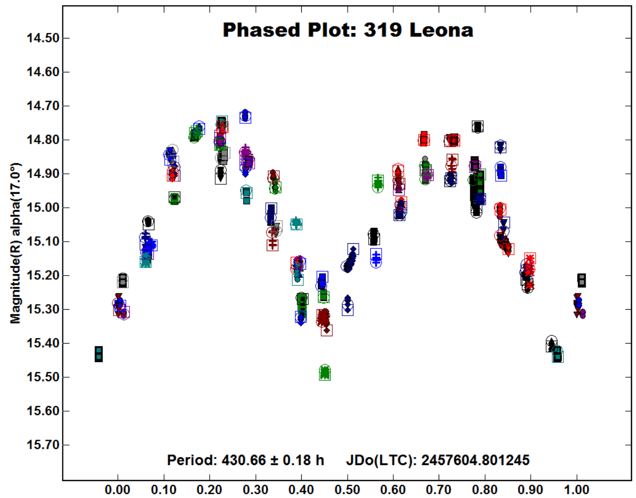

Figure 1. Single period lightcurve of 319 Leona based on 82 sessions 2016 Aug. 4 - Dec. 6 in R band magnitudes, corrected for changes in phase angle and geocentric and heliocentric distances and prepared by MPO Canopus software.

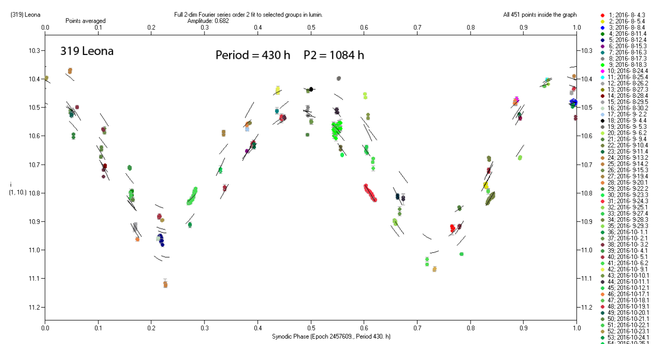

Figure 2. Second order 2 period Fourier series lightcurves of 319 Leona.

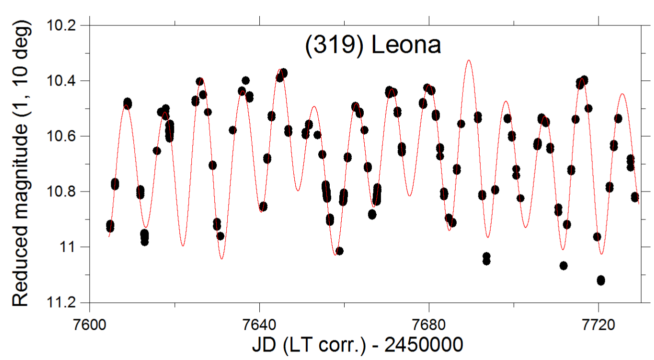

Figure 3. Raw lightcurve of all sessions of 319 Leona fit to a 2 period Fourier model.

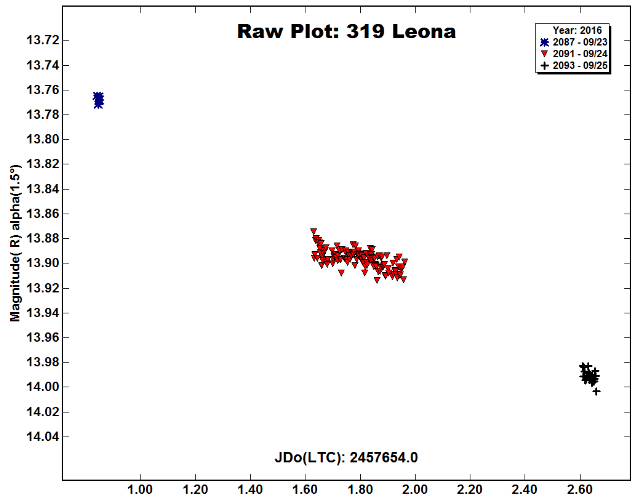

Figure 4. Raw lightcurve of 319 Leona for the interval 2016 Sept. 23-25.

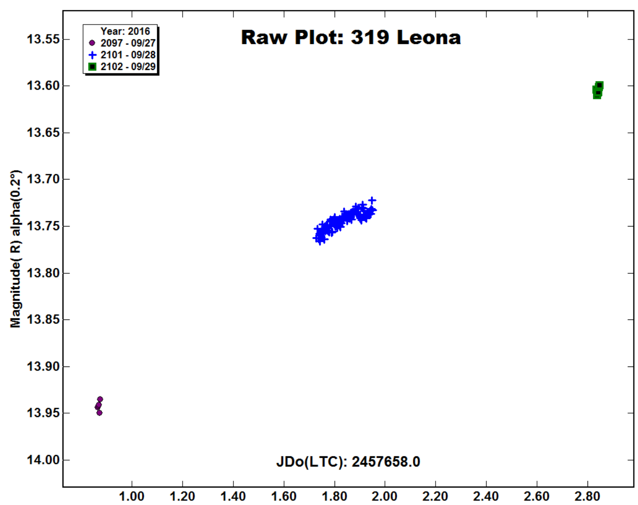

Figure 5. Raw lightcurve of 319 Leona for the interval 2016 Sept. 27-29.

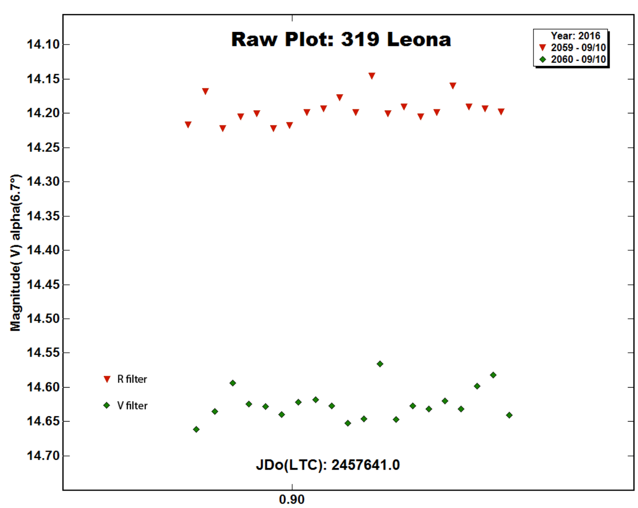

Figure 6. Observations of 319 Leona 2016 Sept. 10 in R and V magnitudes.

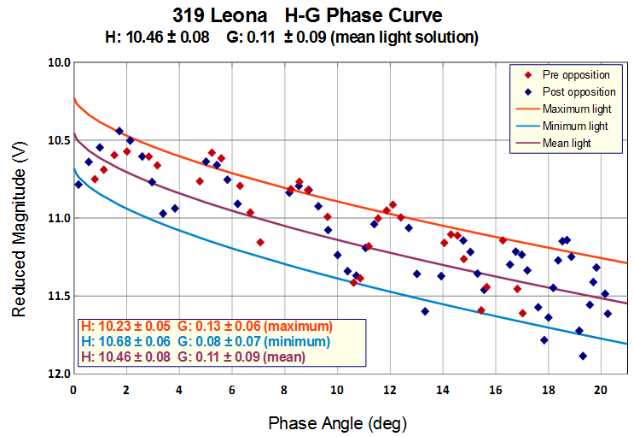

Figure 7. H-G plots for 319 Leona for maximum, mean, and minimum light data points, respectively.

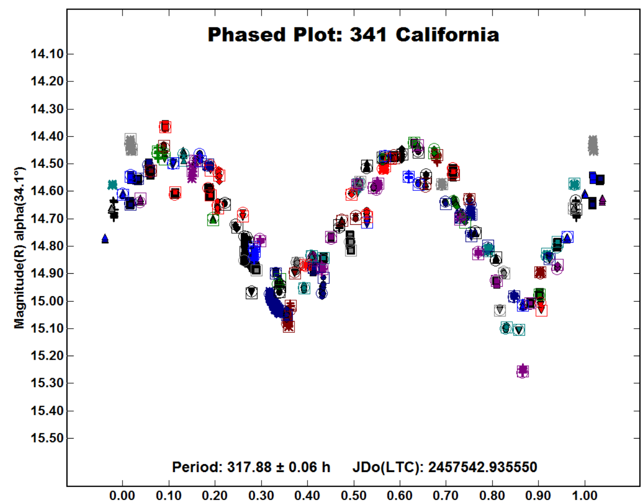

Figure 8. Single period lightcurve of 341 California based on 117 sessions 2016 June 3 - Dec. 7 in R band magnitudes, corrected for changes in phase angle and geocentric and heliocentric distances and prepared by MPO Canopus software.

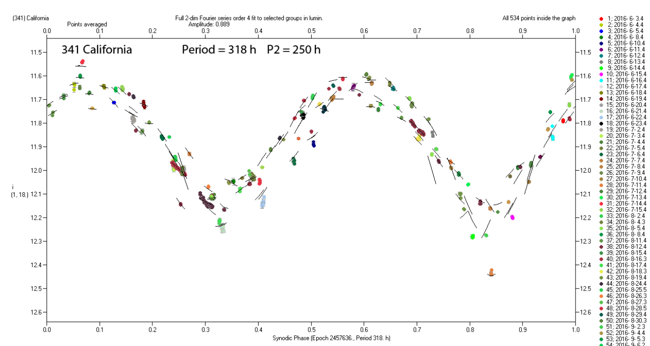

Figure 9. Fourth order 2 period Fourier series lightcurves of 341 California.

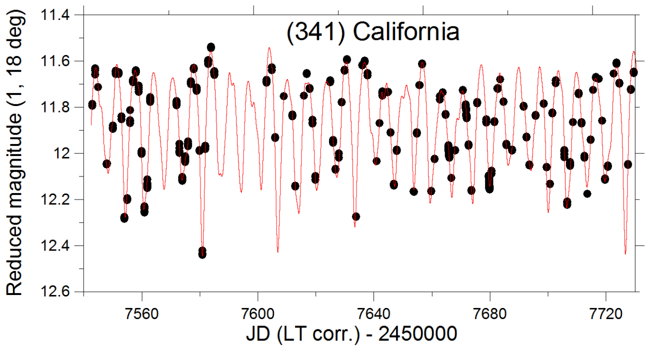

Figure 10. Raw lightcurve of all sessions of 341 California fit to a 2 period Fourier model.

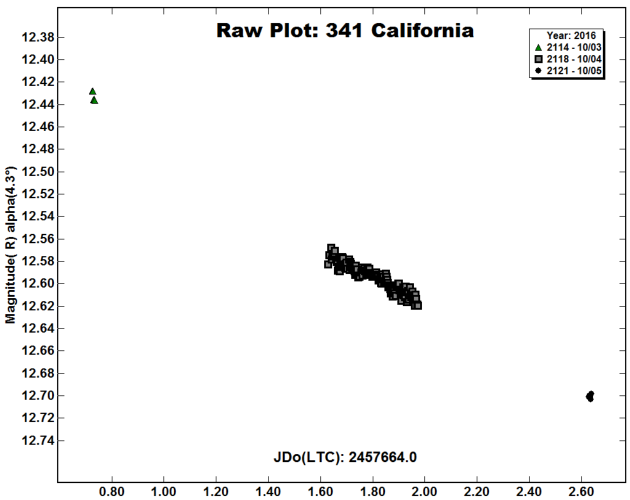

Figure 11. Raw lightcurve of 341 California for the interval 2016 Oct. 3-5.

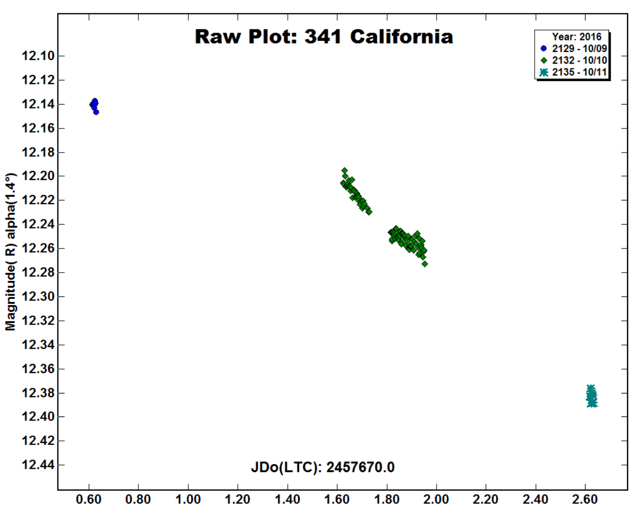

Figure 12. Raw lightcurve of 341 California for the interval 2016 Oct. 9-11.

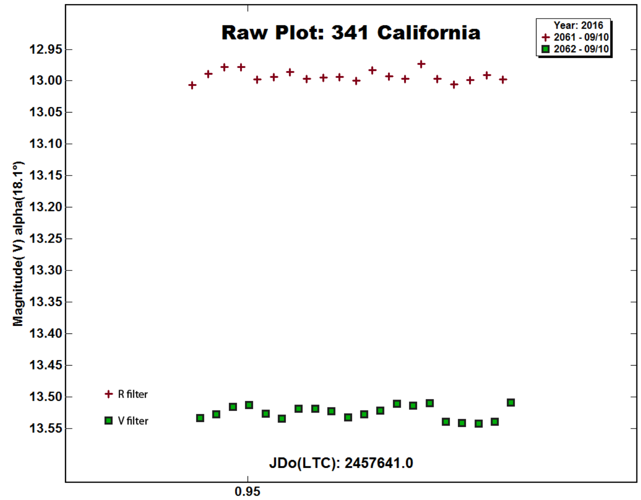

Figure 13. Observations of 341 California 2016 Sept. 10 in R and V magnitudes.

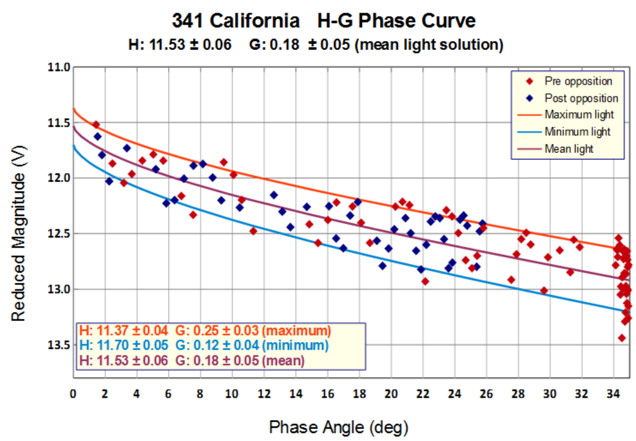

Figure 14. H-G plots for 341 California for maximum, mean, and minimum light data points, respectively.

CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar 2016 are encouraged to report them to this author on or before 2017 April 15. This will be the deadline for receipt of reports which can be included in the "General Report of Position Observations for 2016," to be published in *MPB* Vol. 44, No. 3.

A REVISED ROTATION PERIOD FOR MINOR PLANET 2420 ČIURLIONIS

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CCD photometric observations of minor planet 2420 Čiurlionis (1975 TN) by the Shed of Science Observatory in 2012 October and November and by Cherryvalley Observatory in 2016 October were combined for lightcurve analysis. The combined data set led to a rotation period of P = 15.764 ± 0.002 h and amplitude A = 0.51 ± 0.05 mag.

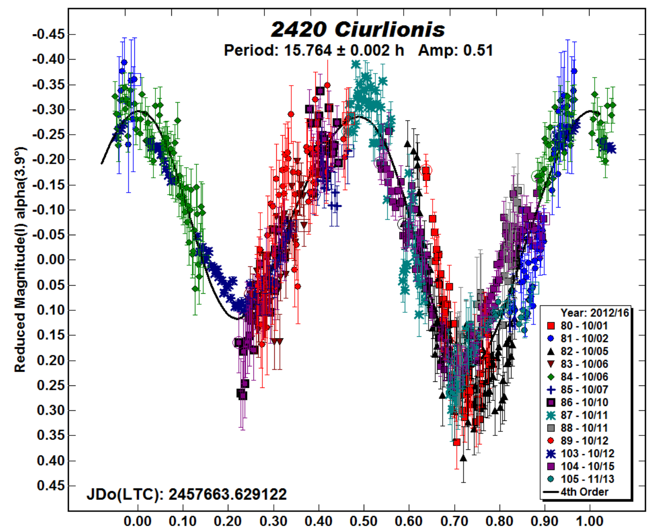
Discovered on 1975 October 3 by N. Chernykh at the Crimean Astrophysical Observatory in Nauchnyj, 2420 Čiurlionis is named in honour of Lithuanian painter and composer Mikalojus Konstantinas Čiurlionis. Based on its orbital parameters of a semi-major axis of a = 2.56 AU, perihelion distance of q = 2.22 AU, eccentricity e = 0.133, and relatively high orbital inclination of i = 14.6°, the asteroid is a member of the Eunomia orbital group (MPC, 2016). Spectrographic observations of 2420 Čiurlionis during the first phase of the Small Main-Belt Asteroid Spectroscopic Survey (SMASS I; Xu *et al.* 1995) determined Čiurlionis to be a type S asteroid. The WISE survey (Mainzer *et al.*, 2011) used H = 12.2 to find a geometric albedo of p_V = 0.327 ± 0.086 and diameter D = 8.44 ± 0.20 km.

Cherryvalley Observatory (MPC I83) is an amateur observatory located in eastern rural Ireland. Observations were made with a 0.2-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/7.6, SBIG STL-1301E CCD camera with a 1280x1024 array of 16-micron pixels, and Cousins I-band Bessel photometric filter. The resulting image scale was 2.15 arcsecond per pixel, unbinned. The Shed of Science Observatory used an *f*/8.5 0.35-m SCT and SBIG ST10XE CCD camera working at a scale of 0.94 arcsec per pixel. Exposures were taken through a Celestron UHC LPR filter. All science images were aligned, dark, and flat-field corrected with mid-exposure times light-time corrected using *MPO Canopus v10.7.7.0* (Warner, 2016). The combined data set, with observations from 2012 and 2016, contained 800 useful data points for period analysis.

The data were reduced in *MPO Canopus* using differential photometry to facilitate easy exportation. Night-to-night zero point calibration was accomplished by selecting up to five comparison stars with near solar colours using the "comp star selector" (CSS) feature. The Cousins I magnitudes for the comparisons were derived using the 2MASS to BVRI formulae developed by Warner (2007). Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.* 1989). See table I for observing circumstances and results.

The night-to-night zero points were adjusted to find the best fit (lowest RMS). Sessions 80-89 were taken by Cherryvalley Observatory in 2016, and sessions 103-105 from the Shed of Science Observatory in 2012. The lightcurve shows an asymmetrical shape with a period of P = 15.764 ± 0.002 h. This is a revision of the period of P = 12.84 h originally reported by Durkee and Syring (2013).

Cherryvalley Observatory's data (575 data points) were tested against the original reported 12.84 h period but the fit proved to be unconvincing. Durkee and Syring (2013) suggested a 16.0 h period as a possibility, but additional observations were required for a definitive solution.



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Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Group
2420	Čiurlionis	2012/10/12-11/13	225	4.8,0.5,12.4	28	-2	12.84	0.02	0.50	0.08	EUN
2420	Čiurlionis	2016/10/01-10/12	575	3.9,2.6,4.4	13	4	15.760	0.002	0.51	0.05	EUN

Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (Harris *et al.*, 1984). Group is the orbital group/family (Warner *et al.* 2009).

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LIGHTCURVE AND ROTATION PERIOD FOR MINOR PLANET (7774) 1992 UU2

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CCD photometric observations in Cousins I-band of minor planet (7774) 1992 UU2 were made in 2016 November. A synodic rotation period of 3.868 ± 0.002 h and amplitude of *A* = 0.33 ± 0.05 mag were determined.

The main-belt asteroid (7774) 1992 UU2 was discovered on 1992 October 19 by K. Endate and K. Watanabe at Kitami. Its orbital period is approximately 3.41 years. The absolute magnitude, *H* = 13.6, and assumed albedo of 0.450 (JPL, 2016) give an estimated diameter of 4.14 km. It is a member of the Flora family of asteroids.

Cherryvalley Observatory (MPC I83) is an amateur-owned facility located in eastern rural Ireland. Observations with a Cousins I-band Bessel photometric filter were conducted with a 0.2-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/7.6 using an SBIG STL-1301E CCD camera with a 1280x1024 array of 16-micron pixels. The resulting image scale was 2.15 arcsecond per pixel. Image acquisition was done with Software Bisque's *TheSky6* Professional and *CCDSoft* v5. All light images were aligned, dark, and flat-field corrected using *CCDSoft v5* with mid-exposure times light-time corrected using *MPO Canopus* v10.7.7.0. A total of 437 useful data points were used in the analysis. Table I gives the observing circumstances and results.

The data were reduced in *MPO Canopus* using differential photometry to facilitate easy exportation. Night-to-night zero point calibration was accomplished by selecting up to five comparison stars with near solar colours using the "comp star selector" (CSS) feature. The Cousins I magnitudes for the comparisons were derived using the 2MASS to BVRI formulae developed by Warner (2007). Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.* 1989).

The lightcurve shows a classical bimodal shape. The period solution of 3.868 ± 0.002 h is in close agreement with the previously published work by Krotz *et al.* (2010), who found a period of 3.866 ± 0.004 h from 21 data points.

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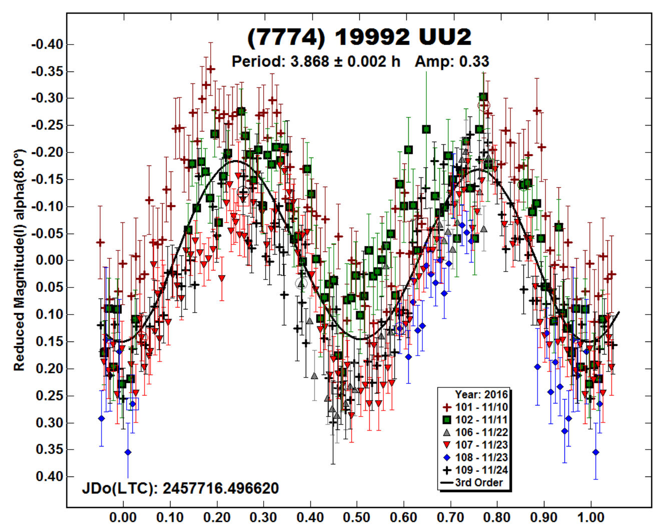

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
7774	1992 UU2	11/10-11/24	437	7.4,1.8,2.4	59	-3	3.868	0.002	0.33	0.05	FLOR

Table I. Observing circumstances. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude (Harris et al., 1984). Grp is the orbital group/family (Warner *et al.* 2009). FLOR = Flora.

ROTATION PERIODS FOR 1751 HERGET, 2022 WEST AND (23997) 1999 RW27

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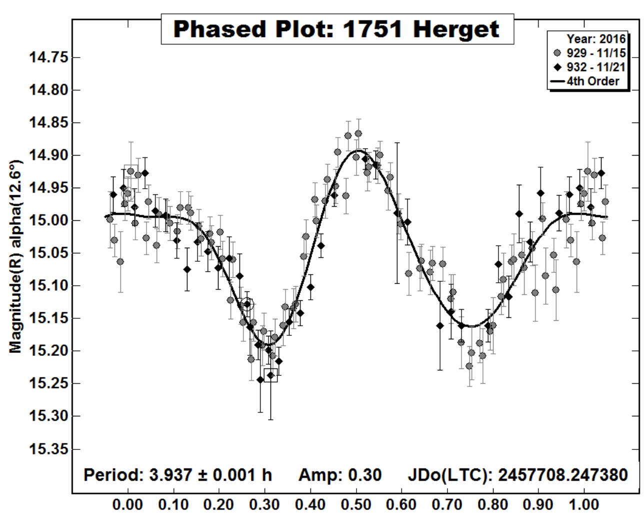
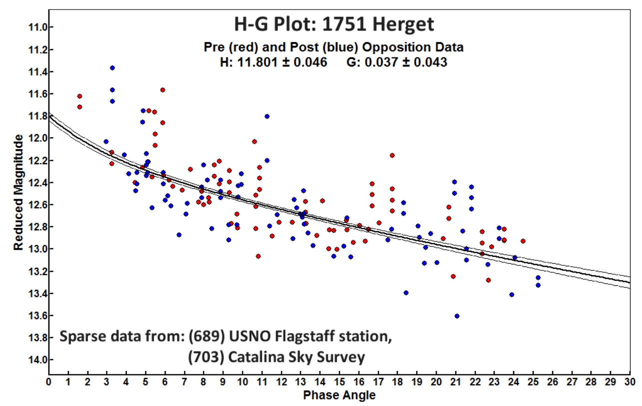
Photometric observations of three main-belt asteroids were made from Italy in order to determine their rotation periods. For 1751 Herget the synodic rotation period is 3.937 ± 0.001 hours, amplitude 0.30 magnitudes. For 2022 West the synodic rotation period is 14.14 ± 0.01 hours, amplitude 0.50 magnitudes. For (23997) 1999 RW27, the synodic rotation period is 17.82 ± 0.01 hours, amplitude 0.18 magnitudes.

CCD photometric observations for three main-belt asteroids were made in the period 2016 October-December at the Balzaretto Observatory (A81) and at the Astronomical Observatory of the University of Siena (K54), using the instrumentation described in the Table II. Data processing and analysis were made at the Balzaretto Observatory with *MPO Canopus* (BDW Publishing, 2016). All the images, acquired with clear-filter, were calibrated with dark and flat frames and converted to R magnitudes using solar-colored field stars from CMC15 catalogue, distributed with *MPO Canopus*. Table I shows the observing circumstances and results.

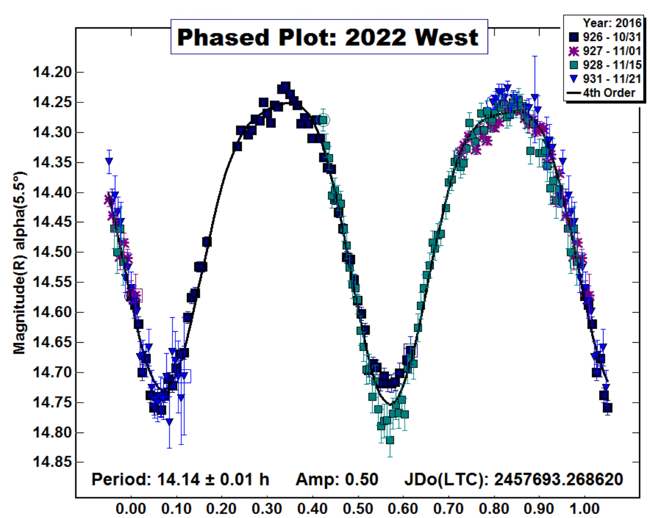
1751 Herget was discovered on 1955 July 27 by Goethe Link Observatory at Brooklyn. The asteroid orbits with a semi-major axis of about 2.789 AU, eccentricity 0.175, inclination 8.13 degrees and an orbital period of 4.66 years. Taxonomic class is S-type (Bus and Binzel, 2002). Its absolute magnitude is H = 11.9 (JPL, 2016) while the WISE satellite infrared radiometry reports a value of 12.20 with a diameter of 10.929 ± 0.248 km based on an optical albedo of 0.195 ± 0.028 (Masiero et al., 2011).





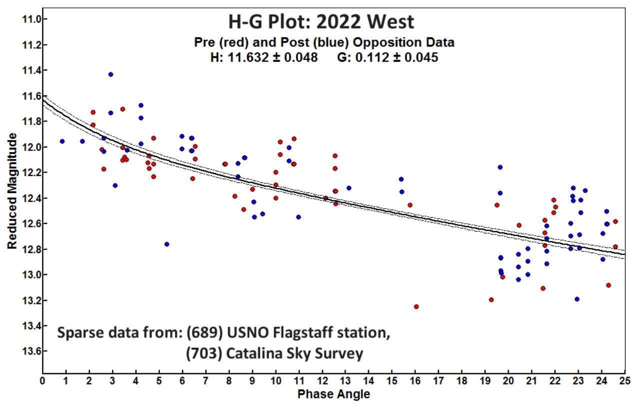
Using sparse photometric data from USNO Flagstaff station (MPC 689; USNO, 2016) and from Catalina Sky Survey (MPC 703; CSS, 2016) we derived H = 11.80 ± 0.05 and G = 0.04 ± 0.04; this H value is close to that one from JPL Small-Body Database Browser. Observations of this asteroid were made at the Astronomical Observatory of the University of Siena on two nights when it was in the same field of 2022 West. The period analysis shows a bimodal solution for P = 3.937 ± 0.001 hours and amplitude A = 0.30 ± 0.04 magnitudes.

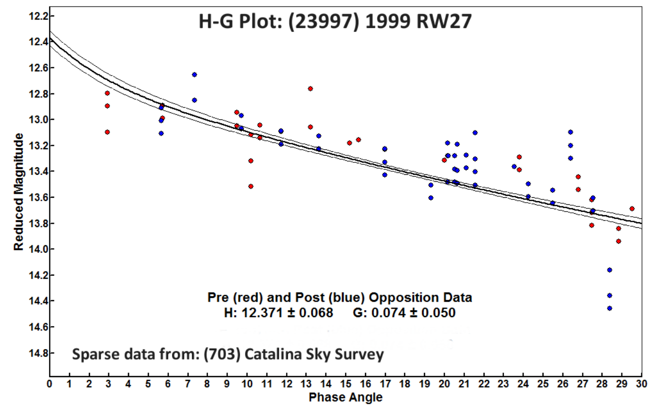
2022 West was discovered on 1938 February 7 by K. Reinmuth at Heidelberg. The asteroid orbits with a semi-major axis of about 2.706 AU, eccentricity 0.119, inclination 5.66 degrees and an orbital period of 4.45 years. Taxonomic class is S-type (Bus and Binzel, 2002). Its absolute magnitude is H = 11.6 (JPL, 2016) while the WISE satellite infrared radiometry reports a value of H = 12.00 with a diameter of 12.916 ± 0.133 km based on an optical albedo of 0.168 ± 0.021 (Masiero et al., 2011). Using sparse photometric data from USNO Flagstaff station (MPC 689: USNO, 2016) and from Catalina Sky Survey (MPC 703; CSS, 2016) we derived H = 11.63 ± 0.05 and G = 0.11 ± 0.05; this H value is close to that one from JPL Small-Body Database Browser. Observations of this asteroid were made on four nights at the Balzaretto Observatory and at the Astronomical Observatory of the University of Siena. The period analysis shows a bimodal solution for P = 14.14 ± 0.01 hours and amplitude A = 0.50 ± 0.04 magnitudes.



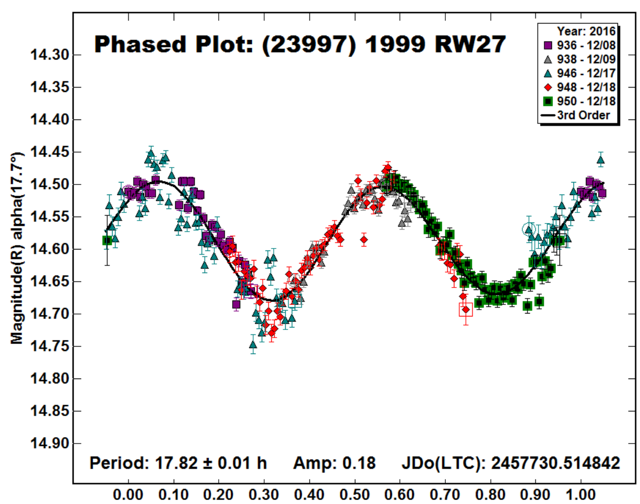
Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
1751	Herget	11/15-11/21	130	12.5,14.8	30	4	3.937	0.001	0.30	0.04
2022	West	10/31-11/21	234	5.5,14.5	29	4	14.14	0.01	0.50	0.04
23997	1999 RW27	12/08-12/18	260	17.7,14.7	96	19	17.82	0.01	0.18	0.05

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).





(23997) 1999 RW27 was discovered on 1999 September 8 by K. Korlevic at Visnjan. The asteroid orbits with a semi-major axis of about 2.605 AU, eccentricity 0.288, inclination 14.04 degrees and an orbital period of 4.21 years. Its absolute magnitude is $H = 12.5$ (JPL, 2016) while the WISE satellite infrared radiometry reports a value of $H = 12.80$ with a diameter of 7.021 ± 0.230 km based on an optical albedo of 0.272 ± 0.066 (Masiero *et al*., 2011). Using sparse photometric data from Catalina Sky Survey (MPC 703; CSS, 2016) we derived $H = 12.37 \pm 0.07$ and $G = 0.07 \pm 0.05$; this H value is close to that one from JPL Small-Body Database Browser. Observations of this asteroid were made on five nights at the Balzaretto Observatory. The period analysis shows a bimodal solution for $P = 17.82 \pm 0.01$ hours and amplitude $A = 0.18 \pm 0.05$ magnitudes.



(MPC code)	Telescope/CCD	Scale arcsec/pix	Exposure (seconds)
A81	8″ SCT f/5.5, SBIG ST7xme	1.65	420
K54	12″ MCT f/5.6, SBIG STL-6303e	2.32 (bin 2x2)	300

Table II. Observing Instrumentations. SCT: Schmidt-Cassegrain. MCT: Maksutov-Cassegrain.

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Some observing sessions at the Astronomical Observatory of the University of Siena were attended by 18 high school students from Liceo "Alessandro Volta" (Colle Val d'Elsa) involved in an interesting vocational guidance project about astronomy: Caterina Aiazzi, Vittorio Barlucchi, Samuele Beconcini, Samuele Boschini, Clelia Carboncini, Rebecca Di Fazio, Gianluca Gerace, Bianca Gozzi, Elisa Guerrera, Laura Hataj, Laila Mourabi, Adele Nannetti, Marie Sophie Pansegrau, Vittorio Parenti, Arianna Porretti, Mariù Soldani, Giulia Tanzini, Caterina Vignolo.

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NEAR EARTH ASTEROID ROTATIONAL ANALYSIS BY ASTRONOMICAL RESEARCH INSTITUTE: 2015 NOVEMBER THRU 2016 AUGUST

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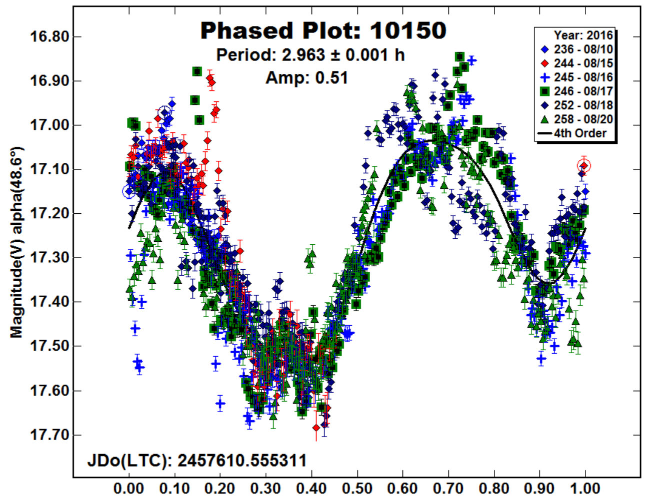
Photometric observations of six near-Earth asteroids (NEA) and one Mars-crosser (MC) were made in 2015 and 2016. We report on the analysis of the data obtained for NEAs (10150) 1994 PN, (88263) 2001 KQ1, (348400) 2005 JF21, (357024) 1999 YR14, (470510) 2008 CJ116, and 2016 LX48 and the Mars-crosser (41588) 2000 SC46.

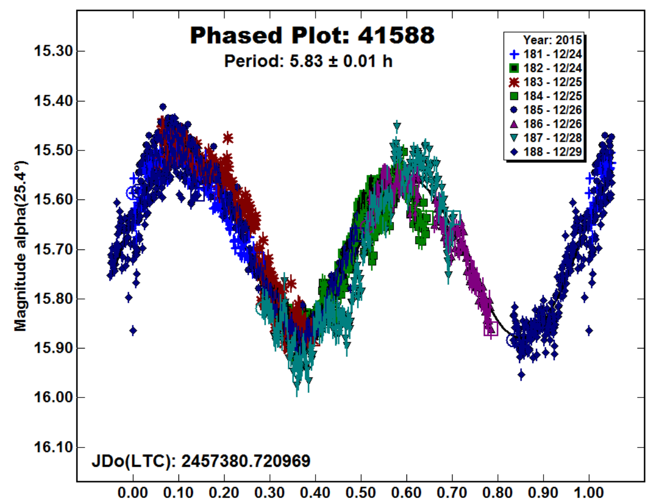
Photometric observations of six near-Earth asteroids (NEA) and one Mars-crosser (MC) were made using 0.61-m and 0.41-m telescopes at Cerro Tololo Inter-American Observatory. The 0.61-m has a 2Kx2K Alta F42 Andor (Apogee) CCD; the 0.41-m has a 2Kx2K Aspen Andor CG230 CCD. All observations were taken with a clear filter to maximize signal to noise.

These telescopes are part of Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) controlled by SKYNET (*https://skynet.unc.edu/*), an automation software package created and operated by the University of North Carolina at Chapel Hill.

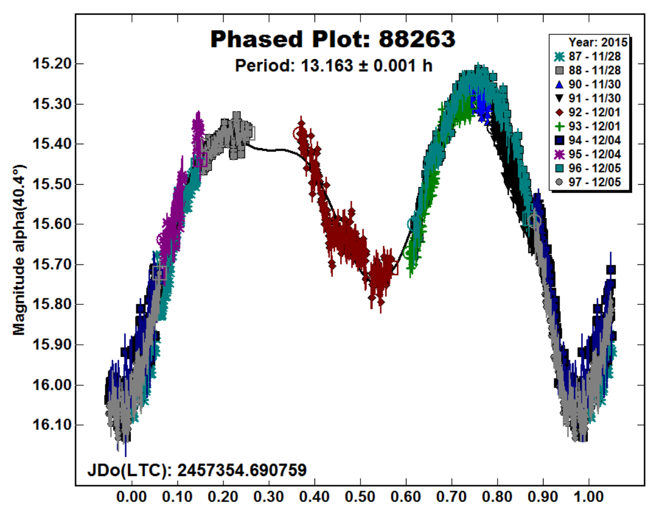
<u>(10150) 1994 PN (NEA; *H* = 15.4)</u>. Warner (2016b) observed (10150) in 2016 May-June (phase angle 〈 = 29°) and found a period of 2.96 h and amplitude of 0.23 mag. Our observations, taken in 2016 August (α = 48-53°), also led to a period of 2.96 h. This larger amplitude is likely accounted for by the different viewing aspect (phase angle bisector longitude about 90° from the Warner observations) and the relatively large phase angle of our observations.



<u>(41588) 2000 SC46 (MC; *H* = 13.1)</u>. This Mars-crossing asteroid was observed on six nights from 2015 Dec 24-29. A period of 5.83 h was determined with an amplitude of 0.40 mag. Ziegler and Hanshaw (2016) reported a matching period of 5.83 h.



<u>(88263) 2001 KQ1 (NEA; *H* = 15.6).</u>



Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
10150	1994 PN	16/08/10-08/20	1064	48.5,53.0	265	4	2.963	0.001	0.51	0.05	NEA
41588	2000 SC46	15/12/24-12/29	1771	25.4,24.5	123	-22	5.83	0.01	0.40	0.03	MC
88263	2001 KQ1	15/11/28-12/05	1657	40.3,45.5	83	-37	13.163	0.001	0.90	0.05	NEA
348400	2005 JF21	15/11/28-12/05	699	22.2,22.4	55	-19	3.450	0.001	0.01	0.01	NEA
357024	1999 YR14	16/08/10-08/12	780	25.9,27.1	327	-14	4.241	0.001	0.90	0.05	NEA
470510	2008 CJ116	16/08/22-08/30	1315	6.8,0.3,1.9	334	-2	27.53	0.01	1.10	0.05	NEA
	2016 LX48	16/08/29-08/31	449	93.3,93.8	284	3	5.68	0.01	1.36	0.05	NEA

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). MC = Mars-crosser.

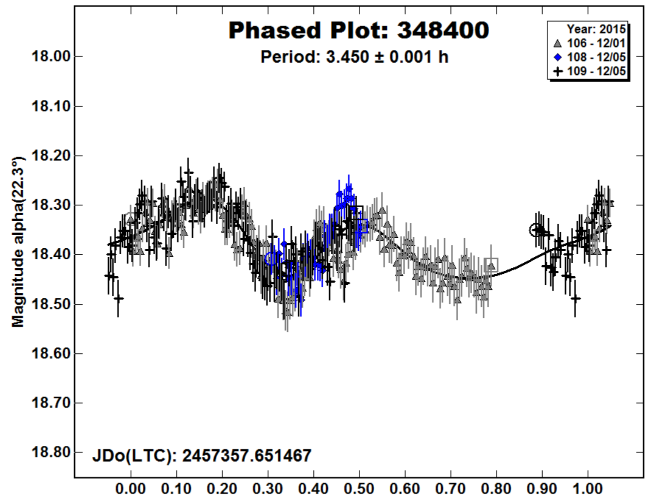
Warner (2016a) observed (88263) in 2015 October (〈 = 38°) and determined a period of 13.16 h with an amplitude of 0.52 mag from a uniform lightcurve with maxima and minima very close to the same depths. Our observations on 2015 November 28 through December 5 (〈 = 40.4°) found the same period of 13.163 h but with an amplitude of 0.9 mag, when the phase angle bisector latitude differed by almost 40°. This larger amplitude was confirmed on multiple nights due to almost two complete rotations occurring each day. Visible and infrared spectral studies over a large range of phase angles would provide more insight.

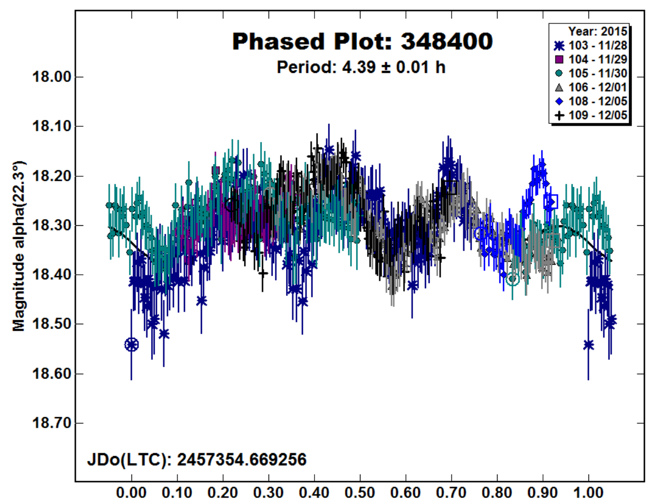
<u>(348400) 2005 JF21 (*H* = 17.3)</u>. Stephens and Warner (2016) reported (348400) to be a binary asteroid with a primary period of 2.41 h with an orbital period of 14.72 h. Oey and Groom (2016) also reported the asteroid to be binary, but found an orbital period of about 29.1 h. Naidu *et al.* (2015) observed (348400) with radar to confirm that it is a binary and suggested that there may be two satellites. Analysis of our observations taken in 2015 Nov/Dec does not support this primary period.

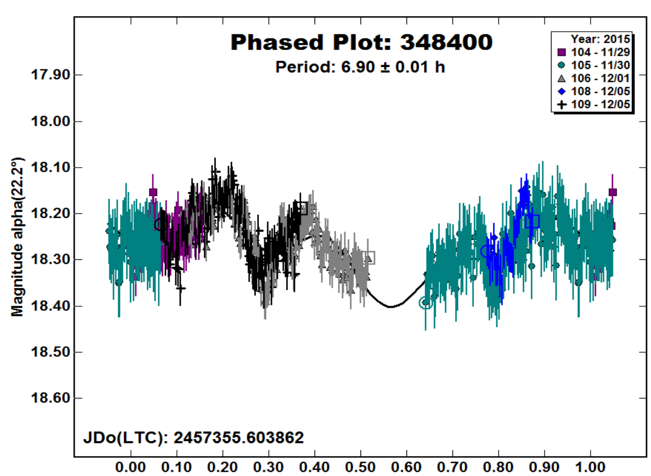
We observed (348400) on six nights, three of which had observations longer than 2.5 hours in a single session. For example, observations on 2015 Dec 1 were collected continuously for 2.71 hours, and there is no evidence for a period shorter than this. Additionally, our amplitude was greater than 0.2 mag, while Stephens and Warner only detected an amplitude of 0.06 mag. Stephens and Warner (2016) observed the object during 2015 June at similar phase angles (~22 degrees) to the new observations of 2015 Nov/Dec. Therefore, an additional period is offered at 3.45 h which is close to half of Stephens and Warner's originally proposed period of 7.14 h.

In an attempt to fit additional nights of data, a potential fit of 6.9 h arose. It is doubtful that the latter is correct, but it was the closest period to 7.14 h that would fit the new data. The confusion in periods could be an indication that (348400) is a slow rotator or our results are influenced by the presence of satellites; however we do not perform a dual period analysis here.

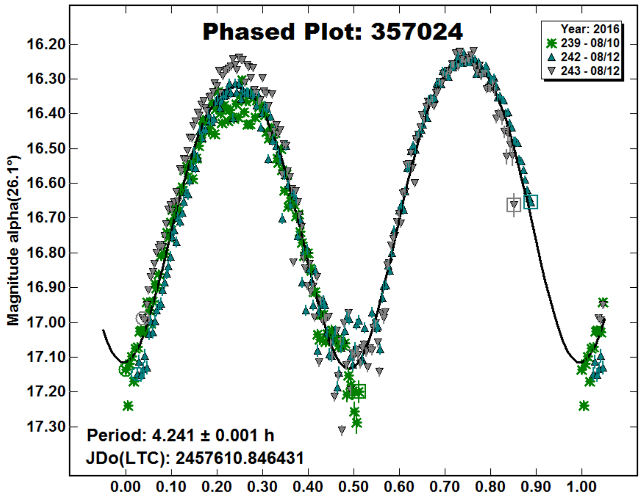
Lastly, Stephens and Warner (2016) observed during closest approach to Earth, which also represents the asteroid's perihelion passage. Observations taken a few months later were in a significantly different portion of the orbit. The significant difference in viewing aspect (phase angle bisector longitude and latitude) between the Warner and Stephens observations and ours could easily explain the differences in amplitude and, possibly, brought the asteroid out of "mutual events season." Even so, our shortest period and that of Stephens and Warner and Oey and Groom differ far beyond the stated errors. Observations at future apparitions will be needed to solve the puzzle.







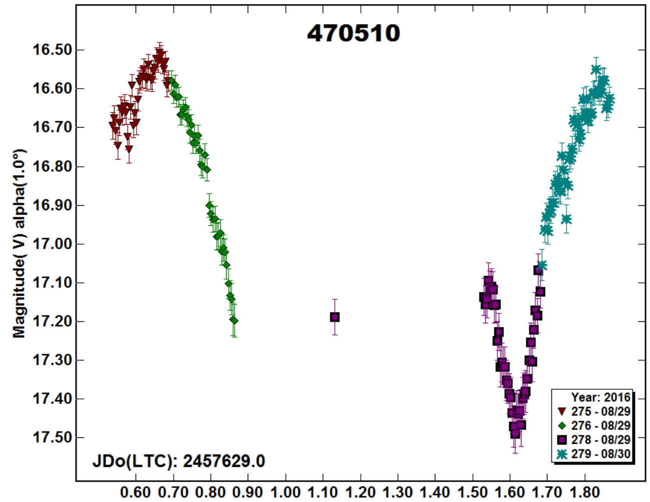
(357024) 1999 YR14 (NEA; *H* = 19.2). (357024) was observed on 2016 Aug 10 and 12, with over seven hours of constant observing on the 12th revealing a period of 4.241h and amplitude of 0.9 magnitude. Warner, 2017 and Carbognani (2017) also reported a period of 4.24 h.

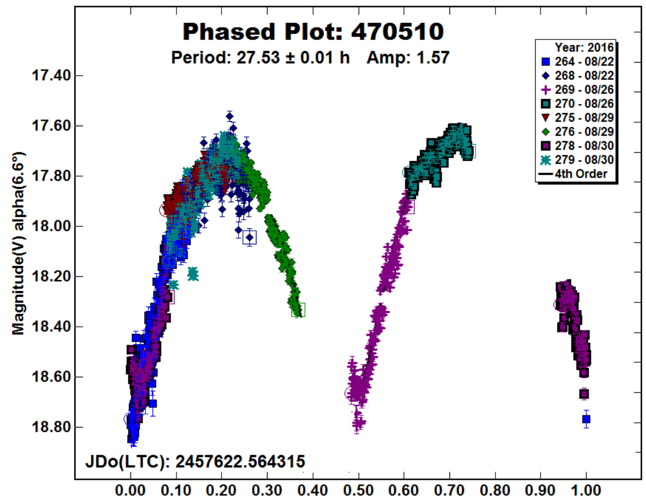


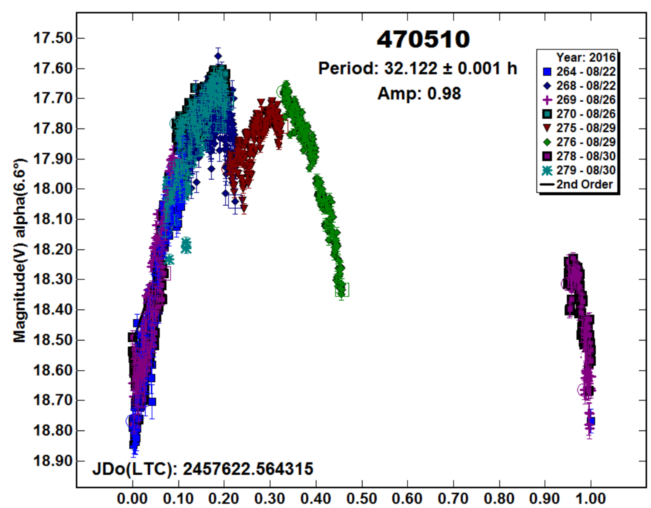
(470510) 2008 CJ116 (NEA; *H* = 19.0). 2008 CJ116 was observed on four nights in 2016 August. Examining our data in elapsed time (first figure plotted for JD2457629.0) suggests a period solution of ~27.5 h for the repeating maxima, with the data showing an ~1.3 mag amplitude. With a period of just over 24 hours, observations on Aug 22, 29, and 30 should cover the same half of the lightcurve while the observations on Aug 26 should cover the other half. We are able to produce a satisfactory composite lightcurve for a period of 27.53 +/- 0.01 hours.

Warner (2017) published a period of 32.26 h. We examined the fit of our data to this longer period. Our data made in to a composite for a 32.26 h period produces a lightcurve that is obviously less satisfactory for a simplifying assumption of a two maxima and two minima lightcurve typical for large amplitudes. The answer to finding a common solution using both data sets may be one of matching the data from a given night to the correct half of the lightcurve. For example, if the period was shorter than 29 h, then the data from Aug 29 and 30 should have shown 2 hours of overlap, including a peak maximum. This is not seen on Aug 30. However based on the overall consistency, we adopt the period of 27.53 h for the proposed solution to report in this paper.

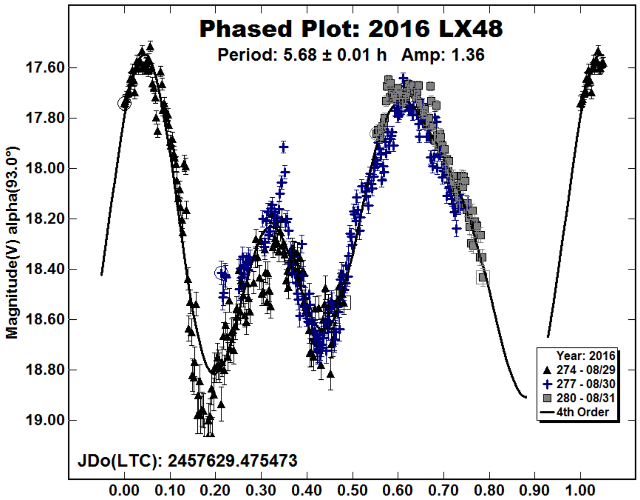
Observations at a future apparition are encouraged, but note that the asteroid will not be brighter than V = 19 mag through 2050 and it will take a substantial telescope to obtain high-quality data any time soon.







2016 LX48 (NEA; *H* = 19.4). 2016 LX48 was observed on 2016 Aug 29-31 at 93° solar phase angle. A period of 5.68 h and amplitude of 1.36 mag were determined. Warner (2017) and Benishek (2017) both reported a period of 5.6 h while Carbognani (2017) reported a period of 3.815 h. However, none of them report an amplitude greater than 0.55 mag while it is clearly seen in our observations the amplitude was larger than 1.0 mag. All four sets of observations were taken within a 14 day window. Differences in view aspect and the larger phase angle at the time of our observations could account for this.



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NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2016 OCTOBER-DECEMBER

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Lightcurves for 33 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 October through December were analyzed for rotation period and signs of satellites or tumbling.

CCD photometric observations of 33 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 October through December. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

Desig	Telescope	Camera
Squirt	0.30-m f/6.3 Schmidt-Cass	ML-1001E
Borealis	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
Eclipticalis	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Australius	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Zephyr	0.50-m f/8.1 R-C	FLI-1001E

Table I. List of CS3-PDS telescope/CCD camera combinations.

All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposure duration varied depending on the asteroid's brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used.

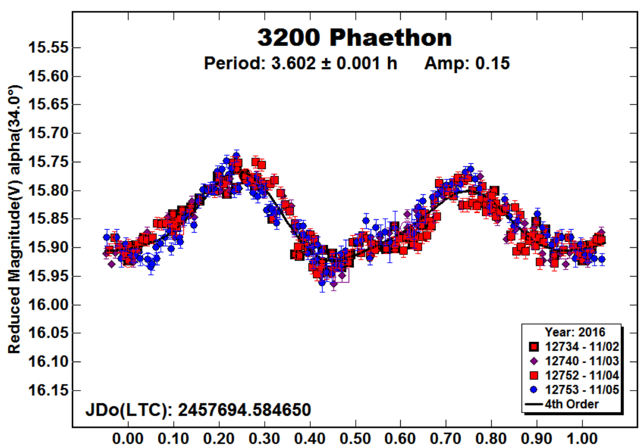
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* or APASS (Henden *et al.*, 2009) catalogs. The MPOSC3 catalog was used as a last resort. This catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI (Warner, 2007). The nightly zero points for the catalogs are generally consistent to about ± 0.05 mag or better, but on occasion reach 0.1 mag and more. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done with *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the given phase angle, *e.g.*, alpha(6.5°), using G = 0.15, unless otherwise stated. The X-axis is the rotational phase, ranging from –0.05 to +1.05.

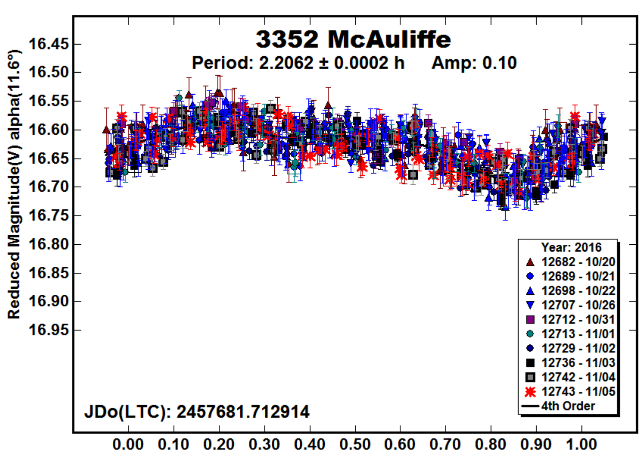
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on a specific asteroid. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html* allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcodes, is also available for download. When possible, readers are strongly encouraged to check against the original references listed in the LCDB.

If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*. The value is provided as a matter of convenience.

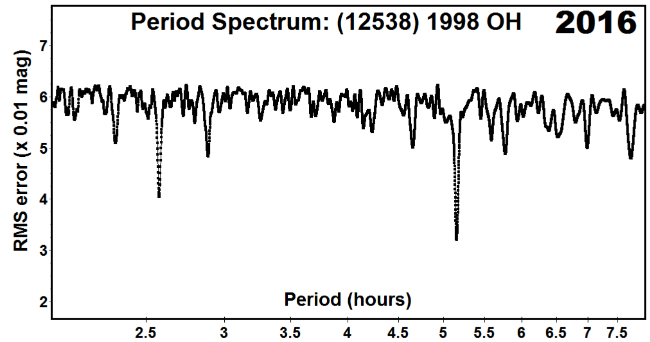
3200 Phaethon. The period for the 5 km Phaethon has been reported several times, e.g., Pravec *et al.* (2004web; 3.6048 h) and Warner (2015b; 3.6039 h). The results from the 2016 PDS observations led to similar results.

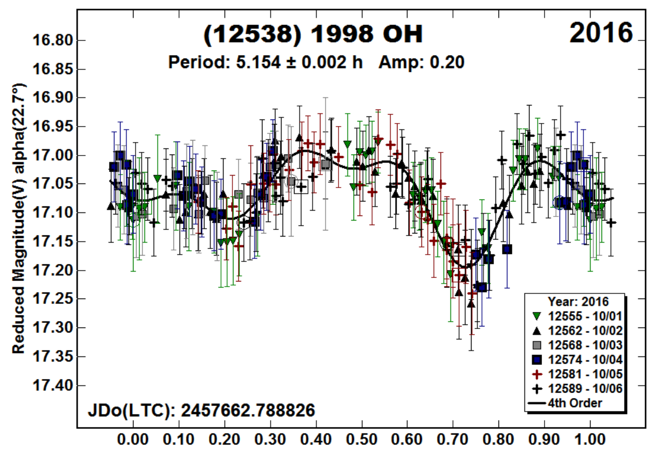


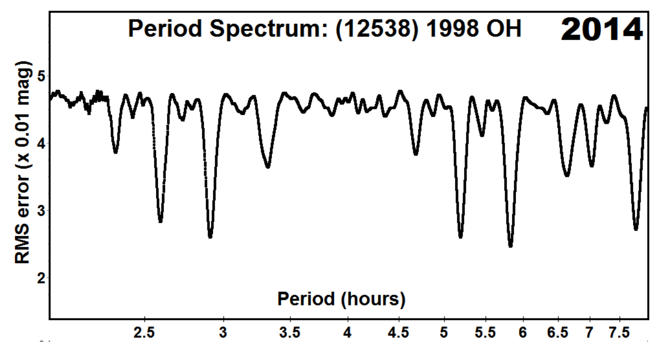
3352 McAuliffe is a suspected binary asteroid (Warner 2012). It was observed twice in 2016 at PDS to try to confirm the binary nature. Neither late-September observations (Warner 2017) nor those a month later (presented here) showed indications of a satellite. Observations at future apparitions are encouraged.

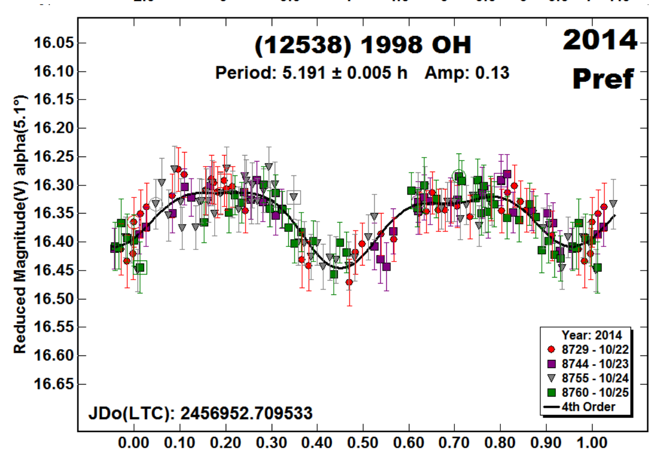


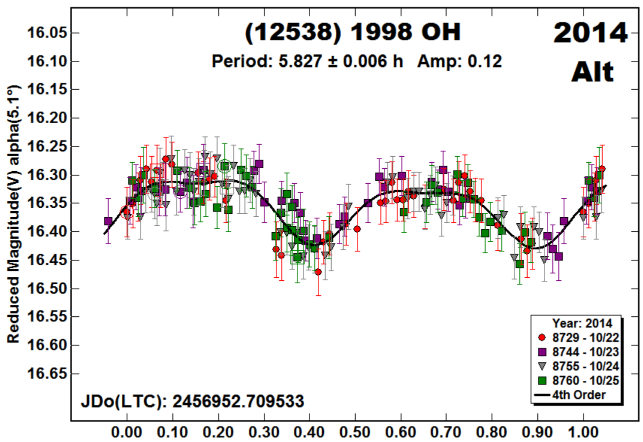
(12538) 1998 OH. As seen in the period spectrum for 2016, the PDS data led to a firm solution of 5.154 h. This was in contradiction to the period of 5.833 h found two years before (Warner 2105b). A reasonable fit of the 2016 data to the longer period could not be found, which led to a re-examination of the 2014 data to see if they would fit the shorter period.









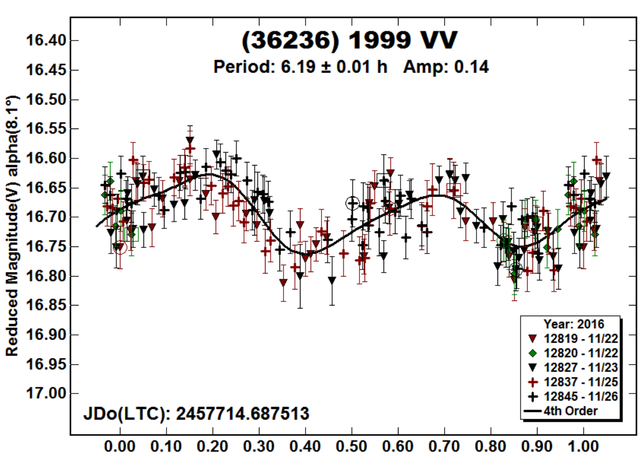


The period spectrum from 2014 shows two distinct possibilities in the range of 5-6 hours, one (5.191 h) being near the period found in 2016. The data from 2014 were forced to fit the two possible solutions. The two lightcurves are essentially identical. This difference made finding the more likely solution less obvious. The two periods differ by 1.5 rotations over the 72 hours from the first data set to the last. Given the symmetry of the two halves of the lightcurves, it was not hard to find a solution that incorrectly matched data to each half.

It should be noted that the 2014 data set consisted of four consecutive nights while the 2016 data included six consecutive nights. The longer data set covered more revolutions and, more so, the shape of the 2016 lightcurve was not symmetrical for the two halves. This allowed finding the more likely solution, although a period of 5.827 h from 2014 cannot be formally excluded.

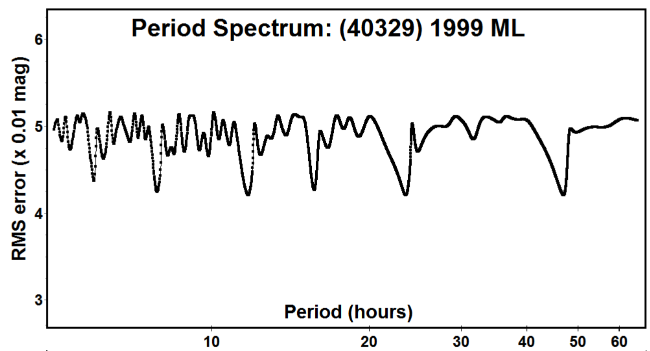
For this paper, a period of 5.154 h is adopted since it is based on a larger data set and is unambiguous. A revised period of 5.191 h is adopted for the 2014 data. Given the ambiguities in 2014, the 0.04 h difference in synodic periods is not a major concern.

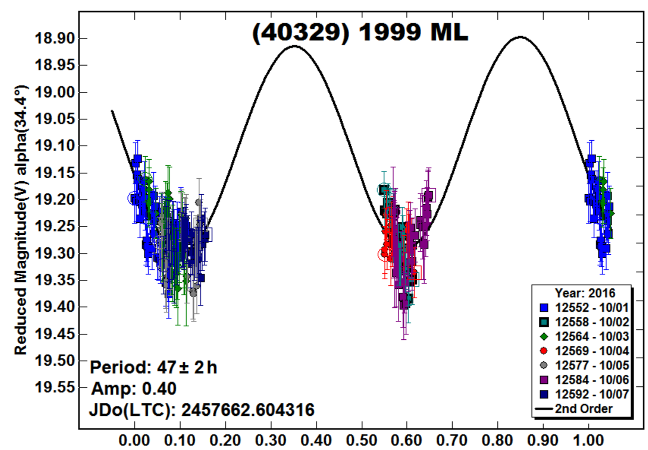
(36236) 1999 VV.



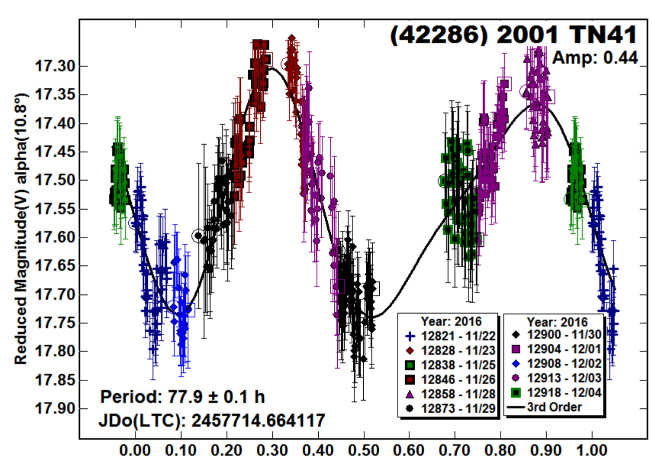
(40329) 1999 ML. Pravec *et al.* (1999web) observed this 850-meter NEA in 1999 September and saw no variation. The PDS data from 2016 did not find a conclusive solution, as shown by the period spectrum. There did seem to be sufficient evidence that a minimum was being captured; the main question was whether or not it was the same minimum.

Different Earth-day commensurate periods were tried to fit the data, but the only one that resulted in a bimodal lightcurve of reasonable proportions was the one fitted to 47 h and so adopted here. The amplitude on the plot is arbitrary since no maximum was found.



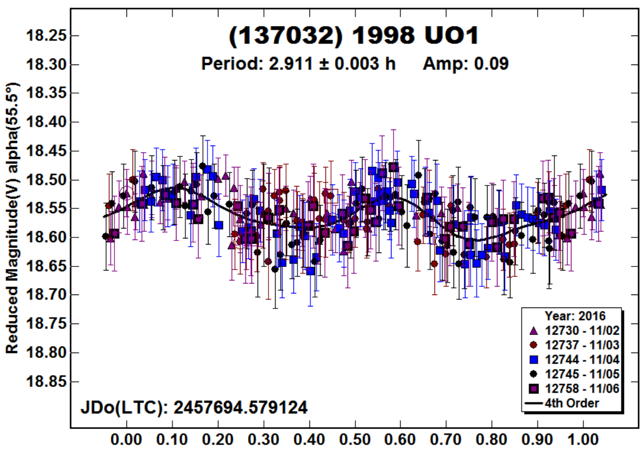


(42286) 2001 TN41. No previous results were found for this 1.5 km NEA. Assuming the shorter damping times for tumbling asteroids adopted by Pravec *et al*. (2014), this asteroid is a good candidate for being in non-principal axis rotation (NPAR, *tumbling*; see Pravec *et al.*, 2005). There may be small indications in the lightcurve, *i.e.*, the slope of individual sessions is not quite in agreement with the slope of the model lightcurve. Long period tumblers require coordinated campaigns with observers at several longitudes so that data can be obtained in as short of time as possible. Otherwise, signs of low-level tumbling may not be distinguishable from changes in the lightcurve due to changing viewing aspect and/or phase angle.

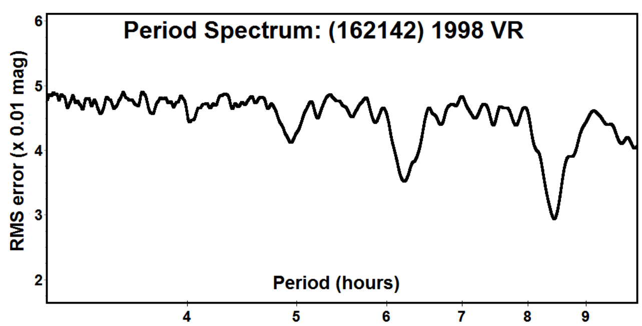


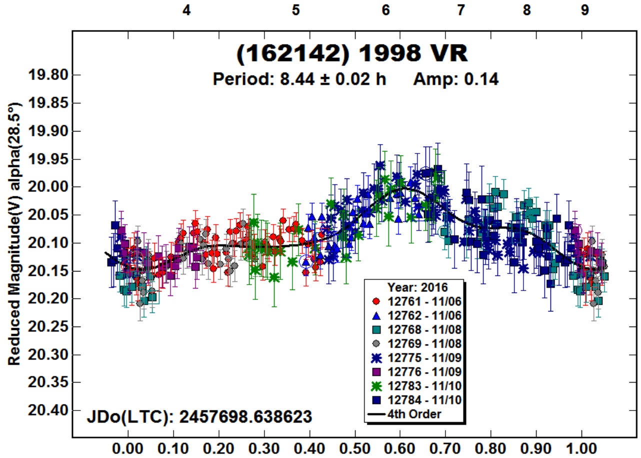
(137032) 1998 UO1. Pravec *et al.* (2004web) found a period of 2.90 h and amplitude of 0.04 based on observations in 2004. Ten years later, they refined the results with 2.916 h and amplitude of 0.08 mag. That same year, Warner (2015b) observed two weeks earlier and found a period of 2.925 h and amplitude of 0.10 mag. However, a period of 3.934 h could not be formally excluded. The two periods are almost exactly a 4:3 ratio.

The asteroid was observed at PDS in 2016 to try to remove the ambiguity. While the period spectrum showed a strong preference for 2.911 h, the low amplitude and SNR leave at least a little room for doubt.

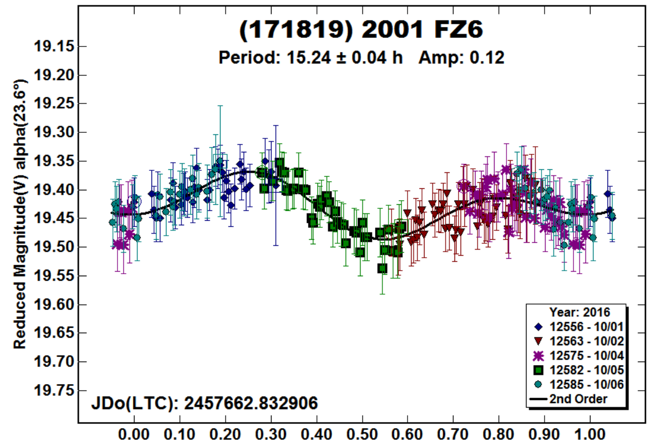


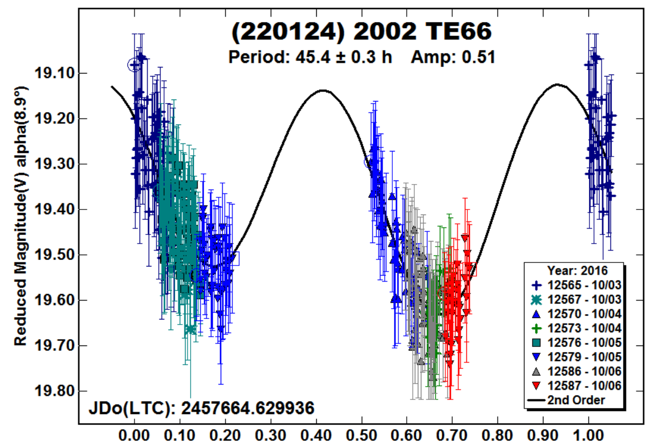
(162142) 1998 VR. At first glance, the lightcurve appears to be monomodal. However, the period spectrum shows a very strong preference for a period of 8.44 h. Looking closer at the lightcurve, there is some indication of a second maximum at 0.1 rotation phase. The fits to either of the two other periods in the spectrum had too many *stragglers*, *i.e.*, data points going the wrong direction compared to the Fourier model lightcurve.



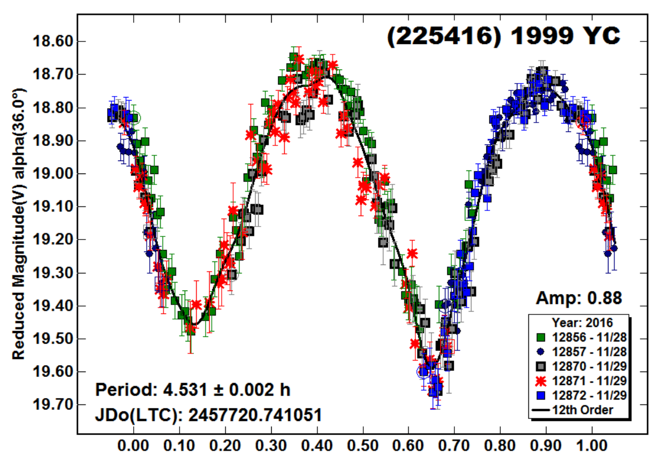


(171819) 2001 FZ6, (220124) 2002 TE66. These appear to be the first published results for these two NEAs. 2001 FZ6 has an estimated diameter of 650 meters while 2002 TE66 is slightly smaller at 620 meters. Attempts to fit the data for 2002 TE66 to other near Earth-day commensurate periods resulted in unrealistic shapes or slopes of the model curve.

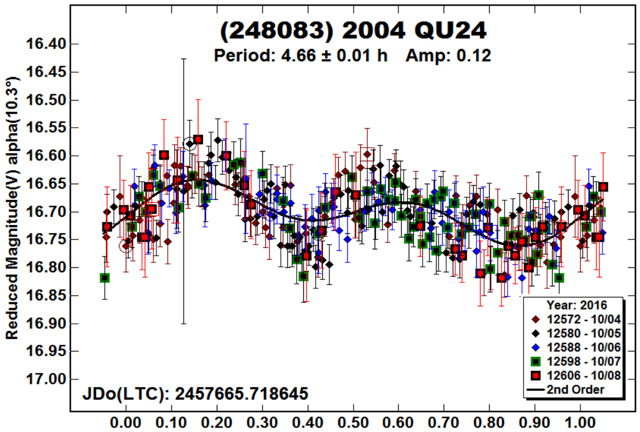




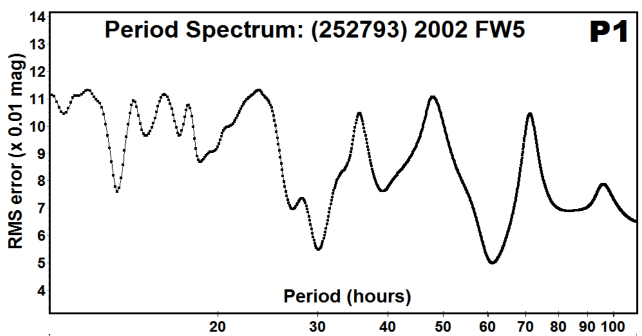
(225416) 1999 YC. Kasuga and Jewitt (2008) found a period of 4.495 h for this 1 km NEA. The PDS data from 2016 led to a period of 4.531 h. While not within 1-sigma errors of one another, the two results are statistically the same for rotation studies.

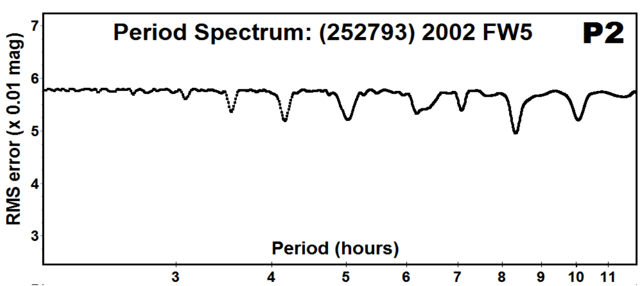


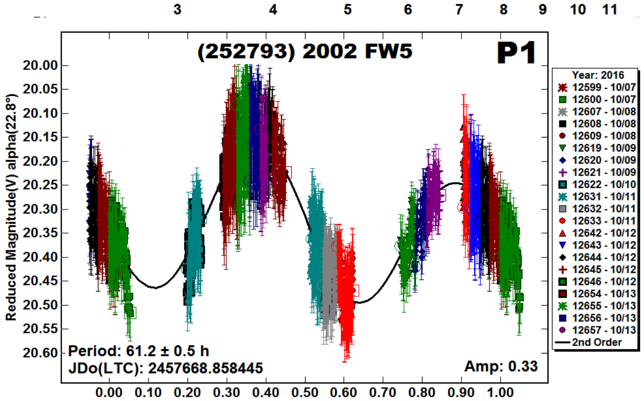
(248083) 2004 QU24. There were no previous periods found in the literature. The WISE mission (Mainzer *et al.*, 2011) found a diameter of 2.36 km and albedo $p_V = 0.126 \pm 0.072$ based on H = 16.0.

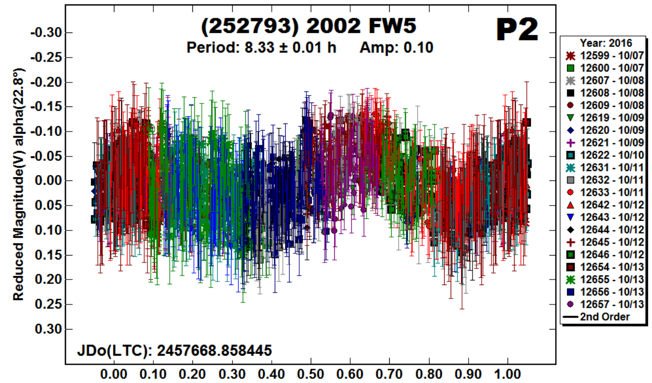


(252793) 2002 FW5. This may be another example of a very wide binary asteroid (see Warner, 2016a) where the primary lightcurve has a long period and large amplitude and is superimposed by a short-period, small-amplitude secondary lightcurve. In these systems, the satellite (short period) is relatively far away from the primary and the orbital period is very long. Detailed observations at future apparitions are encouraged. The next best opportunity is 2017 October at V ~ 17.0 and Dec ~ +3°.



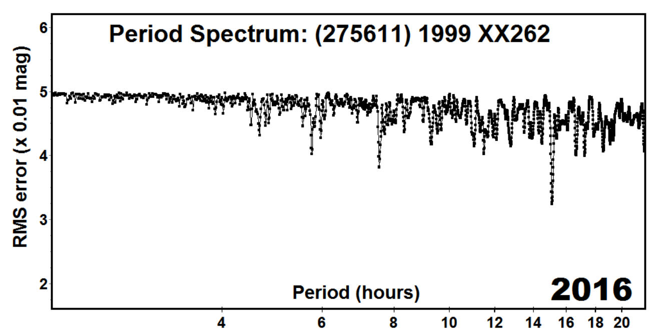


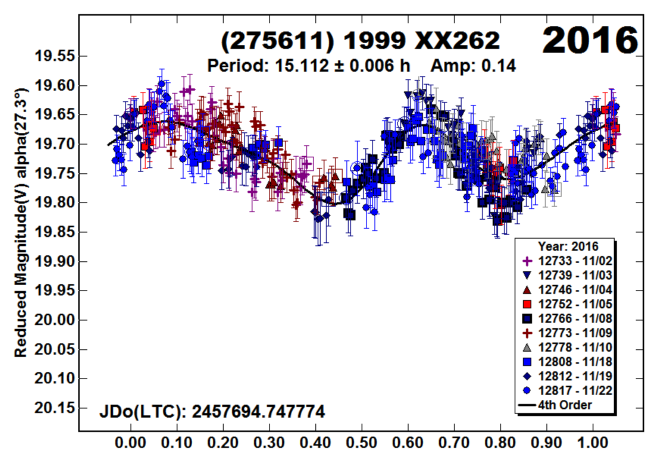


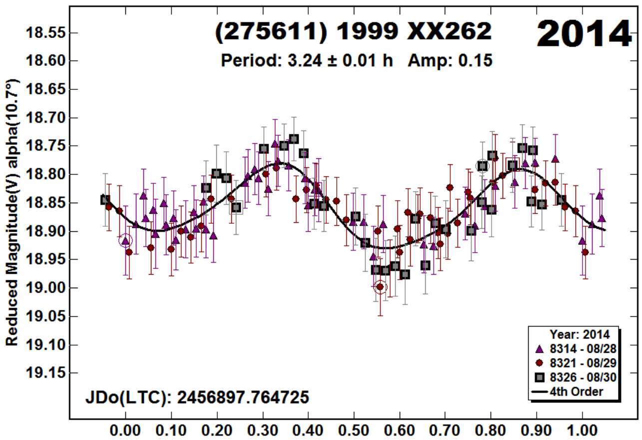


(275611) 1999 XX262. Warner (2015a) found a solution of 3.24 h based on data from 2014 that covered only three nights. The period spectrum based on the 2016 PDS data, which covered 10 nights from Nov 2-22, shows no preference for that period but, instead, strongly favors a period of 15.112 h. Given the short runs on each night, the 2014 period spectrum showed a number of nearly equal solutions near 3.24 h. Even so, those data were impossible to fit to the 15-hour solution; the same applied to the 2016 data being fit to the shorter period.

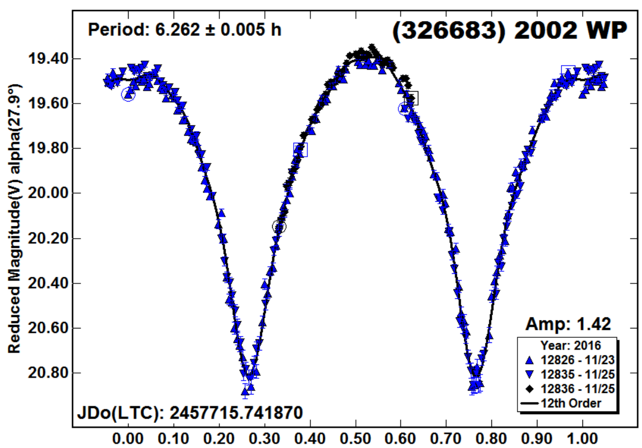
With such divergent and seemingly irreconcilable results, the question was whether or not the same asteroid was being measured. Astrometry on images from both years compared to an ephemeris from the Minor Planet Center showed that the same asteroid was being measured. The next good chance to resolve the mystery comes in 2019 February (V ~ 17.2, Dec ~ +14°).



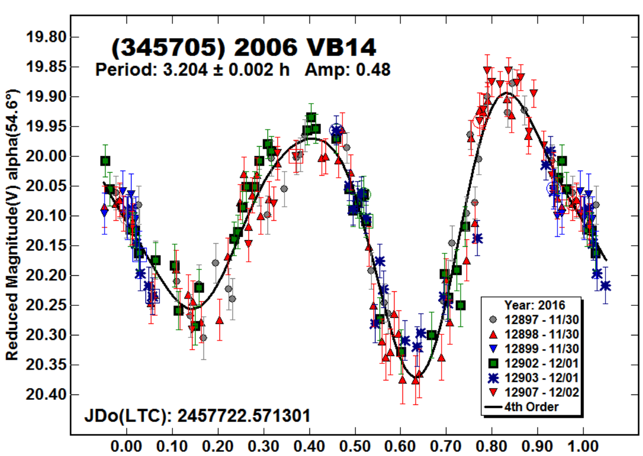




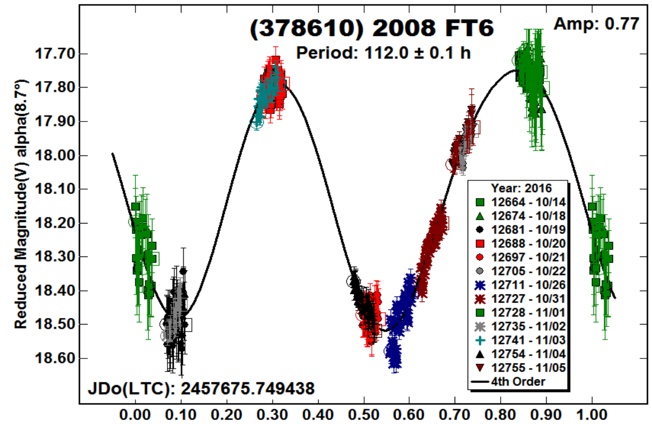
(326683) 2002 WP. Almost a complete cycle of the adopted period of 6.262 h was covered on 2016 Nov 23 and 25, leaving no doubt about the period. The large amplitude implies a highly-elongated body. The lack of "shoulders" on the ascending and descending branches precludes the object being a "contact binary" and, probably, a highly-bifurcated object.



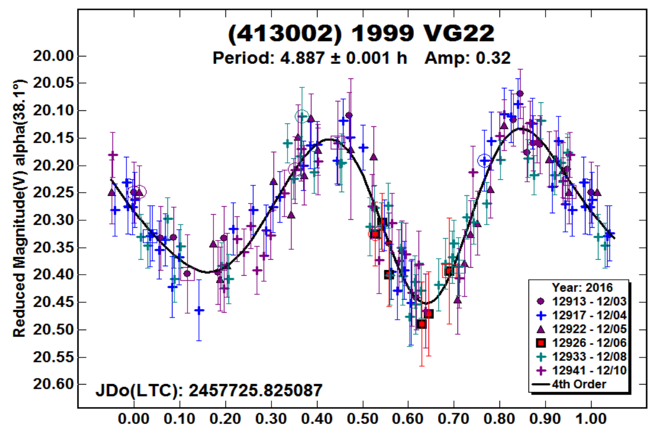
(345705) 2006 VB14. Skiff *et al.* (2012) found a period of 3.25 h for 2006 VB14, a 600-meter NEA. Observations at PDS in late 2014 (Warner, 2016b) and late 2016 found periods of 3.204 h.

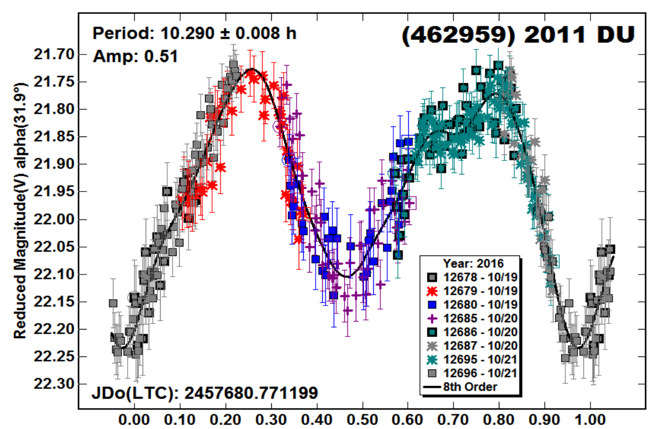


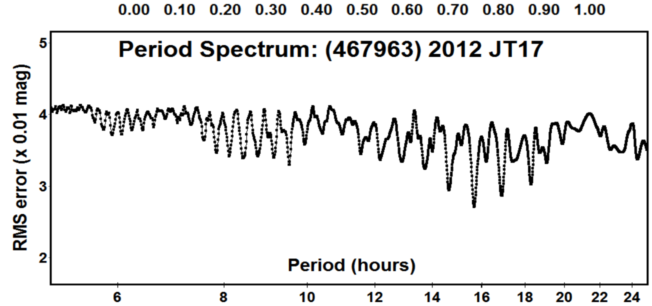
(378610) 2008 FT6. Given the size and apparent period, this NEA is a good candidate for tumbling (Pravec *et al.*, 2005; 2014). There are no outward signs of such in the available data, but the coverage of the lightcurve is incomplete and/or any tumbling may be at a low-level.

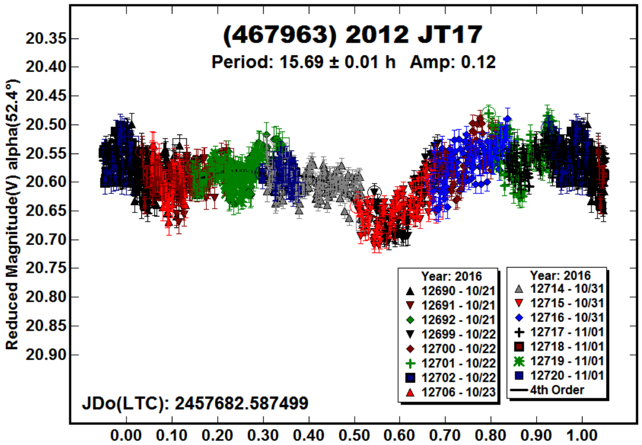


(413002) 1999 VG22, (462959) 2011 DU, (467963) 2012 JT17. These appear to be the first reported periods for these three NEAs. The solutions for 1999 VG2 and 2011 DU are considered secure. The one for 2012 JT17 is a little less so.

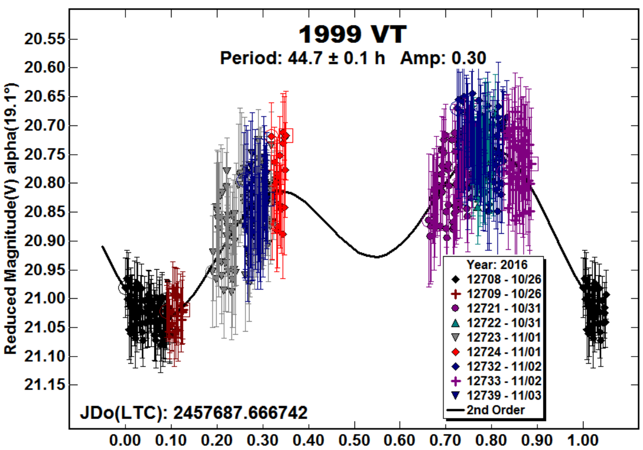




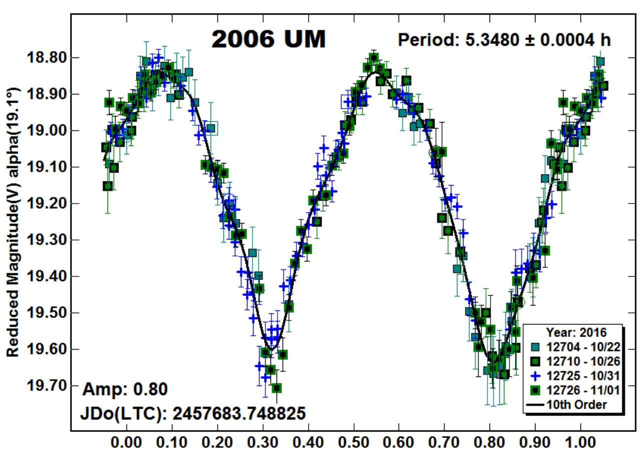




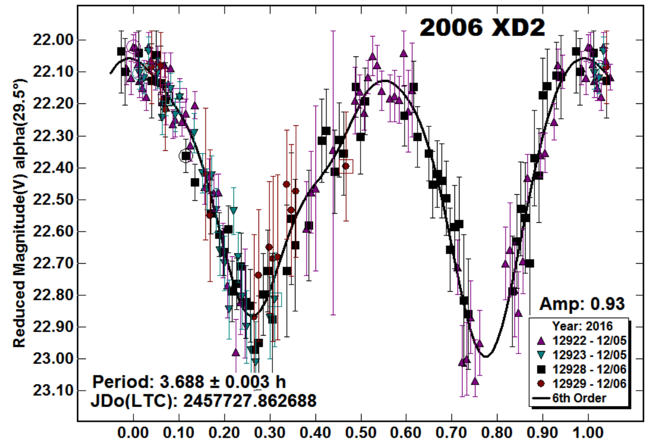
1999 VT. The period of 44.7 h adopted here can hardly be considered definitive. It is a best guess based on the assumption of a bimodal curve and examination of half-period searches.



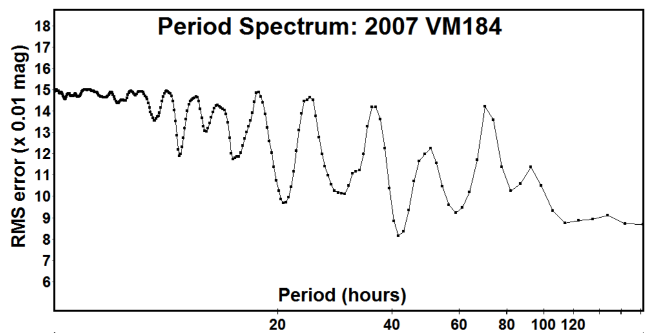
2006 UM. This appears to be the first published period for the 600-meter NEA.

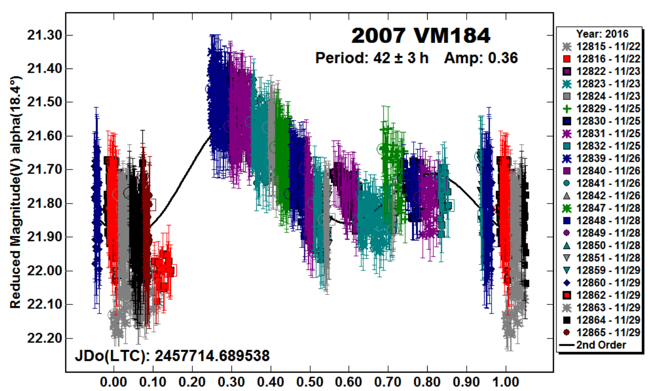


2006 XD2. Miles (2008) found a period of 3.700 h based on data from 2006 December. The PDS data from December 2016 led to essentially the same result: 3.688 h.

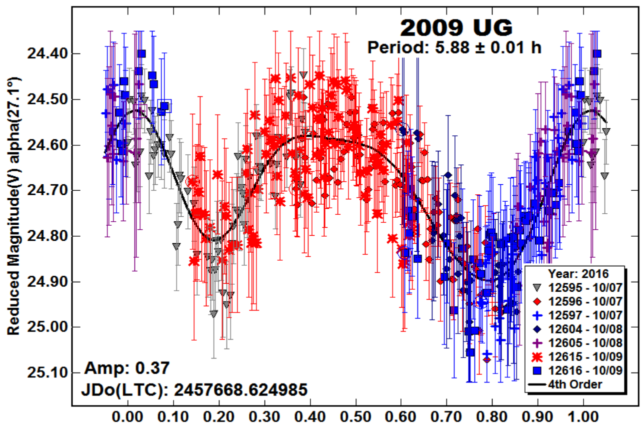


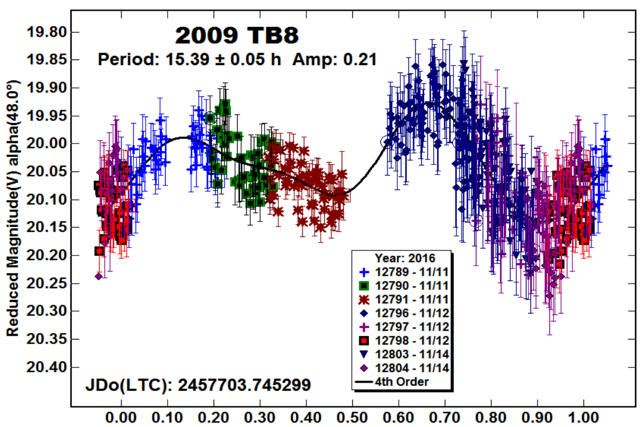
2007 VM184. There is not much confidence in the adopted period of 42 h. The result may be due to a *fit by exclusion*, which is where the Fourier analysis finds a minimum RMS by minimizing the number of overlapping data points. On the other hand, the tumbling damping time for the asteroid is far in excess of the age of the Solar System (Pravec *et al.*, 2014) and so the result may be a dominant period of a tumbler, but not necessarily one of the two actual periods, those of rotation and precession.



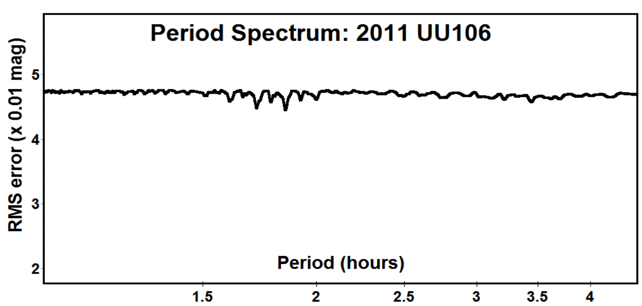


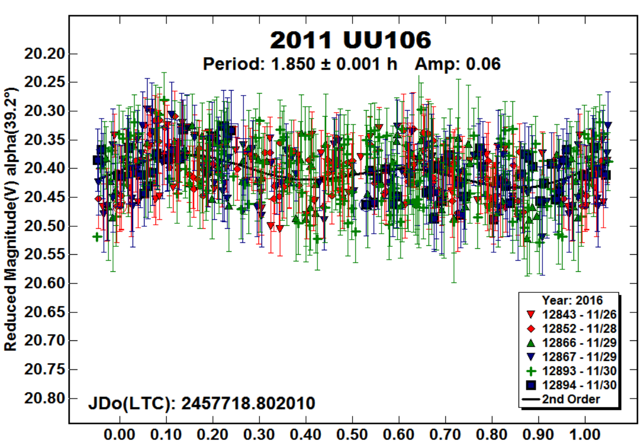
2009 UG, 2009 TB8. These appear to be the first reported periods for these two NEAs. The solution for 2009 TB8 is not as secure as for 2009 UG, but both are valid for rotational studies.





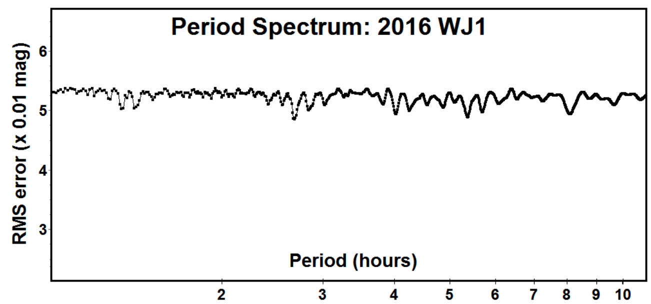
2011 UU106. As the period spectrum indicates, there is no strong solution to be found from the 2016 PDS data. The adopted period is a best guess, even though it does show signs of a low-amplitude bimodal lightcurve.

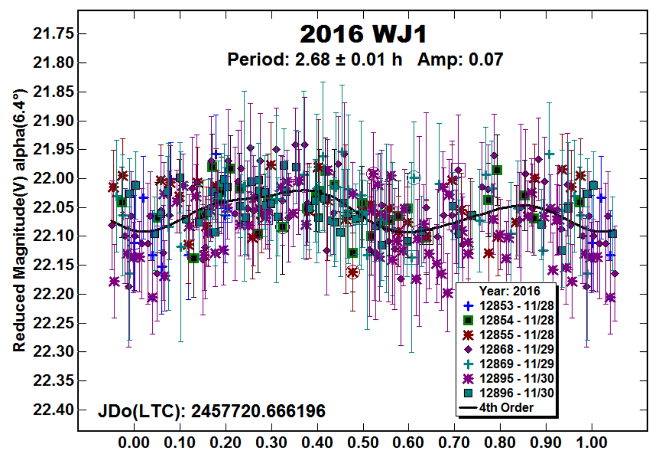




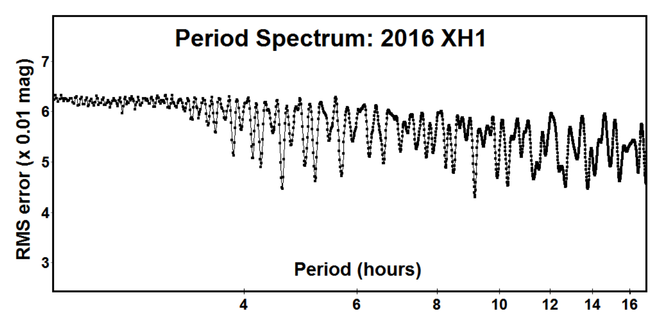
The period is a little faster that the so-called *spin barrier* at about 2.2 hours that roughly defines the separation between rubble pile asteroids and those that are strength-dominated. However, the period is not out-of-line for the estimated diameter of 520 meters. It is important to remember that the spin barrier is not a hard-fast line but a very fuzzy one.

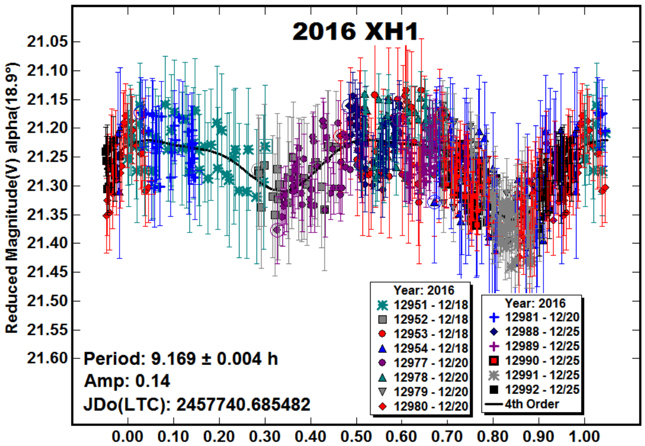
2016 WJ1. The low SNR (large error bars) made for an uncertain solution for this 160 meter asteroid. Given the size, a very fast rotation period, $P < 2$ hours, would not be unexpected. However, if presuming a bimodal lightcurve, the best solution is at 2.68 hours.



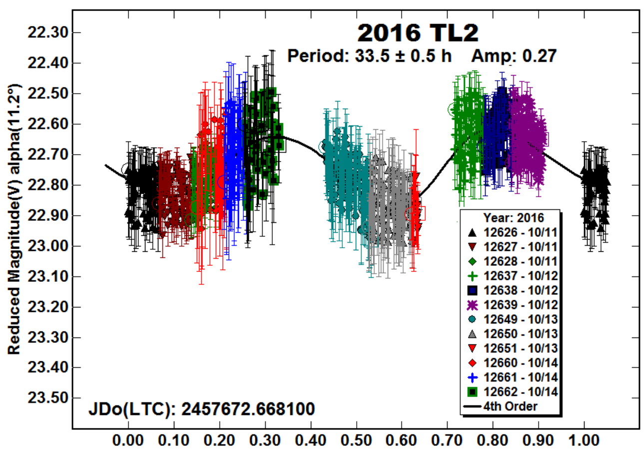


2016 XH1. The amplitude of 0.14 mag is in that area where high-order harmonics may have a similar amplitude to the usually dominant second order (see Harris *et al*., 2014). This means that the assumption of a bimodal lightcurve may not be valid. Despite that, and because of what appears to be sufficient asymmetry of the two halves of the lightcurve, a period of 9.169 h is adopted.

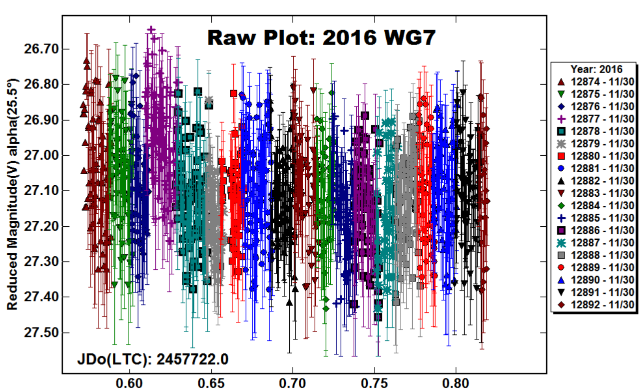




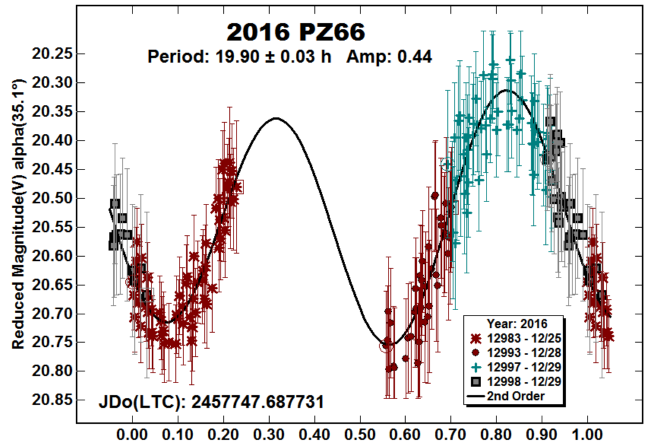
2016 TL2. The solution of 33.5 h is another best guess based on the assumption of a bimodal lightcurve and checks against possible half-period solutions. With an amplitude of 0.27 mag, this almost assures that a bimodal lightcurve is a valid assumption (Harris *et al*., 2014).



2016 WG7. No period could be found from the data obtained on 2016 Nov 30. Often such raw data leads to a very short period, one on the order of minutes, maybe even seconds. The exposures were 10 seconds, which should have been sufficient for a period of at least 55 seconds (see Pravec *et al*., 2000). Searches were made starting at 3.6 seconds in steps of 0.36 sec with no success. The lack of a solution may be simply due to the high noise masking a low-amplitude lightcurve of undetermined period.



2016 PZ66. Despite the incomplete lightcurve, the solution of 19.90 hour is considered secure enough for rotation studies.



Acknowledgements

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This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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Miles, R. (2008). "The 2007 BAA Presidential Address: Asteroids: past, present and future." *J. Brit. Astron. Assoc.* **118**, 187-198.

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
3200	Phaethon	11/02-11/05	339	33.9,33.3	15	32	3.602	0.001	0.15	0.01	NEA
3352	McAuliffe	10/20-11/05	609	11.6,7.6,8.4	39	-8	2.2062	0.0002	0.1	0.01	NEA
12538	1998 OH	10/01-10/06	196	22.7,20.8	46	3	5.154	0.002	0.2	0.02	NEA
36236	1999 VV	11/22-11/26	165	8.1,7.5,7.6	67	-10	6.19	0.01	0.14	0.02	NEA
40329	1999 ML	10/01-10/07	228	34.5,34.8	341	3	47	2	0.4	0.03	NEA
42286	2001 TN41	11/22-12/04	404	10.9,19.0	45	-2	77.9	0.1	0.44	0.03	NEA
137032	1998 UO1	11/02-11/06	254	55.4,51.7	349	14	2.911	0.003	0.09	0.02	NEA
162142	1998 VR	11/06-11/10	304	28.6,33.0	27	-8	8.44	0.02	0.14	0.02	NEA
171819	2001 FZ6	10/01-10/06	206	23.7,19.2	30	1	15.24	0.04	0.12	0.01	NEA
220124	2002 TE66	10/03-10/06	337	8.9,10.4	5	6	45.4	0.3	0.51	0.05	NEA
225416	1999 YC	11/28-11/29	312	36.0,36.6	91	21	4.531	0.002	0.88	0.03	NEA
248083	2004 QU24	10/04-10/08	277	10.3,8.8	24	-7	4.66	0.01	0.12	0.02	NEA
252793	2002 FW5	10/07-10/13	1570	22.8,13.4	30	-1	61.2	0.5	0.33	0.04	NEA
275611	1999 XX262	11/02-11/22	380	27.3,26.0,26.3	55	20	15.112	0.006	0.14	0.02	NEA
326683	2002 WP	11/23-11/25	293	27.9,24.9	70	-16	6.262	0.005	1.42	0.03	NEA
345705	2006 VB14	11/30-12/02	176	54.6,53.9	50	31	3.204	0.002	0.48	0.03	NEA
378610	2008 FT6	10/14-11/05	553	8.7,7.3,16.3	26	-6	112	1	0.77	0.04	NEA
413002	1999 VG22	12/03-12/10	150	38.1,37.9	104	1	4.887	0.001	0.32	0.03	NEA
462959	2011 DU	10/19-10/21	354	31.9,26.9	39	-12	10.29	0.008	0.49	0.03	NEA
467963	2012 JT17	10/21-11/01	1222	51.7,18.0	23	21	15.69	0.01	0.12	0.02	NEA
477327	2009 TB8	11/11-11/14	472	48.0,54.0	75	25	15.38	0.03	0.2	0.03	NEA
	1999 VT	10/26-11/03	509	19.1,18.3,18.9	25	-3	44.7	0.1	0.3	0.03	NEA
	2006 UM	10/22-11/01	213	19.1,13.7	44	-11	5.348	0.0004	0.82	0.03	NEA
	2006 XD2	12/05-12/06	168	29.5,29.9	92	4	3.688	0.003	0.94	0.05	NEA
	2007 VM184	11/22-11/29	1725	18.4,18.1,31.2	54	-8	42	3	0.36	0.05	NEA
	2009 UG	10/07-10/09	411	27.4,32.1	359	0	5.88	0.01	0.38	0.03	NEA
	2011 UU106	11/26-11/30	565	39.2,42.2	94	-1	1.85	0.001	0.06	0.02	NEA
	2016 WJ1	11/28-11/30	280	6.6,9.5	63	-3	2.68	0.01	0.07	0.02	NEA
	2016 XH1	12/18-12/25	615	18.8,15.7,21.8	99	-1	9.169	0.004	0.14	0.02	NEA
	2016 TL2	10/11-10/14	880	11.1,6.7	16	-4	33.5	0.5	0.25	0.04	NEA
	2016 WG7	11/30-11/30	1133	32.0,32.0	52	4	-	-	-	-	NEA
	2016 PZ66	12/25-12/29	183	35.1,35.7	70	0	19.9	0.03	0.44	0.03	NEA

Table II. Observing circumstances. Pts is the number of data points used in the analysis. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range). Grp is the orbital group of the asteroid. See Warner *et al.* (LCDB; 2009; *Icarus* **202**, 134-146.).

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SEVEN NEAR-EARTH-ASTEROIDS AT ASTEROIDS OBSERVERS (OBAS) – MPPD: 2016 JUNE–NOVEMBER

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We report on the results of photometric analysis on seven near-Earth asteroids (NEA) by Asteroides Observers (OBAS). This work is part of the Minor Planet Photometric Database effort that was initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

In this paper we publish the results for seven near-Earth asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). The data and results were made possible thanks to the collaboration of the Astronomical Center Alto Turia (CAAT) observatory located in Aras de los Olmos and operated by members of the Valencia Astronomy Association (AVA) (*http://www.astroava.org*).

Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 NW	Atik 414L+

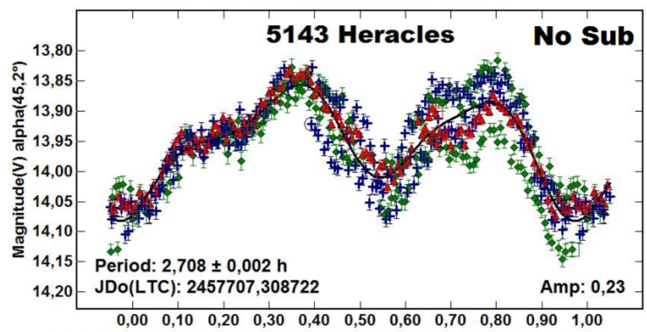
Table I. List of instruments used for the observations. SCT is Schmidt-Cassegrain. R-C is Ritchey-Chrétien. DK is Dall-Kirkham. NW is Newtonian.

Table I shows the equipment at observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website at (*http://www.minorplanet.info/call.html)* and Minor Planet Center (*http://www.minorplanet.net*)

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique.

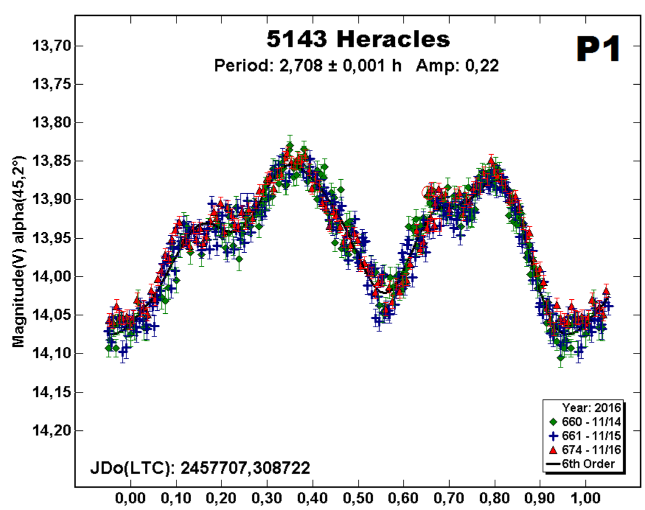
<u>5143 Heracles</u>. This is a main-belt asteroid discovered in 1991. A small satellite was detected with radar in 2012 (Taylor *et al.* 2012). Pilcher et al. (2012), using optical observations at about the same time, reported the object as a suspected binary with a primary period of 2.7063 h. They were not able to determine an orbital period for the suspected satellite. Our observations, made on three nights in 2016 Nov, were the result of a group effort, especially the team at CAAT. At the time of our observations, Heracles was moving at 4 arcseconds/min, which required exposures of less than 60 seconds.

The initial period analysis with *MPO Canopus* found a bimodal lightcurve with a period of 2.708 ± 0.002 h and amplitude of 0.23 mag, which was in good agreement with the period found by Pilcher et al. (2012). However, as seen in the "No Sub" plot, the fit was not very good and there were indications of a second period.



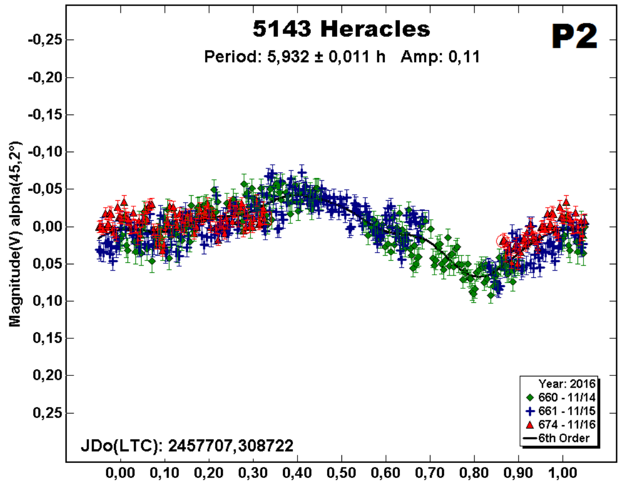
We used the dual-period search utility in *MPO Canopus* to see if there was a second period in the lightcurve. From this, we found the same dominant period, P_1 = 2.708 h, but the fit the Fourier curve was much improved ("P1") after subtracting a second period of P_2 = 5.932 h with an amplitude of 0.11 mag.

The second period is too short to be the orbital period of a satellite, unless the double-period near 11.8 h is adopted. Even so, the shape of the P_2 lightcurve does not show obvious signs of mutual events (occultations/eclipses) caused by a satellite.



Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
5143	Heracles	11/14-11/16	540	43.8,46.9	75	25	2.708	0.002	0.22	0.001	NEA
10150	1994 PN	07/15-07/17	301	35.5,36.4	261	28	2.959	0.005	0.34	0.003	NEA
12538	1998 OH	11/11-11/17	342	4.2,9.0	44	-5	5.088	0.004	0.11	0.004	NEA
66391	1999 KW4	06/19-06/21	475	81.4,83.0	257	57	9.581	0.019	0.27	0.018	NEA
257838	2000 JQ66	09/01-09/20	419	10.1,15.5	340	6	11.075	0.004	0.49	0.005	NEA
331471	1984 QY1	06/22-06/24	292	43.1,41.6	236	25	11.990	0.045	0.49	0.050	NEA
347813	2002 NP1	08/23-08/24	401	21.0,21.0	322	-7	5.907	0.004	0.73	0.004	NEA

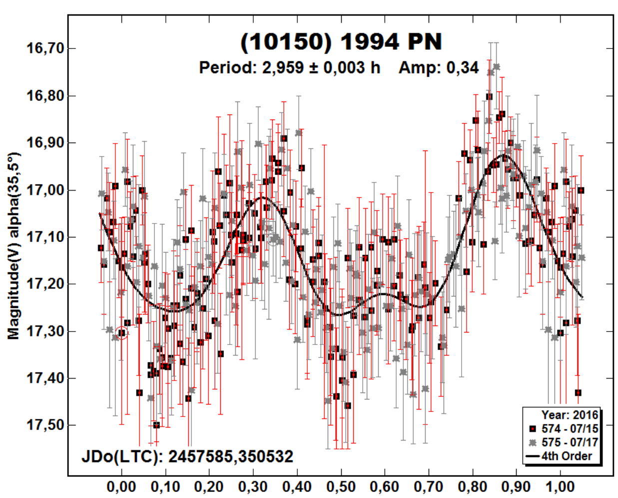
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).



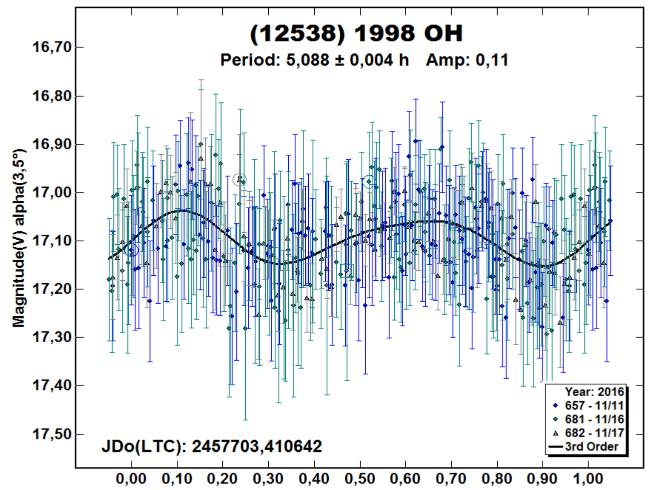
There is the possibility that the second period is due to low-level tumbling of a single body (see Pravec et al., 2005). To prove this would require more data than we had.

Even if the real cause of the two periods cannot be determined, they do seem real and not caused by problems with the images or analysis. This asteroid should be carefully watched at future apparitions with observations made over a week or more to be sure there are enough data.

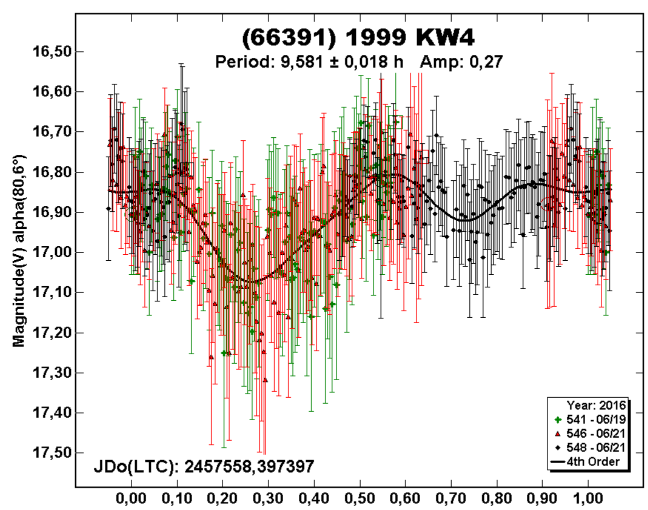
(10150) 1994 PN. This near-Earth asteroid was discovered on 1994 Aug 7 by G.J. Garradd at Siding Spring. The OBAS group made observations on two nights in 2016 July. From our data we derive a rotation period of 2.959 ± 0.003 hours and amplitude of 0.34 magnitudes. This result is consistent with the period of 2.965 h found by Warner (2016b).



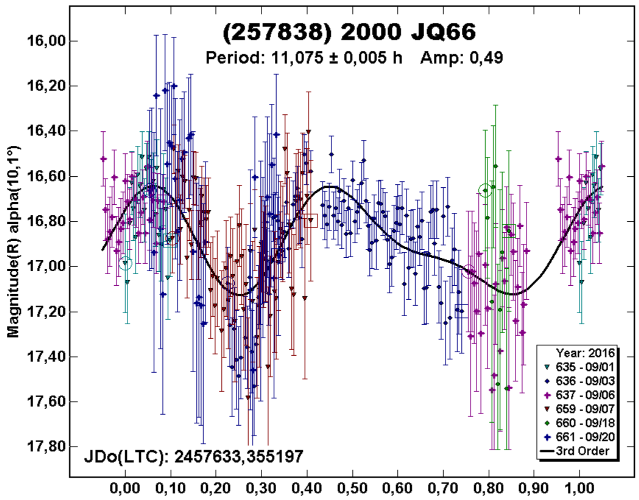
(12538) 1998 OH is an NEA that was discovered 1998-July-18 by NEAT. The OBAS group, especially the team at CAAT, obtained observations on three nights in 2016 November. From our data, we found a rotation period of 5.088 ± 0.004 h and amplitude of 0.11 mag. The period is similar to the 5.154 h found by Warner (2017b).



(66391) 1999 KW4. This NEA was discovered on 1999 May 20 by LINEAR at Socorro. The OBAS group, especially the team at CAAT, obtained observations on three nights in 2016 June. From our data, we found a rotation period of 9.581 ± 0.018 h and amplitude of 0.27 mag. This disagrees with the period of 2.7650 h found by Pravec et al. (2006), who reported this to be a binary asteroid with the satellite's orbital period being 17.45 h.

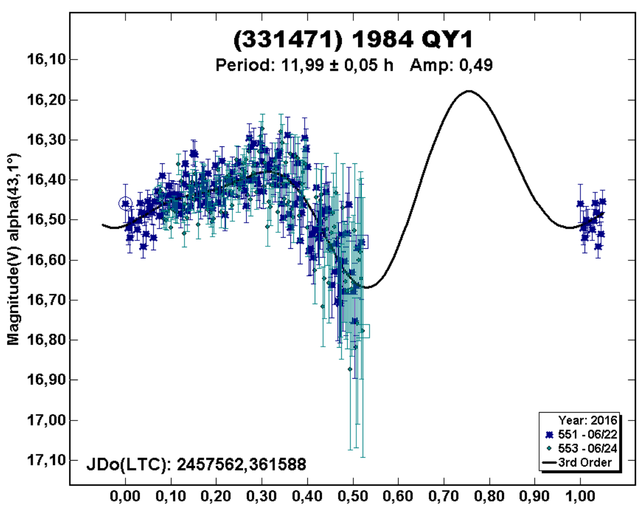


(257838) 2000 JQ66. This NEA was discovered on 2000 May 11 by LINEAR at Socorro. The OBAS group, especially Elche Observatory (MPC I57, *http://observatorioelche.blogspot.com.es),* made observations on six nights in 2016 September. From our data, we found a rotation period of 11.075 ± 0.005 h and amplitude of 0.49 mag. The period is consistent with the 11.094 h found by Warner (2017a).

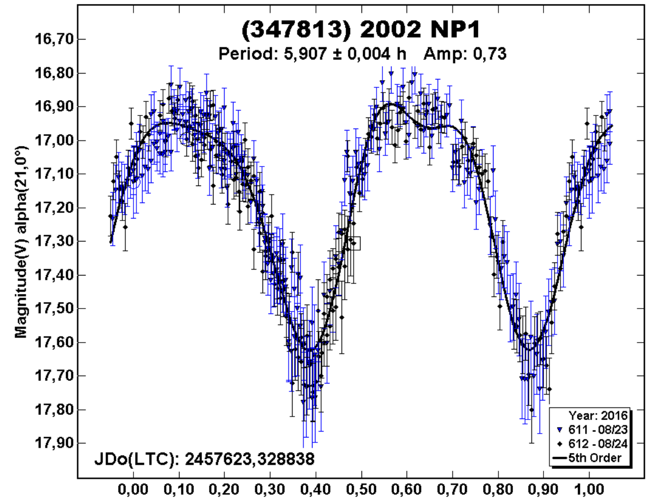


(331471) 1984 QY1. This NEA was discovered on 1984 Aug 27 by Helin and Rose at Palomar. The OBAS group made observations on two nights in 2016 June. The sky motion of the asteroid was 3 arcseconds/min, which required keeping exposures to less than 60 seconds.

From our data, we derived a rotation period of 11.99 ± 0.05 h and amplitude of 0.49 mag. The period differs from the 45.5 h found by Warner and Benishek (2016a), who reported that the asteroid was tumbling and that 36.6 h was a possible solution for the second period.



(347813) 2002 NP1 is an NEA. It was discovered on 2002 Jul 5 by LINEAR at Socorro. The OBAS group made observations on two nights in 2016 August. From our data, we derive a rotation period of 5.907 ± 0.004 h, which is consistent with the period of 5.915 h found by Warner (2017a).



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We would like to express our gratitude to Brian Warner for supporting the CALL web site and his suggestions made to OBAS group.

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PERIOD DETERMINATION OF MAIN-BELT ASTEROID (26274) 1998 RH75

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Photometric observations of the inner main-belt asteroid (26274) 1998 RH75 were made on three nights in 2016 March. Analysis gave a bimodal lightcurve with a synodic period of 3.1296 ± 0.0001 h and amplitude of 0.55 ± 0.02 mag.

(26274) 1998 RH75 (also designated 2000 AM204) was selected as a target for photometric observations because Carvano *et al.* (2010) classified it as a C_p, L_p, and Q_p type asteroid. Obtaining lightcurve data was the next step to better understand this 3-4 km diameter, high inclination (12.39°; MPC, 2016) asteroid.

Observations were obtained at Cerro Tololo Inter-American Observatory using a 0.41-m *f*/10 Skynet PROMPT 2 telescope and an Andor Aspen CG230 CCD camera with a 15 µm 2048x2048 array. The system has an image scale of 0.75 arcsec/pixel and a field-of-view of 25.76x25.76 arcminutes. We used differential photometry through *MPO Canopus* software (Warner, 2011) for our lightcurve analysis. *MPO Canopus* reported the period and its uncertainty to a precision of 0.0001 h when we determined the period with the lowest RMS value.

Our result of P = 3.1296 h puts 1998 RH75 well within range of other main-belt asteroid periods. It showed no abnormalities in the lightcurve during its rotation. There were no reports on 1998 RH75 in the Asteroid Lightcurve Database (Warner *et al*., 2009).

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We would like to give a special thanks to Vivian Hoette and Austin Caughey for their unwavering support. We would also like to acknowledge the University of North Carolina for the control and maintenance of Skynet (*https://skynet.unc.edu/*) that made all of these observations possible.

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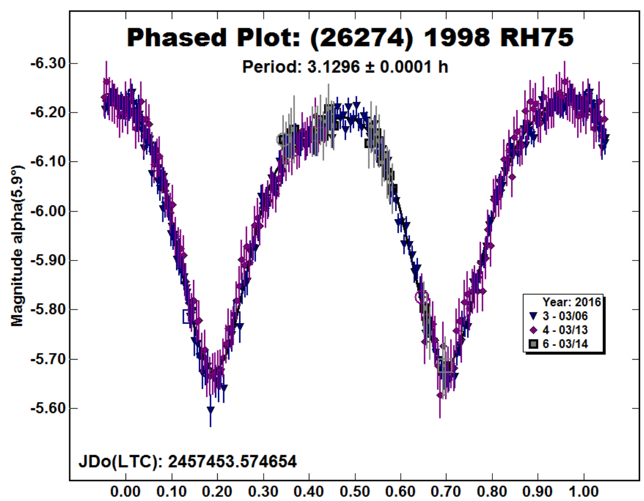

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
26274	1998 RH75	03/06-03/14	360	6.0,1.7	176	-2	3.1296	0.0001	0.55	0.02	MB-I

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

ROTATION PERIOD DETERMINATIONS FOR 396 AEOLIA, 398 ADMETE, 422 BEROLINA, AND 555 NORMA

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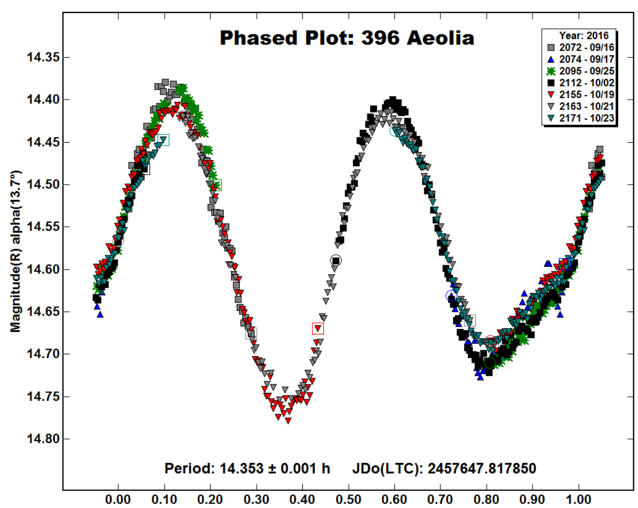
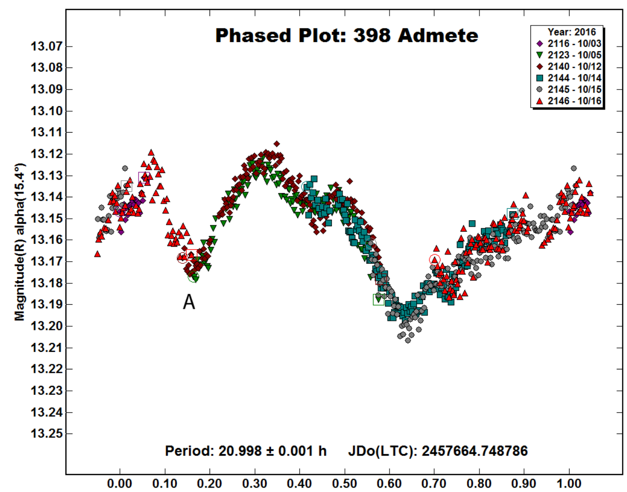
Synodic rotation periods and amplitudes are found for 396 Aeolia 14.353 ± 0.001 hours, 0.36 ± 0.02 magnitudes; 398 Admete 20.993 ± 0.001 hours, 0.07 ± 0.01 magnitudes; 422 Berolina 25.978 ± 0.001 hours, 0.16 ± 0.02 magnitudes; 555 Norma 19.508 ± 0.002 hours, 0.25 ± 0.02 magnitudes.

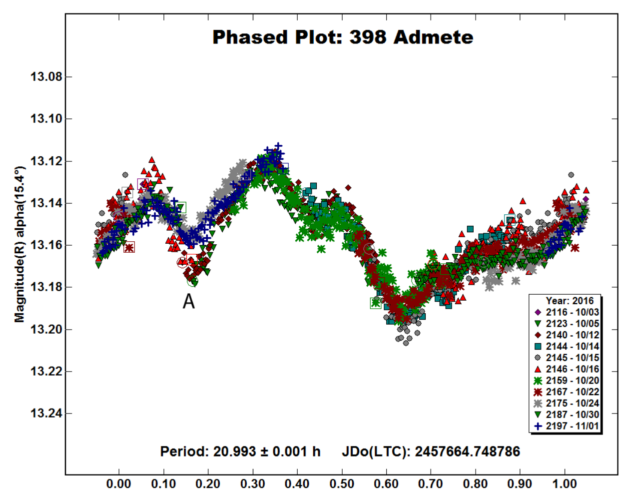
Observations to obtain the data used in this paper were made at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. Exposures were 60 seconds, unguided, with a clear filter. Photometric measurement and lightcurve construction is with *MPO Canopus* software. To reduce the number of points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes.

396 Aeolia. Previously published period determinations are by Lagerkvist (1978), >12 hours, and by Behrend (2011), 22.2 hours. New observations on 7 nights 2016 Sept. 16 – Oct. 23 provide a good fit to a period of 14.353 ± 0.001 hours, amplitude 0.36 ± 0.02 magnitudes, and rule out both of the previously published periods.



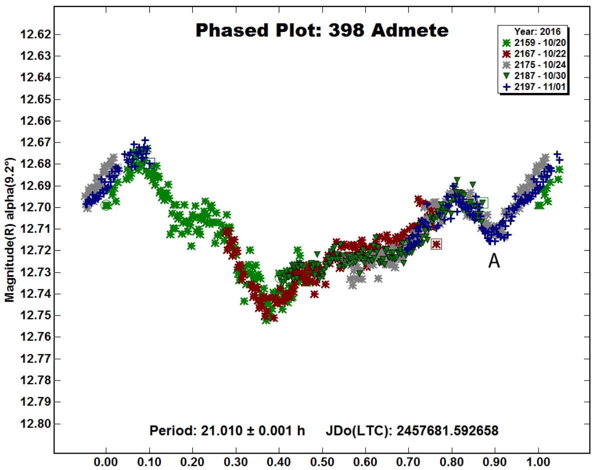
398 Admete. The only previously published period determination appearing in the Light Curve Data Base (Warner et al. 2009) is by Alvarez (2014), period 11.208 hours, amplitude 0.13 magnitudes. This period is uncertain because there are no deep minima in his published period spectrum. New observations on 11 nights 2016 Oct. 3 – Nov. 1 provide a good fit to a period of 20.993 ± 0.001 hours with an irregular lightcurve of amplitude 0.07 ± 0.01 magnitudes. The secondary minimum A on the lightcurves decreased in depth from about 0.04 magnitudes near phase angle 11 degrees Oct. 12 – 17 to about 0.02 magnitudes near phase angle 7 degrees Oct. 24 – Nov. 1. To illustrate the change in shape of minimum A with changing phase angle, lightcurves are plotted for 6 sessions Oct. 3 -16 and for 5 sessions Oct. 20 – Nov. 1. The period spectrum is also presented. An attempt to draw a lightcurve phased to the period spectrum minimum near 11.2 hours produced a complete misfit. The 11.208 hour period by Alvarez (2014) is ruled out.

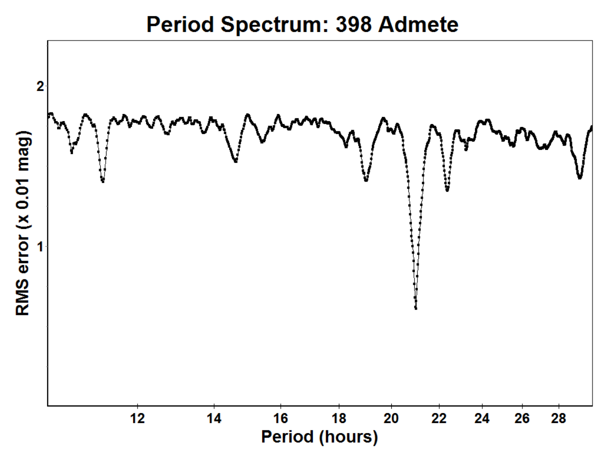




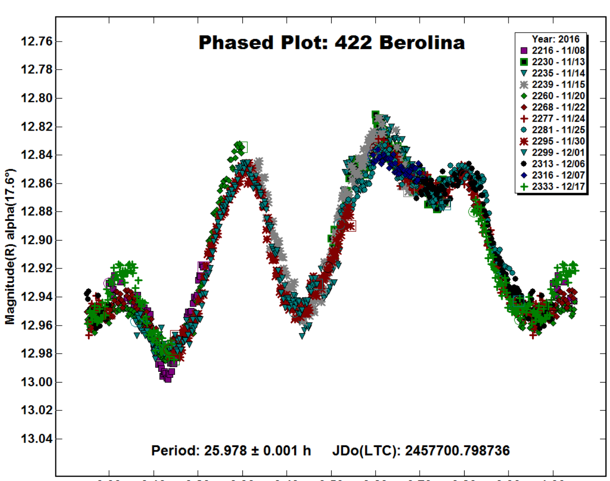
Number	Name	2016 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
396	Aeolia	09/16-10/23	2224	14.2, 1.2	29	2	14.353	0.001	0.36	0.02
398	Admete	10/03-11/01	4590	15.5, 6.5	38	12	20.993	0.001	0.07	0.01
422	Berolina	11/08-12/17	5358	17.5, 4.2, 6.0	77	6	25.978	0.001	0.16	0.01
555	Norma	10/26-11/23	2572	3.4, 1.6, 7.8	41	-3	19.508	0.002	0.25	0.02

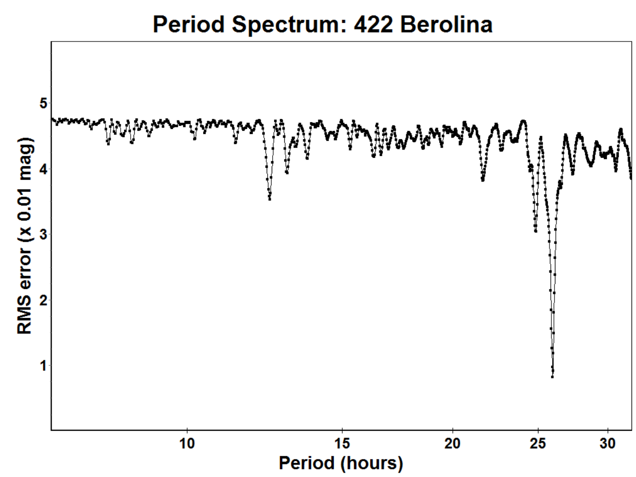
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date, unless a minimum (second value) was reached. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).



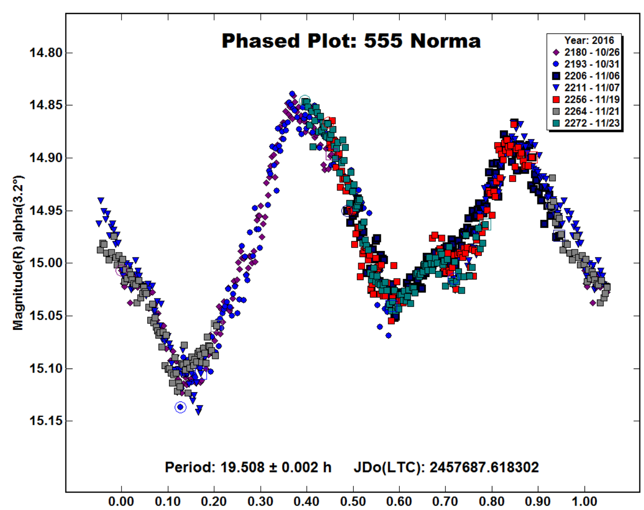


422 Berolina. Previous period determinations are by Harris and Young (1983), > 15.0 hours; Harris and Young (1989), 12.79 hours; and Behrend (2011), 9.05 hours. New observations on 13 nights 2016 Nov. 8 – Dec. 17 provide a good fit to an irregular lightcurve with period 25.978 ± 0.001 hours, amplitude 0.16 ± 0.01 magnitudes. The period spectrum between 7 hours and 32 hours is presented. Attempts to fit lightcurves to periods near all other minima on the period spectrum produced complete misfits. The periods by Harris and Young (1989) and Behrend (2011) are ruled out.





555 Norma. Previously published period and amplitude determinations are by Behrend (2007), 30.6 h, 0.20 mag at celestial longitude 195 degrees, and by Stephens (2012), 19.55 h, 0.06 mag at celestial longitude 95 degrees. New observations on 7 nights 2016 Oct. 26 – Nov. 23 provide a good fit to a period of 19.508 ± 0.002 hours, amplitude 0.25 ± 0.02 magnitudes near celestial longitude 40 degrees. This is consistent with Stephens (2012), but the 30.6 hour period of Behrend is ruled out. The amplitude is much smaller at celestial longitude 95 degrees than at celestial longitude 40 degrees and 140 degrees. This suggests the celestial longitude of the rotational pole is located fairly near 95 degrees or 275 degrees.



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ASTEROID LIGHTCURVE ANALYSIS AT TACANDE OBSERVATORY: 3679 CONDRUSES, 4871 RIVERSIDE, 4895 EMBLA, AND 5403 TAKACHIHO

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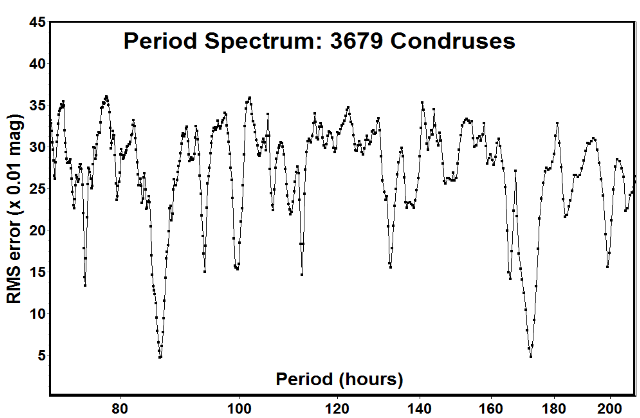
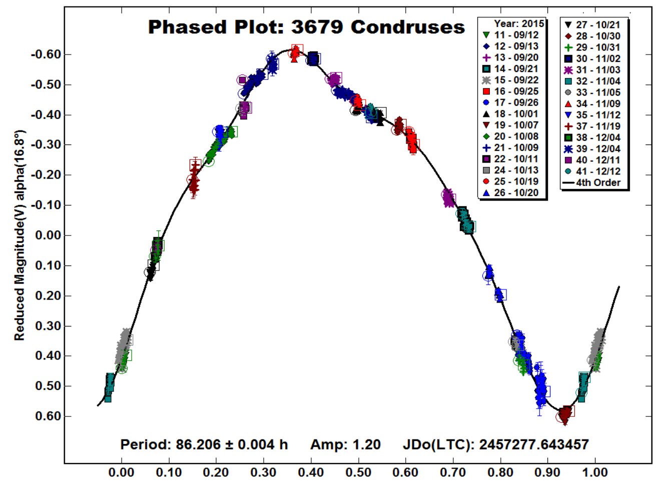
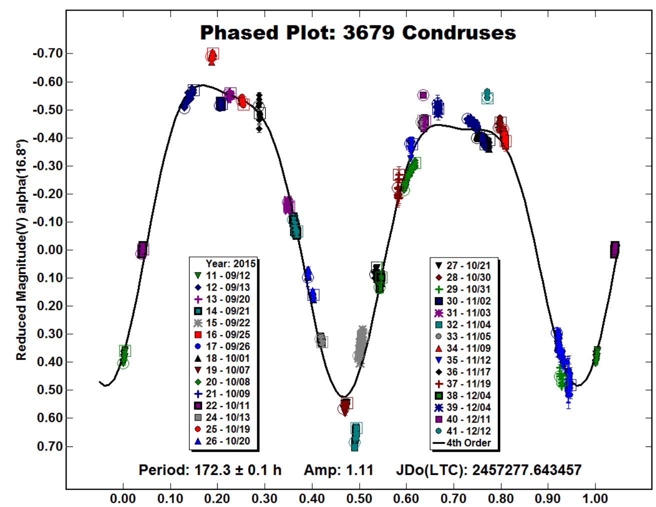
Lightcurves for four asteroids were obtained at Tacande Observatory from 2015 September to 2016 November: 3679 Condruses, 4871 Riverside, 4895 Embla, and 5403 Takachiho.

The observations reported here were all obtained using a 0.5-m *f*/2.9 Astrograph, FLI ML-3200 CCD camera, and Johnson V filter. All images were bias, dark and flat field corrected and have an image scale of 0.98 arc seconds per pixel. Differential photometry measurements were made in *MPO Canopus* (Warner, 2016). V magnitudes for comparison stars were extracted from the AAVSO Photometric All-Sky Survey (APASS; Henden et al., 2009*)* catalog. Table I gives the observing circumstance and results.

3679 Condruses is a main-belt asteroid discovered by Debehogne at La Silla in 1984. A total of 723 data points were obtained over 29 nights during the period 2015 Sep 12 – Dec 12. The best fit lightcurve shows a period of 86.206 h ± 0.004 h and amplitude of 1.20 ± 0.01 mag. Pravec et al. (2015web) reported a period *P* > 32 h.





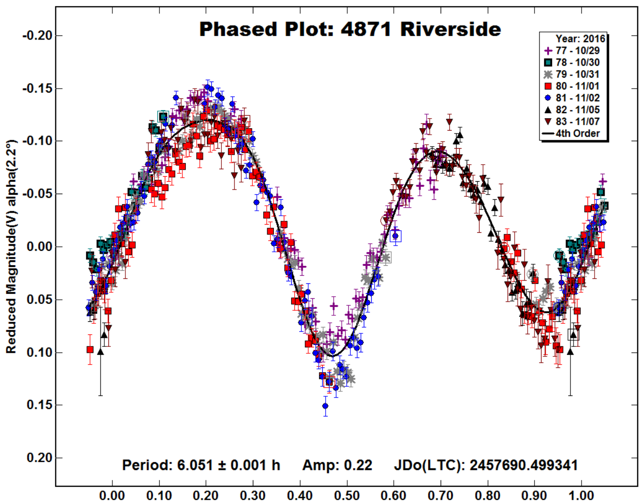


Harris et. al (2014) suggest, due to the large amplitude, that the lightcurve shape will be bimodal. The period spectrum suggests that a period of 172.3 hours is also a possible fit, so the second lightcurve is preferred, with a period of 172.3 h ± 0.1 h and amplitude of 1.11 ± 0.01 mag, suggesting that the asteroid rotated 12 times during the period of observation.

4871 Riverside is a main-belt asteroid discovered by Koishikawa at Ayashi in 1989. A total of 467 data points were obtained over seven nights from 2016 Oct 29 to Nov 7. The average magnitude was 15.6 and average SNR was 150. The lightcurve shows a period of 6.051 h ± 0.001 h and amplitude of 0.22 ± 0.01 mag, suggesting that the asteroid rotated 36 times during the period of observation.

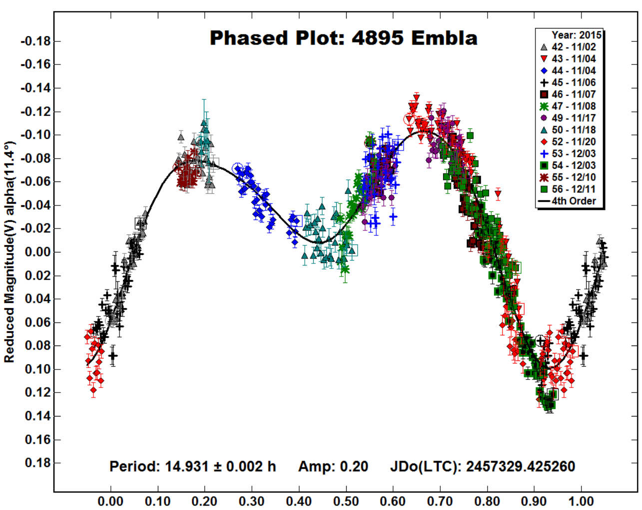
Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3679	Condruses	15/09/12-15/12/12	723	16.8,4.8,30.6	14	6	172.3	0.1	1.20	0.01	FLOR
4871	Riverside	16/10/29-16/11/07	467	2.1,6.3	35	3	6.051	0.001	0.22	0.01	FLOR
4895	Embla	15/11/02-15/12/11	591	11.4,2.7,13.6	56	4	14.931	0.002	0.20	0.01	MB-I
5403	Takachiho	15/12/15-16/03/30	291	15.4,0.5,19.1	128	1	3.959	0.001	0.29	0.01	EOS

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

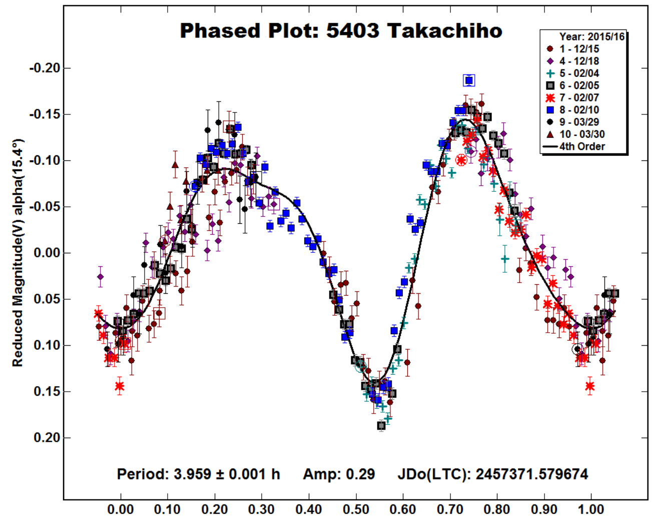


4895 Embla is a main-belt asteroid discovered by Jensen at Brorfelde in 1986. A total of 591 data points were obtained over 13 nights from 2015 Nov 2 to Dec 11. The average magnitude was 15.3 and average SNR was 217. The lightcurve shows a period of 14.931 h ± 0.002 h and amplitude of 0.20 ± 0.01 mag, suggesting that the asteroid rotated 62 times during the period of observation.

Pravec et al. (2015web), who observed in early 2015 Nov, reported a period of 14.90 h and amplitude of 0.19 mag.



5403 Takachiho is a main-belt asteroid discovered by Kushida and Inoue at Yatsugatake in 1990. A total of 291 data points were obtained over eight nights from 2015 Dec 15 to 2016 Mar 30. The average magnitude was 16.3 and average SNR was 136. The lightcurve shows a period of 3.959 h ± 0.001 h and amplitude of 0.29 ± 0.01 mag, suggesting that the asteroid rotated 642 times during the period of observation.



Acknowledgements

The measurements reported make use of the AAVSO Photometric All-Sky Survey (APASS) catalog, which is funded by the Robert Martin Ayers Sciences Fund. Thank you to Joan Genebriera for maintaining the equipment at Tacande Observatory in La Palma.

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ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2016 OCTOBER-DECEMBER

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(Received: 2017 Jan 10)

Lightcurves for 14 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 October through December.

CCD photometric observations of 14 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 October through December. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

Desig	Telescope	Camera
Squirt	0.30-m f/6.3 Schmidt-Cass	ML-1001E
Borealis	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
Eclipticalis	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Australius	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Zephyr	0.50-m f/8.1 R-C	FLI-1001E

Table I. List of CS3-PDS telescope/CCD camera combinations.

All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposure duration varied depending on the asteroid's brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid.

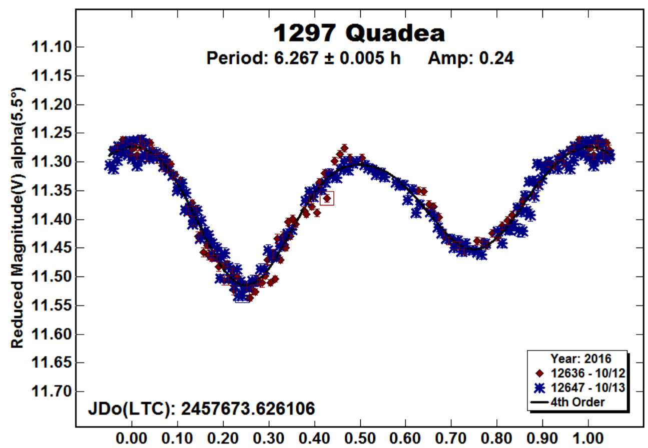
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* or APASS (Henden *et al.*, 2009) catalogs. The MPOSC3 catalog was used as a last resort. This catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI (Warner, 2007). The nightly zero points for the catalogs are generally consistent to about ± 0.05 mag or better, but on occasion reach 0.1 mag and more. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done with *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the given phase angle, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The X-axis is the rotational phase ranging from –0.05 to 1.05.

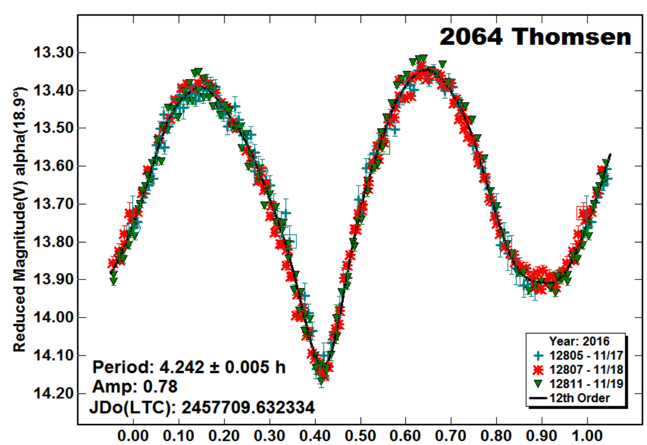
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html* allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcodes, is also available for download. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

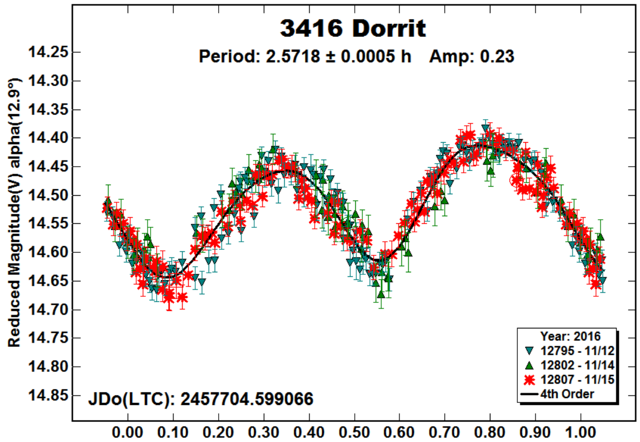
1297 Quadea is a member of the Eos orbital group (Warner *et al.*, 2009) with an estimated size of 23 km. It was observed as a target of opportunity, *i.e.*, it was in the same field as the planned target. Waszczak *et al.* (2015) found a period of 6.2675 h; Behrend (2005web) reported 6.267 h; Oliver *et al*. (2008) found a period of 6.256 h. The period reported here agrees with those earlier results.



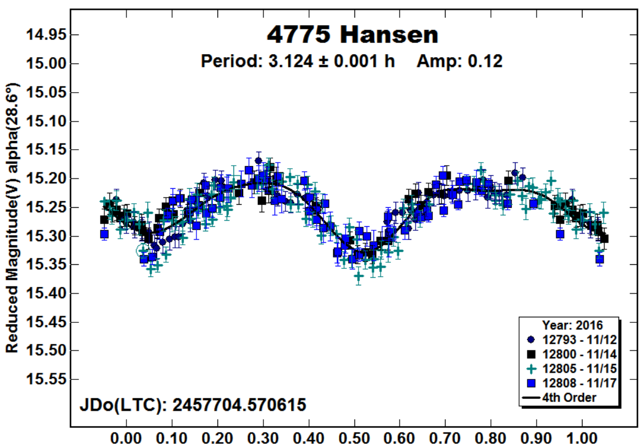
2064 Thomsen. Previous results for this 13 km Mars-crosser have all been near 4.23 h, *e.g.,* Wisniewski (1991) and Warner (2015). The results here are in statistical agreement.



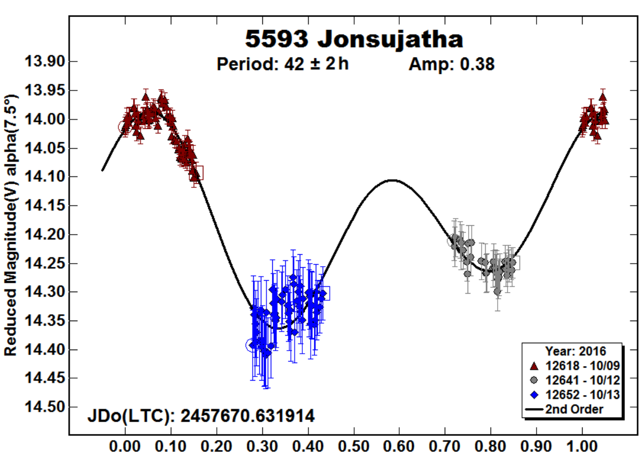
3416 Dorrit. Dorrit is a Mars-crosser with an estimated diameter of 6 km. Bennefeld *et al*. (2009b) found a period of 2.714 h. Warner (2010; 2015) found a period of 2.574 h. The 2016 observations from PDS led to a period of 2.5718 h. They could not be fit to the longer period found by Bennefeld *et al.*



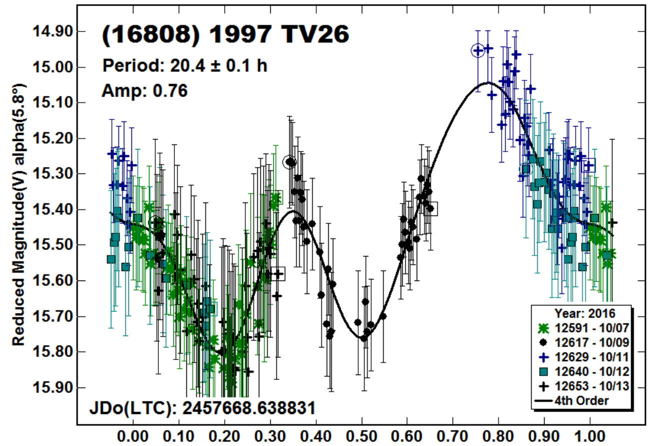
4775 Hansen was one of several Mars-crossers observed in late 2016 while waiting for the moon to clear the sky, a so-called "full moon project." Pravec *et al.* (2016web) found a period of 3.1185 h based on data from 2016 August. The PDS data were obtained in mid-November and lead to a slightly longer synodic period of 3.124 h. The amplitude decreased from August to November despite the phase angle increasing. This may be explained by the significant difference (almost 50°) in phase angle bisector longitude (see Harris *et al.*, 1984). In other words, the November observations may have been more pole-on, and so the amplitude decreased.



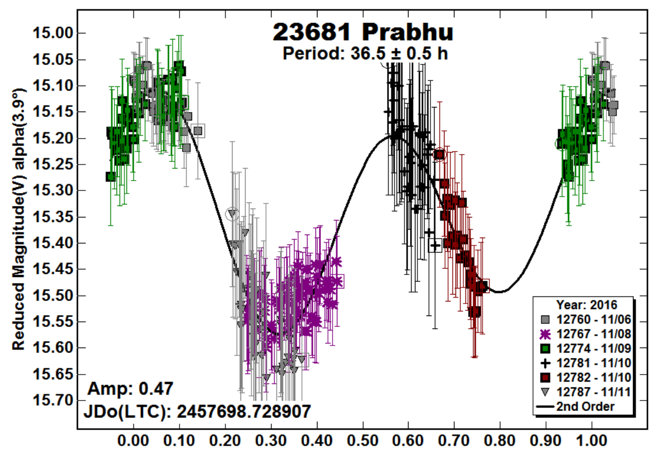
5593 Jonsujatha. These appear to be the first results for this Baptistina member. The solution is tenuous, at best.



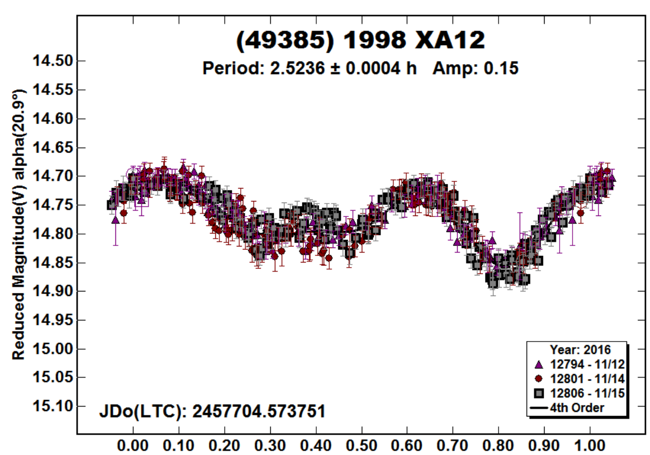
(16808) 1997 TV26. The long period and low SNR made finding a solution for this Nysa asteroid difficult.



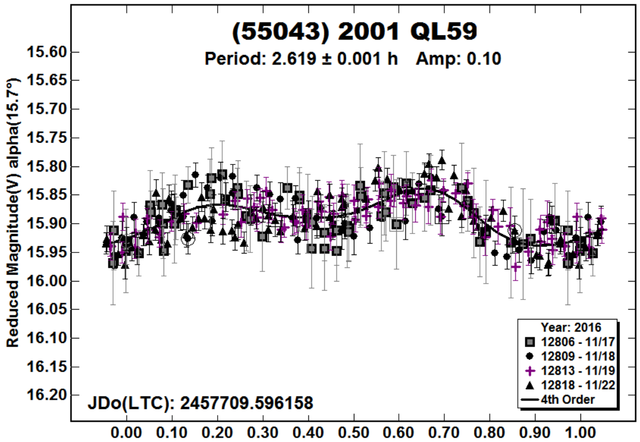
23681 Prabhu. This was another target of opportunity that managed to stay in the field of the planned target for several days. Given the apparent amplitude, a bimodal solution made the most sense, thus reducing the chances that another Earth-day commensurate period is the actual period.



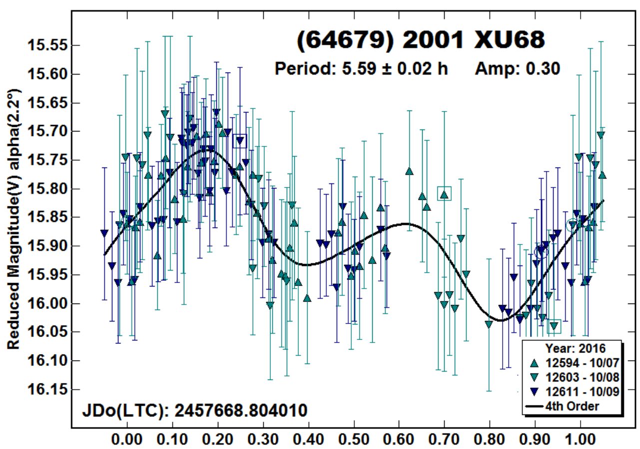
(49385) 1998 XA12. Other reported periods by Warner (2006) and Behrend (2016web) are in good agreement with the period reported here. Despite different phase angle bisector longitudes and because of similar phase angles, the amplitude of the lightcurve has always been close to 0.15 mag.



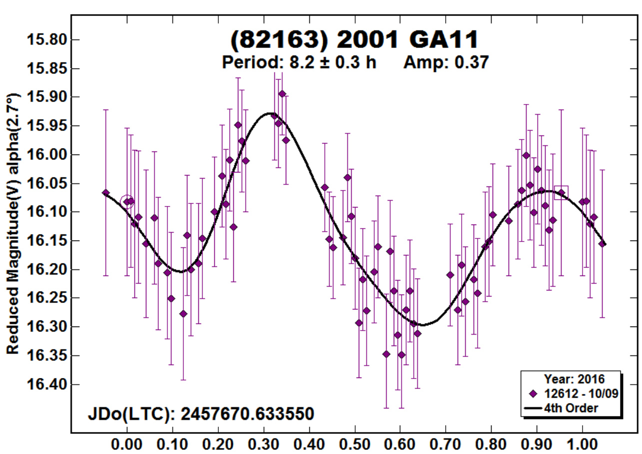
(55043) 2001 QL59. This Mars-crosser was another *full moon project*. No previous results were found in the literature.



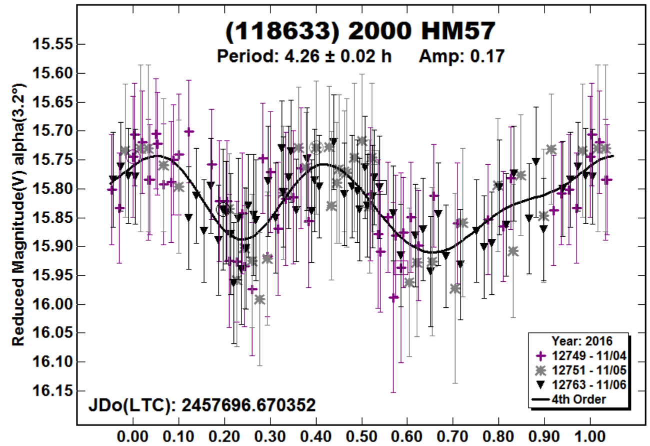
(64679) 2001 XU68 is a Vestoid that was in the same field as a targeted Hilda asteroid for three nights. It was near the edge of useful SNR for photometry, thus the large error bars. Despite this, a reasonably good result was found, though it should not be considered definitive.



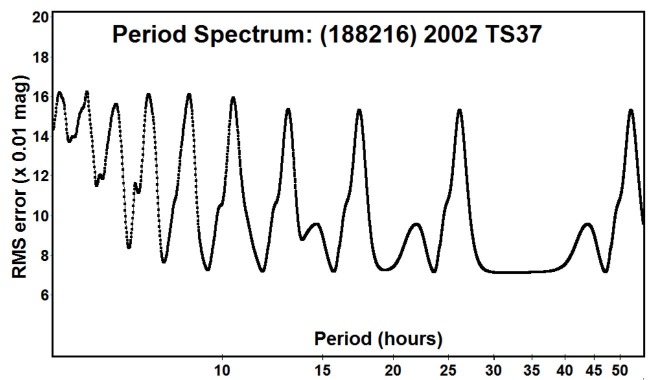
(82163) 2001 GA11. A Flora member, 2011 GA11 was in the field of a planned target for only one night. Even so, a fairly good solution was found since the data covered almost a full cycle of the adopted period.

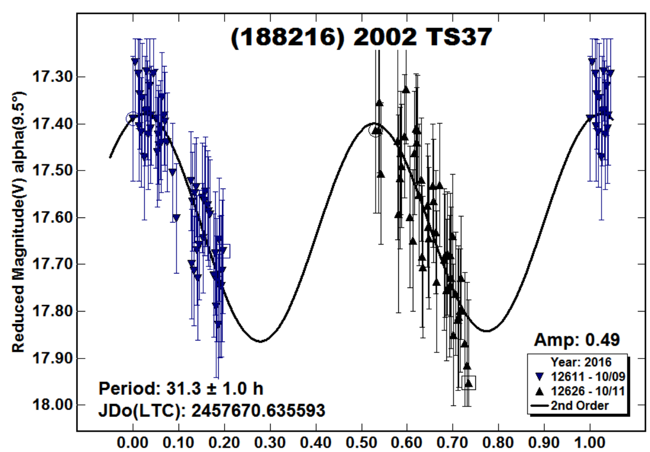


(118633) 2000 HM57. Another target of opportunity, this Nysa member was observed for three consecutive nights. Despite, again, low SNR, a useful synodic period was found.



(188216) 2002 TS37. As the period spectrum shows, there were a number of possible solutions for 2002 TS37, a member of the Flora group. The adopted period of 31.34 hours is based on the assumption of a bimodal lightcurve, appropriate spacing of the extrema, and trying to fit to a half-period.





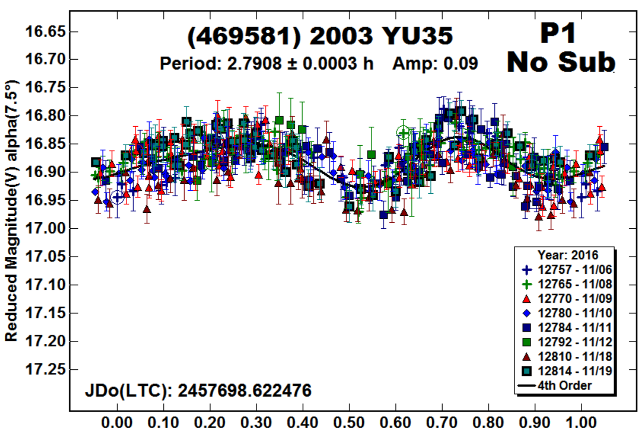
A search for half-periods of less than 12 hours found several solutions, but they were improbable because of the extreme asymmetry. For example, most had a maximum to minimum taking at least 0.6 and usually 0.7+ rotation phase, leaving only 0.4 and less of the period to rise from minimum to maximum. Also, those solutions presumed that the two nights covered the same portion of the lightcurve.

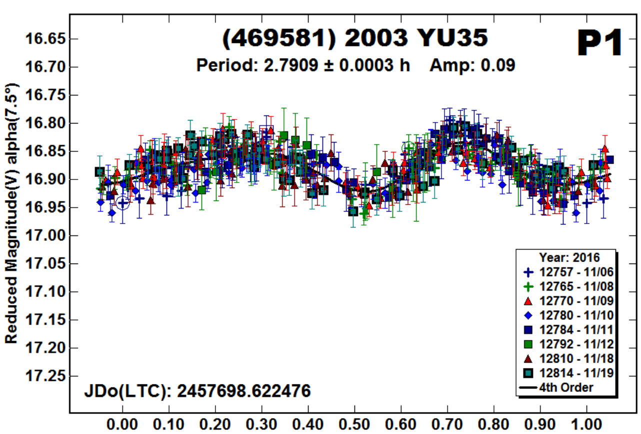
Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Group
1297	Quadea	10/12-10/13	247	5.5,5.3	26	11	6.267	0.005	0.24	0.01	EOS
2064	Thomsen	11/17-11/19	373	18.9,19.6	26	8	4.242	0.005	0.78	0.03	MC
3416	Dorrit	11/12-11/15	294	12.9,14.3	38	14	2.5718	0.0005	0.23	0.02	MC
4775	Hansen	11/12-11/17	254	28.7,29.6	23	14	3.124	0.001	0.12	0.01	MC
5593	Jonsujatha	10/09-10/13	154	7.5,9.4	2	-2	42	2	0.38	0.02	BAP
16808	1997 TV26	10/07-10/12	210	5.8,7.9	1	-2	20.43	0.05	0.81	0.02	NYSA
23681	Prabhu	11/06-11/11	239	3.9,5.9	36	-4	36.5	0.5	0.45	0.04	MB-M
49385	1998 XA12	11/12-11/15	409	20.8,20.9	41	26	2.5236	0.0004	0.15	0.01	MC
55043	2001 QL59	11/17-11/22	252	15.7,17.8	34	-8	2.619	0.001	0.1	0.01	MC
64679	2001 XU68	10/07-10/09	128	2.2,2.5	14	4	5.59	0.02	0.26	0.04	V
82163	2001 GA11	10/09-10/09	68	2.7,2.7	14	4	8.2	0.3	0.35	0.04	FLOR
118633	2000 HM57	11/05-11/06	140	3.7,4.1	36	-3	4.26	0.02	0.17	0.03	NYSA
188216	2002 TS37	10/09-10/11	100	9.6,10.7	3	-2	33.1	1.0	0.49	0.05	FLOR
469581	2003 YU35	11/06-11/19	426	7.5,6.2,7.6	49	8	2.7909[P]	0.0003	0.09	0.01	MB-M

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are, respectively, the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). The Group column gives the orbital group to which the asteroid belongs. The definitions and values are those used in the LCDB (Warner *et al.*, 2009). BAP = Baptistina; FLOR = Flora; H = Hungaria; MC = Mars-crosser; MB-M = middle main-belt; V = Vestoid. [P] period for presumed primary of a binary system.

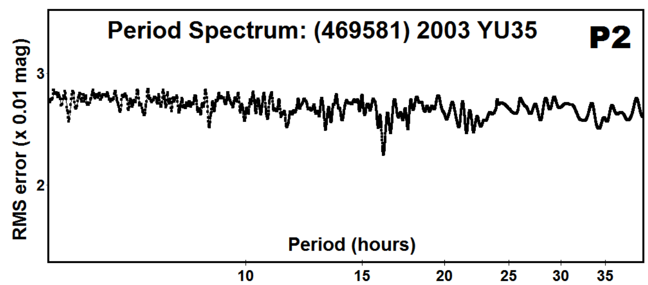
When the possibility of the two nights representing opposing halves of the lightcurve was explored, a more reasonable half-period of 15.7 hours was found, leading to the solution of 31.3 hours adopted here. The Fourier analysis found a formal error of 0.01 h, but this is far too optimistic given the lack of coverage.

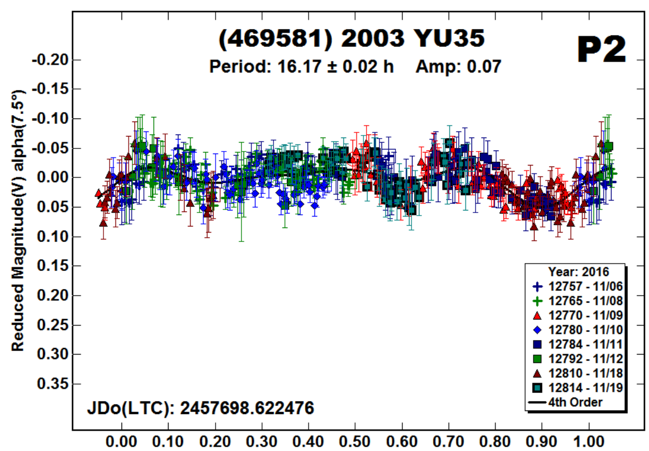
(469581) 2003 YU3. The estimated size and period of 2.79 h make this middle main-belt asteroid a good candidate for being a binary asteroid.





The somewhat large scatter in the single period solution (P1: No Sub) prompted a dual-period search using *MPO Canopus*. This led to a somewhat better fitting primary period (P1) but only a weak secondary solution, as shown by the period spectrum.





Regardless, the period of 16.17 h (P2) fits within the typical range for the orbital period of a small satellite and the dip at 0.6 rotation phase is similar to a mutual event (occultation or eclipse). However the rest of the lightcurve is not quite as expected, casting doubts on the true nature of the asteroid. If nothing else, these results should make it a priority target at future apparitions.

Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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ASTEROIDS OBSERVED FROM CS3: 2016 OCTOBER - DECEMBER

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(Received: 2017 Jan 11)

CCD photometric observations of eight asteroids were obtained from the Center for Solar System Studies from 2016 October to December.

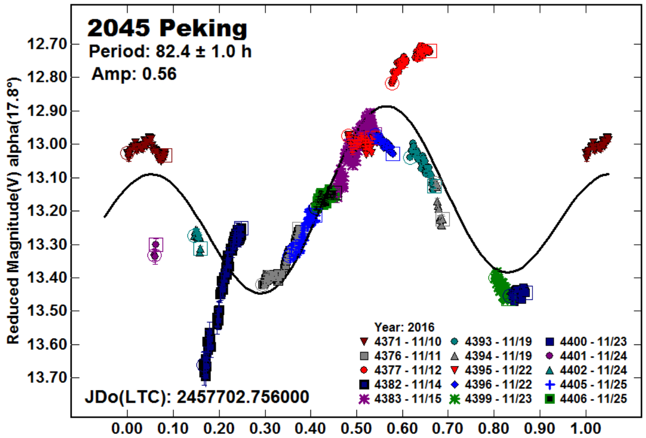
The Center for Solar System Studies "Trojan Station" (CS3, MPC U81) has two telescopes which are normally used in program asteroid family studies. When those targets are too dim to continue observations during bright moon times, brighter targets away from the Moon suitable for future shape modeling studies are selected to keep the telescopes operating. Eight asteroids, usually with known short rotational periods were selected for observations in the week nearest the Full Moon.

All images were made with a 0.4-m or a 0.35-m SCT using an FLI ML-Proline 1001E or FLI ML-Microline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. Image processing, measurement, and period analysis were done using MPO Canopus (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Johnson V magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in MPO Canopus was used to limit the comparison stars to near solar color.

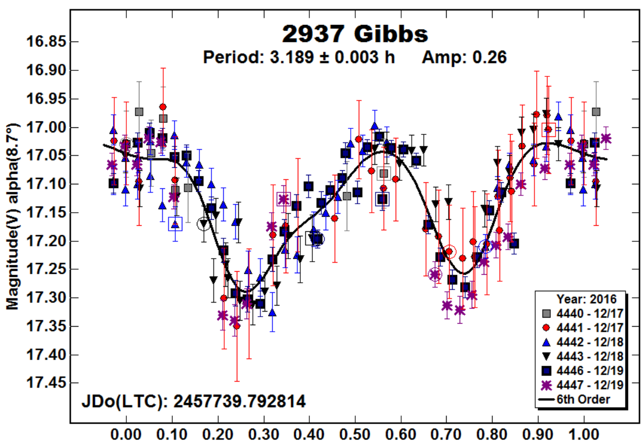
In the lightcurve plots, the "Reduced Magnitude" is Johnson V corrected to a unity distance by applying -5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using G = 0.15. The X-axis rotational phase ranges from -0.05 to 1.05.

The amplitude indicated in the plots is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

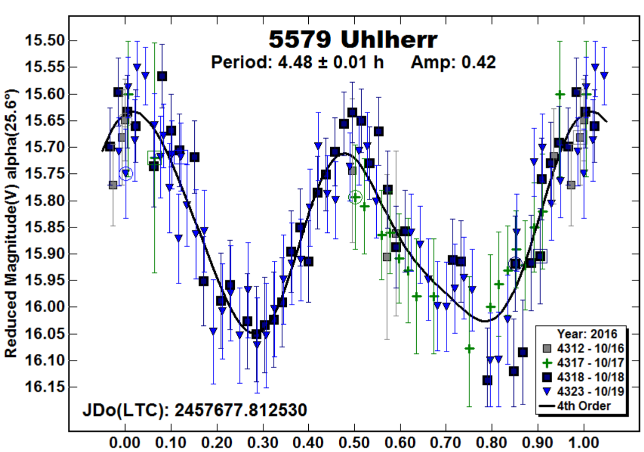
2045 Peking. This Vestoid was selected because it is bright. With no previously reported results in the asteroid lightcurve database (LCDB; Warner et al., 2009), it was suspected there are observations residing in 'dusty file cabinets'. Although this phrase is quickly becoming an anachronism. Suspicions were confirmed when after a few nights of observations, it became apparent that Peking has a long rotational period. Still, most of these long periods have been found for the brighter asteroids. The mystery has been partially solved when Peking started showing clear signs of tumbling. Specifically, observations on 12 and 14 November deviate dramatically from the best fit Fourier model curve. As is the case with most long period tumbling asteroids, sufficient observations could not be obtained to determine a secondary frequency.



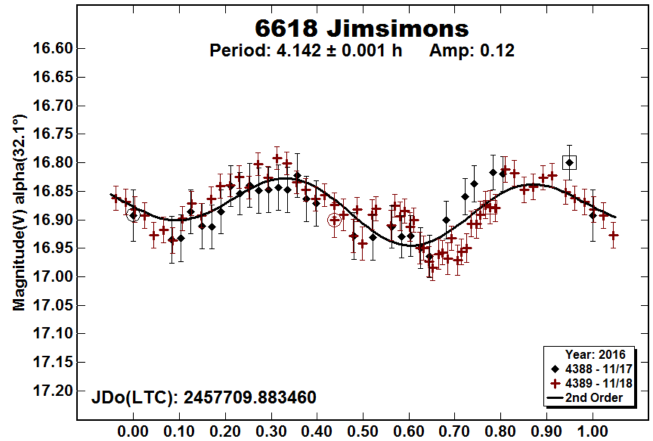
2937 Gibbs. Behrend (2005) reported rotational periods of 3.06 and 3.06153 h. The former result is from a single night. The more precise period is a denser dataset but contains a number of noisy outliers which might skew the result. Our result is in good agreement with those observations from 2005.



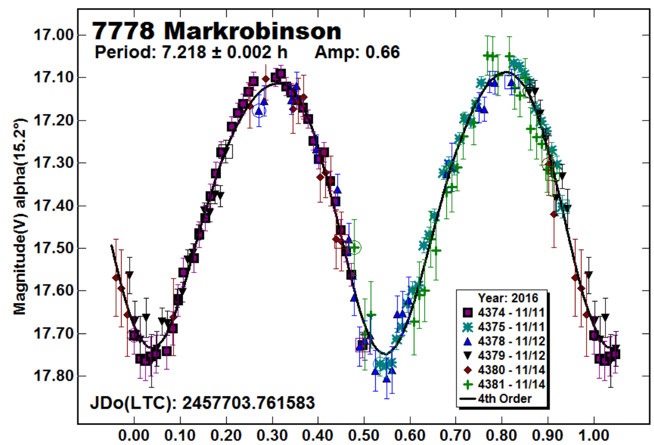
5579 Uhlherr. We have studied this Hungaria in the past as part of a Hungaria family pole position study. Warner (2009b, 2012, 2015) previously found a period near of 4.5 h. Our result this year is in agreement with the earlier findings.



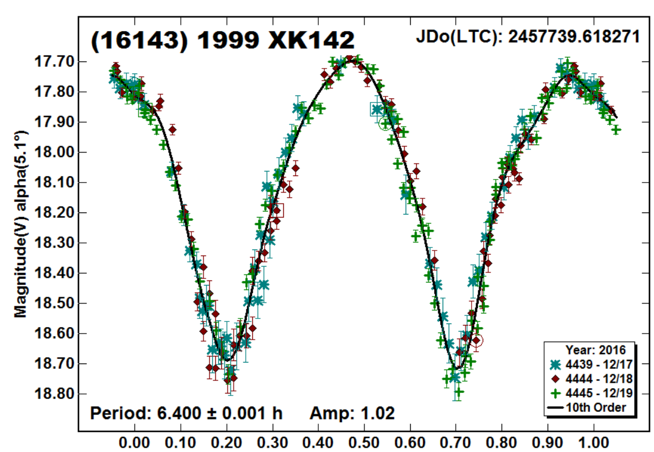
6618 Jimsimons. This asteroid has also been well studied in the past as part of the Hungaria family pole position study. Warner (2009a, 2012, 2014) observed it three times finding rotational periods near 4.14 h. Our period is in good agreement with those results.



7778 Markrobinson. Behrend (2008) and Warner (2009a) both observed this Mars Crosser in 2008 June, both finding a rotational period near 7.23 h. This result is in good agreement.



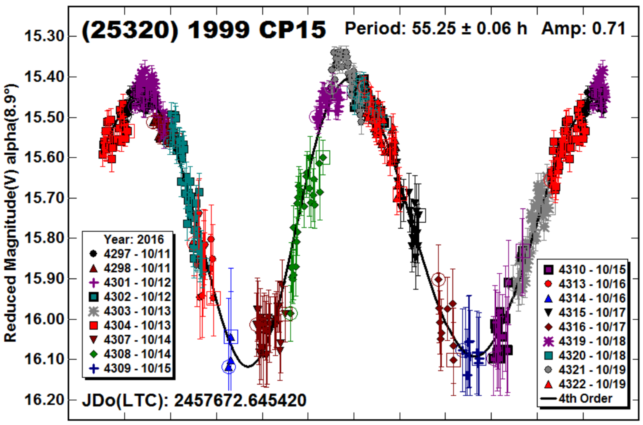
(16143) 1999 XK142. Using sparse data from the Palomar Transient Factory, Waszczak *et al.* (2015) and Chang *et al.* (2015) reported periods near 6.4 h. Our dense lightcurve this year confirms the results from these sparse data surveys.



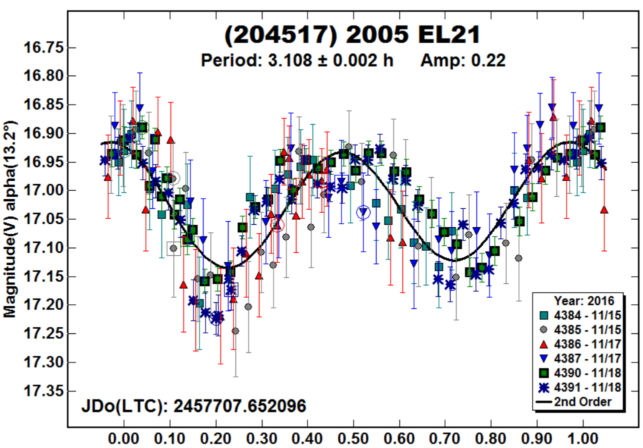
(25320) 1999 CP15. There were no previously reported rotation periods of this long period Hungaria in the asteroid lightcurve database (LCDB; Warner et al., 2009).

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp.	A.E.	Grp
2045	Peking	11/10-11/25	615	17.8,12.8	89	8	82.4	1.0			V
2937	Gibbs	12/17-12/19	161	8.7,7.9	103	-7	3.189	0.003	0.26	0.03	MC
5579	Uhlherr	10/16-10/19	119	25.6,24.6	63	-17	4.48	0.01	0.42	0.03	H
6618	Jimsimons	11/17-11/18	90	32.1,32.0	109	27	4.171	0.012	0.12	0.02	H
7778	Markrobinson	11/11-11/14	156	15.2,14.1	79	-12	7.218	0.002	0.66	0.02	MC
16143	1999 XK142	12/17-12/19	235	5.1,4.7	89	9	6.400	0.001	1.02	0.02	MC
25320	1999 CP15	10/11-10/19	477	8.9,11.7	15	14	55.25	0.06	0.71	0.03	H
204517	2005 EL21	11/15-11/17	177	13.2,14.0	44	-12	3.108	0.002	0.22	0.03	MC

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009c).



(204517) 2005 WL21. Using sparse data from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a rotational period of 3.1024 h. Our denser lightcurve confirms this result.



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Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Ap. J.* **150**, A75.

LIGHTCURVE ANALYSIS OF TROJAN ASTERIODS AT THE CENTER FOR SOLAR SYSTEM STUDIES 2016 OCTOBER - DECEMBER

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Lightcurves for six Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2016 October to December.

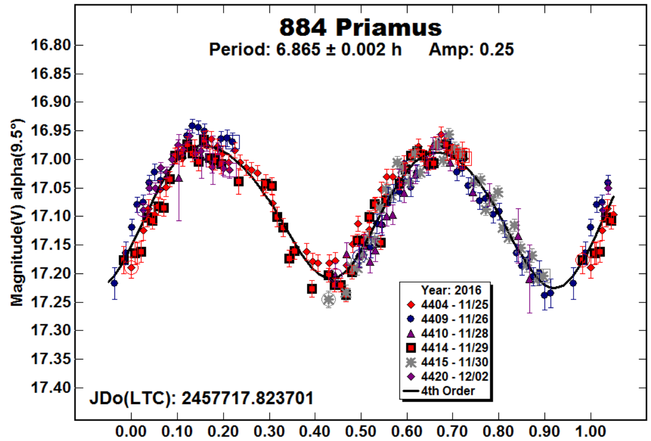
CCD Photometric observations of six Trojan asteroids were obtained at the Center for Solar System Studies “Trojan Station” (CS3, MPC U81). For three years, CS3 has been conducting a study of Jovian Trojan asteroids. As part of this study, data are being accumulated for family rotational and shape model studies. It is anticipated that for most Jovian Trojans, two to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed and can be supplemented with reliable sparse data for the brighter Trojan asteroids. For most of these targets, we were able to get preliminary pole positions and create shape models from sparse data and the dense lightcurves obtained to date. These preliminary models will be improved as more data are acquired at future oppositions.

All images were made with a 0.4-m SCT using an FLI ML-Proline 1001E or a 0.35-m SCT with a FLI ML-Microline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars from the CMC-15 catalog or the MPOSC3 catalog. The MPOSC3 catalog converted to approximate Johnson V magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

In the lightcurve plots, the “Reduced Magnitude” is Johnson V corrected to a unity distance by applying -5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using G = 0.15. The X-axis rotational phase ranges from -0.05 to 1.05.

The amplitude indicated in the plots is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

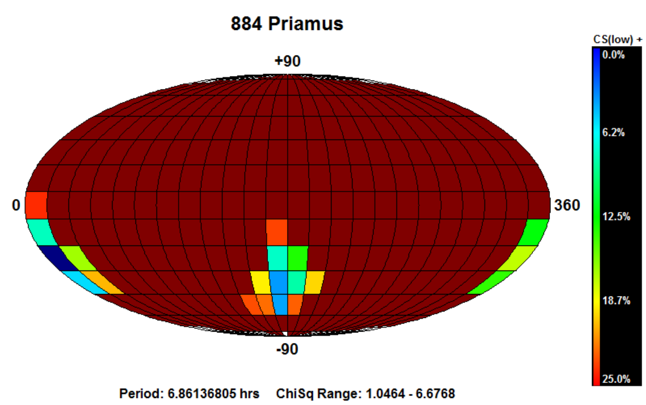
<u>884 Priamus</u>. This large Trojan has been well studied over the years. Mottola *et al* (2011), French *et al* (2011b), and Stephens *et al* (2015, 2016b) each found synodic rotational periods near 6.86 h. When the data was combined with our previous data and sparse data we were able to create a preliminary shape model with a sidereal rotational period of 6.86137 ± 0.00001 h.



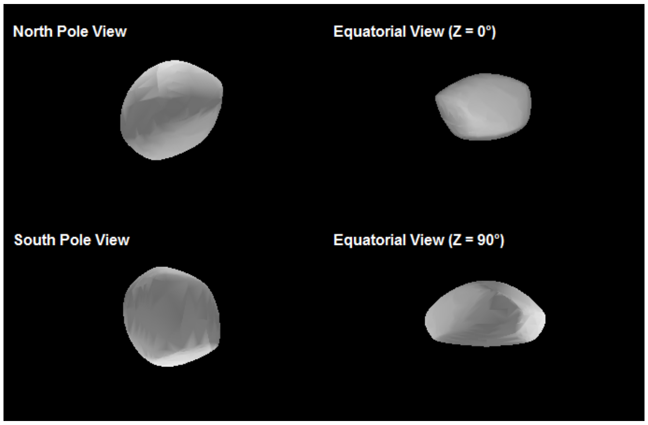
The sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (*http://hamilton.dm.unipi.it/asdys2/*). This sparse data was combined with our dense data from 2010, 2015 and 2016 using *MPO LCInvert*, (Bdw Publishing) a Windows-based program that incorporates the algorithms developed by Kassalainen *et al.* (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values.

Upon finding a period, a search for the spin pole axis is made by forcing the pole solution to one of 315 distinct longitude-latitude pairs allowing the period to “float”. This creates a plot which is an equal area projection of the ecliptic sphere. The colors range from deep blue (lowest χ^2) to red which represents χ^2 values greater than 10 percent of the lowest χ^2 solutions. In a perfect solution, there is one or two small islands of blue in a sea of reds. Often there are two solutions that differ by 180° in longitude because it is not certain when the viewing aspect at a given time is looking at the north or the south pole.

The preliminary shape model for 884 Priamus shows two possible pole solutions approximately 180° apart. The preferred solution is at 0.5° longitude and -32.3° latitude. Additional data at future oppositions should improve on this pole solution.

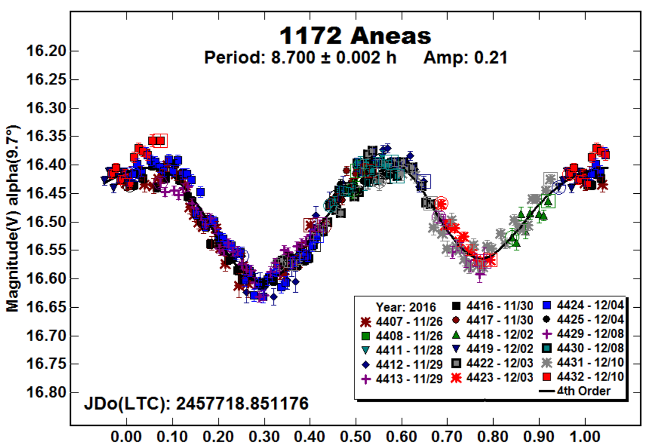


The pole search plot shows the sky in equatorial coordinates in 312 discrete regions that are 15x15°. The region representing the pole solution with the lowest χ^2 value is dark blue. As the colors move from blue to green to red, the difference, in percent from the lowest χ^2 value increases. Those regions that are dark red (maroon) are > 1.25x the lowest value.

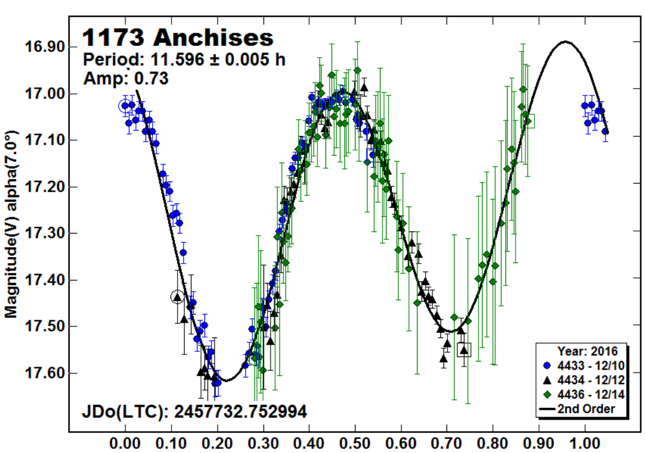


The preliminary model for 884 Priamus shows an elongation of about 1.5 to 1.

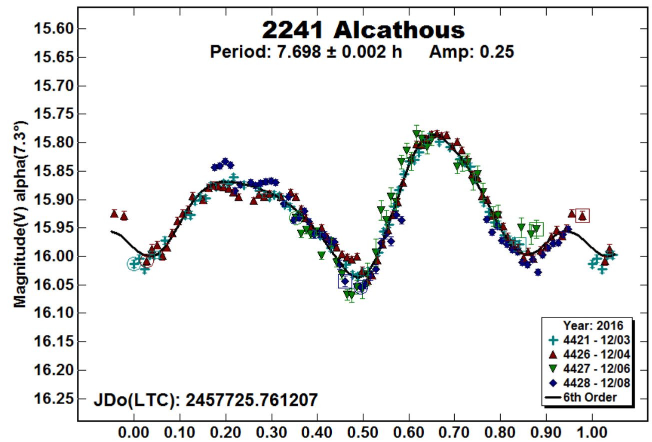
1172 Aneus. The synodic period found using CS3 data from 2016 for this large Trojan is in good agreement with previous results (Mottola 2011, French 2011a, Stephens 2015 and 2016a). When combined with sparse data and our previous data, we were able to create a preliminary shape model with a sidereal rotational period of 8.70297 ± 0.00001 h.



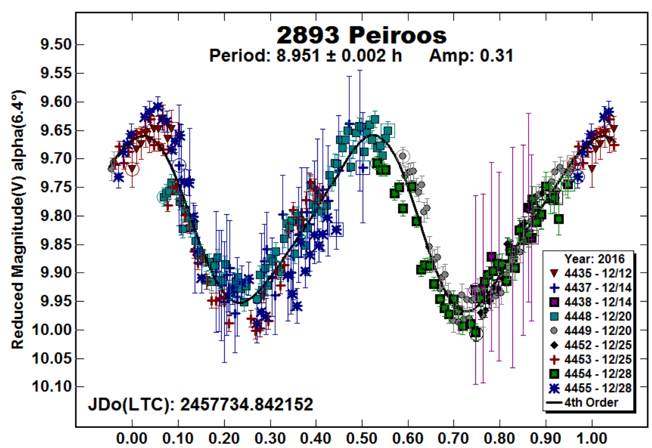
1173 Anchises. French (1987) found a synodic rotational of 11.60 h. We were able to extract the times and magnitudes from that paper and combine it with our data from last year (Stephens *et al* 2016a) and available sparse data to create a preliminary shape model and determine the sidereal period to be 11.609374 ± 0.000002 h.



2241 Alcathous. The synodic period found in 2016 using CS3 data agrees with previous synodic results (Mottola 2011, French 2011a, Stephens 2014, 2015, 2016a). The data collected this year, when combined with our previous data and available sparse data was used to create a preliminary shape model with a sidereal rotational period of 7.68988 ± 0.00001 h.



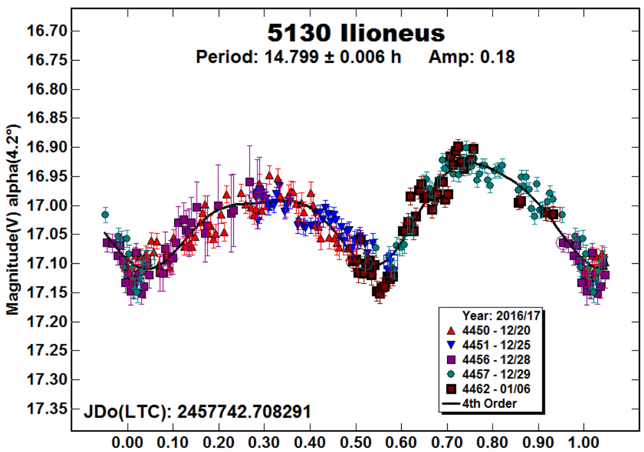
2893 Peiroos. Gonano *et al* (1991) observed this Trojan in 1989 finding a synodic rotational period of 8.96 h. We observed it last year (Stephens *et al* 2016a) finding a synodic rotational period of 8.99 h. When that data was combined with this year's data and sparse data, we were able to create a preliminary shape model with a sidereal period of 8.95310 ± 0.00001 h.



5130 Ilioneus. Mottola *et al.* (2011) observed this Trojan in 1994 reporting a synodic period of 14.768 h. Using sparse data from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a synodic rotational period of 14.7429 h. We observed it last year (Stephens *et al* 2016a) finding a synodic period of 14.783 h. This year's result is in good agreement with those previous findings, but we did not have sufficient sparse data to create a shape model.

Number	Name	2016 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
884	Priamus	11/25-12/02	211	9.5,9.1	132	-1	6.865	0.002	0.25	0.02	TR-J
1172	Aneas	11/26-12/10	328	9.7,9.0	164	-12	8.7	0.002	0.21	0.02	TR-J
1173	Anchises	12/10-12/14	180	7.0,6.5	122	-2	11.596	0.005	0.73	0.04	TR-J
2241	Alcathous	12/03-12/08	225	7.3,6.5	109	-6	7.698	0.002	0.25	0.02	TR-J
2893	Peiroos	12/12-12/25	323	6.4,4.2	116	1	8.951	0.002	0.31	0.02	TR-J
5130	Ilioneus	12/20-01/06	249	4.2,2.5	106	-12	14.799	0.006	0.18	0.02	TR-J

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



Acknowledgements

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(24465) 2000 SX155: A NEW BINARY HUNGARIA

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CCD photometry observations made in 2016 October and November of the Hungaria asteroid (24465) 2000 SX155 showed it to be binary. The primary lightcurve has a period of 2.66087 ± 0.00005 h and an amplitude 0.08 ± 0.02 mag. The orbital period of the satellite is 9.252 ± 0.001 h, the shortest detected so far.

(24465) 2000 SX155 was observed as part of an on-going asteroid lightcurve program at the Center for Solar System Studies (CS3) that concentrates mostly on near-Earth, Hungaria asteroids, and Jovian Trojans.

Rotational periods were determined three times in the past (Warner 2009, 2012, 2015). Those lightcurves had a range of results of 5.71 h, 9.156 h, and 21.46 h which could not be reconciled to each other. The possibility of a secondary period due to the rotation of an undetected satellite was discussed as a possibility for the discrepancy.

The observing circumstances of (24465) 2000 SX155 differed from those of previous years.

Year	Phase	L_{PAB}	B_{PAB}
2008	6.1	40.6	1.3
2012	20.2	31.6	20.2
2015	9.8	190.0	9.8
2016	18.1, 1.0, 12.6	37.0	1.0

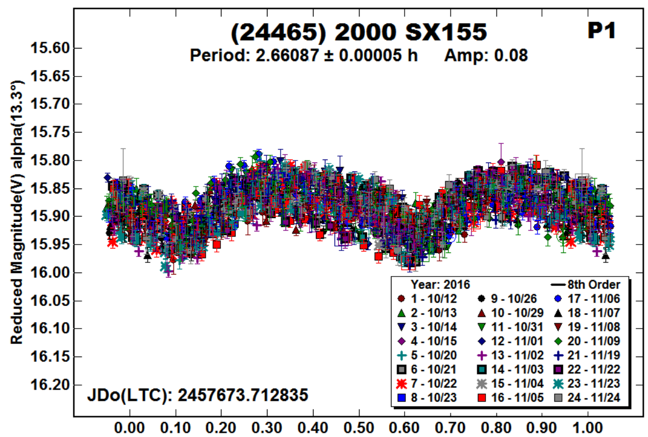
Table I. Observing circumstances for (24465) 2000 SX155. The last two columns are the phase angle bisector longitude and latitude (see Harris *et al.*, 1984).

The observations were made by Stephens using a 0.40-m Schmidt-Cassegrain telescope with Finger Lakes ProLine PL-1001E CCD camera. The 300-second exposures were unguided and made without a filter.

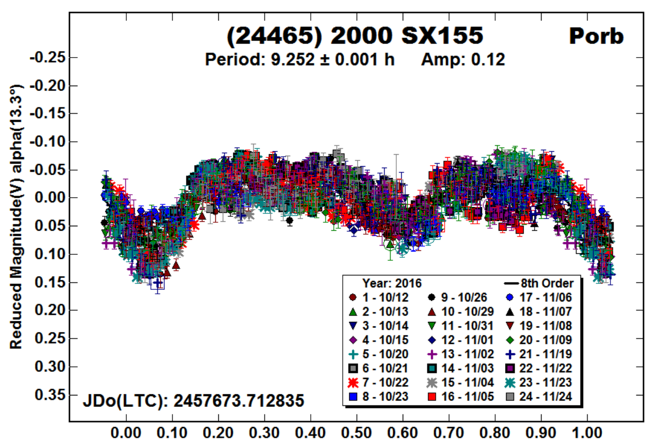
The raw images were flat-field and dark subtracted before being measured in *MPO Canopus*. Night-to-night linkage was aided by the Comp Star Selector utility which helps find near-solar color comparison stars, thus reducing color difference issues. Stars were chosen from the MPOSC catalog, which is based on the 2MASS catalog (*http://irsa.ipac.caltech.edu/Missions/2mass.html*). The J-K magnitudes in 2MASS were converted to Johnson V magnitudes using formulae by Warner (2007). Generally, the zero points are within ±0.05 of one another, but larger adjustments can be required to minimize the RMS value from the Fourier analysis.

Period analysis was also done in *MPO Canopus*, which employs the FALC Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

In the dual-period search process, an initial value is found for the dominant (usually shorter) period. The Fourier model lightcurve is subtracted from the data set in the succeeding search for a second period. The Fourier curve for that second period is subtracted from the data set in a new search for the dominant period. If, for example, the dominant solution produces a trimodal instead of bimodal lightcurve (the latter being the presumptive choice), the initial search is started anew but the period search range is restricted to eliminate finding the trimodal solution. The iterative process continues until both periods stabilize and it produces reasonable lightcurves.



The dual period analysis found a primary lightcurve of P_1 = 2.66087 ± 0.00005 h, A_1 = 0.08 ± 0.02 mag ("P1" plot). Subtracting this lightcurve from the data set and doing a period search found a solution that clearly shows *mutual events* (occultations and/or eclipses) due to a satellite ("Porb" plot). The lightcurve has a period of P_{ORB} = 9.252 ± 0.001 h, A_{ORB} = 0.05-0.12 mag. This is the shortest orbital period detected so far.



Number	Name	2016 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
24465	2000 SX155	10/12-11/24	1406	13.4,0.9,18.1	37	1	2.66087	0.00001	0.12	0.01	H

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

Using the shallower event of 0.05 mag and

$$Ds/Dp = \sqrt{1 - 10^{0.4m}}$$

where m is the depth of the shallower event in magnitudes, gives *Ds/Dp* ≥ 0.22 ± 0.02. Since neither event was total, the estimate is a minimum value and could be larger.

Outside the events, the lightcurve was displayed a faint signal of a third period. Petr Parvec (private communication) looked at the data set and found a possible third period of 6.2847 h. This might possibly belong to a third body.

Each observing run covered about eight hours, sufficient to cover most of the orbital period. It's likely that the 2012 Warner observations found the orbital period which was reported as the primary period. The 2008 observations might have been a 2:1 alias of the primary period.

Acknowledgements

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This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

The purchase of a FLI-Proline 1001E CCD cameras was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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SPIN-SHAPE MODEL LIGHTCURVES

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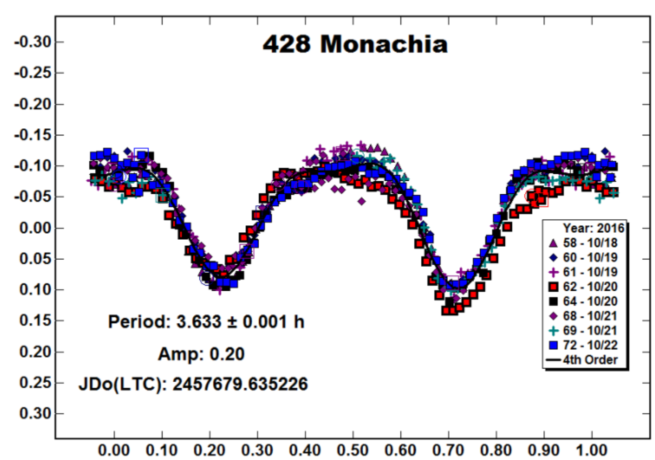
We obtained lightcurves for five asteroids from the Spin/Shape Modeling Opportunities listed in the "Lightcurve Photometry Opportunities: 2016 October-December" article by Warner et al. (2016).

The asteroids for which we report results were selected from the list of shape/spin modeling (SSMO) opportunities given by Warner et al. (2016). We selected photometry opportunities based on asteroid brightness and the modeling opportunities based on known periods of less than eight hours. This allowed the possibility of at least one cycle to be obtained per night provided we could observe the object all night.

Our observations were obtained with three Celestron 0.35-m telescopes and SBIG CCD cameras at Etscorn Campus Observatory (Klinglesmith and Franco, 2016). The images were processed and calibrated using *MPO Canopus* 10.4.7.6 (Warner, 2015). The exposures were between 180 and 420 seconds through clear filters depending on the brightness of the asteroids. The multi-night data sets for each asteroid were combined with the FALC algorithm (Harris et al., 1989) within *MPO Canopus* to provide synodic periods for each asteroid.

Discovery information was obtained from the JPL small bodies node (JPL, 2016). The five asteroids were suggested as possible targets in order to derive their spin / shape models (Warner et al. 2016). Table I contains the observation circumstances and results. Table II is a compilation of the previously obtained lightcurves with references. The data for observations other than in this paper were obtained from the Asteroid Lightcurve Data Exchange Format (ALCDEF) web site (*http://www.alcdef.org*).

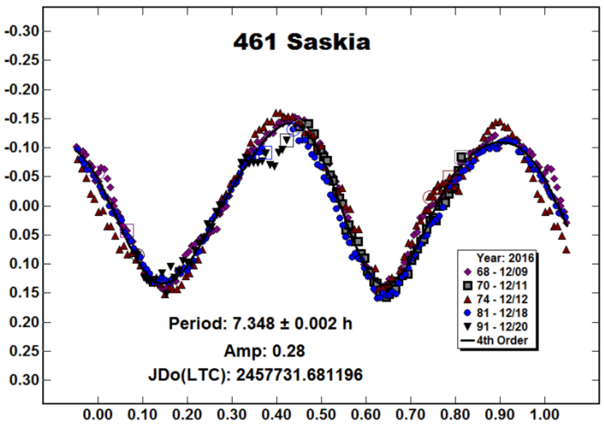
428 Monachia is a main-belt asteroid discovered by W. Villiger at Munich on 1897 Nov 18. It is also known as 1897 DK. We observed it on five nights between 2016 Oct 18-22. We obtained a synodic period of 3.622 ± 0.001 h and amplitude of 0.20 mag.



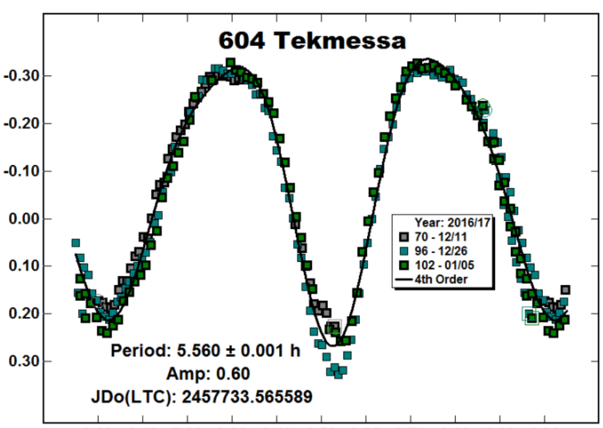
Number	Name	20yy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
428	Monachia	16/10/18-16/10/22	515	7.0,9.5	15	0	3.633	0.001	0.20	0.05	FLOR
461	Saskia	16/12/09-16/12/20	475	5.3,0.9	89	-2	7.348	0.002	0.28	0.03	MB-O
604	Tekmessa	16/12/11-17/01/05	244	9.5, 17.6	60	5	5.560	0.001	0.60	0.01	MB-O
1777	Gehrels	16/12/18-17/01/08	260	3.0,11.7	81	4	2.836	0.001	0.22	0.05	MB-M
1848	Delvaux	16/10/04-16/10/20	129	3.9,10.0	2	1	3.639	0.001	0.64	0.10	KOR

Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The solar phase angle values are for the start and end of the single night of observations. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

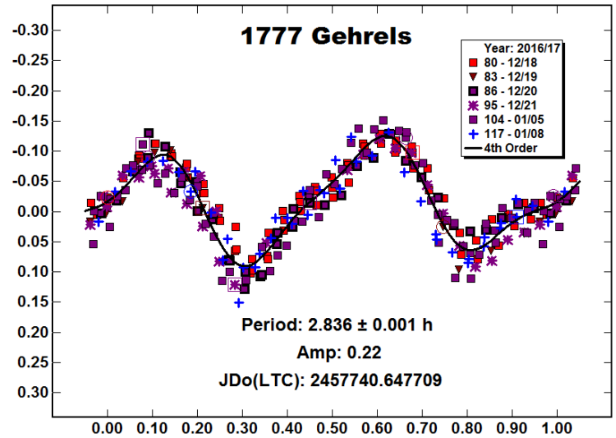
461 Saskia is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1900 Oct 22. It is also known as 1900 FP. We observed it on five nights between 2016 Dec 9-20. We obtained a synodic period of 7.348 ± 0.002 h and amplitude of 0.28 mag.



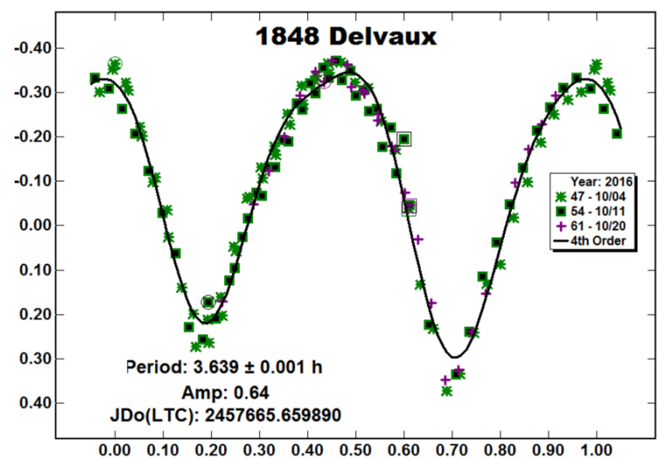
604 Tekmessa is a main-belt asteroid discovered by J.H. Metcalf at Taunton on 1906 Feb 16. It is also known as 1906 TK. We observed it on three nights between 2016 Dec 11 and 2017 Jan 5. We obtained a synodic period of 5.560 ± 0.001 h and amplitude of 0.60 mag.



1777 Gehrels is a main-belt asteroid discovered by PLS at Palomar on 1960 Sep 24. It is also known as 4007 P-L. We observed it on six nights between 2016 Dec 18 and 2017 Jan 8. We obtained a synodic period of 2.836 ± 0.001 h and amplitude of 0.22 mag.



1848 Delvaux is a main-belt asteroid discovered by E. Delporte at Uccle on 1933 Aug 18. We observed it on three nights between 2016 Oct 4-20. We obtained a synodic period of 2.639 ± 0.001 h and amplitude of 0.64 mag.



Acknowledgements

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Number	Name	References	Date	L_{pab}	B_{pab}	Phase	Period	Amp
428	Monachia	This paper	2016 Oct 20	15	0	8.3	3.633	0.20
		Wisniewski 1997	1998 Sep 15	22	-1	19.6	3.63384	0.26
		Behrend 2007	2007 Jan 21	124	8	5.2	3.6335	0.29
		Kryszczynska 2012	2009 Oct 31	19	1	12.7	3.6342	0.29
		Warner 2014	2014 Mar 18	127	-1	22	3.633	0.34
		Behrend 2016	2016 Oct 04	14	-1	2	3.6335	0.18
461	Saskia	This paper	2016 Dec 14	89	-2	1.6	7.348	0.28
		Buchheim 2006	2006 Jan 08	96	-2	5.3	7.34	0.25
		Behrend 2007	2007 Apr 20	197	1	4.8	7.348	0.36
		Klinglesmith 2013	2013 May 12	230	2	0.7	7.349	0.26
604	Tekmessa	This paper	2016 Dec 24	60	5	14.2	5.560	0.60
		Behrend 2006	2006 Jan 15	80	5	14.6	5.55959	0.52
		Baker 2011	2010 Sep 17	3	1	4.2	5.5596	0.49
		Klinglesmith 2013	2013 May 17	190	0	12.4	5.560	0.49
1777	Gehrels	This paper	2016 Dec 28	81	4	7.2	2.836	0.22
		Wisniewski 1997	1990 Nov05	29	3	6.5	2.840	0.27
		Stephens 2005	2005 Mar 12	169	-1	1.3	2.8358	0.26
		Behrend 2005	2005 Mar 12	169	-1	1.3	2.837	0.24
		Behrend 2007	2007 Nov 24	27	3	14.8	2.83552	0.26
		Behrend 2010	2010 Jul 09	252	-4	14.8	2.83	0.21
		Pravec 2005	2005 Mar 12	169	-1	1.3	2.8356	0.23
		Pravec 1990	1990 Nov 05	29	3	6.5	2.8356	0.21
1848	Delvaux	This paper	2016 Oct 12	2	1	7.1	3.639	0.64
		Behrend 2004	2004 Feb 15	140	0	2.2	3.638	0.62
		Slivan 2008	2003 Mar 19	140	0	13.8	3.639	0.68
		Behrend 2011	2011 Oct 15	350	1	12.5	3.65	0.69
		Arredondo 2014	2014 Mar 04	163	0	0.1	3.639	0.57

Table II. Previous results for the SSMO asteroids observed for this paper. The date is the approximate mid-date of the observing run as reported in the respective papers.

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LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2016 SEPTMEBER-DECEMBER

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Lightcurves for 19 Hilda asteroids were obtained at the Center for Solar System Studies (CS3) from 2016 August through December.

CCD photometric observations of 19 Hilda asteroids were made at the Center for Solar System Studies (CS3) from 2016 September through December. This is another in a planned series of papers on this group of asteroids, which is located between the outer main-belt and Jupiter Trojans in a 3:2 orbital resonance with Jupiter. The goal is to determine the spin rate statistics of the group and find pole and shape models when possible. We also look to examine the degree of influence that the YORP effect (Rubincam, 2000) has on distant objects and to compare the spin rate distribution against the Jupiter Trojans, which can provide evidence that the Hildas are more "comet-like" than main-belt asteroids.

Table I lists the telescopes and CCD cameras that are combined to make observations. Up to nine telescopes can be used for the campaign, although seven is more common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel. All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposures varied depending on the asteroid's brightness and sky motion.

Telescopes	Cameras
0.30-m *f*/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m *f*/9.1 Schmidt-Cass	FLI Proline 1001E
0.35-m *f*/11 Schmidt-Cass	SBIG STL-1001E
0.40-m *f*/10 Schmidt-Cass	
0.50-m *f*/8.1 Ritchey-Chrétien	

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* or APASS (Henden *et al.*, 2009) catalogs. The MPOSC3 catalog was used as a last resort. The last catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI (Warner, 2007). The nightly zero points for the catalogs are generally consistent to about ±0.05 mag or better, but on occasion reach 0.1 mag and more. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done with *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the given phase angle, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The X-axis is the rotational phase ranging from –0.05 to 1.05.

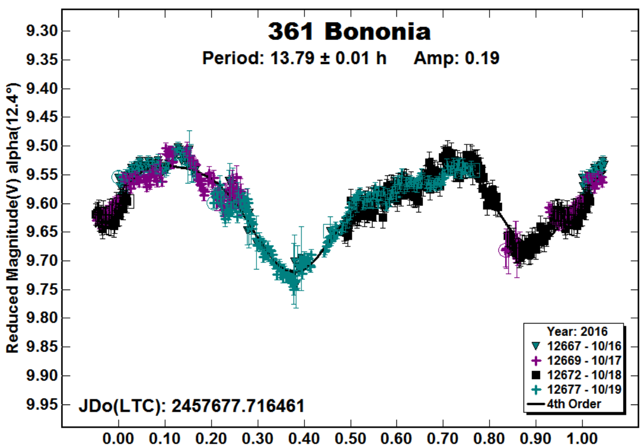
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Obs
361	Bononia	10/16-10/19	677	12.5,11.8	60	9	13.79	0.01	0.19	0.01	BDW
958	Asplinda	12/17-12/20	216	6.6,7.5	68	7	17.55	0.03	0.18	0.01	BDW
1439	Vogtia	10/07-10/12	287	3.7,4.9	0	-3	12.898	0.006	0.33	0.02	BDW
1529	Oterma	08/31-09/11	271	18.3,17.7	53	-8	8.956	0.002	0.12	0.01	DRC
2246	Bowell	10/20-10/22	227	3.2,3.6	16	-5	4.993	0.003	0.20	0.02	BDW
2483	Guinevere	10/07-10/11	356	1.7,2.4	14	5	14.730	0.002	0.89	0.02	BDW
3415	Danby	12/03-12/10	245	12.3,10.7	115	-1	2.837	0.001	0.11	0.01	BDW
3923	Radzievskij	09/02-09/24	304	18.4,16.7	56	-4	39.93	0.02	0.95	0.03	DRC
5368	Vitagliano	09/29-10/09	551	3.7,1.5	19	-4	59.36	0.05	0.29	0.03	RDS
5653	Camarillo	12/08-12/10	229	15.6,16.8	69	13	4.835	0.001	0.43	0.02	BDW
15505	1999 RF56	10/20-11/02	481	1.2,4.1	24	4	15.11	0.02	0.10	0.02	RDS
16927	1998 FX68	07/05-07/30	781	15.5,11.6	33	+11	33.856	0.003	0.73	0.04	DRC
19034	Santorini	12/02-12/25	576	1.1,9.3	68	1	247	2	0.43	0.05	BDW
26761	Stromboli	10/04-10/11	364	0.9,0.6,1.6	13	2	15.96	0.03	0.12	0.02	RDS
31817	1999 RK134	10/14-10/20	285	4.8,3.2	36	6	9.856	0.005	0.21	0.02	BDW
56982	2000 SE189	11/06-11/11	286	4.1,3.7	49	10	43.2	0.1	0.47	0.03	BDW
62408	2000 SU176	11/23-11/25	174	3.6,4.0	57	9	3.197	0.002	0.17	0.02	BDW
87811	2000 SO145	11/04-11/11	327	2.7,5.0	36	-4	55.2	0.2	0.45	0.05	BDW
193449	2000 WW146	11/03-11/10	478	8.2,6.4	54	-13	38.44	0.06	0.20	0.03	RDS

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984), unless two values are given (first/last date in range). The Obs column gives the observer.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html* allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcodes, is also available for download. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

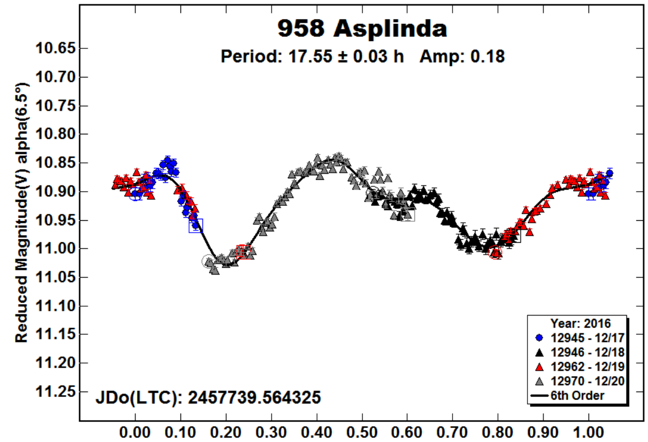
361 Bononia. The first reported period for the 140 km Bononia came from Binzel and Sauter (1992), who found 13.83 h. Hanus *et al.* (2015), using a combination of dense-in-time and sparse-in-time data, found a sidereal period of 13.80634 h and two possible pole positions with ecliptic longitude-latitudes of (294°, +13°) and (115°, +45°). Our period of 13.79 h is in good agreement with the earlier results.



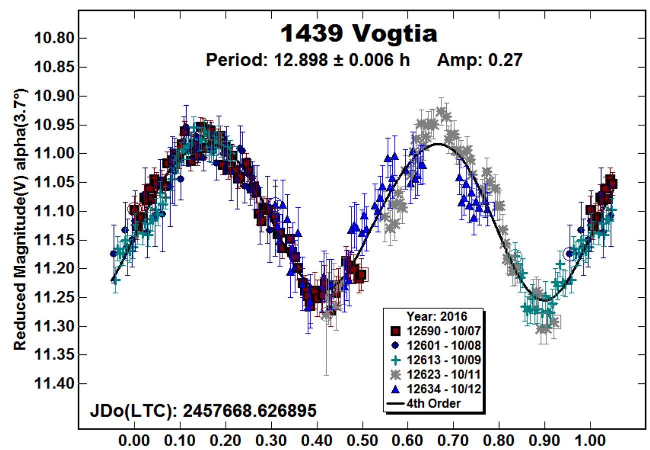
958 Asplinda. Dahlgren *et al.* (1998) found a period of 25.3 h based on two consecutive nights in 1994 February. However, their phased lightcurve, which was based on an assumed bimodal shape that covered about 0.6 rotation phase, went from a minimum to a maximum in only 0.15 rotation phase.

Given the amplitude of about 0.6 mag, it is a reasonable assumption that the lightcurve would be fairly symmetrical and so not have significantly different halves and, therefore, the time from one extreme to the next would be about 0.25x the period. A shorter period would come closer to meeting the requirement.

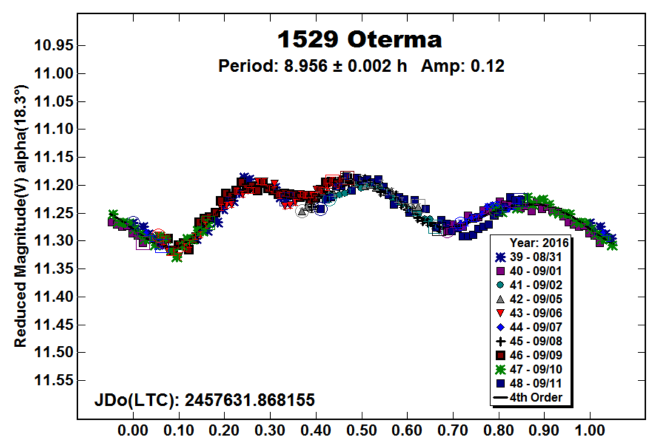
The CS3 data obtained in 2016 led to a period of 17.55 h, which we consider secure. From this, we surmise that Dahlgren *et al.* may have presumed that the two nights represented the same half of the bimodal lightcurve instead of each night being part of an opposing half.



1439 Vogtia. Dahlgren *et al.* (1998) found a period of 12.95 h using two data sets, one from 1993 December and the other from 1994 December. The latter provided coverage of most of the presumed period and so their result seems reasonably secure. The analysis of our 2016 observations supports the 12.9 h period.



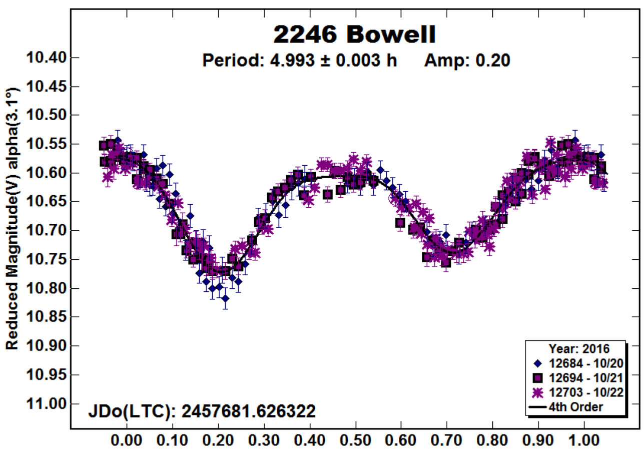
1529 Oterma.



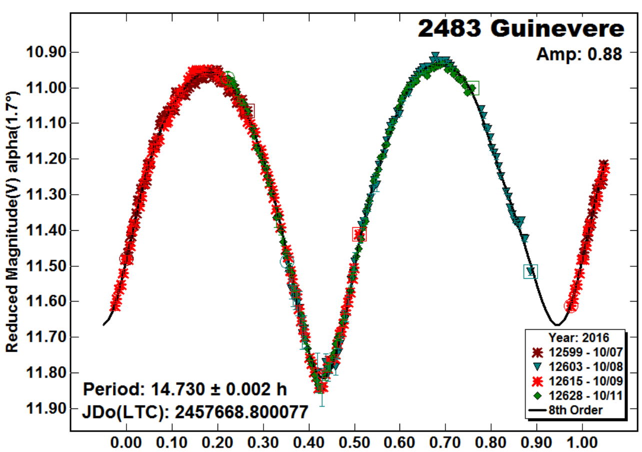
Dahlgren *et al.* (1998) found a period of 15.75 h based on four nights in 1994 January-February. If the session from Jan 24.9 is removed, the resulting lightcurve is nearly symmetrical, raising the possibility that their period is the result of a *rotational alias*, *i.e.*, where the actual number of rotations over the span of the observations is not certain.

The 2016 CS3 data led to a lightcurve that was not symmetrical, which helped avoid finding a period based on an inaccurate count of rotations. Our data set was also much more extensive, covering 10 days with 7 of those being consecutive. We consider the resulting period of 8.956 h to be secure and adopt it as the more likely rotation period for the 54 km asteroid.

2246 Bowell. Our result of 4.993 h is in good agreement with the period of 4.992 h found by Dahlgren *et al.* (1998). The asteroid was not only discovered by but is named for Edward ("Ted") Bowell, who was on the staff at Lowell Observatory for many years. He is an expert in several areas of asteroid research, celestial mechanics and astrometry being among them. He is a strong supporter of amateur astronomers wanting to do high-level research. We take this opportunity to say "Thanks, Ted" for all your support and contributions.

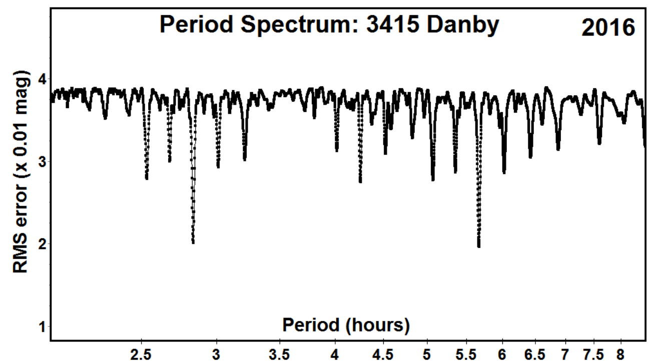


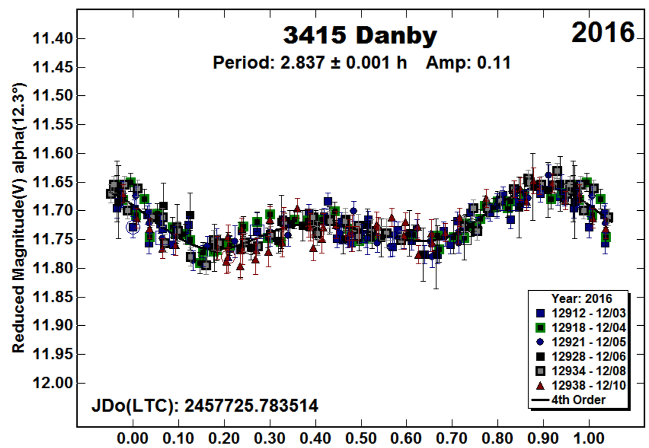
2483 Guinevere. Dahlgren *et al.* (1998) found a period of 14.733 h for Guinevere. Durech *et al.* (2016) reported a similar sidereal period along with a pole with ecliptic longitude-latitude coordinates of either (19°, +70°) or (194°, +59°). Our period of 14.730 h is in good agreement with the earlier results.

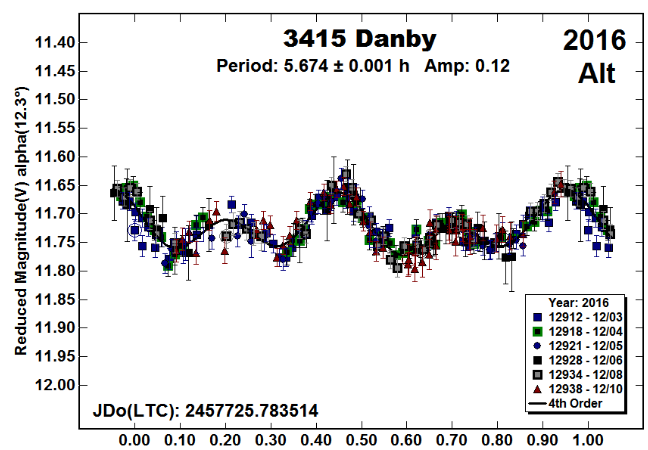


3415 Danby. The namesake for asteroid 3415 is John Michael Anthony Danby (1929-2009) who published a classic textbook on Celestial Mechanics (Danby 1962) that is still in print. Danby also helped found the journal *Celestial Mechanics* and the Division for Dynamical Astronomy of the American Astronomical Society. For the estimated 32 km asteroid 3415 Danby, Dahlgren *et al.* (1998) found a period of 2.851 h. However, subsequent results were all near the double period (5.6 h) and were quadramodal (four minimum-maximum pairs per rotation), *e.g.*, Warner and Higgins (2008; 5.666 h) and Behrend (2007web, 2015web; 5.6706 h). In all cases, the amplitude of the lightcurve was < 0.20 mag. This is about the upper limit of where harmonics from higher orders can have nearly the same amplitude as the usually dominant second order (Harris *et al.* 2014) and so calls into question whether or not the true solution is a bimodal or quadramodal lightcurve.

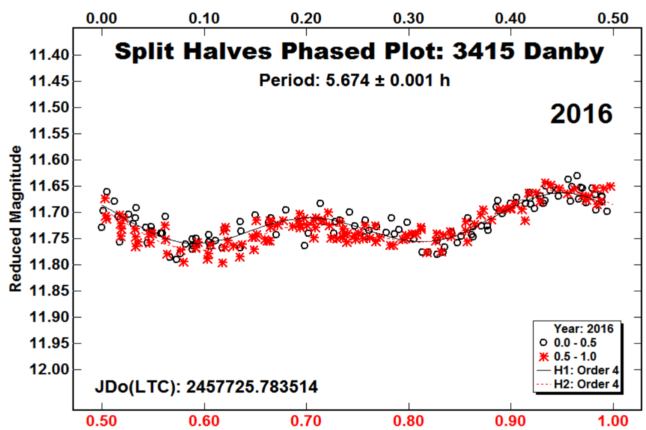
The period spectrum based on the 2016 CS3 shows two dominant solutions of nearly equal strength. The one with the shorter period is represented by a bimodal lightcurve while the other requires a quadramodal lightcurve. Both lightcurves are shown below.



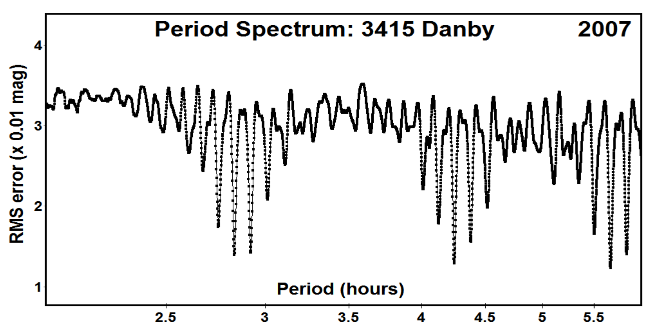


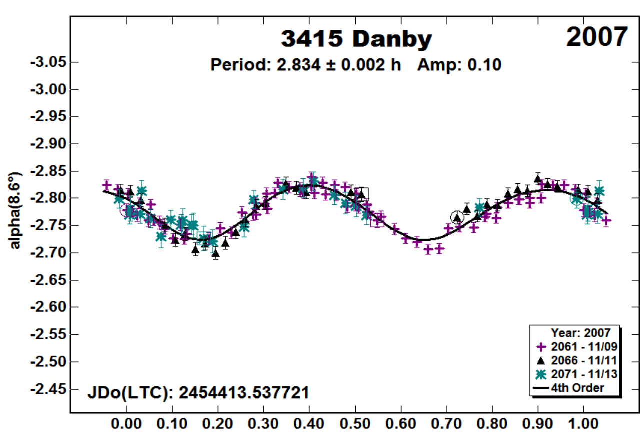


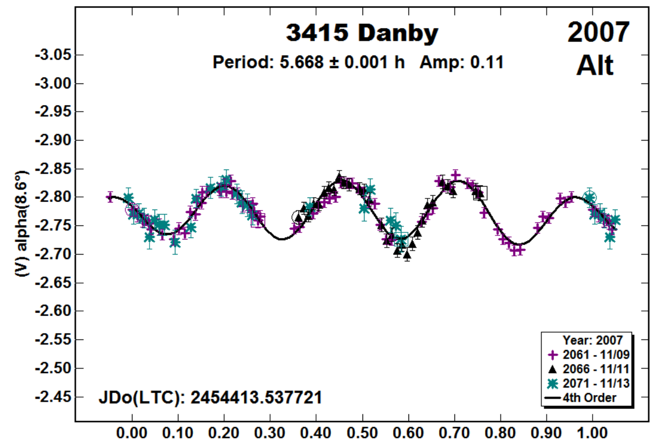
Since either solution fits the data equally well, the assumption of a bimodal lightcurve is not unequivocal. So, it would seem difficult, if not impossible, to adopt one period over the other. However, there is a technique that can be used to help resolve the ambiguity. The process is to produce a so-called *split-halves* plot where the longer period is assumed but the two halves are superimposed over one another to judge the degree of symmetry in the lightcurve. Harris *et al.* (2014) used this technique with success to determine that an extraordinary asteroid with an unusually fast period was just an ordinary one once it was shown that the double-period was the correct solution. We used this technique on the 2016 data and found that the two halves were too symmetrical and so adopted the shorter period of 2.837 h, similar to what Dahlgren *et al.* found.



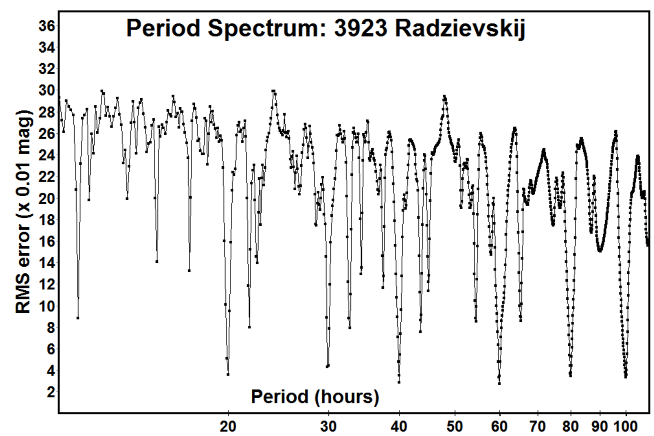
These results prompted another look at the data obtained by Warner and Higgins (2008). The period spectrum again showed a number of nearly equal solutions, each being about double the previous one. We forced the 2007 data to find periods of about 2.8 and 5.6 hours. It seems clear to us that the shorter period is the better choice since the quadramodal lightcurve appears to be a *fit by exclusion*, which is where the Fourier analysis finds the lowest RMS by minimizing the number of overlapping data points.

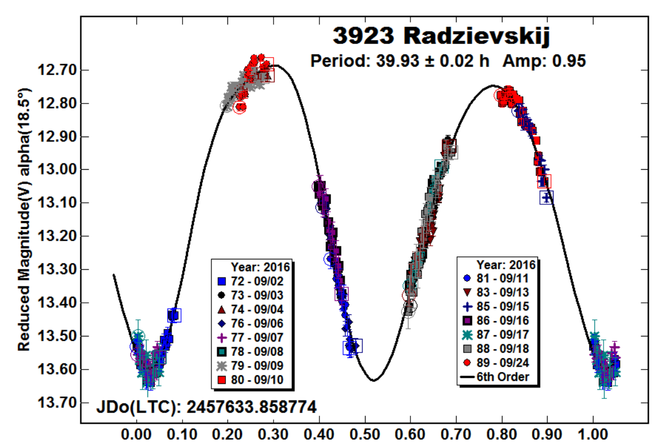






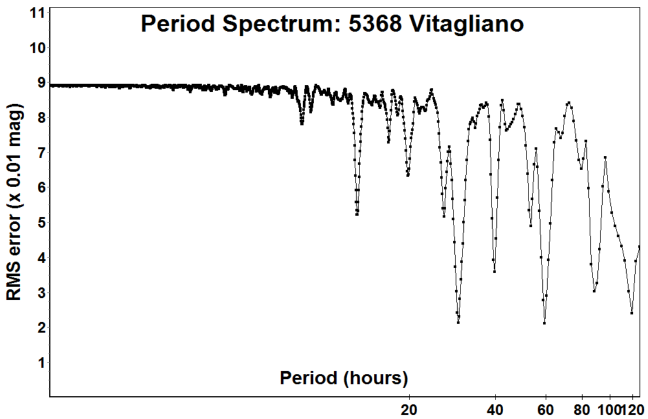
<u>3923 Radzievskij</u>. Dahlgren *et al.* (1998) found a period of 39 h based on two consecutive nights in 1994 February. They based their "probable" solution assuming the two nights were opposing halves for a bimodal lightcurve. Our data set leads to the same result using the same presumption of a bimodal lightcurve, though we consider it more secure given the several overlapping sessions.

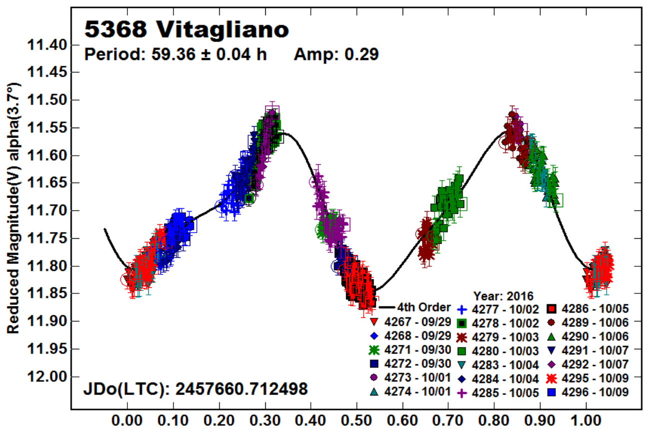




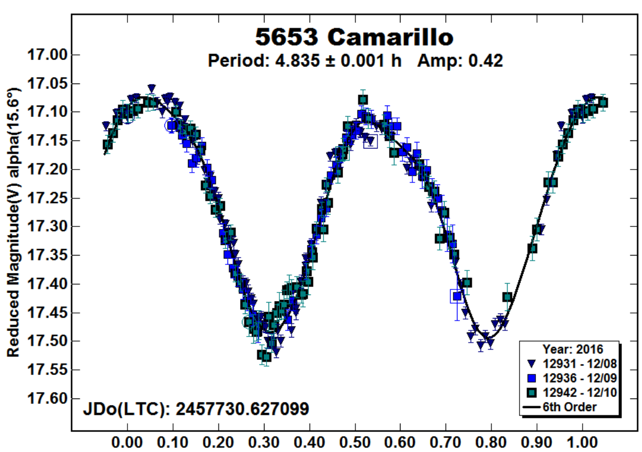
<u>5368 Vitagliano</u>. Dahlgren *et al.* (1998) found a bimodal lightcurve with period of 31 h based on four consecutive nights in 1995 February. That lightcurve seems sufficiently asymmetrical to accept the result. However, there is almost no overlap of data, which leads to the speculation that the result might be another case of a *fit by exclusion* or a *rotational alias*.

The period spectrum based on the 2016 CS3 data shows valid solutions for 30 and 60 h. We have chosen the latter because the much more extensive data set results in a bimodal lightcurve and there are a number of overlapping sessions that remove most of the *rotational alias* concerns.

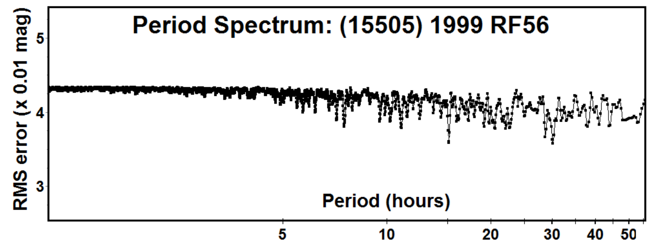


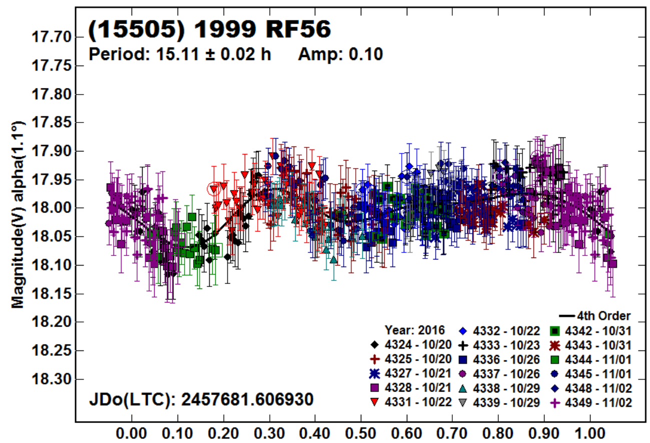


5653 Camarillo. Previously reported periods were all near 4.83 h, *e.g.*, Mottola *et al*. 1995, Pravec *et al.* (1999 web), and Wazczak *et al*. (2015). Our period of 4.835 h concurs with those earlier results.



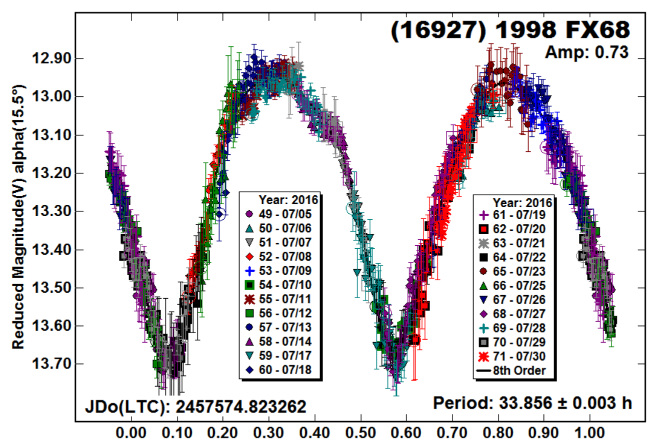
(15505) 1999 RF56. We found no entry in the asteroid lightcurve database (LCDB; Warner *et al.* 2009) for this 28 km Hilda. Analysis of observations on 9 nights spanning about 14 days resulted in an asymmetric, low-amplitude lightcurve with a period of 15.11 h. The fits to periods half and double our adopted result were not convincing.





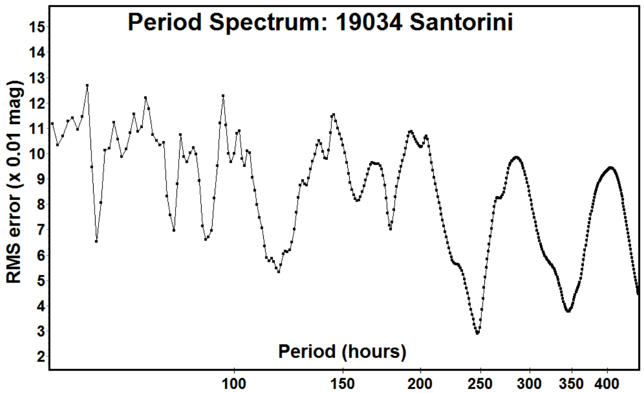
(16927) 1998 FX68. The LCDB (Warner *et al.* 2009) did not have any reported periods, though it does include an entry from Sonnett *et al*. (2015), who reported a lightcurve amplitude of 0.92 mag based on infrared observations.

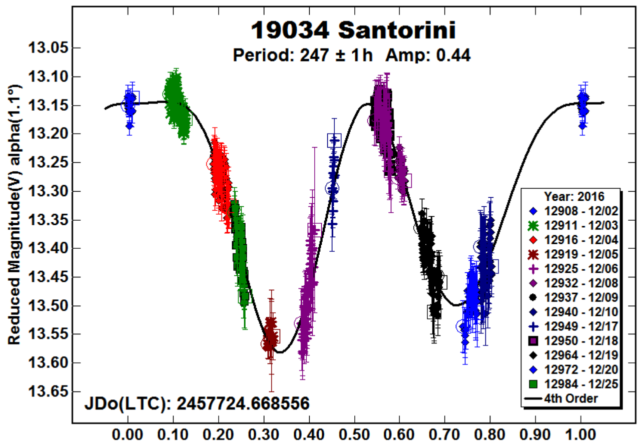
The large amplitude and relatively low phase angle at which our observations were made virtually assure a bimodal lightcurve (Harris *et al.*, 2014). This leads to what we consider a secure period of 33.856 h.



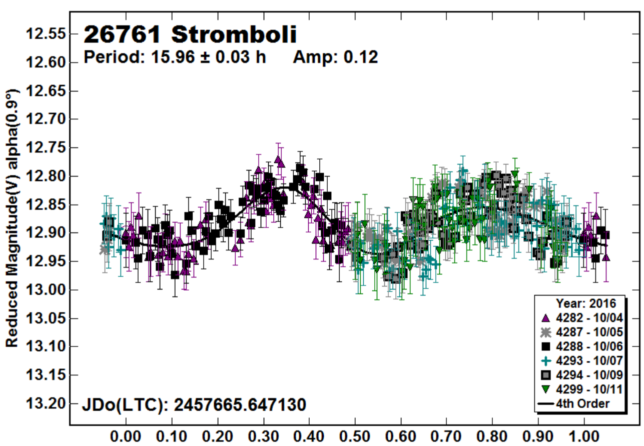
19034 Santorini. These appear to be the first reported results for Santorini, which has an estimated diameter of 15 km. Assuming the period of 247 h is correct, the asteroid is a good candidate for *tumbling* (non-principal axis rotation: NPAR; see Pravec *et al.* 2014 and references therein).

There are no outward signs of tumbling, such as the slope of the data from a given session not matching the slope of the model lightcurve. However, the data set is somewhat limited and there is almost no coverage of a second cycle to confirm if the lightcurve repeats itself. Any tumbling is probably at a low-level and so hidden within the noise and uncertainties of the night-to-night zero point calibrations.

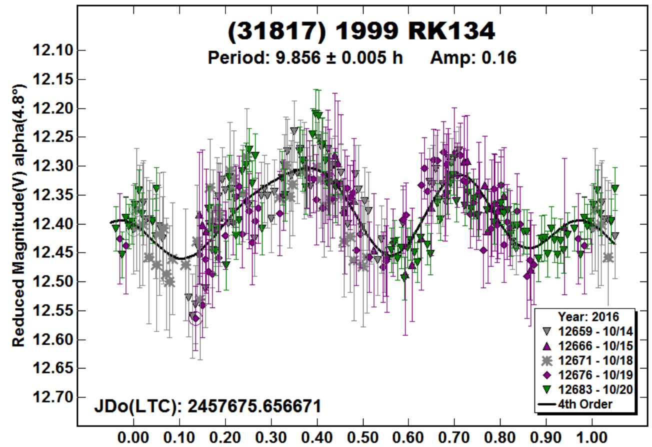




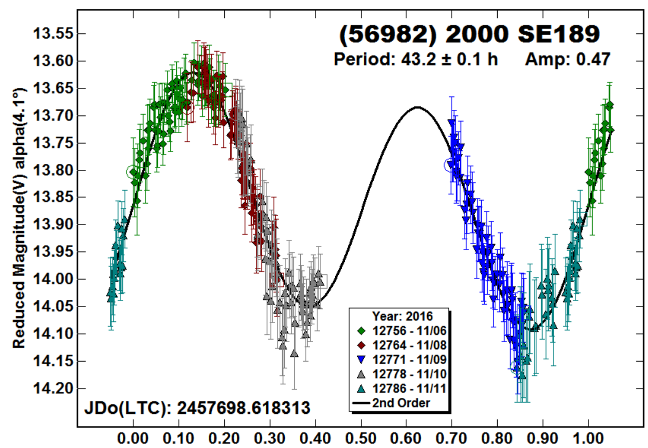
26761 Stromboli. There is no previously reported rotational period for this Hilda in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). Observations on five nights spanning a week show a classic bimodal lightcurve with at 15.96 h rotational period.



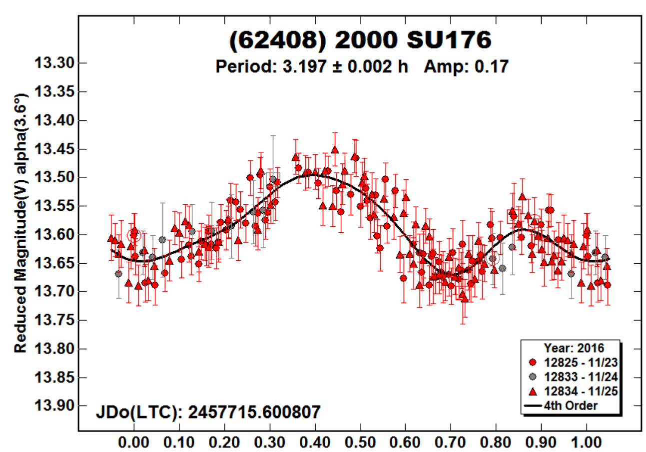
(31817) 1999 RK134. Waszczak *et al.* (2015) used limited dense-in-time data from the Palomar Transient Factory to find a period of 9.429 h for this 23 km Hilda. Our data were somewhat noisy, but they still led to a reasonably secure result of 9.856 h. Given our denser data set, we have adopted our period as being the more likely solution.



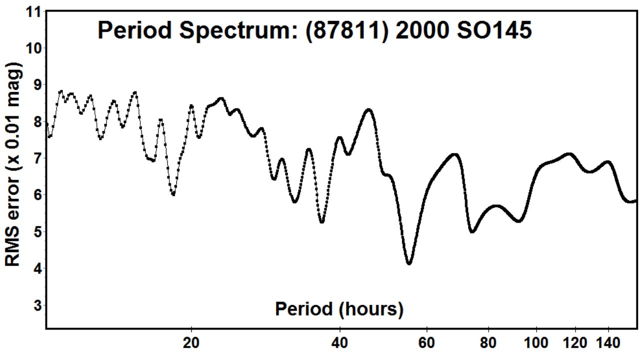
(56982) 2000 SE189. Despite the lack of complete coverage of the bimodal lightcurve at 43.2 h, we believe this to be a fairly secure result since both minimums and one maximum were covered and there is duplicate coverage for rotation phases 0.0-0.3. This is another case where a bimodal solution is virtually assured due the amplitude and phase angle (Harris *et al.*, 2014). There were no previous entries in the LCDB (Warner *et al.*, 2009).

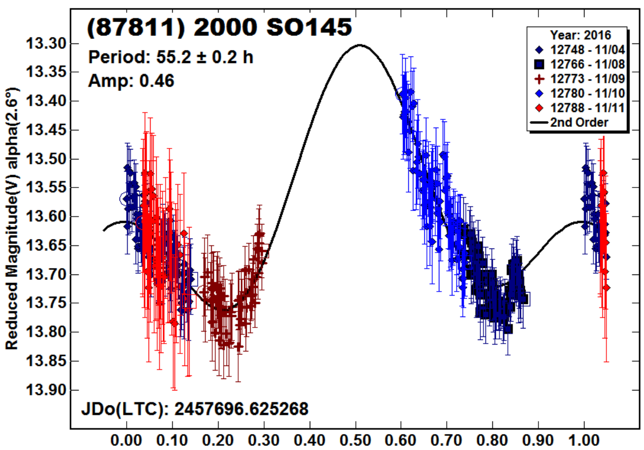


(62408) 2000 SU176. The apparently first-time result of 3.197 h is considered secure due to data from each of three consecutive nights covering more than one cycle of the adopted period.

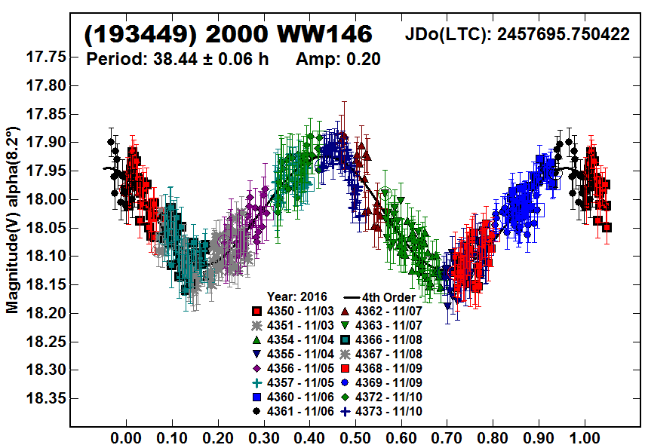


(87811) 2000 SO145. Despite the strong preference in the period spectrum for a period near 55 h, the large gaps in the lightcurve and uncertainty about the maximums do not lead to a secure solution. However, it is sufficiently likely to be used in rotation rate studies.





(193449) 2000 WW146. This Hilda was not in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) and no results could be found in a search of the literature or web sites. We consider the period of 38.44 h to be secure.



Acknowledgements

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ROTATION PERIOD DETERMINATION FOR 3077 HENDERSON AND 12044 FABBRI

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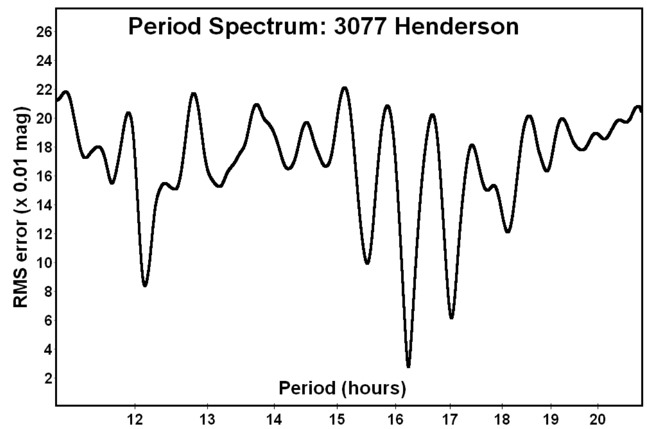
Photometric observations of two main-belt asteroids were made from the Astronomical Observatory of the University of Siena (Italy) in order to determine their rotation periods. For 3077 Henderson, the synodic rotation period was found to be 16.235 ± 0.003 h with a lightcurve amplitude of 0.67 mag. For 12044 Fabbri, the synodic rotation is 4.422 ± 0.001 h with a lightcurve amplitude of 0.14 mag.

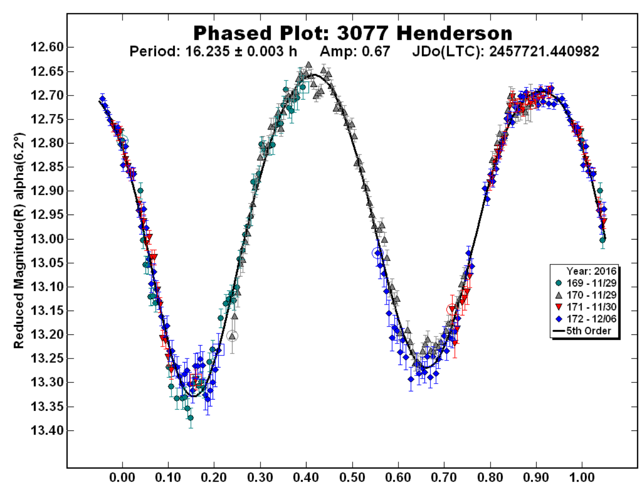
CCD photometric observations of two main-belt asteroids were carried out in 2016 November-December at the Astronomical Observatory of the University of Siena (K54) using a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E CCD camera, and clear filter; the pixel scale was 2.30 arcsec with 2x2 binning. All exposures were 300 seconds. Data processing and analysis were done with *MPO Canopus* (Warner, 2016). All images were calibrated with dark and flat-field frames and converted to R magnitudes using solar-colored field stars from the CMC15 catalogue distributed with *MPO Canopus*. Table I shows the observing circumstances and results.

A search of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) indicates that our results appear to be the first reported lightcurve results for these objects.

3077 Henderson (1982 SK) was discovered on 1982 September 22 by E. Bowell at the Anderson Mesa station, Lowell Observatory, at Flagstaff, AZ. The asteroid orbits with a semi-major axis of about 2.241 AU, eccentricity 0.055, inclination 1.47 degrees, and an orbital period of 3.35 years. Its absolute magnitude is H = 12.7 (JPL, 2016; MPC, 2016). The same value was used by the WISE infrared survey to find a diameter of 5.175 ± 0.080 km and albedo of 0.549 ± 0.071 (Masiero *et al.*, 2011).

Our observations of this asteroid were conducted on four nights from 2016 Nov 29 through Dec 7. A total of 308 data points were used in the subsequent analysis. As shown in the period spectrum, the analysis shows a clear solution with a bimodal lightcurve with a period P = 16.235 ± 0.003 h and amplitude A = 0.67 ± 0.03 mag.





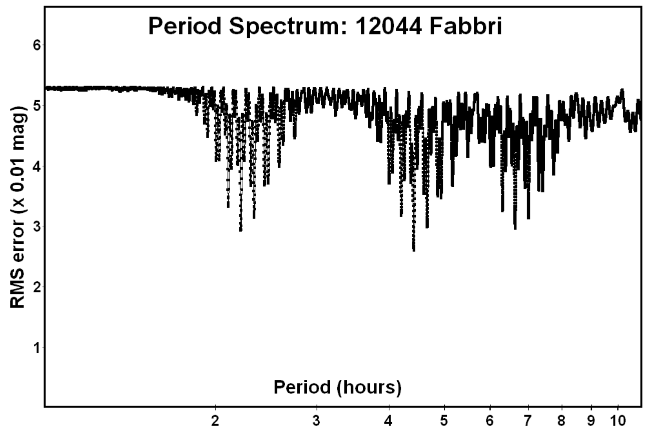
12044 Fabbri (1997 FU) was discovered on 1997 March 29 by M. Tombelli and G. Forti at Montelupo. The asteroid orbits with a semi-major axis of about 2.592 AU, eccentricity 0.139, inclination 13.99 degrees, and period of 4.17 years. The absolute magnitude is H = 12.7 (JPL, 2016; MPC, 2016). The WISE infrared survey used H = 12.5 to find a diameter of 7.344 ± 0.160 km and optical albedo of 0.327 ± 0.032 (Masiero *et al.*, 2011).

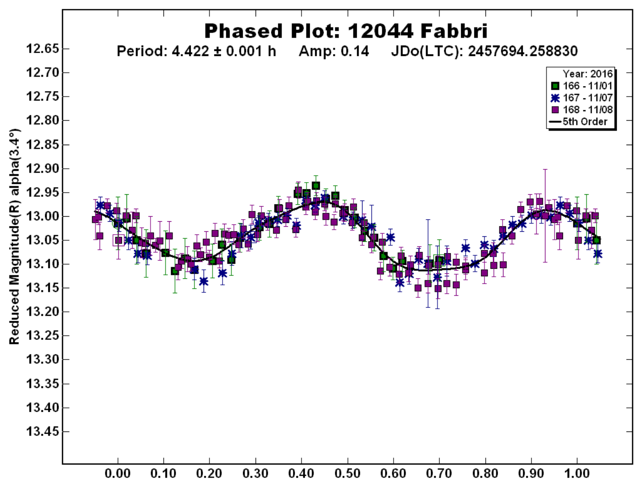
Our observations of this asteroid were conducted on three nights from 2016 Nov 1-9, collecting a total of 159 data points. The

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
3077	Henderson	11/28-12/07	308	6.7,1.6	77	1	16.235	0.003	0.67	0.03
12044	Fabbri	11/01-11/09	159	3.9,0.5,0.8	45	-1	4.422	0.001	0.14	0.02

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given at the start and end of each date range, unless it reached a minimum, which is the second of three values. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

period analysis favors a solution with a bimodal lightcurve with a period $P = 4.422 \pm 0.001$ h and amplitude $A = 0.14 \pm 0.02$ mag.





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The authors thank Maura Tombelli, one of the discoverers of 12044 Fabbri, for her life-long efforts in the observation of small solar system bodies and in the popularization of astronomy, and – moreover – for her exquisite friendship. The observing sessions of 3077 Henderson were attended by students of the course in Physics and Advanced Technologies at the Department of Physical Sciences, Earth and Environment (DSFTA, 2016) as part of their internship astronomical activities: Edoardo Chianese, Cristina Cicali, Marco Lorenzetti, Edoardo Maggioni, Teodora Palmas, Anna Poggialini, Stefano Scali, Bartolomeo Trefoloni. Some observing sessions of 3077 Henderson were also attended by a group of high school students from Liceo "Alessandro Volta" (Colle Val d'Elsa) and from Liceo "Tito Sarrocchi" (Siena) involved in an interesting vocational guidance project about astronomy: Caterina Aiazzi, Vittorio Barlucchi, Samuele Beconcini, Federico Benincasa, Samuele Boschini, Clelia Carboncini, Rebecca Di Fazio, Gianluca Gerace, Bianca Gozzi, Elisa Guerrera, Laura Hataj, Laila Mourabi, Adele Nannetti, Marie Sophie Pansegrau, Vittorio Parenti, Arianna Porretti, Mariù Soldani, Giulia Tanzini, Caterina Vignolo. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

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EDITOR'S NOTE: The authors are to be particularly congratulated for their involvement of more than two dozen students during the course of these observations !

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 ≥ 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 mag/arcsec^2 on average). The image scale is 1.44 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 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.

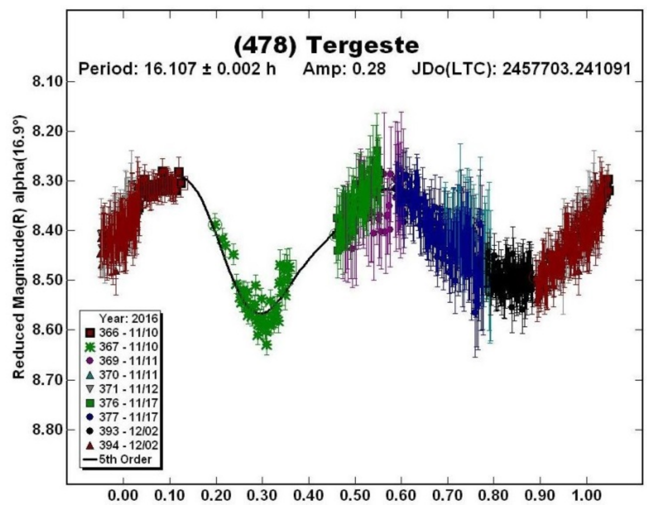
All images were obtained in 1x1 binning mode and were taken without any photometric filter. The SNR for the target assured a lightcurve of sufficient quality and low data dispersion. Dark and bias frames and twilight sky flat-fields were applied to each science image.

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 ± 0.05 mag or better, but on occasion reach 0.1 mag and more.

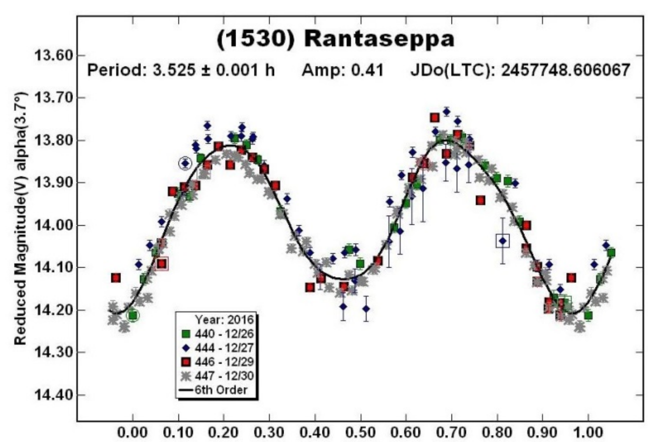
The StarBGone star subtraction algorithm in *MPO Canopus* was used when needed in order to remove the effect of stars located in the asteroid's path. This is most effective when the star's SNR is equal to or lower than asteroid's SNR. (Aznar, 2013).

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 ± 0.002 h.



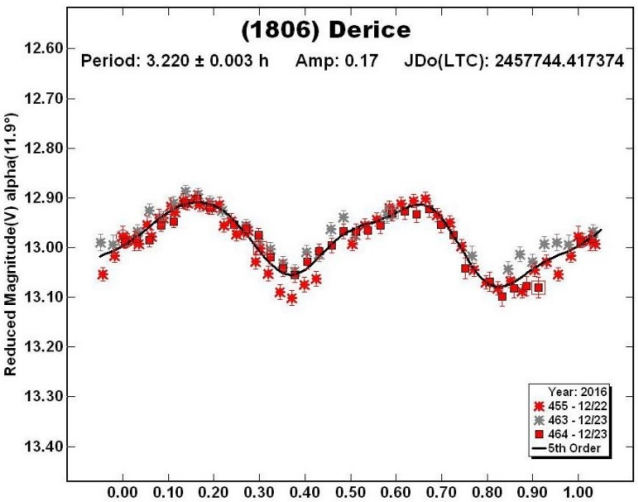
1530 Rantaseppa. Pravec *et al.* (2016) found a period of 3.5258 h for this asteroid. The result here of 3.525 ± 0.001 h, based on 182 data points over four sessions, is in good agreement. The maximum amplitude of 0.41 mag indicates an elongated body with *a/b* = 1.43, assuming the view was equatorial.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



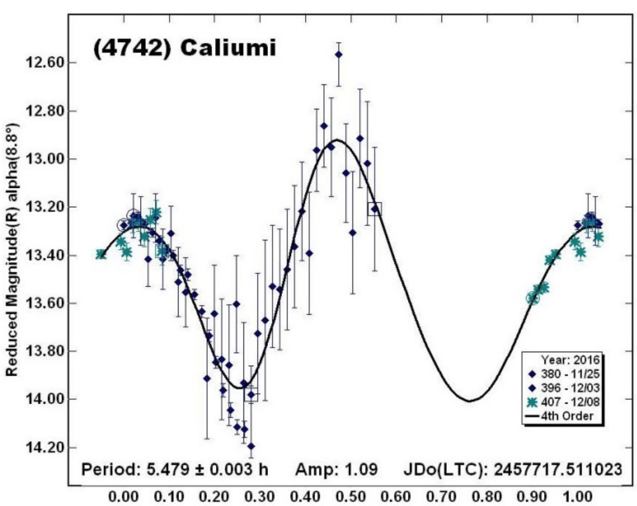
Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	a/b	b/c
478	Tergeste	16/11/10-12/20	606	16.8,18.4	352	12	16.107	0.002	0.28	0.02	1.87	0.86
1530	Rantaseppa	16/12/26-12/30	182	3.8,1.4	101	1	3.525	0.003	0.41	0.03	1.43	0.78
1806	Derice	16/12/22-12/23	108	11.9,11.3	109	-1	3.220	0.003	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.

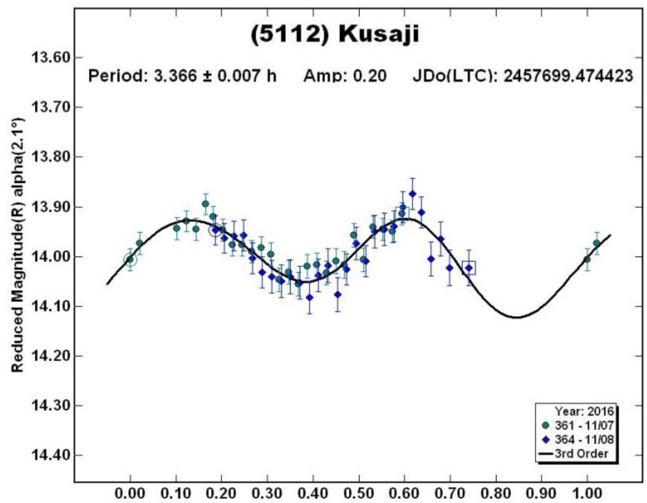
(1806) Derice. All previous analysis indicates a rotation period of about 3.22 h, e.g., Pravec *et al*. (2016) found 3.2236 h, which is very close to the period reported here.



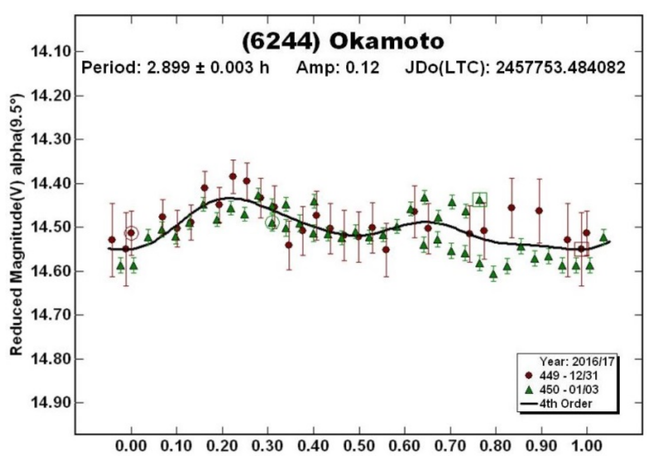
(4742) Caliumi. A period of 5.479 h was derived from data obtained on three nights and matches the one found by Pravec *et al*. (2016). The maximum measured amplitude (α = 8.8°) was 1.09 mag. Using Zappala *et al.* (1990), the amplitude at α = 0° would be about 0.96 mag, or an *a/b* ratio of 1.43.



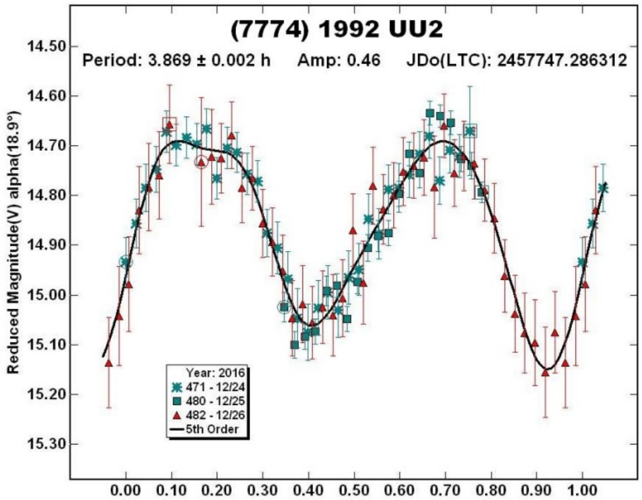
5112 Kusaji. Chiorny *et al.* (2016) found 5112 Kusaji to be a binary asteroid with a primary rotation period of 2.7995 h and satellite orbital period of 20.74 h. Based on a data set of only two sessions, a period of 3.366 hours was found but this is based on an incomplete lightcurve. Poor weather prevented additional observations.



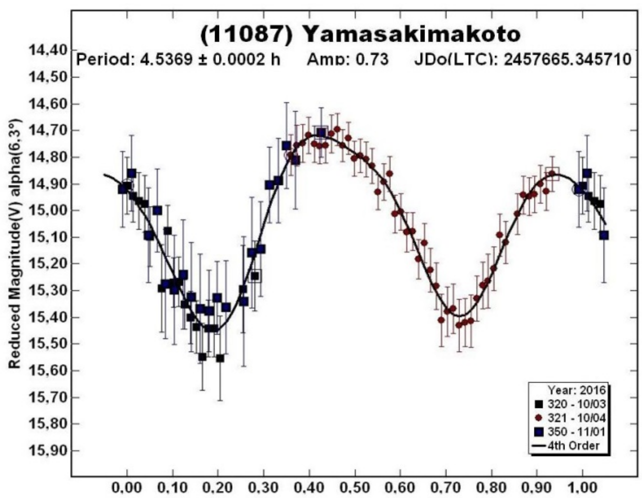
6244 Okamoto. Higgins *et al.* (2006) discovered this be a binary asteroid with a primary rotation period of 2.8958 h and satellite orbital period of 20.32 h. Analysis of data obtained from 2016 Dec 31 to 2017 Jan 3 gives a period of 2.8958 ± 0.003 hours.



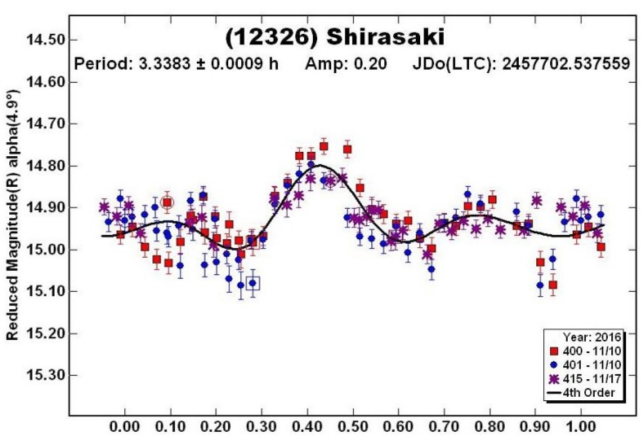
(7774) 1992 UU2. Krotz et al. (2010) found a period of 3.87 h. Our analysis on data from 2016 December indicates a similar result: 3.869 ± 0.002 h. Using Zappala *et al*. (1990), the estimated amplitude at α = 0° is 0.35 mag, which leads to *a/b* = 1.39.



(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* ~ 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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ROTATIONAL PERIOD OF THREE MAIN-BELT ASTEROIDS

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CCD photometric observations of three main-belt asteroids were made to find the synodic period and amplitude of their lightcurves: 1264 Letaba, *P* = 33.27 ± 0.01 h, *A* = 0.15 mag; 2407 Haug, *P* = 6.162 ± 0.002 h, *A* = 0.32 mag; and 5464 Weller, *P* = 3.288 ± 0.002 h, *A* = 0.35 mag.

Three main-belt asteroids were chosen for for CCD photometric observatons from the lists created by Warner (2016a, 2016b). Asteroid 1264 Letaba was flagged with a U = 1 rating (Warner et al., 2009), which means that given period in the LCDB is probably wrong. The other two asteroids, 2407 Haug and 5464 Weller, had no previous periods reported. The observations were made with a Marcon 0.30-m *f*/8 Ritchey-Chretien and SBIG ST-9 CCD camera with a photometric Astrodon Cousins R filter. The exposures varied depending on the asteroid's brightness. Image reduction was performed with *MPO Canopus* (Warner, 2015) and the Comparison Star Selector routine.

1264 Letaba. Even though relatively bright, the asteroid was a difficult target because it was moving through rich star fields and so field stars often made accurate photometry impossible. To get measurements of the best possible quality, each frame was manually inspected and accepted only if field stars did not interfere with the asteroid. The data were than analyzed with *MPO Canopus* and the ANOVA method in *Peranso* (Paunzen and Vanmunster, 2015) period analysis software, which gave periods consistent with one another. The final results show a period of 33.27 ± 0.01 h and amplitude of 0.15 mag. The results are in very good agreement with Stephens (2003), who reported a period of 32.16 ± 0.03 and amplitude 0.20 ± 0.03 mag.

2407 Haug. The phased plot shows a bimodal curve with a period of 6.162 ± 0.002 h and amplitude of 0.32 mag.

5464 Weller. After three nights of observations, the result was a period of 3.288 ± 0.002 h and an amplitude of 0.35 mag.

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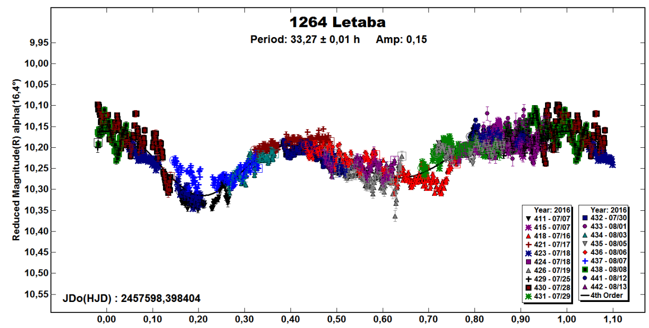

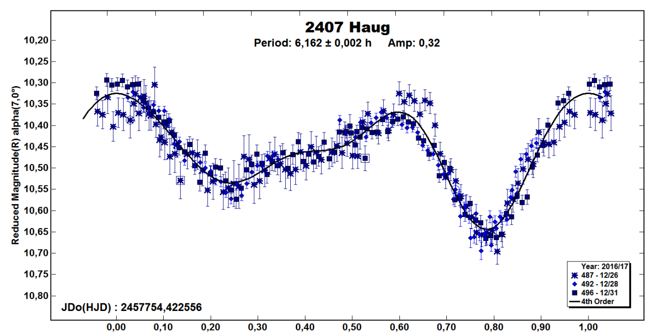

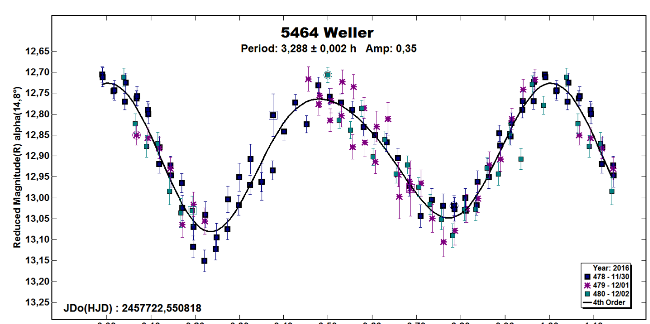

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Exp
1264	Letaba	07/07-08/13	2439	16.37-15.52	306	31	33.27	0.01	0.15	0.05	120
2407	Haug	12/26-12/31	269	6.96-8.86	79	3	6.162	0.002	0.32	0.05	240
5464	Weller	11/30-12/02	126	14.78-14.10	96	15	3.288	0.002	0.35	0.07	300

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Exp is the exposure, in seconds.

LIGHTCURVE OF 1563 NOEL AT LOW PHASE ANGLE

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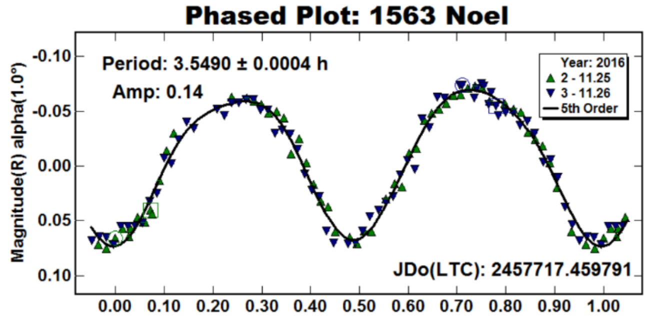
The R-band lightcurve of the Flora family asteroid 1563 Noel is presented. The observations were obtained at the Bulgarian National Astronomical Observatory Rozhen (MPC Code 071) during two nights in 2016 November when the asteroid was at a low phase angle.

Flora family member 1563 Noel was officialy discovered on 1943 March 7 by Belgian astronomer Sylvain Arend at the Royal Observatory of Belgium in Uccle. This asteroid classified as a transitional Sa-subtype on the Bus-DeMeo taxonomic scheme (DeMeo *et al.*, 2009) and belongs to the Flora family, which is one of the largest groups of stony asteroids in the main belt (JPL, 2016). According to the asteroid lightcurve database (LCDB; Warner *et al.*, 2009), the calculated diameter of Noel is 9.0 km and assumed albedo is 0.24. The asteroid was selected from the list of asteroid Shape/Spin Modeling Opportunities published by Warner *et al.* (2016a). The resulting dense lightcurve, combined with other dense lightcurves and sparse data from asteroid surveys, will be helpful for shape modeling.

The observations were made with a 50/70-cm Schmidt telescope equipped with an FLI PL16803 4096x4096 CCD with 9 µm pixels. All images used 1x1 binning, resulting in a scale of approximately 1.1 arc seconds per pixel. All asteroid images were taken through an R filter with exposure times of 170 s. Science images were reduced with dark frames and flat-fields to a precision of better than 1%. Aperture photometry of the asteroid and comparison stars was performed using *CCDPHOT* by Buie (1998). For lightcurve analysis, we used *MPO Canopus* v10.7.7.0 (Warner, 2016b), which produces composite lightcurves, calculates rotational periods, provides the Fourier analysis fitting procedure, and estimates the amplitude of the lightcurve.

The asteroid was observed for about four hours on each of two consecutive nights: 2016 Nov 24 and 25. The first night was one day after opposition, when the asteroid reached a minimum solar phase angle of 0.7°. During our observations, the phase angle increased from 0.9° to 1.5°. The asteroid was V ~ 14.8 at the time.



A fifth-order Fourier fit reveals a symmetric lightcurve with almost equal heights and shapes of the peaks. The period is 3.5490 ± 0.0004 h with an amplitude of 0.14 ± 0.01 mag. This is in the range of periods (3.548-3.550 h) published by Pravec *et al.* (2015) during their Photometric Survey for Asynchronous Binary Asteroid Targets. The lightcurve amplitude in 2016 was the same as reported by Oey (2009) using observations from 2008 April, when the asteroid was at a phase angle of 4°.

Acknowledgements

Apostolovska gratefully acknowledges observing grant support from the Institute of Astronomy and Rozhen National Astronomical Observatory, Bulgarian Academy of Sciences.

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Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1563	Noel	11/24-11/26	120	0.9,1.5	62	1	3.5490	0.0004	0.14	0.01	FLOR

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

LIGHTCURVE ANALYSIS OF (222317) 2000 TE1

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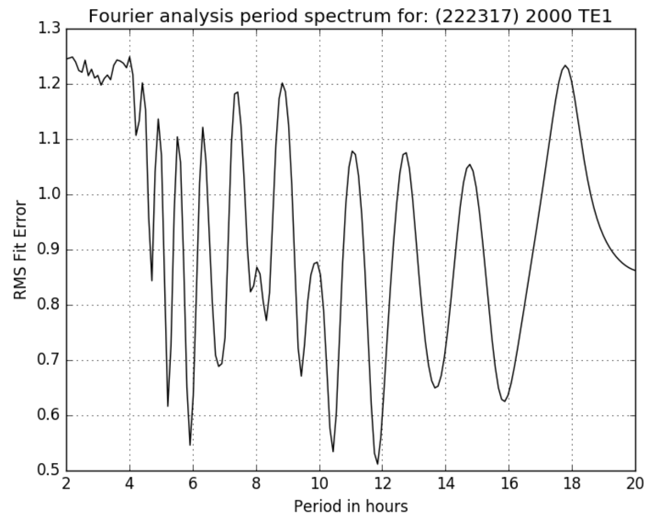
CCD photometric observations of the main-belt asteroid (222317) 2000 TE1 were made on 2014 December 23 and 25. From the lightcurve, we obtained a possible synodic period of 11.83 ± 0.04 h with an amplitude of 0.63 mag.

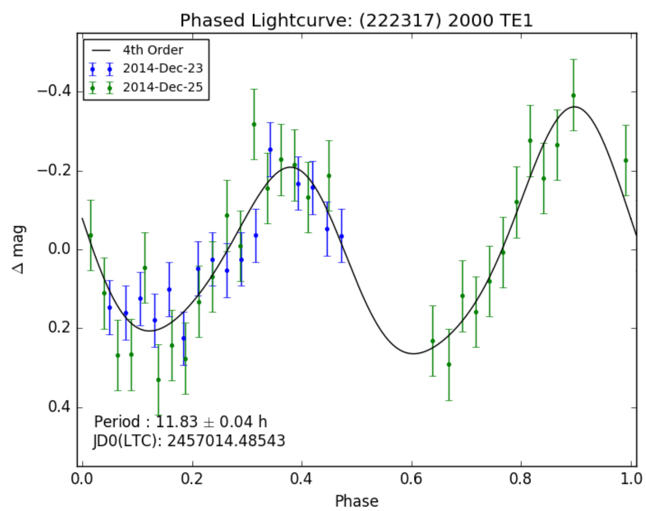
The Remote Observatory Theoretical Astrophysics Tübingen (ROTAT) from which we report our results uses a 60-cm remotely operated telescope located on the OHP site (Observatoire de Haute-Provence) at Haute-Provence (France), which is about 100 km north-east of Marseille. ROTAT was formerly located and operated in Tübingen, by the Dept. for Theoretical Astrophysics, University of Tübingen. Image acquisition was made with an SBIG STL-1100M CCD camera attached to the *f*/3.2 Newtonian focus of the ROTAT telescope, resulting in a scale of 1.94 arcsec/pixel at 2x2 binning. A Johnson-Cousins V filter was used. All images were measured with *Astrometrica* (Raab, 2013). Dark and flat-field images were applied to the science images.

Main-belt asteroid (222317) 2000 TE1 was chosen because the telescope was able to observe only at very high declinations due to technical problems with the dome. Unfortunately, we were able to observe this object for only two nights. The next possibility for ROTAT will be 2018 October, when the magnitude will again be V ~ 19.

The lightcurve analysis was performed with a bundle of Python scripts. A Fourier analysis similar to the FALC method developed by Harris (Harris *et al.* 1989) and the Phase Dispersion Minimization algorithm (PDM; Stellingwerf 1978) were used. The PDM algorithm is provided by the *PyAstronomy* package (*https://github.com/sczesla/PyAstronomy*).

Magnitudes were reduced to unity distance and times were corrected for light-time. The observations show a fair amount of noise. From a 4-th order Fourier fit, we obtained a synodic period P = 11.83 ± 0.04 h with an amplitude of 0.63 mag. However, a period of P = 5.90 h ± 0.02 h is also possible. A period scan using the PDM method slightly favored this shorter period over the larger one. Nevertheless we prefer P = 11.83. The Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) does not contain any previously reported results for this asteroid.





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Number	Name	2014 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
222317	2001 TE	12/23-12/25	46	27.8,28.0	92	46	11.83	0.04	0.63	0.03	MB-O

Table I. Observing circumstances and results. Pts is the number of data points. The solar phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

SIXTEEN ASTEROIDS LIGHTCURVES AT ASTEROIDS OBSERVERS (OBAS) - MPPD: 2016 JUNE-NOVEMBER

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(Received: 2017 Jan 15 Revised: 2017 Feb 13)

We report on the photometric analysis result of sixteen main-belt asteroids (MBA) done by Asteroids Observers (OBAS). This work is part of the Minor Planet Photometric Database tasks, initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

In this paper we publish the result of sixteen asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). As it is indicated in previous papers, this database is focused on collecting lightcurves of main-belt asteroids using photometric techniques. This database shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

Observatory	Telescope (m)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	Atik 314L+
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 NW	Atik 414L+

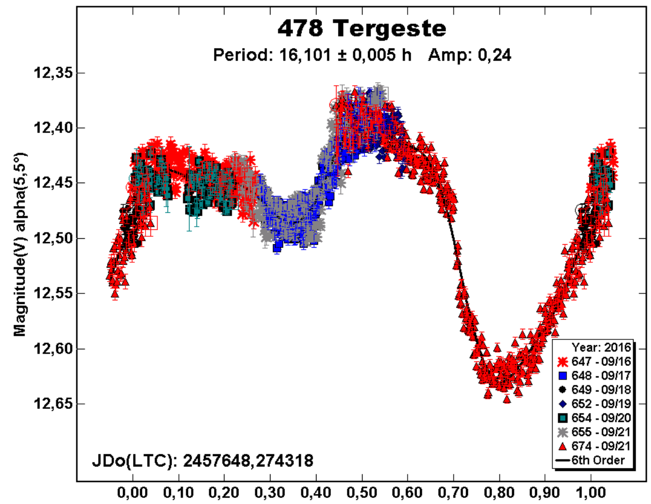
Table I. List of instruments used for the observations. SCT: Schmidt-Cassegrain: R-C: Ritchey-Chrétien; DK: Dall-Kirkham. NW: Newtonian.

Table I shows the equipment at observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website at *http://www.minorplanet.info/call.html*, paying special attention to keeping the asteroid's magnitude within reach of the telescopes being used. We tried to observe asteroids at a phase angle of less than 14°, but this was not always possible.

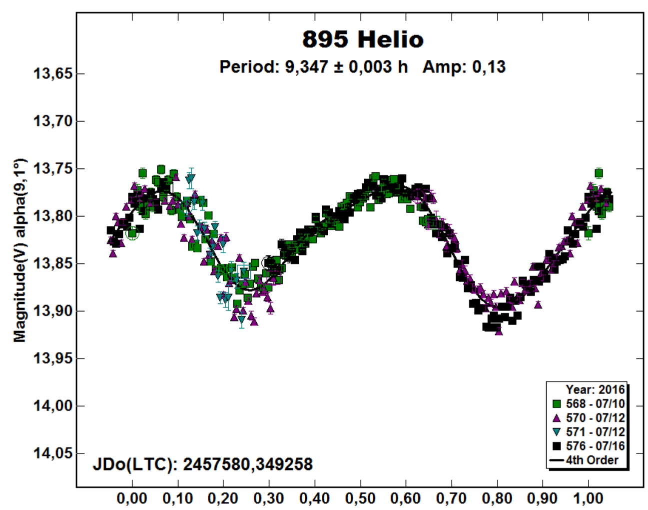
Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. For more information about technic topics see Aznar et al. (2016).

Table II lists the individual results along with the range of dates for the observations and the number of nights that observations were made.

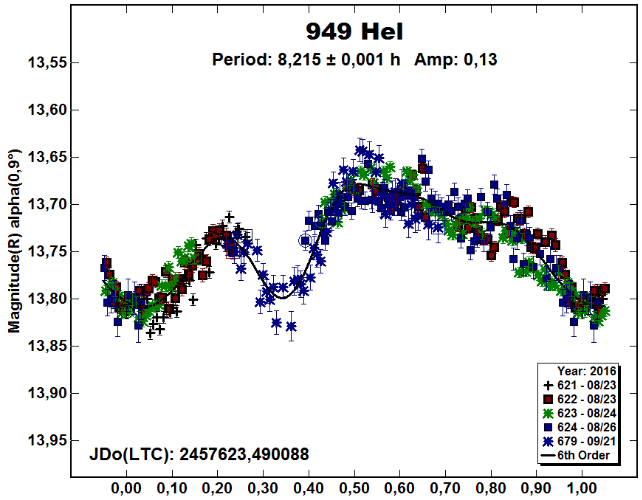
478 Tergeste, Our period of 16.101 ± 0.005 h is consistent with Behrend (2005), who found 16.104 h



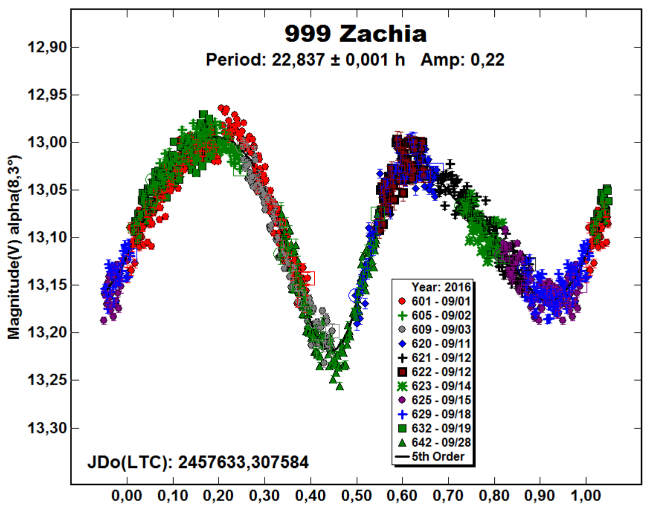
895 Helio. Previous results include Behrend (2005; 9.396 h) and Polakis (2016; 9.391 h). Our analysis found 9.347 ± 0.003 h.



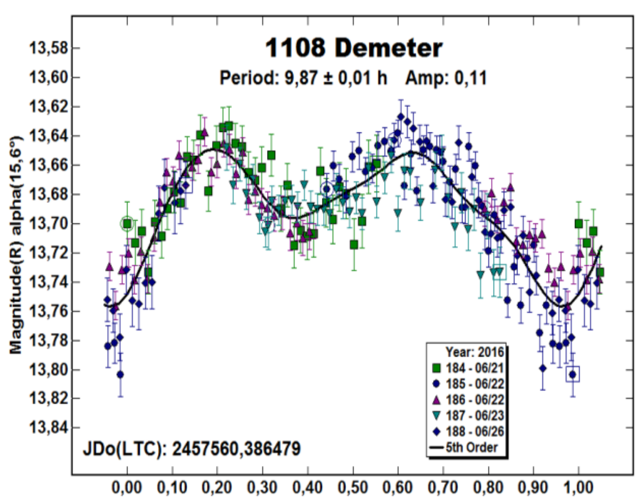
949 Hel. Our period of 8.215 ± 0.01 h differs from the 10.85 h period found by Behrend (2004).



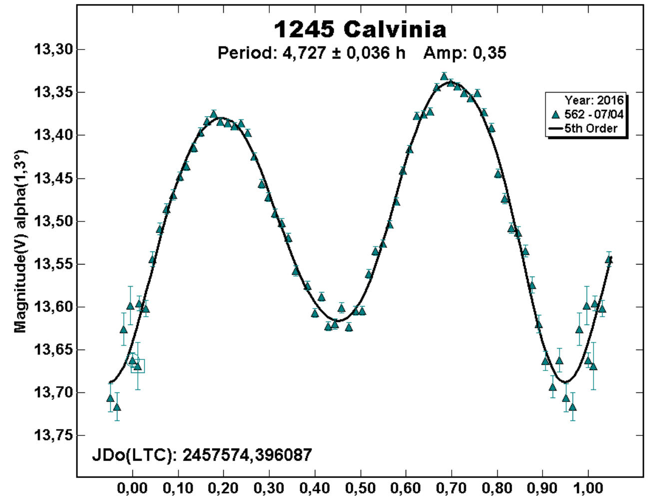
999 Zachia. Warner (2000) found a period of 22.77 h, which is similar to our result of 22.837 ± 0.001 h.



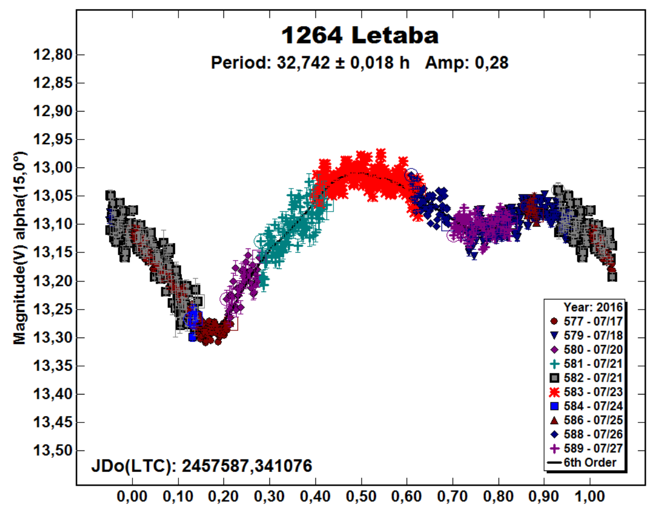
1108 Demeter. Our period of 9.87 ± 0.01 h is consistent with Polakis (2016), who found 9.846 h



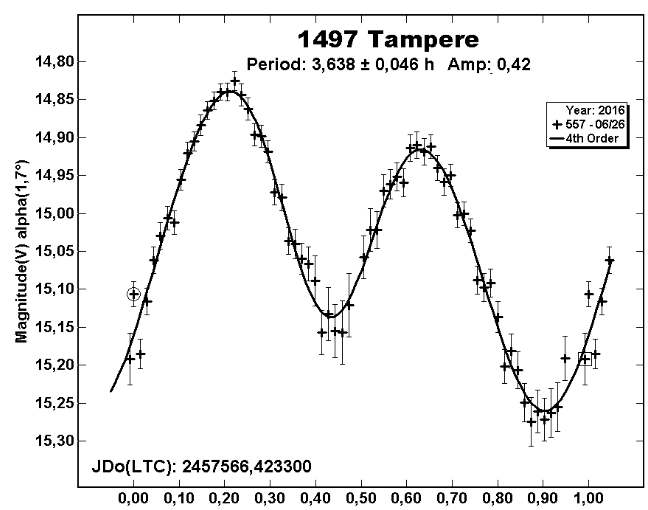
1245 Calvinia. Our period of 4.727 ± 0.036 h is consistent with Durech (2016), who reported a *sidereal* period of 4.85148 h.



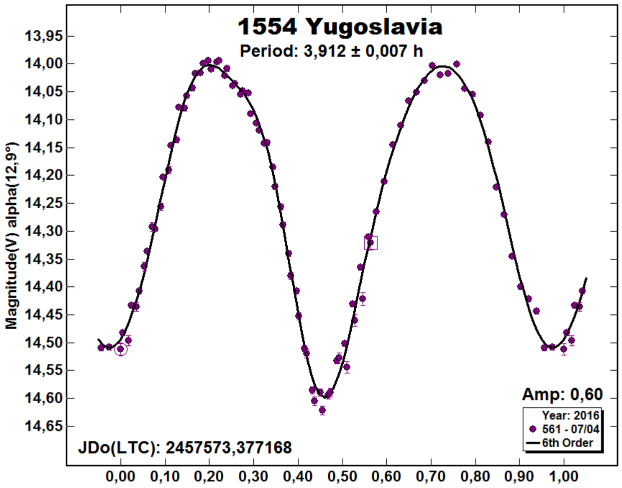
1264 Letaba. Stephens (2003) found a period 32.16 h; this is consistent with our result of 32.742 ± 0.018 h.



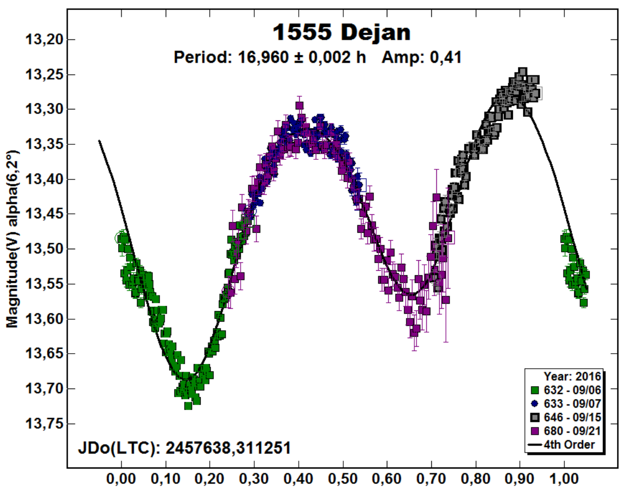
1497 Tampere. Our analysis found a period of 3.638 ± 0.046 h. Waszczak et al. (2015) and Chang et al. (2015) both found a period very close to 3.3 h.



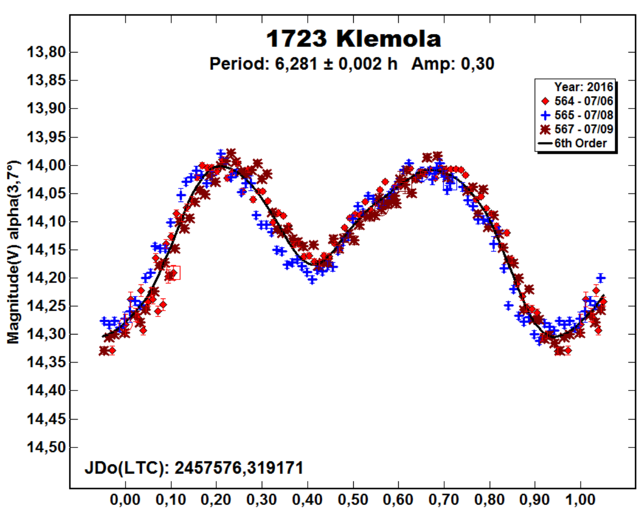
1554 Yugoslavia. Benishek (2013) and Ruthroff (2013) each found a period of about 3.89 h. Our result of 3.912 ± 0.007 h is consistent with those earlier results.



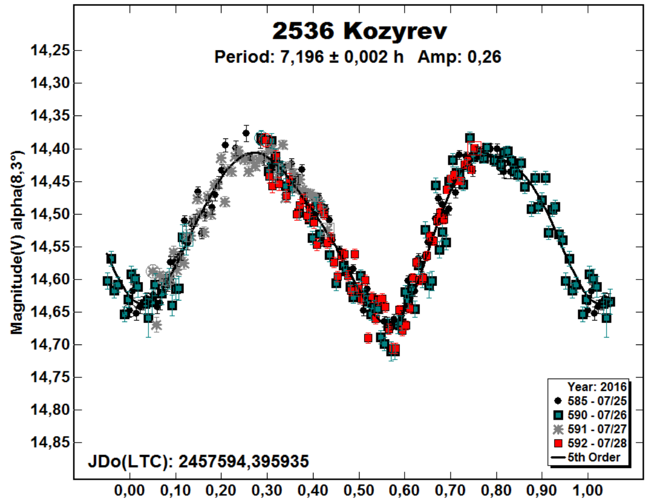
1555 Dejan. We found a period of 16.960 ± 0.002 h. There no previous results found in the asteroid lightcurve database (LCDB; Warner et al., 2009).



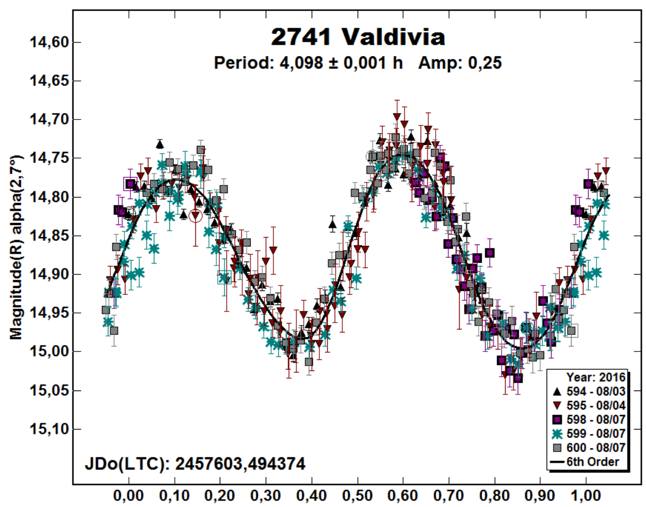
1723 Klemola. Our period of 6.281 ± 0.002 h is consistent with Durech (2016; 6.25609 h *sidereal*) and Waszczak et al. (2015; 6.255 h).



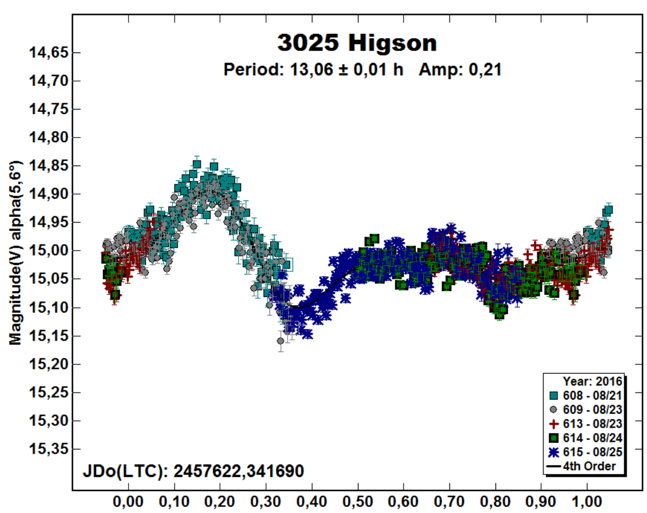
2536 Kozyrev. Skiff (2011) reported a period of 7.188 h; our result of 7.196 ± 0.002 h is consistent with that earlier result.



2741 Valdivia. We found a period of 4.098 ± 0.001 h. This is consistent with Pray (2004; 4.096 h), Hanus (2016; 4.096 h), and Waszczak et al. (2015; 4.096 h).



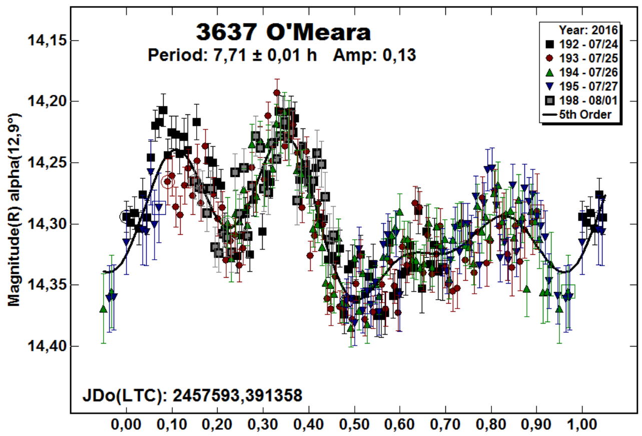
3025 Higson. Our period of 13.060 ± 0.010 h is not consistent with Behrend (2010), who found a period of 10.8 h.



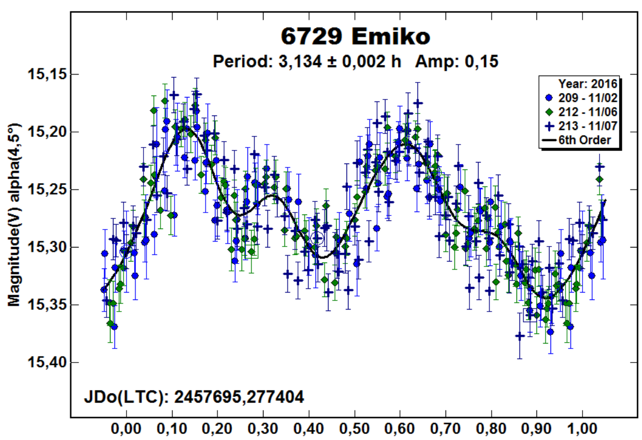
Number	Name	2016 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E.	Amp	A.E.	Grp
478	Tergeste	09/16-09/21	1237	5.5,6.0	350	14	16.101	0.007	0.24	0.005	MB-O
895	Helio	07/10-07/16	372	9.1,8.2	308	21	9.347	0.002	0.13	0.003	MB-O
949	Hel	08/23-09/21	338	0.8,10.2	329	2	8.215	0.001	0.13	0.001	MB-O
999	Zachia	09/01-09/28	1221	8.2,12.6	345	11	22.837	0.001	0.22	0.001	MB-M
1108	Demeter	06/21-06/26	247	14.8,16.7	261	20	9.870	0.012	0.11	0.010	PHO
1245	Calvinia	07/04-07/04	68	1.2,1.2	283	3	4.727	0.040	0.35	0.036	KOR
1264	Letaba	07/17-07/27	1077	15.1,14.5	306	31	32.742	0.020	0.28	0.018	MB-O
1497	Tampere	06/26-06/26	65	2.1,2,1	279	1	3.638	0.050	0.42	0.046	KOR
1554	Yugoslavia	07/04-07/04	87	12.9,12.9	299	16	3.912	0.011	0.60	0.007	EUN
1555	Dejan	09/06-09/21	439	6.1,5.2	352	5	16.960	0.002	0.41	0.002	MB-M
1723	Klemola	07/06-07/09	267	3.8,3.6	287	9	6.281	0.003	0.30	0.002	EOS
2536	Kozyrev	07/25-07/28	313	7.7,6.2	312	313	7.196	0.002	0.26	0.002	FLOR
2741	Valdivia	08/03-08/07	387	2.7,3.3	311	5	4.098	0.001	0.25	0.001	MB-M
3025	Higson	08/21-08/25	787	5.5,6.0	326	15	13.060	0.010	0.21	0.010	MB-O
3637	O'Meara	07/24-08/01	326	12.8,14.8	289	20	7.710	0.012	0.13	0.010	EUN
6729	Emiko	11/02-11/07	221	4.4,5.3	40	8	3.134	0.010	0.15	0.002	EUN

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

3637 O'Meara. The period of 5.49 h reported by Behrend (2008) is not consistent with our period of 7.710 ± 0.010 h.



6729 Emiko. Our period of 3.134 ± 0.002 h is not consistent with Behrend (2008), who found 5.49 h.



Acknowledgements

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3792 PRESTON: ANOTHER TWO-PERIOD CASE

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Photometric observations of the main-belt asteroid 3792 Preston during its 2016 apparition carried out from Europe and North America clearly revealed the existence of a secondary rotational lightcurve component. Although certain shallow attenuations that could represent satellite mutual eclipse/occultation events were detected on several occasions, the attempts to determine a unique orbital period from the available data were unsuccessful.

The main-belt (Phocaea family) asteroid 3792 Preston was discovered on 1985 March 22 at Palomar by C. S. Shoemaker. At a rather favorable photometric target (an estimated magnitude of V ~ 15.7 at its brightest on 2016 Feb 8), it was selected by Benishek from the Potential Lightcurve Targets list for 2016 February (*http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*) to be observed at the Sopot Astronomical Observatory (SAO). The goal was to verify the only known rotation period at that time of 2.93 hours (Behrend, 2009) and rated U = 2+ in the asteroid lightcurve database (LCDB; Warner et al., 2009). The first photometric observations at the SAO started on 2016 January 20 using a 0.35-m S-C telescope operating at f/6.3 and a SBIG ST-8XME CCD without filters.

The initial SAO data showed lightcurve deviations that raised a suspicion about the existence of a secondary lightcurve component. Furthermore, possible shallow mutual events (eclipse/occultation) were observed on a few occasions, which raised further interest in verifying the existence of a satellite and possible determination of its orbital period. An analysis of the initial data performed by Petr Pravec confirmed that 3792 Preston might be a binary candidate.

To ensure effective continuation of data gathering, a call for collaboration among observers was made by Pravec and Benishek through the Photometric Survey for Asynchronous Binary Asteroids website. Frederick Pilcher from the Organ Mesa Observatory in New Mexico, USA, Romain Montaigut and Arnaud Leroy from the OPERA Observatory in France, and Albino Carbognani from the Astronomical Observatory of the Aosta Valley Autonomous Region (OAVdA) in Italy accepted participation in the observing campaign. Pilcher used a 0.35-m Schmidt-Cassegrain telescope (SCT) with a SBIG STL-1001E CCD camera and clear filter. Montaigut and Leroy used a 0.20-m *f*/3.8 Newtonian telescope and ATIK 314L CCD camera without filters. Carbognani used an *f*/7.8 0.81-m Bowen-Waughan reflector and FLI-1001E CCD camera with a Cousins R photometric filter.

Differential aperture photometry with up to five comparison stars of near solar color ($0.5 \leq$ B-V ≤ 0.9) was performed by Benishek, Carbognani, and Pilcher using the Comparison Star Selector (CSS) feature in *MPO Canopus* (Warner, 2016) by selecting the Johnson V magnitudes (Pilcher and Benishek) from the AAVSO Photometric All-Sky Survey catalog (APASS; Henden *et al.*, 2009) and the Cousins R magnitudes (Carbognani) taken from the MPOSC3 hybrid catalog. The MPOSC3 catalog contains BVRcIc magnitudes derived from 2MASS J and K magnitudes by the formulae developed by Warner (2007). PSF photometry with elliptical Gaussian shapes and 10 comparison stars similar in color to the asteroid was carried out in PRISM software by Montaigut and Leroy, who used the R-band magnitudes from the USNO-A2.0 catalog to calibrate the measurements. Due to the apparent inconsistencies in the magnitude calibration procedures among the authors, it was necessary to adjust further the zero-points of particular data sets to achieve the best alignment in terms of minimum RMS residuals in Fourier analysis.

As of 2016 March 28, a total of 27 data sets (*sessions*) has been obtained: 19 by Benishek, 6 by Pilcher, 1 by Montaigut and Leroy and 1 by Carbognani.

The period analysis of the overall data and lightcurve plot production were performed by Pravec using his custom period analysis software. Due to the large time span of more than two months in which the observations were carried out and, therefore, changes in the viewing geometry and the lightcurve shape, the total combined data set was divided into two subsets that were analyzed separately. The first subset comprised the data obtained from 2016 January 23 through February 25; the second subset contained data obtained from 2016 March 1-28. Some of the sessions were excluded from the analysis due to their short duration and/or noisy data.

Number	Name	2016 mm/dd	Phase	L_{PAB}	B_{PAB}	Period 1 (h)	P.E.	Amp	Grp
3792	Preston	01/23-02/25	25.1,22.9.23.0	146	34	2.92768	0.00004	0.18	PHO
3792	Preston	03/01-03/28	23.3,26.2	152	33	2.92754	0.00005	0.22	PHO

Number	Name	2016 mm/dd	Phase	L_{PAB}	B_{PAB}	½ Period 2 (h)	P.E.	Amp	Grp
3792	Preston	01/23-02/25	25.1,22.9,23.0	146	34	11.926	0.005	0.03	PHO
3792	Preston	03/01-03/28	23.3,26.2	152	33	11.909	0.007	0.04	PHO

Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then 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_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude. Grp is the asteroid family/group (Warner *et al.*, 2009).

The final result of the period analysis established that two rotational components were, in fact, present. The summary of the observing circumstances and the period results associated with the primary (P_1) and the secondary component (P_2) for both subsets are given in the Table I. This confirms the primary rotation period previously found by Behrend (2009) from data obtained by Federico Manzini. Behrend (2016) using data obtained in collaboration with Henk de Groot found a period of 2.9274 h. Carbognani (2016) independently found 2.947 h. Both values are consistent with the P_1 results presented in this paper. The $P_2/2$ shown in Table I was derived by Pravec and represents one-half the actual period. Figs. 1 and 4 show the lightcurve of the primary. Figs. 2 and 5 shows the secondary lightcurve. Figs 3 and 6 show the period spectra for the half-period for P_2.

Since the secondary period (23.8 h) is nearly commensurate with the Earth's rotation, it was not possible to cover the entire cycle with the data obtained by the observers from Europe and North America during one apparition; hence the data gaps in the corresponding lightcurves. This should be taken into account in any future campaign in order to include observers from the broadest scope of longitudes and preferably spaced apart by 120 degrees in longitude.

It is also important to note that Pravec, Pilcher, and Benishek independently attempted to find an orbital period value (P_{ORB}) for a possible satellite, based on the suspected shallow attenuation events. These attempts were unsuccessful due to the lack of data: a small number of detected attenuations cannot be safely argued to be mutual (eclipse/occultation) events. None of the derived values for P_{ORB} proved to be reliable. Although unconfirmed, the period of about 46.9 hours, based on the period spectrum, is a strong possibility.

Even though the second rotational component was detected unequivocally, this is still not sufficient evidence to confirm that the asteroid is binary. The presence of the secondary lightcurve component may also be the result of a low-amplitude tumbling (Pravec, private communication). Without a clear detection of mutual events and a unique solution for their (orbital) period, we take this case as a probable binary, but not a secure binary detection (see Section 4.2.4 of Pravec et al., 2016).

This asteroid definitely deserves to be the focus of future photometric observing campaigns in order to find out its true nature.

Acknowledgements

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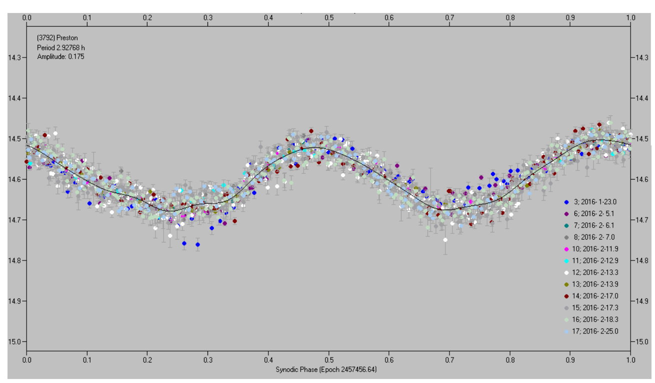

Fig. 1. The primary rotational lightcurve component for 3792 Preston obtained from the 2016 January – February data.

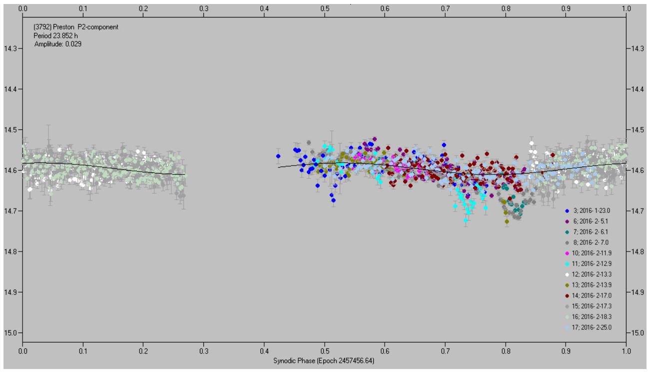

Fig. 2. The secondary rotational lightcurve component for 3792 Preston obtained from the 2016 January – February data phased to a period of 23.852 hours.

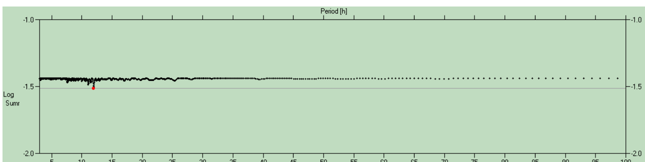

Fig. 3. The period spectrum for the half of the secondary period obtained from the 2016 January-February data.

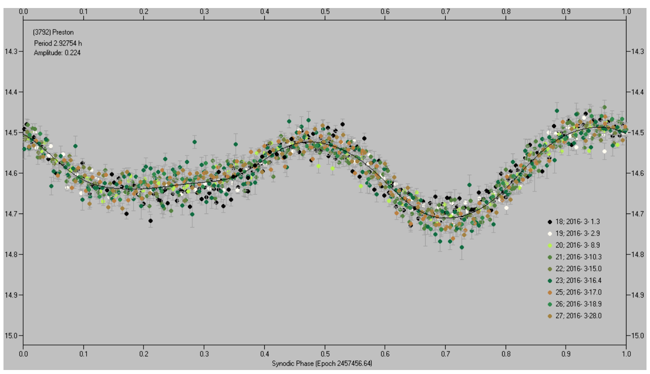

Fig. 4. The primary rotational lightcurve component for 3792 Preston obtained from the 2016 March data.

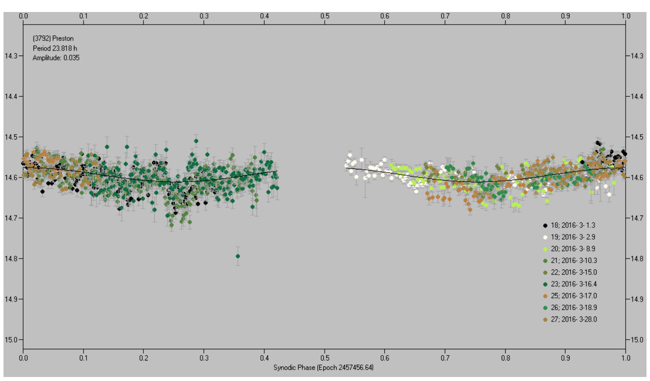

Fig. 5. The secondary rotational lightcurve component for 3792 Preston obtained from the 2016 March data phased to a period of 23.818 hours.

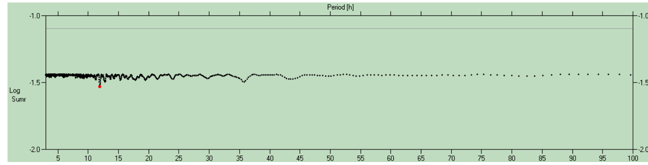

Fig. 6. The period spectrum for the half of the secondary period obtained from the 2016 March data.

LIGHTCURVES AND SYNODIC ROTATION PERIODS FOR 3067 AKHMATOVA, 5397 VOJISLAVA, 5823 ORYO, 5909 NAGOYA, AND (23997) 1999 RW27

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CCD photometric observations on five main-belt asteroids were carried out from 2016 September to December. The resulting lightcurves and synodic periods are presented here for 3067 Akhmatova, 5397 Vojislava, 5823 Oryo, 5909 Nagoya, and (23997) 1999 RW27.

Photometric observations of five main-belt asteroids were conducted at Sopot Astronomical Observatory (SAO) from 2016 September to December for the purpose of determining their synodic rotation periods. The observations were made with a 0.35-m Meade LX200GPS Schmidt-Cassegrain telescope with an *f*/6.3 focal reducer and an SBIG ST-8 XME CCD camera. The exposures were unfiltered and unguided for all targets. The camera was operated in a 2x2 binning mode, which provided an image scale of 1.66 arcsec/pixel. Prior to measurements, all images were corrected using dark and flat field frames.

Photometric reduction, lightcurve construction, and period analysis were conducted using *MPO Canopus* (Warner, 2016). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq B\text{-}V \leq 0.9$) was performed using the Comparison Star Selector (CSS) utility. This helped ensure a satisfactory quality level of night-to-night zero point calibrations and correlation of the measurements within the standard magnitude framework. To calibrate field comparison stars, the Johnson V magnitudes from the AAVSO Photometric All-Sky Survey catalog (APASS; Henden *et al.,* 2009) Data Release 9 were used. In some instances, small zero point adjustments were necessary in order to achieve the best match between individual data sets in terms of minimum RMS residual of a Fourier fit.

Table I summarizes the observing circumstances and results.

<u>3067 Akhmatova</u>. This asteroid was observed over a single night in 2016 December within the Photometric Survey for Asynchronous Binary Asteroids (BinAstPhot Survey; Pravec et al., 2006). It was observed in 2009 and 2011 by other observers within the same survey. No evidence of a satellite was found. Unlike the 2009 and 2011 apparitions, when the lightcurves showed amplitudes of 0.30 mag and 0.24 mag, respectively, the 2016 lightcurve had amplitude of 0.77 mag. This suggests that the asteroid was observed at a higher asterocentric latitude than at the past apparitions. The previous results, all for a bimodal lightcurve,

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	AE	Grp
3067	Akhmatova	12/17-12/18	79	20.6,20.5	120	6	3.69	0.02	0.77	0.03	FLOR
5397	Vojislava	09/11-11/01	324	16.3,4.2,12.4	17	7	54.048	0.008	0.25	0.02	EUN
5823	Oryo	10/23-10/28	146	6.4,7.8	25	11	2.7939	0.0002	0.32	0.01	MB-O
5909	Nagoya	12/08-12/10	150	6.8,7.4	71	7	3.784	0.0001	0.24	0.02	FLOR
23997	1999 RW27	12/10-12/12	185	16.9,16.4	96	19	17.4	0.1	0.23	0.02	MB-O

Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The solar phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (Harris et al. 1984). Grp is the asteroid family/group (Warner et al., 2009).

include 3.68629 h (Pravec et al., 2009), 3.68589 h (Pravec et al., 2011) and 3.6863 h (Waszczak et al., 2015). The period of 3.69 ± 0.02 h is in good agreement with the previous results.

5397 Vojislava. There only previously reported result for this asteroid was by Behrend (2008), where the data indicated $P > 24$. The first data sets obtained at SAO in 2016 September also indicated a long period. The observations started well before opposition on 2016 Oct 7, and continued until 2016 Nov 1. Given the amplitude of the resulting lightcurve (0.25 mag.) and the data cover a range of relatively low phase angles, the bimodal solution with a period of 54.048 ± 0.008 h can be regarded as valid with a high degree of reliability.

5823 Oryo. Two previous period determinations for this asteroid are those by Chang et al. (2014; 2.79 h) and Waszczak et al. (2015; 2.8010 h). The period analysis of SAO data, obtained during three nights in 2016 October 2016 at low phase angles, led to a bimodal lightcurve with an amplitude of 0.32 mag and period of 2.7939 ± 0.0002 h. This period is consistent with the earlier results.

5909 Nagoya. No previously reported periods were found for Nagoya. This was another BinAstPhot Survey target observed at SAO over two nights in 2016 December at low phase angles. Period analysis performed by the author yielded a bimodal solution with a period of 3.784 ± 0.001 h and amplitude of 0.24 mag. An independent period analysis by Pravec of the same data shows an identical result for the period (Pravec, 2016).

(23997) 1999 RW27. This is another asteroid with no previous rotation period determinations found. The observations were made in 2016 December during only two nights. Bad weather conditions prevented further observations, which were needed to establish a fully secure period solution. Even so, the limited data set led to a plausible period solution.

The period analysis produced several possible solutions with comparable RMS errors. The data gave a poor fit to a monomodal lightcurve with $P = 8.9$ h and an incomplete, presumably bimodal lightcurve, at $P = 13.1$ h despite reliable night-to-night zero point calibration. The final choice is for a bimodal lightcurve with a period of P = 17.4 ± 0.1 h and amplitude of 0.23 mag. Observations of this object at future apparitions may allow finding a secure period and so are strongly encouraged.

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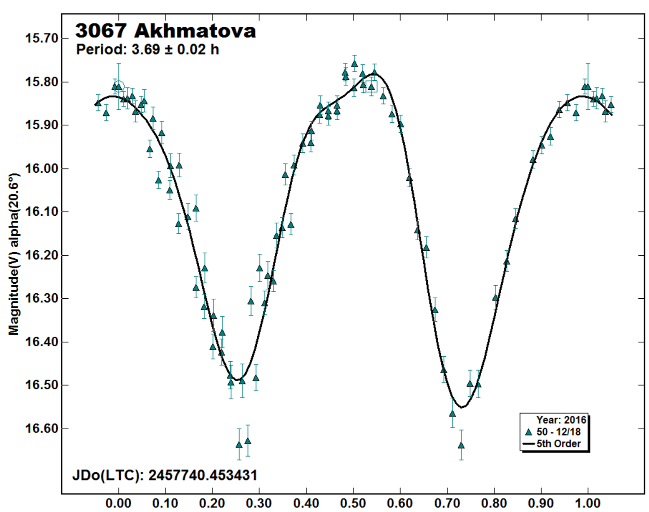

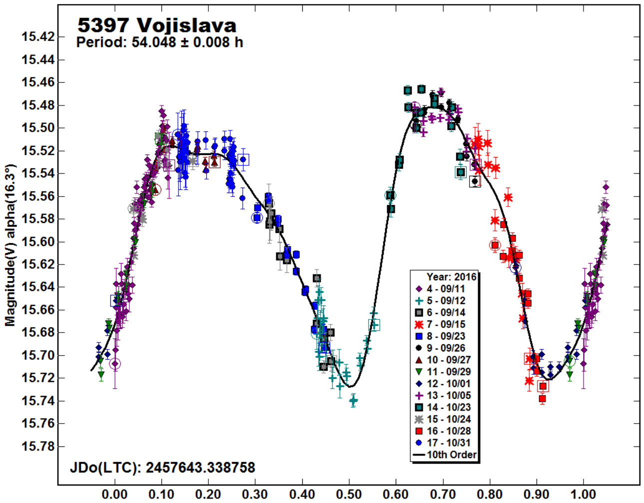

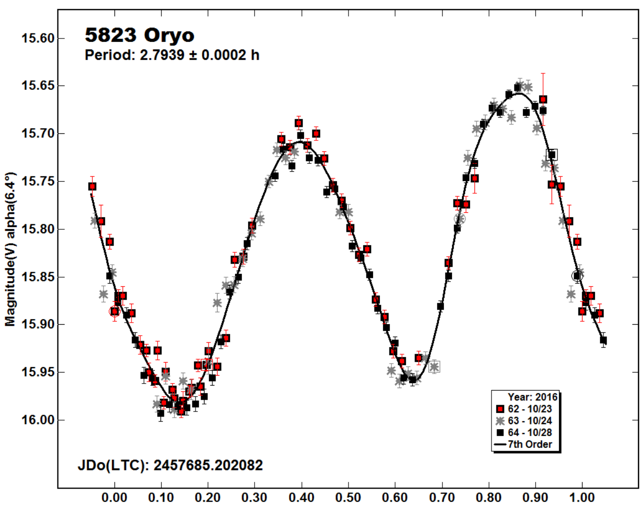

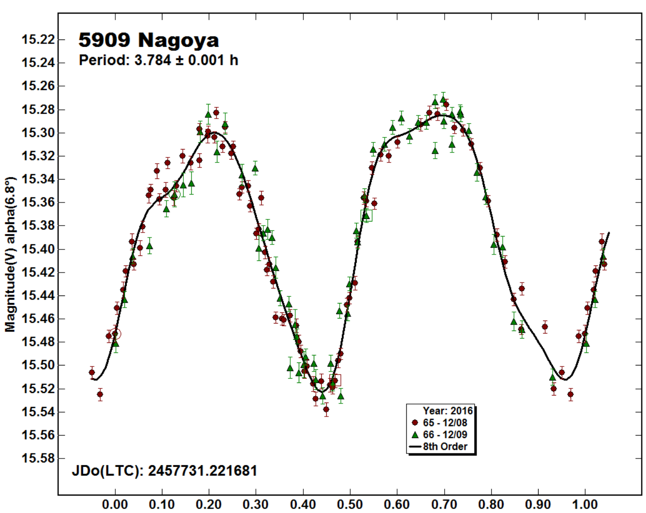

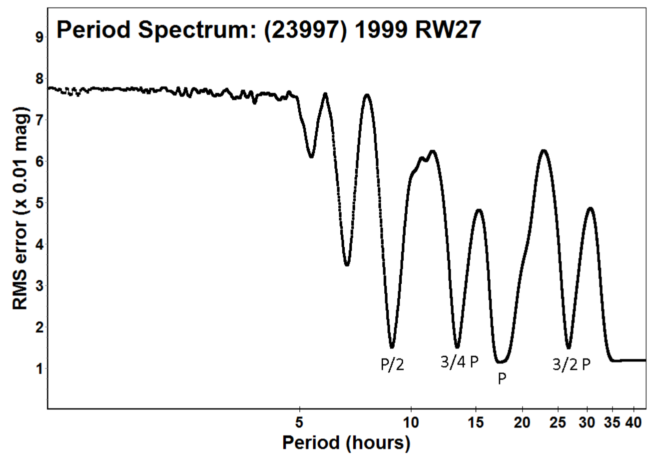

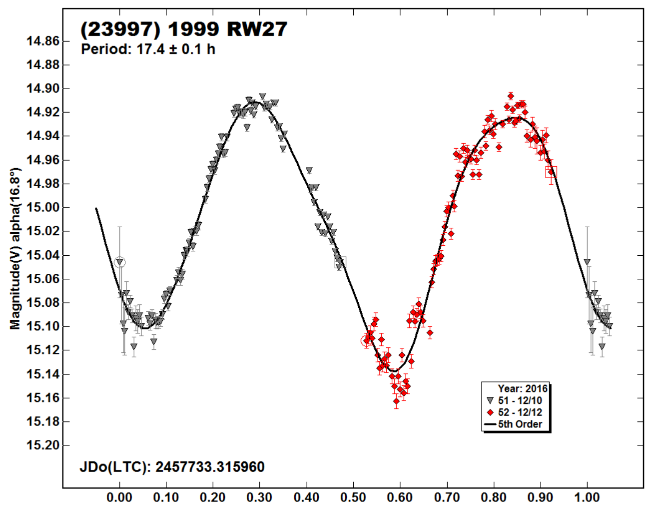

ROTATION PERIOD DETERMINATION OF ASTEROIDS 5059 SAROMA AND 5399 AWA

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Photometric observations were made in 2016 December and 2017 January of the main-belt asteroids 5059 Saroma and 5399 Awa. For Saroma, analysis of the data suggests a period of 4.074 ± 0.001 h. For Awa, a likely period of 41.215 ± 0.008 h was found.

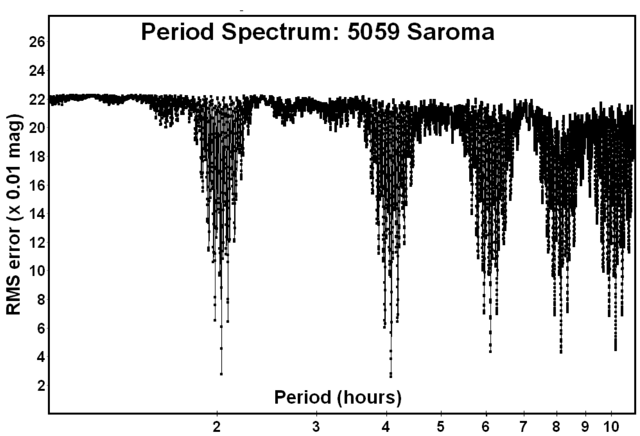
Photometric observations of the main-belt asteroids 5059 Saroma and 5399 Awa were made at the Astronomical Observatory of the University of Siena (K54), Italy, with a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope equipped with an SBIG STL-6303E NABG CCD camera and clear filter. The image scale was 2.26

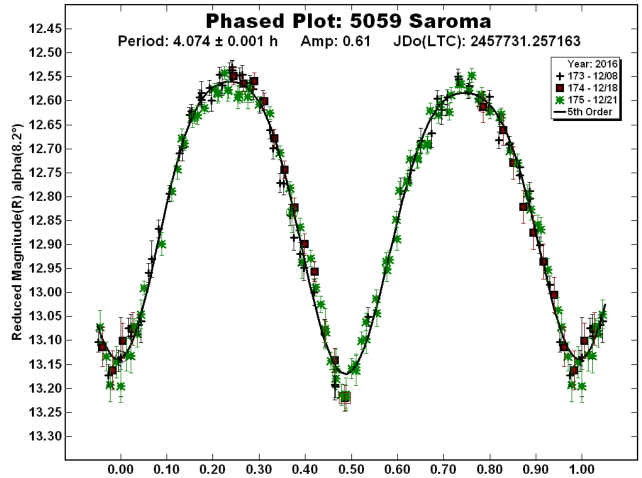
arcsec/pixel with 2x2 binning. Exposure times were 300 seconds. Table I gives the observation circumstances and results. Differential photometry measurements were performed using the Comp Star Selector (CSS) procedure in *MPO Canopus* (Warner, 2012) that allows selecting of up to five comparison stars of near solar color. The magnitudes from the CMC-15 catalog were used for the comparison stars. Period analysis was performed using *MPO Canopus* and its implementation of the FALC (Fourier Analysis for Lightcurves) algorithm by Harris (Harris *et al.*, 1989). Additional adjustments of the magnitude zero-points for each data set were carried out in order to reach the minimum RMS value from the Fourier analysis and so achieve the best alignment among lightcurves.

A search of the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) and literature found no previous entries for either asteroid.

5059 Saroma (1988 AF) is a main-belt asteroid discovered at Kitami on 1988 January 11 by K. Endate and K. Watanabe. It is named for a lake in Abashiri National Park in eastern Hokkaido (MPC 20838). It orbits with a semi-major axis of about 2.59 AU, eccentricity 0.13, and a period of 4.18 years (JPL, 2017). Observations were made on three nights from 2016 December 8-21 with a total of 185 data points collected. As seen in the period spectrum, the analysis yielded several possible solutions with comparable RMS errors.

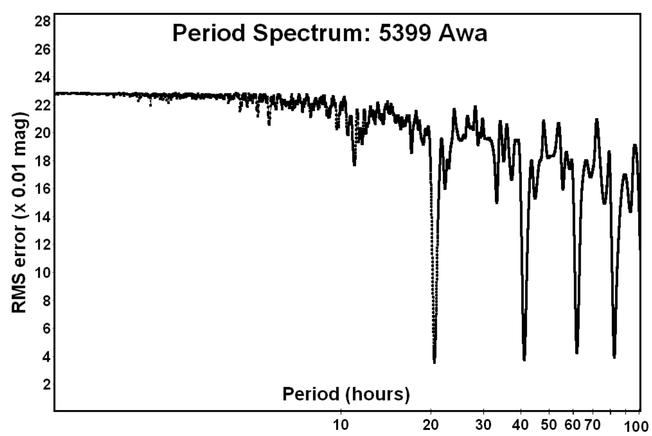
We concluded that the most likely value of the synodic period is associated with a bimodal lightcurve phased to 4.074 ± 0.001 h and amplitude of 0.61 ± 0.03 mag.





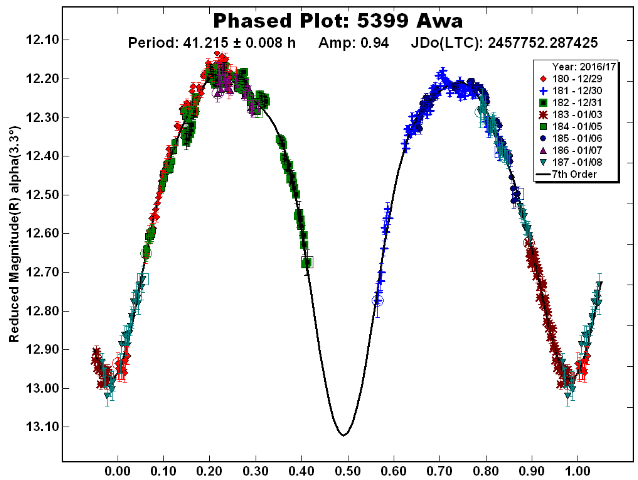
5399 Awa (1989 BT) was discovered on 1989 January by M. Iwamoto and T. Furuta. It was named by the first discoverer for the town in the northern part of Shikoku Island in which he lives. The asteroid orbits with a semi-major axis of about 2.81 AU, eccentricity 0.18, and a period of 4.70 years (JPL, 2017). Observations were made on eight nights from 2016 Dec 29 through 2017 Jan 8, collecting 478 useful data points. The period analysis yielded a few possible solutions with nearly comparable RMS values.

We concluded that the most likely value of the synodic period is associated with a bimodal lightcurve phased to 41.215 ± 0.008 h with an amplitude of 0.94 ± 0.11 mag.



Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
5059	Saroma	12/08-12/21	185	8.6,4.3	89	8	4.074	0.001	0.61	0.03
5399	Awa	12/29-01/08	478	3.8,1.7	105	-1	41.215	0.008	0.94	0.11

Table I. Observing circumstances and results. Pts is the number of data points. The solar phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).



Acknowledgements

This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

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ASTEROID LIGHTCURVE ANALYSIS AT ASTRONOMICAL OBSERVATORY – UNIVERSITY OF SIENA (ITALY): 2016 OCTOBER-DECEMBER

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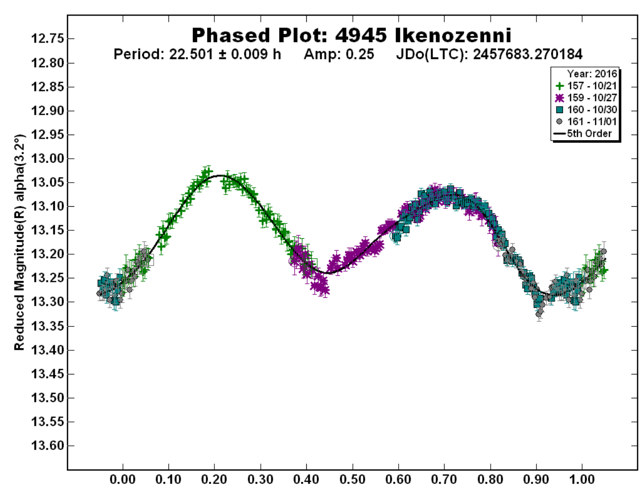
CCD photometric observations were made from 2016 October to December with the goal of finding the synodic rotation periods of four asteroids: 4945 Ikenozenni, 7333 Bec-Borsenberger, 7487 Toshitanaka, and (10704) 1981 RQ1.

Lightcurve analysis was performed on CCD images taken at the Astronomical Observatory of the University of Siena (Italy). The observations were made with a 0.30-m *f*/5.6 Maksutov-Cassegrain, SBIG STL-6303E NABG CCD camera, and clear filter; the pixel scale was 2.26 arcsec with 2x2 binning. Exposures were 300 seconds. The images were calibrated using *Maxim DL* software. *MPO Canopus* was used to measure the images, do Fourier period analysis, and produce the lightcurves. Table I lists the asteroids that were observed and the results of the analysis. Orbital data and discovery circumstances were taken from the JPL Small Bodies Node (JPL, 2016).

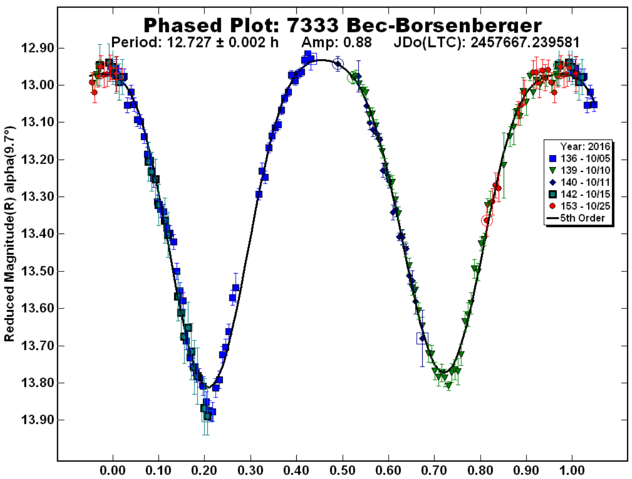
4945 Ikenozenni. This is a main-belt asteroid discovered on 1938 September 17 by Suzuky and Urata. It's has a typical main-belt asteroid orbit with a semi-major axis of about 2.57 AU, eccentricity 0.317, and orbital period of about 4.12 years. We observed this asteroid from 2016 October 21 to November 1. The collaborative observations resulted in four sessions with a total of 309 data points. The analysis found a bimodal lightcurve with a period of 22.501 ± 0.009 h and amplitude of 0.25 ± 0.02 mag.



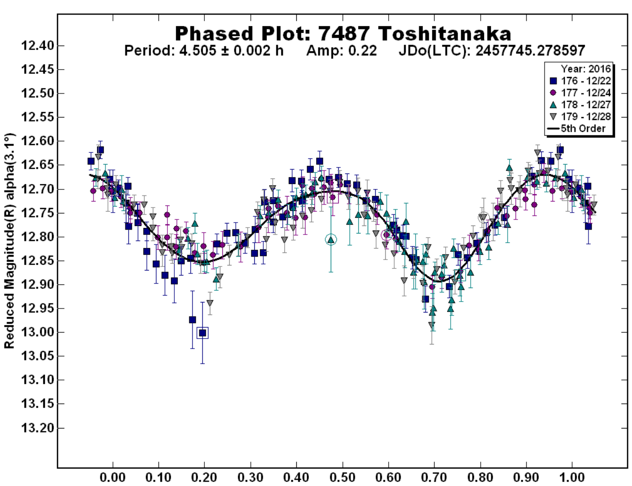
Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4945	Ikenozenni	10/21-11/01	309	3.7,3.2	33	-2	22.501	0.009	0.25	0.02	MB-I
7333	Bec-Borsenberger	10/05-10/15	208	10.0,7.8	22	13	12.727	0.002	0.88	0.02	MB-I
7487	Toshitanaka	12/22-12/28	239	3.5,1.2	97	-3	4.505	0.002	0.22	0.05	EUN
10704	1981 RQ1	10/21-11/01	314	2.8,2.7	33	-3	7.507	0.001	0.70	0.05	V

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

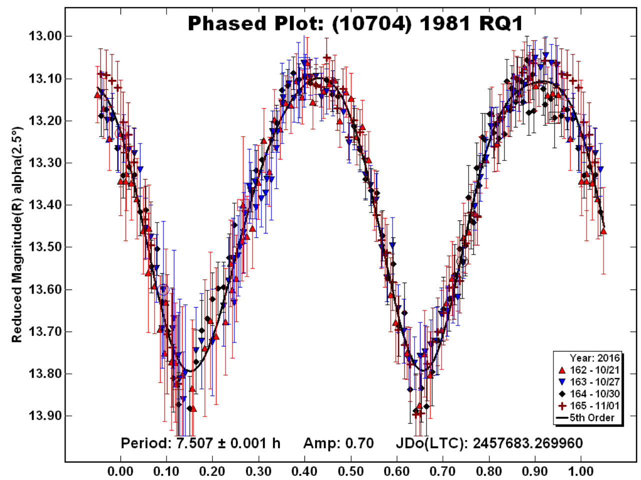
7333 Bec-Borsenberger. This is a main-belt asteroid discovered on 1987 September 29 by E. Bowell. It has an orbit with a semi-major axis of about 2.578 AU, eccentricity 0.188, and orbital period of about 4.14 years. We observed the asteroid from 2016 October 5-15. The collaborative observations resulted in four sessions with a total of 208 data points. Analysis found a lightcurve with a synodic period of 12.727 ± 0.002 h and amplitude of 0.88 ± 0.02 mag.



7487 Toshitanaka is a main-belt asteroid discovered on 1984 December 28 by T. Kobayashi. Its orbit has a semi-major axis of about 2.690 AU, eccentricity 0.167, and period of about 4.41 years. We observed Toshitanaka from 2016 December 22- 28. The collaborative observations resulted in four sessions with a total of 239 data points. The analysis found a bimodal lightcurve with a synodic period of 4.505 ± 0.002 h and amplitude of 0.22 ± 0.05 mag.



(10704) 1981 RQ1 is a main-belt asteroid discovered on 1981 September 1 by H. Debehogne. It has a typical main-belt orbit with semi-major axis of about 2.90 AU, eccentricity 0.097, and orbital period of about 4.94 years. We observed the asteroid from 2016 October 21 to November 1. The collaborative observations resulted in four sessions with a total of 314 data points. The analysis found a lightcurve with a synodic period of 7.507 ± 0.001 h and amplitude of 0.70 ± 0.05 mag.



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LIGHTCURVE ANALYSIS OF THE NEAR-EARTH ASTEROID 2016 NL15

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CCD photometric observations of the near-Earth asteroid 2016 NL15 were made in 2016 mid-December. A collaboration of three observers at widely-separated longitudes proved critical in finding the synodic period of 23.22 h, nearly commensurate with an Earth day.

The near-Earth asteroid (NEA) 2016 NL15 came within about 0.077 AU of Earth in 2016 mid-December. CCD photometric observations were made to determine its synodic rotation period. Table I gives the equipment used by the authors while Table II shows the dates of observations and observing circumstances during the campaign.

OBS	Telescope	Camera
Warner	0.35-m *f*/9.1 SCT 0.50-m f/8.1 R-C	SBIG STL-1001E FLI PL-1001E
Sota	1.5-m f/8 R-C 0.9-m f/12.5 Cass	VersArray 2048B
Aznar	0.35-m f/10 SCT	SBIG STL-1001XE

Table I. List of observers and equipment.

Obs	2016 Dec	Sess	α	L_{PAB}	B_{PAB}
Warner	17-20 25	1-13 22-24	68.6,54.6 36.1,35.7	61,70 82	31,26 17
Sota	21-22	14,18	48.4,47.3	75	23
Aznar	21-22 22-23 24-25 27-28	15-17 19-20 21 25-28	48.1,43.7 43.8,43.6 36.8 29.1,28.5	76 77 81 86	22 21 18 14

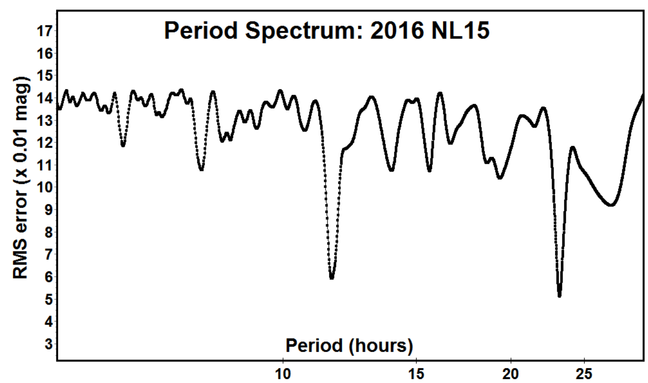
Table II. Dates of observation for each observer. α is the solar phase angle at the earliest and latest observation. The last two columns are the phase angle bisector longitude and latitude during each block of observations (see Harris *et al.*, 1984).

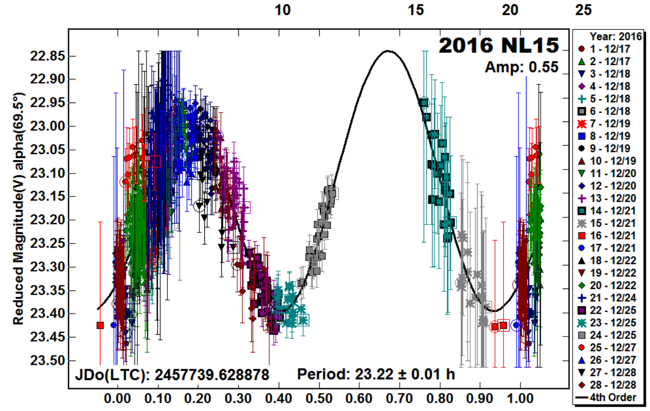
The 2016 apparition at V ~ 16.8 was only one of two through 2039 where NL15 exceeds V ~ 18. At all other apparitions, it is well below 20^{th} magnitude and so out of reach of even larger telescopes usually available to backyard astronomers. This made it important to find a synodic period during this opportunity if at all possible. The other favorable apparition is in 2019, when the asteroid will be V ~ 17.8.

The initial observations were made between 2016 Dec 17-20 at the Center for Solar System Studies (CS3) – Palmer Divide station located in Landers, CA. Analysis of those data showed that the asteroid had a period that was longer than 10 hours and likely close to being commensurate with an Earth day. However, it was not possible to determine with certainty if the period was 12, 16, or 24 hours since the individual observing runs were not long enough to cover even a half cycle of a presumed bimodal lightcurve. This prompted a request for additional observations. Aznar and Sota observed the asteroid on several nights from their locations in Spain, or about 125° east of CS3.

MPO Canopus was used to measure images using the Comp Star Selector utility to find near solar-color stars for ensemble differential photometry. The asteroid was too far north to use the CMC-15 catalog (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* and the number of near solar-color stars was too small in the APASS catalog (Henden *et al.*, 2009). This meant using the MPOSC3 catalog provided with *MPO Canopus*. This catalog contains BVRI magnitudes derived from J-K magnitudes in the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) using formulae developed by Warner (2007).

Aznar sent his and Sota's data to Warner, who created a combined data set for Fourier period analysis. This was done in *MPO Canopus* using the FALC algorithm developed by Harris (Harris *et al.*, 1989). Despite having a much lower SNR (exposures were short due to a large sky motion) and larger scatter, the Aznar and Sota data reduced the ambiguities to either 12 or 24 hours, as seen in the period spectrum. Even with a high phase angle, the 0.56 mag amplitude of the lightcurve virtually assured that the solution would be a bimodal shape (Harris *et al.*, 2014), and so we have adopted a synodic period of 23.22 ± 0.01 h as the likely rotation period for 2016 NL15.





Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2016 NL15	12/17-12/28	645	68.6,28.6	61,86	31,14	23.22	0.01	0.55	0.03	NEA

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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Harris, A.W., Pravec, P., Galad, A., Skiff, B.A., Warner, B.D., Vilagi, J., Gajdos, S., Carbognani, A., Hornoch, K., Kusnirak, P., Cooney, W.R., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.

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TARGET ASTEROIDS! OBSERVING CAMPAIGNS FOR APRIL THROUGH JUNE 2017

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(Received: 2017 Jan 15)

Asteroid campaigns to be conducted by the *Target Asteroids!* program during the April-June 2017 quarter are described. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and easier to observe for small telescope users and 2) analogous to (101955) Bennu and (162173) Ryugu, targets of the OSIRIS-REx and Hayabusa-2 sample return missions.

Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for robotic sample return. The program also focuses on the study of asteroids that are analogous to (101955) Bennu and (162173) Ryugu, the target asteroids of the NASA OSIRIS-REx and JAXA Hayabusa-2 sample return missions respectively. Most target asteroids are near-Earth asteroids (NEA) though observations of relevant Main Belt asteroids (MBA) are also requested.

Even though many of the observable objects in this program are faint, acquiring a large number of low S/N observations allows many important parameters to be determined. For example, an asteroid's phase function can be measured by obtaining photometry taken over a wide range of phase angles. The albedo can be constrained from the phase angle observations, as there is a direct correlation between phase function and albedo (Belskaya and Shevchenko 2000). The absolute magnitude can be estimated by extrapolating the phase function to a phase angle of 0°. By combining the albedo and absolute magnitude, the size of the object can be estimated.

An overview of the *Target Asteroids!* program can be found at Hergenrother and Hill (2013).

Current Campaigns

Target Asteroids! continues to conduct a number of dedicated campaigns on select NEAs and analog carbonaceous MBAs during the quarter. These campaigns have a primary goal of conducting photometric measurements over a large range of phase angles.

Target Asteroids! objects brighter than V = 17.0 are presented in detail. A short summary of our knowledge of each asteroid and 10-day (shorter intervals for objects that warrant it) ephemerides are presented. The ephemerides include rough RA and Dec positions, distance from the Sun in AU (r), distance from Earth in AU (Δ), V magnitude, phase angle in degrees (PH) and elongation from the Sun in degrees (Elong).

We ask observers with access to large telescopes to attempt observations of spacecraft accessible asteroids that are between V magnitude ~17.0 and ~20.0 during the quarter (contained in the table below).

Asteroid Number	Name	Peak V Mag	Time of Peak Brightness
(136635)	1994 VA1	19.6	early Apr
(137799)	1999 YB	19.6	late Jun
(141018)	2001 WC47	16.7	late Jun

The campaign targets are split up into two sections: carbonaceous MBAs that are analogous to Bennu and Ryugu; and NEAs analogous to the Bennu and Ryugu or provide an opportunity to fill some of the gaps in our knowledge of these spacecraft targets (examples include very low and high phase angle observations, phase functions in different filters and color changes with phase angle).

The ephemerides listed below are just for planning purposes. In order to produce ephemerides for your observing location, date and time, please use the Minor Planet Center's Minor Planet and Comet Ephemeris Service:

http://www.minorplanetcenter.net/iau/MPEph/MPEph.html

or the *Target Asteroids!* specific site created by Tomas Vorobjov and Sergio Foglia of the International Astronomical Search Collaboration (IASC) at

http://iasc.scibuff.com/osiris-rex.php

Analog Carbonaceous Main Belt Asteroid Campaigns

(62) Erato (a=3.13 AU, e=0.17, i=2.2°, H = 8.8)
Asteroid Erato is the 5th brightest member of the carbonaceous Themis family at H = 8.8 (Nesvorny 2015). The family's namesake asteroid has been observed to have water ice and organics on its surface (Campins et al. 2010, Rivkin and Emery 2010). Some members also exhibit cometary activity confirming the presence of ices.

Erato reached a minimum phase angle of 0.1° and peak brightness of V = 13.9 on March 1. Maximum phase angle occurs in late May at 17.1°. It is a Ch or B type asteroid with a rotation period of 9.2 hours and a small amplitude of ~0.15 magnitudes (Hanus et al. 2011, Harris et al. 2015, Neese 2010). Time series lightcurve and color photometry across a range of phase angles are requested. Observations of Erato continue our request from the previous quarter.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	10 28	+11 33	2.51	3.36	14.1	10	143
04/11	10 25	+11 52	2.62	3.38	14.2	12	133
04/21	10 23	+11 59	2.75	3.39	14.4	14	123
05/01	10 24	+11 54	2.89	3.41	14.6	15	113
05/11	10 26	+11 39	3.04	3.42	14.7	16	104
05/21	10 30	+11 14	3.19	3.43	14.9	17	95

(379) Huenna (a=3.14 AU, e=0.19, i=1.7°, H = 8.9)
Similar to Erato, Huenna is also a member of the Themis family. It ranks as the 6th brightest Themis member at H = 8.9 (Nesvorny 2015). Similar to other Themis objects, Huenna is carbonaceous (B or C type) (Neese 2010).

Huenna reached a minimum phase angle of 0.6° and peak brightness of V = 13.3 on February 28. It has a rotation period of 14.1 hours with a small amplitude of ~0.1 magnitudes (Behrend 2014, Warner 2010). Both Huenna and Erato are located within a few degrees of each other for the entire quarter providing an easy opportunity to observe two large Themis family objects during the night. Time series lightcurve and color photometry across a range of phase angles are requested. Observations of Huenna continue our request from the previous quarter.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	10 28	+09 13	2.85	3.71	14.6	9	144
04/11	10 25	+09 37	2.95	3.71	14.8	11	134
04/21	10 23	+09 52	3.07	3.72	14.9	13	123
05/01	10 23	+09 57	3.20	3.72	15.1	14	113
05/11	10 24	+09 51	3.34	3.72	15.2	15	104
05/21	10 27	+09 36	3.49	3.72	15.3	15	95

Near-Earth Asteroid Campaign Targets

(143404) 2003 BD44 (a=1.97 AU, e=0.61, i=2.7°, H = 16.8)
Little is known about 2003 BD44 other than its Apollo type orbit that takes it from 0.77 to 3.16 AU from the Sun. On March 20, it passes through opposition and reaches a very low phase angle of 0.3°. It will remain bright for a few weeks after opposition as it peaks at V = 13.3 on April 12 and passes within 0.056 AU of Earth on April 18. The asteroid finally fades below V = 17 on April 22 when it phase angle will reach over 130°. Time series lightcurve and color photometry across a range of phase angles are requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	11 31	+05 42	0.16	1.15	14.0	17	160
04/04	11 19	+08 30	0.13	1.12	13.8	24	153
04/07	11 02	+12 20	0.11	1.09	13.6	32	144
04/10	10 36	+17 47	0.09	1.07	13.4	43	133
04/13	09 54	+25 36	0.07	1.04	13.3	58	118
04/16	08 40	+35 38	0.06	1.01	13.5	80	97
04/19	06 39	+43 15	0.06	0.99	14.5	107	70
04/22	04 32	+41 55	0.06	0.96	16.7	133	45

2014 JO25 (a=2.07 AU, e=0.89, i=25.2°, H = 18.1)
2014 JO25 is another NEA of which we know little about its physical characteristics. JO25 starts the quarter interior to Earth and difficult to observe. On April 17, it blasts out of the Sun's glare and becomes visible at V = 17-18. Close approach occurs on April 19 at 0.012 AU. Peak brightness occurs on April 19/20 at V = 10.7. The close flyby results in an optimal time of observation of only a few days. Time series lightcurve and color photometry across a range of phase angles are requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/18	23 32	+36 22	0.03	0.98	17.4	140	39
04/19	22 06	+60 33	0.02	1.00	13.6	115	64
04/20	13 17	+32 34	0.02	1.02	10.7	44	135
04/21	12 35	+05 04	0.03	1.03	11.8	25	154
04/22	12 24	-03 00	0.05	1.05	12.8	24	155

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2017 APRIL-JUNE

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We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling via lightcurve inversion. We also include lists of objects that will be the target of radar observations. Lightcurves for these objects can help constrain pole solutions and/or remove rotation period ambiguities that might not come from using radar data alone.

We present several lists of asteroids that are prime targets for photometry during the period 2017 April-June.

In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB; Warner *et al.*, 2009) documentation for an explanation of the U code:

http://www.minorplanet.info/lightcurvedatabase.html

The ephemeris generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.5 during any month in the current year, *e.g.*, limiting the results by magnitude and declination.

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

We refer you to past articles, e.g., *Minor Planet Bulletin* **36**, 188, for more detailed discussions about the individual lists and points of advice regarding observations for objects in each list.

Once you've obtained and analyzed your data, it's important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It's also important to make the data available at least on a personal website or upon request. We urge you to consider submitting your raw data to the ALCDEF page on the Minor Planet Center web site:

http://www.minorplanetcenter.net/light_curve

We believe this to be the largest publicly available database of raw lightcurve data that contains 2.5 million observations for more than 11500 objects.

Now that many backyard astronomers and small colleges have access to larger telescopes, we have expanded the photometry opportunities and spin axis lists to include asteroids reaching V = 15.5 or brighter.

Lightcurve/Photometry Opportunities

Objects with U = 3– or 3 are excluded from this list since they will likely appear in the list below for shape and spin axis modeling. Those asteroids rated U = 1 should be given higher priority over those rated U = 2 or 2+, but not necessarily over those with no period. On the other hand, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
5605	Kushida	04 01.0	14.9	-5			
2881	Meiden	04 01.4	14.7	-2	3.48	0.10-0.17	2
10041	Parkinson	04 12.1	15.4	+8			
5976	Kalatajean	04 14.1	14.8	-12			
17469	1991 BT	04 17.4	15.4	-11	17.1719	0.23	2
2572	Annschnell	04 26.6	15.2	-11	6.328	0.76	2+
16405	1985 DA2	04 26.8	15.0	-27			
1581	Abanderada	04 27.9	14.5	-11			
24388	2000 AB175	05 03.0	15.5	-24			
6250	Saekohayashi	05 05.7	15.1	-17	82.6	0.78	2+
3176	Paolicchi	05 08.3	15.0	-14	20.4	0.31	2
23738	1998 JZ1	05 15.7	15.0	-22	6.2952	0.35	2
3704	Gaoshiqi	05 16.9	14.9	-19	9.7725	0.20-0.21	2+
1582	Martir	05 17.2	15.1	-8	9.84	0.31-0.36	2
1939	Loretta	05 18.0	14.4	-20	25.	0.12	1
3977	Maxine	05 21.3	14.7	-12	3.081	0.25	2+
10185	Gaudi	05 24.0	15.1	-21			
5894	Telc	06 01.3	15.2	-31	17.65	0.66	2+
4562	Poleungkuk	06 03.3	15.0	-24	9.4754	0.73	2
14309	Defoy	06 04.0	15.5	-6			
7238	Kobori	06 07.7	15.1	-21			
4371	Fyodorov	06 08.1	14.8	-25			
6383	Tokushima	06 08.4	15.5	-21			
14007	1993 TH14	06 08.7	15.5	-16			
1048	Feodosia	06 09.8	12.5	-37	10.46	0.14-0.14	2
3469	Bulgakov	06 11.4	14.8	-14	6.48	0.09	1
13593	1994 NF1	06 11.9	15.5	-18	113.7389	0.64	2
983	Gunila	06 12.8	13.5	-19	8.37	0.05-0.25	2
3109	Machin	06 12.8	14.6	-34	20.3	0.46	2
1322	Coppernicus	06 13.0	13.8	-14	3.967	0.04-0.22	2
4297	Eichhorn	06 17.4	14.7	-16			
8149	Ruff	06 17.4	14.9	-25			
18017	1999 JC124	06 19.4	15.5	-13			
3991	Basilevsky	06 19.6	14.2	-26	5.44	0.09-0.15	2
12822	1996 XD1	06 23.9	15.5	-23			
3656	Hemingway	06 26.4	14.7	-24	5.6257	0.87	2
16210	2000 CY61	06 27.2	15.5	-30	9.6329	0.89	2
3356	Resnik	06 27.7	14.4	-21	32.	0.1	2
31832	2000 AP59	06 27.7	15.2	-33	64.	0.8	2
5134	Ebilson	06 28.3	15.2	-25			
6281	Strnad	06 28.5	15.5	-46			

Low Phase Angle Opportunities

The Low Phase Angle list includes asteroids that reach very low phase angles. The "α" column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the "opposition effect." Use the on-line query form for the LCDB

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

to get more details about a specific asteroid.

You will have the best chance of success working objects with low amplitude and periods that allow covering at least half a cycle every night. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data must be reduced to the average magnitude of the asteroid for each night. This reduction requires that you determine the period and the amplitude of the lightcurve; for long period objects that can be difficult. Refer to Harris *et al.* (1989; *Icarus* **81**, 365-374) for the details of the analysis procedure.

As an aside, some use the maximum light to find the phase slope parameter (*G*). However, this can produce a significantly different value for both *H* and *G* versus when using average light, which is the method used for values listed by the Minor Planet Center.

The International Astronomical Union (IAU) has adopted a new system, H-G_{12}, introduced by Muinonen *et al.* (2010; *Icarus* **209**, 542-555). However it will be some years before it becomes the general standard and, furthermore, it is still in need of refinement. That can be done mostly through having more data for more asteroids, but only if there are data at very low and moderate phase angles. Therefore, we strongly encourage observers to obtain data for these objects not only at very low phase angles, but to follow them well before and/or after opposition, *i.e.*, out to phase angles of 15-30 degrees.

Num	Name	Date	α	V	Dec	Period	Amp	U
333	Badenia	04 01.7	0.45	14.5	-06	8.192	0.20-0.33	3-
720	Bohlinia	04 05.9	0.43	13.3	-05	8.919	0.16-0.46	3
332	Siri	04 09.9	0.31	13.5	-07	8.007	0.10-0.35	3
279	Thule	04 19.1	0.48	14.5	-09	23.896	0.02-0.10	3
459	Signe	04 19.4	0.14	14.6	-11	5.536	0.25-0.43	3
258	Tyche	04 19.5	0.26	12.6	-11	10.041	0.09-0.43	3
1704	Wachmann	04 22.5	0.70	14.7	-14	3.314	0.40	3
118	Peitho	04 27.0	0.90	12.6	-11	7.805	0.08-0.33	3
1502	Arenda	04 29.5	0.61	15.0	-13	45.8	0.4	2
1261	Legia	05 02.1	0.62	14.7	-14	8.693	0.13	2+
1167	Dubiago	05 02.2	0.12	14.3	-16	14.3	0.23	2
305	Gordonia	05 03.8	0.55	13.2	-14	12.893	0.16-0.23	3
6669	Obi	05 04.8	0.58	14.8	-15			
2847	Parvati	05 07.0	0.93	14.1	-18			
1223	Neckar	05 08.4	0.19	14.6	-18	7.81	0.16-0.45	3
1545	Thernoe	05 09.6	0.19	14.9	-17	17.20	0.76	3
248	Lameia	05 11.5	0.87	12.8	-20	11.912	0.10-0.17	3
168	Sibylla	05 12.8	0.81	12.9	-16	47.009	0.16	3
104	Klymene	05 13.9	0.22	13.2	-19	8.984	0.26-0.3	3
171	Ophelia	05 15.1	0.94	12.3	-16	6.665	0.14-0.46	3
431	Nephele	05 16.6	0.77	13.0	-17	18.821	0.03-0.30	2
1638	Ruanda	05 16.9	0.14	14.2	-19	4.2397	0.06-0.10	3
3704	Gaoshiqi	05 16.9	0.19	15.0	-19	9.773	0.20-0.21	2+
1939	Loretta	05 17.9	0.16	14.5	-20	25.	0.12	1
534	Nassovia	05 18.0	0.98	13.9	-17	9.382	0.15-0.37	3
726	Joella	05 18.0	0.82	14.1	-22	13.04	0.12	3
4077	Asuka	05 23.4	0.90	15.0	-18	7.919	0.40	3-
1292	Luce	05 24.1	0.68	14.4	-22	6.954	0.12-0.26	3
1423	Jose	05 25.3	0.18	14.8	-21	12.307	0.68-0.85	3
27	Euterpe	05 25.7	0.49	10.4	-20	10.408	0.13-0.21	3
1319	Disa	05 27.2	0.36	13.4	-22	7.080	0.26-0.27	3
86	Semele	05 27.7	0.63	13.5	-19	16.634	0.09-0.18	3
116	Sirona	05 28.2	0.17	11.2	-22	12.028	0.42-0.55	3
394	Arduina	05 29.6	0.18	12.8	-22	16.53	0.28-0.54	3
596	Scheila	05 30.6	0.32	11.7	-21	15.848	0.06-0.10	3
263	Dresda	06 01.9	0.39	14.2	-21	16.809	0.32-0.55	3
1666	van Gent	06 02.5	0.50	14.6	-23	4.165	0.23-0.42	3
363	Padua	06 03.2	0.47	12.6	-24	8.401	0.14	3
1765	Wrubel	06 04.8	0.76	13.9	-25	5.260	0.33	3
1589	Fanatica	06 07.2	0.85	15.0	-21	2.58	0.16-0.18	3
1010	Marlene	06 07.4	0.73	14.7	-21	31.06	0.17-0.32	2+
4371	Fyodorov	06 08.2	0.91	14.9	-25			
481	Emita	06 08.7	0.93	13.1	-26	14.35	0.09-0.30	2
321	Florentina	06 12.8	0.87	14.0	-26	2.871	0.31-0.52	3
2571	Geisei	06 14.2	0.73	14.9	-25	7.823	0.50	3-
8149	Ruff	06 17.5	0.61	15.0	-25			
1123	Shapleya	06 17.9	0.55	14.4	-25	52.92	0.38	3-
12447	Yatescup	06 21.7	0.55	14.8	-24			
1078	Mentha	06 22.1	0.30	14.6	-23	85.	0.87	3
691	Lehigh	06 22.2	0.31	13.4	-24	12.891	0.12-0.16	2+
40	Harmonia	06 23.4	0.23	9.3	-23	8.910	0.13-0.36	3
4942	Munroe	06 24.8	0.40	14.8	-24			
832	Karin	06 26.1	0.19	14.9	-23	18.348	0.30-0.65	3
767	Bondia	06 27.2	0.38	13.8	-24			
539	Pamina	06 27.6	0.19	13.3	-23	13.903	0.10-0.22	3
76	Freia	06 28.2	0.69	13.4	-21	9.973	0.05-0.33	3
5134	Ebilson	06 28.3	0.55	15.3	-25			
1784	Benguella	06 29.1	0.08	14.0	-23			
10	Hygiea	06 29.8	0.21	9.1	-24	27.630	0.09-0.33	3

Shape/Spin Modeling Opportunities

Those doing work for modeling should contact Josef Ďurech at the email address above. If looking to add lightcurves for objects with existing models, visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site

http://astro.troja.mff.cuni.cz/projects/asteroids3D

An additional dense lightcurve, along with sparse data, could lead to the asteroid being added to or improving one in DAMIT, thus increasing the total number of asteroids with spin axis and shape models.

Included in the list below are objects that:

1. Are rated U = 3– or 3 in the LCDB
2. Do not have reported pole in the LCDB Summary table
3. Have at least three entries in the Details table of the LCDB where the lightcurve is rated U ≥ 2.

The caveat for condition #3 is that no check was made to see if the lightcurves are from the same apparition or if the phase angle bisector longitudes differ significantly from the upcoming apparition. The last check is often not possible because the LCDB does not list the approximate date of observations for all details records. Including that information is an on-going project.

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
1967	Menzel	04 03.0	15.2	-1	2.835	0.24-0.39	3
773	Irmintraud	04 04.9	13.3	-24	6.7514	0.09-0.15	3
1186	Turnera	04 05.0	13.8	+1	12.085	0.25-0.34	3
294	Felicia	04 05.9	15.0	+1	10.4227	0.19-0.35	3
888	Parysatis	04 07.0	14.0	+11	5.9314	0.22-0.26	3
1388	Aphrodite	04 07.1	15.3	+3	11.9432	0.34-0.65	3
6867	Kuwano	04 07.3	15.2	+0	7.367	0.52-0.70	3
3447	Burckhalter	04 08.0	14.2	-21	59.8	0.30-0.39	3
332	Siri	04 09.9	13.4	-7	8.0074	0.10-0.35	3
1016	Anitra	04 15.2	14.8	-13	5.9295	0.27-0.50	3
1864	***Daedalus***	***04 17.1***	***15.0***	***-24***	***8.572***	***0.85-1.04***	***3***
459	Signe	04 19.3	14.6	-11	5.5362	0.25-0.54	3
3115	Baily	04 19.6	15.0	-22	16.012	0.08-0.17	3-
458	Hercynia	04 23.2	15.0	+3	21.806	0.10-0.36	3
592	Bathseba	04 24.9	14.3	-3	7.7465	0.22-0.32	3
118	Peitho	04 26.9	12.6	-11	7.8055	0.08-0.33	3
1011	Laodamia	04 27.9	15.1	-5	5.1725	0.41-0.45	3
483	Seppina	04 29.5	13.5	+3	12.727	0.14-0.29	3
611	Valeria	04 30.0	13.8	-5	6.977	0.08-0.16	3
901	Brunsia	05 01.9	14.0	-19	3.1363	0.09-0.28	3
305	Gordonia	05 03.7	13.2	-14	12.893	0.16-0.23	3
939	Isberga	05 04.3	14.8	-20	2.9173	0.20-0.25	3
2105	Gudy	05 08.8	15.5	-49	15.795	0.18-0.52	3-
131	**Vala**	**05 10.6**	**12.5**	**-15**	**5.1812**	**0.09-0.32**	**3**
715	Transvaalia	05 10.9	13.7	-19	11.83	0.19-0.32	3
4786	**Tatianina**	**05 13.1**	**15.0**	**-5**	**2.9227**	**0.19-0.25**	**3**
1129	Neujmina	05 13.3	14.8	-26	5.0844	0.06-0.20	3
598	Octavia	05 15.0	14.3	-8	10.8903	0.28-0.28	3
563	Suleika	05 15.9	13.2	-12	5.69	0.13-0.28	3
633	Zelima	05 17.1	14.2	-3	11.73	0.14-0.53	3
522	Helga	05 17.8	14.2	-14	8.129	0.13-0.31	3

Num	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
1225	Ariane	05 19.8	14.6	-24	5.5068	0.30-0.36	3
374	**Burgundia**	**05 22.9**	**11.9**	**-15**	**6.972**	**0.05-0.18**	**3**
1292	Luce	05 24.1	14.3	-22	6.9541	0.17-0.26	3
1069	Planckia	05 24.6	13.7	-1	8.665	0.14-0.42	3
2004	Lexell	05 29.5	15.4	-26	5.4429	0.42-0.51	3
81	Terpsichore	05 30.9	13.4	-32	10.943	0.06-0.10	3
1536	Pielinen	06 03.6	15.2	-20	66.22	0.75-0.85	3
481	Emita	06 08.8	13.1	-26	14.412	0.09-0.30	3
6384	**Kervin**	**06 09.9**	**15.1**	**-26**	**3.6203**	**0.06-0.16**	**3**
6009	**Yuzuruyoshii**	**06 11.0**	**15.4**	**+9**	**3.0302**	**0.10-0.15**	**3**
477	Italia	06 12.5	12.7	-32	19.413	0.15-0.32	3
1830	Pogson	06 12.8	15.1	-17	2.57	0.10-0.18	3
619	Triberga	06 16.7	13.5	-1	29.311	0.30-0.45	3
1123	Shapleya	06 18.0	14.4	-25	52.92	0.38	3-
815	Coppelia	06 18.8	14.7	-35	4.421	0.17-0.24	3
5806	Archieroy	06 20.8	15.2	-47	12.163	0.34-0.47	3
911	Agamemnon	06 22.3	15.3	-48	6.592	0.04-0.29	3
4106	Nada	06 25.1	14.8	-36	5.832	0.48-0.71	3
101	Helena	06 26.9	11.3	-40	23.08	0.09-0.13	3
1523	Pieksamaki	06 27.5	15.1	-30	5.3202	0.28- 0.5	3
2151	Hadwiger	06 28.4	14.9	-46	5.872	0.07-0.38	3
368	Haidea	06 30.7	13.3	-13	9.823	0.15-0.23	3

Radar-Optical Opportunities

There are several resources to help plan observations in support of radar.

Future radar targets:
http://echo.jpl.nasa.gov/~lance/future.radar.nea.periods.html

Past radar targets:
http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html

Arecibo targets:
http://www.naic.edu/~pradar/sched.shtml
http://www.naic.edu/~pradar

Goldstone targets:
http://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html

However, these are based on *known* targets at the time the list was prepared. It is very common for newly discovered objects to move up the list and become radar targets on short notice. We recommend that you keep up with the latest discoveries the Minor Planet Center observing tools

In particular, monitor NEAs and be flexible with your observing program. In some cases, you may have only 1-3 days when the asteroid is within reach of your equipment. Be sure to keep in touch with the radar team (through Dr. Benner's email listed above) if you get data. The team may not always be observing the target but your initial results may change their plans. In all cases, your efforts are greatly appreciated.

Use the ephemerides below as a guide to your best chances for observing, but remember that photometry may be possible before and/or after the ephemerides given below. Note that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

MPC: *http://www.minorplanetcenter.net/iau/MPEph/MPEph.html*
JPL: *http://ssd.jpl.nasa.gov/?horizons*

In the ephemerides below, ED and SD are, respectively, the Earth and Sun distances (AU), V is the estimated Johnson V magnitude, and α is the phase angle. SE and ME are the great circles distances (in degrees) of the Sun and Moon from the asteroid. MP is the lunar phase and GB is the galactic latitude. "PHA" indicates that the object is a "potentially hazardous asteroid", meaning that at some (long distant) time, its orbit might take it very close to Earth.

About YORP Acceleration

Many, if not all, of the targets in this section are near-Earth asteroids. These objects are particularly sensitive to YORP acceleration. YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) is the asymmetric thermal re-radiation of sunlight that can cause an asteroid's rotation period to increase or decrease. High precision lightcurves at multiple apparitions can be used to model the asteroid's *sidereal* rotation period and see if it's changing.

It usually takes four apparitions to have sufficient data to determine if the asteroid rotation rate is changing under the influence of YORP. So, while obtaining a lightcurve at the current apparition may not result in immediately seeing a change, the data are still critical in reaching a final determination. This is why observing asteroids that already have well-known periods can still be a valuable use of telescope time. It is even more so when considering BYORP (binary-YORP) among binary asteroids where that effect has stabilized the spin so that acceleration of the primary body is not the same as if it would be if there were no satellite.

Name	Grp	Period	App	Last	Bin	R SNR
2000 HA24	NEA	-	-	-	-	**42 G**
2003 HF2	NEA	-	-	-	-	**3400 A**
2002 VU94	NEA	7.89	1*	2014	-	**110 A**
2003 BD44	NEA	-	-	-	-	**46 A**
2014 JO25	NEA	-	-	-	-	**33000 A** **1880 G**
2016 JP	NEA	-	-	-	-	**36 A**
1999 KW4	NEA	2.765	2	2001	Y	**47 A**
2005 UP156	NEA	40.5	1	2014	-	**656 A** **37 G**
2007 LE	NEA	2.603	1	2012	Y	**201 A**
Jason	NEA	51.7#	1	2013	-	**305 A** **187 G**
2007 WV4	NEA	-	-	-	-	**1460 A** **831 G**
2010 VB1	NEA	-	-	-	-	**1030 A** **58 G**
2010 NY65	NEA	4.979	1	2016	-	**3660 A** **208 G**

Table I. Summary of radar-optical opportunities in 2017 Apr-Jun. Data from the asteroid lightcurve database (Warner *et al.,* 2009; *Icarus* **202**, 134-146). * Observed twice during same apparition. # Tumbler; second period about 238 h.

To help focus efforts in YORP detection, Table I gives a quick summary of this quarter's radar-optical targets. The Grp column gives the family or group for the asteroid. The period is in hours and, in the case of binary, for the primary. The App columns gives the number of different apparitions at which a lightcurve period was reported while the Last column gives the year for the last reported period. The Bin column is 'Y' if the asteroid has one or more satellites (a '?' indicates a suspected binary). The last column indicates the estimated radar SNR using the tool at

http://www.naic.edu/~eriverav/scripts/radarscript.php

The estimate in Table I is based on using the Arecibo (A) or Goldstone (G) radar. Goldstone is the default if a close approach is outside the declination range of Arecibo. The estimate uses the current MPCORB absolute magnitude (*H*), a period of 3.0 hours if it's not known, and the approximate minimum Earth distance during the three-month period covered by this paper.

If the SNR value is in bold text, the object was found on the radar planning pages listed above. Otherwise, the search tool at

http://www.minorplanet.info/PHP/call_OppLCDBQuery.php

was used to find known NEAs that were V < 18.0 during the quarter. An object was placed on the list only if the estimated radar SNR > 10. This would produce a very marginal signal, not enough for imaging, but might allow improving orbital parameters.

(138404) 2000 HA24 (Mar-Apr, *H* = 19.1)

The rotation period for 2000 HA24, a 500-meter NEA, is apparently unknown. Late March and later will be the better time to observe the asteroid. It will still be relatively bright and farther away from the galactic plane.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/15	16 56.7	-47 10	0.07	1.00	16.1	80.5	96	61	-0.94	-2
03/20	15 30.7	-44 04	0.08	1.03	15.7	60.9	115	36	-0.56	+10
03/25	14 30.3	-38 53	0.09	1.06	15.6	44.6	132	96	-0.12	+20
03/30	13 50.0	-33 34	0.10	1.08	15.7	31.7	145	155	+0.05	+28
04/04	13 23.0	-28 52	0.12	1.11	15.8	21.8	156	101	+0.53	+34
04/09	13 04.6	-24 57	0.14	1.14	16.0	15.4	162	36	+0.95	+38
04/14	12 52.0	-21 45	0.16	1.16	16.3	13.1	165	39	-0.93	+41
04/19	12 43.5	-19 11	0.19	1.19	16.7	14.7	163	97	-0.54	+44
04/24	12 38.1	-17 08	0.22	1.21	17.1	17.9	158	159	-0.09	+46
04/29	12 35.2	-15 31	0.25	1.23	17.6	21.4	153	118	+0.09	+47

(215588) 2003 HF2 (Mar-Apr, *H* = 19.4)

This NEA has an estimated diameter of 390 meters, so its rotation period is very likely more than 2 hours. The first few days of April will provide the best opportunity to find a rotation period. Because of the large phase angle, be careful about assuming a bimodal shape for the lightcurve, even if the amplitude exceeds 0.5 mag. The sky motion will be about 22 arcsec/min on April 1, but by April 8, it will be down to 5 arcsec/min.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/30	06 41.7	+19 09	0.05	1.00	15.7	86.7	91	65	+0.05	+7
03/31	07 40.8	+18 40	0.05	1.01	15.6	73.6	104	64	+0.12	+19
04/01	08 25.1	+17 32	0.06	1.02	15.6	63.8	113	60	+0.20	+28
04/02	08 57.3	+16 18	0.07	1.04	15.7	56.7	120	53	+0.30	+35
04/03	09 21.0	+15 11	0.08	1.05	15.9	51.6	125	45	+0.42	+40
04/04	09 38.8	+14 14	0.09	1.06	16.1	47.9	128	35	+0.53	+43
04/05	09 52.6	+13 26	0.10	1.07	16.4	45.2	131	25	+0.64	+46
04/06	10 03.6	+12 46	0.12	1.08	16.6	43.1	132	14	+0.74	+48
04/07	10 12.4	+12 11	0.13	1.09	16.8	41.6	134	3	+0.83	+50
04/08	10 19.8	+11 42	0.14	1.10	17.0	40.3	134	8	+0.90	+51

(90075) 2002 VU94 (Mar-Apr, *H* = 15.2, PHA)

A period of about 7.89 h was found for this NEA during the 2014 apparition (Warner, 2015). At that time, the lightcurve showed a strong dependency on phase angle, being almost twice as large at 40° than at 4°. The observing window is short this time around because of interference from the moon and decreasing solar elongation. However, there are additional opportunities starting in August, when the sky motion will be only 1.3 arcsec/min.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/25	09 20.2	-08 03	0.44	1.35	15.4	30.9	136	158	-0.12	+28
03/26	09 18.4	-07 46	0.44	1.34	15.4	31.9	135	154	-0.06	+28
03/27	09 16.7	-07 29	0.44	1.34	15.4	32.9	133	144	-0.02	+28
03/28	09 15.0	-07 11	0.43	1.33	15.4	33.9	132	132	+0.00	+27
03/29	09 13.3	-06 53	0.43	1.32	15.4	34.9	131	118	+0.01	+27
03/30	09 11.7	-06 35	0.42	1.31	15.4	36.0	130	104	+0.05	+27
03/31	09 10.1	-06 16	0.42	1.30	15.4	37.0	128	90	+0.12	+27
04/01	09 08.5	-05 57	0.42	1.29	15.4	38.0	127	76	+0.20	+27
04/02	09 07.0	-05 37	0.41	1.29	15.4	39.1	126	62	+0.30	+27

(143404) 2003 BD44 (Mar-Apr, *H* = 16.8, PHA)

The rotation period for this NEA is not known. The estimated size is 1.3 km, so a rotation period of less than ~2 hours is not likely. The radar team is interested in lightcurves and photometric characterization, *e.g.*, albedo or taxonomic class, of the asteroid. 2003 BD44 makes a "comeback" in October (though about five magnitudes fainter), so keep it on the observing list.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/15	12 04.3	-01 34	0.31	1.31	15.3	5.6	173	21	-0.94	+59
03/19	11 59.9	-00 36	0.27	1.27	14.7	1.5	178	70	-0.65	+60
03/21	11 57.2	-00 00	0.25	1.25	14.4	0.8	179	95	-0.47	+60
03/23	11 54.0	+00 42	0.24	1.23	14.4	3.2	176	120	-0.28	+60
03/25	11 50.3	+01 31	0.22	1.21	14.4	5.9	173	147	-0.12	+60
03/27	11 46.0	+02 29	0.20	1.19	14.3	8.8	170	176	-0.02	+61
03/29	11 41.0	+03 36	0.18	1.18	14.2	11.9	166	154	+0.01	+61
03/31	11 35.1	+04 57	0.16	1.16	14.1	15.5	162	123	+0.12	+61
04/02	11 28.0	+06 33	0.15	1.14	13.9	19.5	158	91	+0.30	+61
04/04	11 19.3	+08 31	0.13	1.12	13.8	24.0	153	60	+0.53	+61

2014 JO25 (Apr, *H* = 18.1, PHA)

The radar team is hoping to do high-res imaging of this 700-m NEA. They are looking for optical astrometry in the days and weeks prior to their runs in mid-April as well as lightcurves and photometric classification. The MPC ephemeris page gives a sky motion of 143 arcsec/min on April 20, but it is down to a slothful 1 arcsec/min by moth's end.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	13 16.5	+32 47	0.02	1.02	10.7	44.3	135	115	-0.44	+82
04/21	12 35.0	+05 07	0.03	1.03	11.8	25.3	154	132	-0.34	+68
04/22	12 24.5	-03 00	0.05	1.05	12.8	23.8	155	145	-0.25	+59
04/23	12 19.8	-06 39	0.07	1.07	13.6	24.3	154	158	-0.16	+55
04/24	12 17.2	-08 43	0.09	1.08	14.1	24.9	153	168	-0.09	+53
04/25	12 15.6	-10 03	0.11	1.10	14.6	25.5	152	167	-0.03	+52
04/26	12 14.5	-10 58	0.13	1.12	15.0	26.0	151	155	+0.00	+51
04/27	12 13.7	-11 39	0.15	1.14	15.4	26.5	150	141	+0.01	+50
04/28	12 13.2	-12 10	0.17	1.15	15.7	26.9	149	127	+0.04	+50
04/29	12 12.9	-12 35	0.19	1.17	16.0	27.3	148	113	+0.09	+49

2016 JP (Apr, *H* = 21.2, PHA)

The observing window for this 170-meter NEA is very short. Given the size, a super-fast period is not out of the question. Keep exposures as short as possible until you can establish a likely period. The sky motion will start at about 15 arcsec/min and decrease to about 10 arcsec/min during the ephemeris interval. Both optical astrometry and photometry (lightcurve) would be appreciated by the radar team.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/26	08 55.4	+46 45	0.07	1.01	18.6	88.7	87	95	+0.00	+40
04/27	09 29.1	+46 15	0.07	1.01	18.5	83.8	92	88	+0.01	+46
04/28	09 58.8	+45 15	0.08	1.02	18.5	79.3	96	81	+0.04	+51
04/29	10 24.4	+43 59	0.08	1.02	18.5	75.4	100	73	+0.09	+56
04/30	10 46.1	+42 33	0.09	1.03	18.5	71.9	103	65	+0.18	+60
05/01	11 04.6	+41 04	0.09	1.04	18.6	68.9	106	57	+0.27	+64
05/02	11 20.2	+39 36	0.10	1.04	18.6	66.2	109	49	+0.38	+67
05/03	11 33.6	+38 11	0.11	1.05	18.7	63.9	111	42	+0.49	+70

(66391) 1999 KW4 (May, *H* = 16.5)

Based on observations in 2000 and 2001, Pravec *et al.* (2006) found this NEA to be a binary with an orbital period for the satellite of 17.45 h. The primary has a period of 2.765 h. The amplitude of the primary lightcurve may be on the order of 0.10-0.15 mag, but assume nothing. Given the orbital period, a campaign involving several observers over a wide range of longitudes will provide the best solution in the shortest amount of time. Mid-May to early June is the only time to catch 1999 KW4.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/18	21 09.8	-00 51	0.23	1.06	15.9	70.7	97	14	-0.60	-31
05/19	21 05.3	+01 03	0.22	1.07	15.8	69.8	98	19	-0.50	-29
05/20	21 00.5	+03 04	0.21	1.07	15.7	68.9	100	30	-0.40	-27
05/21	20 55.3	+05 12	0.21	1.07	15.6	68.0	101	43	-0.30	-24
05/22	20 49.7	+07 29	0.20	1.07	15.5	67.1	102	56	-0.20	-22
05/23	20 43.7	+09 53	0.19	1.07	15.4	66.2	104	71	-0.12	-20
05/24	20 37.1	+12 25	0.19	1.08	15.3	65.3	105	85	-0.05	-17
05/25	20 30.0	+15 04	0.18	1.08	15.3	64.5	106	99	-0.01	-14
05/26	20 22.2	+17 50	0.18	1.08	15.2	63.7	107	112	+0.00	-11
05/27	20 13.8	+20 42	0.18	1.08	15.1	63.0	108	124	+0.02	-8
05/28	20 04.7	+23 38	0.17	1.08	15.1	62.3	109	132	+0.07	-4
05/29	19 54.8	+26 37	0.17	1.08	15.0	61.8	110	134	+0.15	-1
05/30	19 44.0	+29 37	0.17	1.08	15.0	61.4	110	132	+0.24	+3
05/31	19 32.4	+32 35	0.17	1.08	15.0	61.2	110	125	+0.34	+6
06/01	19 19.8	+35 28	0.17	1.08	15.0	61.1	111	116	+0.45	+10

(190166) 2005 UP156 (May, *H* = 17.1)

Warner (2015) found a period of 40.5 h for this 1.1 km NEA. There is a chance it could be tumbling, so try to follow it for as long as possible, maybe with a collaborator at a different longitude, and get high-quality data with consistent night-to-night zero points. The radar team is looking for optical photometry and characterization. Opportunities for observations continue every month through about October, though July may not good because the asteroid will be at very low galactic latitudes.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/20	15 50.7	-04 04	0.24	1.24	15.2	12.9	164	104	-0.40	+37
05/22	15 52.6	-03 13	0.23	1.23	15.2	14.0	163	130	-0.20	+37
05/24	15 54.7	-02 20	0.22	1.23	15.1	15.2	162	157	-0.05	+37
05/26	15 56.9	-01 27	0.22	1.22	15.1	16.5	160	163	+0.00	+37
05/28	15 59.4	-00 32	0.21	1.21	15.0	17.8	159	138	+0.07	+37
05/30	16 02.0	+00 23	0.20	1.20	15.0	19.2	157	110	+0.24	+37
06/01	16 04.9	+01 19	0.19	1.19	15.0	20.6	156	85	+0.45	+37
06/03	16 08.1	+02 16	0.19	1.19	14.9	22.0	154	61	+0.65	+37

2007 LE (May-Jun, *H* = 19.7, PHA)

This is another binary NEA (Hicks *et al.*, 2012; Brozovic *et al.*, 2012). The primary period is 2.60 h. The orbital period is not well-known. Hicks *et al*. found 33 hours while Brozvic *et al.*, using radar, estimated the period as 13 h. Be prepared for anything in – or outside – that range. Optical photometry and characterization are on the radar team's wish list.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/24	21 00.5	+30 50	0.10	1.02	17.6	82.4	92	78	-0.05	-10
05/26	20 49.3	+19 48	0.09	1.03	17.1	74.5	101	106	+0.00	-15
05/28	20 37.5	+06 29	0.08	1.05	16.7	64.9	111	140	+0.07	-20
05/30	20 25.1	-08 03	0.08	1.06	16.4	54.9	121	171	+0.24	-24
06/01	20 12.0	-21 57	0.09	1.07	16.3	46.4	130	146	+0.45	-27
06/03	19 58.3	-33 47	0.10	1.09	16.4	40.5	136	115	+0.65	-28
06/05	19 44.0	-43 05	0.11	1.10	16.6	37.3	139	87	+0.82	-27
06/07	19 29.3	-50 08	0.12	1.11	16.9	35.8	140	64	+0.94	-26
06/09	19 14.3	-55 25	0.14	1.13	17.2	35.3	140	47	+1.00	-25
06/11	18 59.2	-59 22	0.16	1.14	17.4	35.3	139	40	-0.98	-24
06/13	18 44.2	-62 21	0.18	1.16	17.7	35.5	139	47	-0.89	-23
06/15	18 29.6	-64 35	0.20	1.17	18.0	35.7	138	61	-0.75	-22

6063 Jason (Jun, *H* = 15.9)

The radar team, which is planning on high-res imaging, will be looking for optical photometry and characterization support for this 2-km NEA. Warner (2014) found a rotation period of about 52 hours, but since the asteroid is very likely a tumbler (non-principal axis rotation), a secondary period is very possible. One suggested during the 2013 apparition was about 233 hours. High-quality data with well-established zero points will be required. An additional opportunity to observe Jason comes in late July.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/15	15 34.6	+03 27	0.29	1.25	15.0	31.1	141	94	-0.75	+44
06/17	15 37.8	+01 32	0.31	1.28	15.2	30.1	141	117	-0.55	+43
06/19	15 40.6	-00 06	0.34	1.30	15.4	29.5	141	142	-0.34	+41
06/21	15 43.1	-01 31	0.37	1.33	15.6	29.1	141	165	-0.14	+40
06/23	15 45.5	-02 45	0.40	1.35	15.9	28.8	140	156	-0.02	+39
06/25	15 47.7	-03 51	0.43	1.38	16.0	28.7	139	129	+0.01	+37
06/27	15 49.8	-04 49	0.47	1.40	16.2	28.6	139	101	+0.12	+36
06/29	15 51.8	-05 42	0.50	1.43	16.4	28.6	138	74	+0.30	+35

(418094) 2007 WV4 (Jun, *H* = 19.3, PHA)

The rotation period for this 400 meter NEA is not known, so the radar team will appreciate optical photometry. The sky motion on June 4 will be about 25 arcsec/min, but it quickly drops to only 2 arcsec/min by the end of the ephemeris interval.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/04	14 07.4	+65 46	0.04	1.01	15.5	91.0	87	69	+0.74	+50
06/05	15 00.2	+60 34	0.05	1.02	15.8	83.2	94	68	+0.82	+50
06/06	15 24.5	+56 53	0.06	1.03	16.1	78.3	98	67	+0.89	+50
06/07	15 38.2	+54 16	0.08	1.03	16.4	74.8	101	67	+0.94	+49
06/08	15 47.0	+52 21	0.09	1.04	16.7	72.2	103	68	+0.98	+49
06/09	15 53.0	+50 53	0.10	1.05	16.9	70.2	104	69	+1.00	+48
06/10	15 57.5	+49 43	0.12	1.05	17.1	68.5	105	72	-1.00	+48
06/11	16 00.9	+48 47	0.13	1.06	17.3	67.1	106	75	-0.98	+48
06/12	16 03.6	+48 00	0.14	1.07	17.5	65.9	107	80	-0.94	+47

2010 VB1 (Jun, *H* = 23.2, NHATS)

There is no known rotation period for 2010 VB1, an NEA with an estimated diameter of only 70 meters. This will likely be a super-fast rotator, so, here again, keep exposures as short as possible until there is some indication of the rotation period. The sky motion also requires short exposures, ranging from 25 down to 11 arcsec/min during the ephemeris interval. Optical photometry and characterization support will be appreciated.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/15	12 43.4	+43 32	0.03	1.01	18.7	92.5	86	132	-0.75	+74
06/16	13 27.9	+37 37	0.03	1.02	18.2	83.0	96	133	-0.65	+77
06/17	14 05.9	+30 42	0.03	1.02	17.9	73.3	105	135	-0.55	+73
06/18	14 37.2	+23 33	0.03	1.03	17.7	64.1	114	140	-0.44	+66
06/19	15 02.5	+16 48	0.03	1.03	17.6	55.9	123	146	-0.34	+58
06/20	15 22.9	+10 48	0.03	1.04	17.6	49.0	130	153	-0.23	+51
06/21	15 39.6	+05 40	0.03	1.04	17.7	43.2	135	160	-0.14	+45
06/22	15 53.3	+01 21	0.04	1.05	17.8	38.6	140	163	-0.07	+39
06/23	16 04.7	-02 15	0.04	1.05	17.9	34.9	144	159	-0.02	+35
06/24	16 14.4	-05 16	0.05	1.06	18.0	32.0	147	150	+0.00	+31

(441987) 2010 NY65 (Jun-Jul, *H* = 21.5, PHA, YORP)

Warner (2016) found a period of 4.979 h for this 150-meter NEA. The radar team, in addition to looking for optical photometry and characterization support, will be trying to do high-res imaging. The sky motion will start at 36 arcsec/min and end at 5 arcsec/min during the ephemeris interval. Those with larger telescopes might be able to get some additional data points after the full moon around July 9.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/26	14 32.4	+49 10	0.02	1.02	16.5	86.8	92	80	+0.05	+61
06/27	15 25.9	+40 42	0.03	1.02	16.4	74.5	104	83	+0.12	+56
06/28	15 55.4	+34 00	0.03	1.03	16.5	65.9	112	81	+0.20	+50
06/29	16 13.6	+29 01	0.04	1.04	16.7	59.9	118	76	+0.30	+46
06/30	16 25.8	+25 16	0.05	1.04	16.9	55.6	122	69	+0.40	+42
07/01	16 34.5	+22 24	0.05	1.05	17.2	52.4	125	62	+0.50	+40
07/02	16 41.1	+20 09	0.06	1.05	17.4	49.9	127	54	+0.60	+37
07/03	16 46.3	+18 19	0.07	1.06	17.6	48.1	129	46	+0.69	+36

IN THIS ISSUE

This list gives those asteroids in this issue for which physical observations (excluding astrometric only) were made. This includes lightcurves, color index, and H-G determinations, etc. In some cases, no specific results are reported due to a lack of or poor quality data. The page number is for the first page of the paper mentioning the asteroid. EP is the "go to page" value in the electronic version.

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The deadline for the next issue (44-3) is April 15, 2017. The deadline for issue 44-4 is July 15, 2017.