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763 CUPIDO: A TUMBLING ASTEROID

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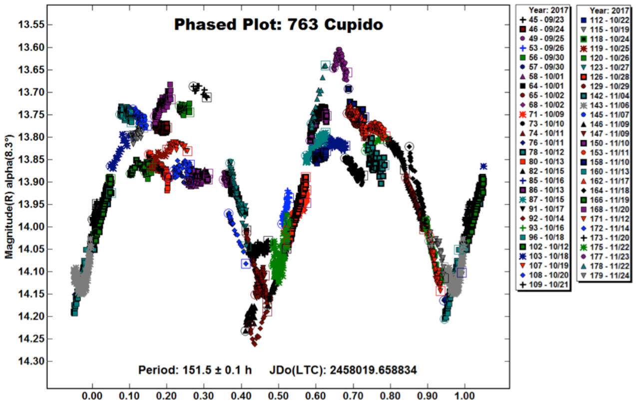
We find that 763 Cupido is a tumbling asteroid with a principal period near 151.5 h, amplitude 0.45 ± 0.10 mag. The second period is too close to being commensurate with the principal period to be reliably found. Possible periods may be near 101 hours (2/3 of the principal period), or 121 hours (4/5 of the principal period).



The only previously published period of 763 Cupido is a very uncertain 14.88 h with amplitude 0.03 mag (Behrend, 2005). Pilcher initiated a more comprehensive investigation on 2017 Sep 23. By mid-October, a principal period near 152 hours with large discordances suggesting tumbling behavior became apparent. Pilcher then invited Benishek, Klinglesmith, and Odden et al. to collaborate. Petr Pravec (personal communication) used simultaneous dual period software to confirm tumbling, but the second tumbling period was close to being commensurate with 152 hours and could not be found reliably. We continued observations until 2017 Nov 24, at which time a total of 10526 data points had been acquired in 57 sessions. Pravec (personal communication) used the simultaneous dual period software with the expanded data set. A principal period near 151 h with tumbling was confirmed, PAR = –2 (Pravec et al., 2005), Due to the previously mentioned commensurability, the second tumbling period still could not be obtained reliably, with possible periods near 101 h (2/3 of principal period) or near 121 h (4/5 of principal period). We present a single period lightcurve plotted by *MPO Canopus* that provides a best fit to 151.5 h with amplitude 0.45 ± 0.10 mag. The lightcurve was plotted with target magnitudes calibrated from R band magnitudes of solar-colored stars on the Carlsbad Meridian Catalog 15 (CMC15) with no adjustments. Star magnitudes in the CMC15 catalog are usually consistent across the sky within 0.05 magnitudes. Occasional larger discrepancies occur. Still further magnitude discordances may arise from differences in the optical paths and CCD sensors of the several contributing observatories. It is not possible to determine to what extent magnitude discrepancies on the lightcurve are due to these instrumental and calibration effects and which are caused by different presented target cross sections at different phases of the tumbling cycle. On this lightcurve, the large data set has been binned in subsets of 3 data points with a maximum time difference between each point of 5 minutes.

Number	Name	2017/mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
763	Cupido	09/23-11/24	10526	8.3,4.7,26.0	13	6	151.5	0.1	0.45	0.10

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).

Acknowledgments

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Editor’s Note: The broad collaboration and cooperation of this observer team, bringing forth such an interesting result, is a cause for celebration. Bravo !

LIGHTCURVE ANALYSIS FOR SEVEN MAIN-BELT ASTEROIDS

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Synodic rotation periods were determined for seven main-belt asteroids: 763 Cupido, 151.1 ± 0.1 h; 882 Swetlana, 29.867 ± 0.009 h; 916 America, 37.294 ± 0.013 h; 920 Rogeria, 12.244 ± 0.003 h; 1182 Ilona, 29.8553 ± 0.0023 h; 1283 Komsomolia, 32.175 ± 0.005 h; and 1639 Bower, 22.181 ± 0.003 h. All the data have submitted to the ALCDEF database.

CCD photometric observations of seven main-belt asteroids having long periods were performed at Command Module Observatory (MPC V02) in Tempe. Images at V02 were taken using a 0.32-m *f*/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a ‘clear’ glass filter. Exposure times for all the images were 2 minutes. The image scale after 2x2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results.

Images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2017). The 45x30 arcmin field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B\text{-}V < 0.95$ to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. The *MPO Canopus* internal star catalogue was useful in selecting comp stars of suitable color and brightness.

Comp star magnitudes were derived from a combination of CMC15 (Muiñoz et al. 2014), APASS DR9 (Munari et al. 2015), and GAIA1 G (Sloan $r' = G + 0.066$ for stars of asteroidal color) catalogues to set the zero-points each night. In most regions the Sloan r′ data sources for brighter stars yielded very similar magnitudes (within about 0.05 mag total range), so mean values rounded to 0.01 mag precision were used.

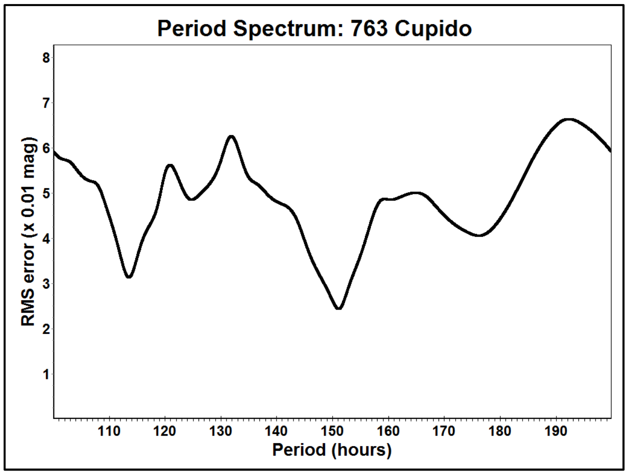
This careful adjustment of the comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required, or shifts of only a few hundredths of a magnitude in a series.

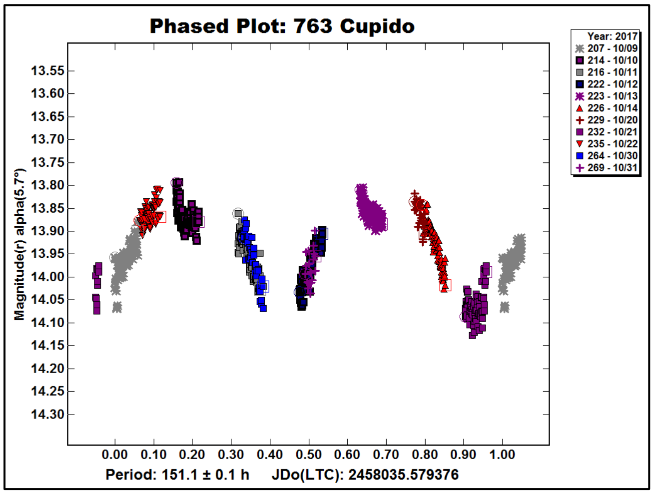
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comp stars, the asteroid itself, and the actual period-fit. Period determination was done using the *MPO Canopus* Fourier-type FALC fitting method (cf. Harris et al., 1989).

The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All of the new data for these seven asteroids may be found in the ALCDEF (*http://alcdef.org*) database.

<u>763 Cupido</u> is a Flora-family asteroid that was discovered in 1917 by Franz Kaiser at Heidelberg. The only reported period is that of Behrend (2005), who computed 14.88 h based on limited observations. Using an exhaustive data set, Pilcher et al. (2018, this issue) found a period of 151.5 h, with tumbling confirmed.

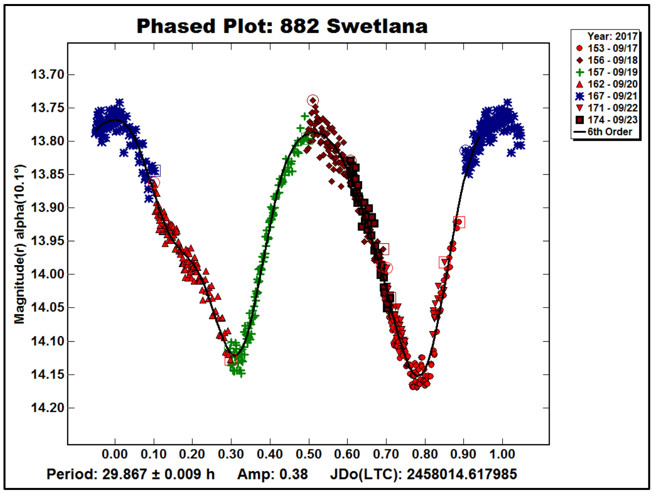
A total of 717 observations on 11 nights were obtained. A period spectrum between 100 h and 200 h revealed a solution at 151.1 ± 0.1 h, in good agreement with the result of Pilcher et al. The amplitude is 0.24 ± 0.02 mag and the RMS error on the fit is 0.024 mag.





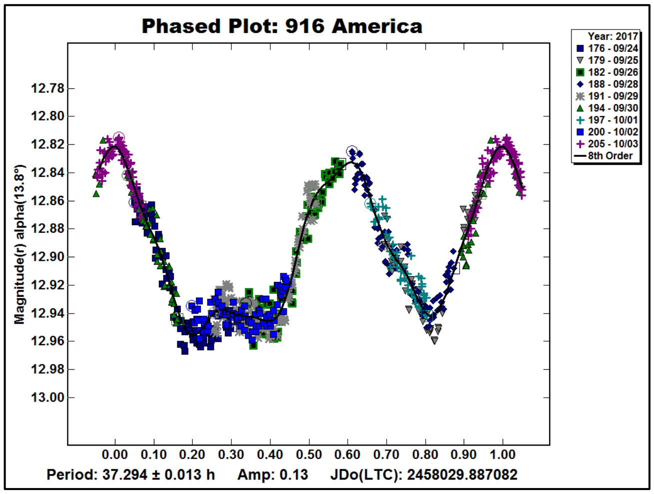
882 Swetlana is an outer-belt asteroid with a highly eccentric orbit. It was discovered in 1917 by Grigorij Neujmin at Simeis. The only previous period is that of Behrend (2006), who found a period of 26.016 ± 0.12 h from observations on two nights in 2006.

A total of 698 images were gathered during seven nights in 2017 September, producing a rotational period of 29.867 ± 0.009 h. This result disagrees slightly with Behrend's. The amplitude is 0.38 ± 0.02 mag. The fit has an RMS error of 0.016 mag.



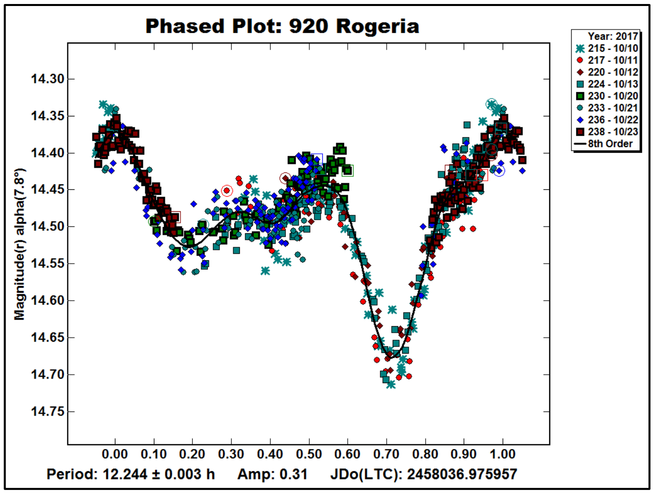
916 America. This asteroid was discovered by Grigorij Neujmin at Simeis in 1915. The rotational period has been computed only once. Di Martino (1986) shows a result of 38 h, with an amplitude of 0.28 mag.

Observations during nine nights in 2017 September and October produced 731 data points that were used to produce the lightcurve. The resulting period is 37.294 ± 0.013 h, which agrees well with Di Martino's result. The full amplitude is 0.13 ± 0.01 mag; the RMS scatter of the fit is 0.009 mag.



920 Rogeria. Karl Reinmuth at Heidelberg discovered this Eunomia-family asteroid in 1919. A query of the LCDB turns up two entries: Behrend (2012) shows a result of 9.05 ± 0.05 h, while Pravec (2012) gives 8.09 h.

A total of 725 observations of 916 Rogeria were made on eight nights in 2017 October. This effort produced a rotational period of 12.244 ± 0.003 h, which is roughly 50 percent larger than Pravec's result. The amplitude is 0.31± 0.03 mag, and the RMS error on the 8th-order fit is 0.025 mag.

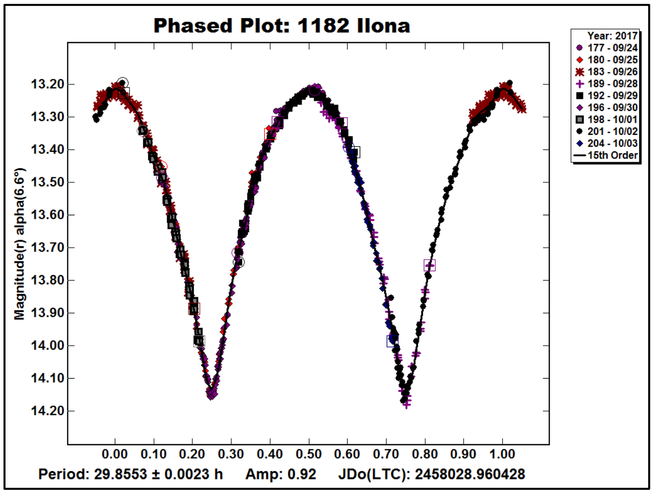


Number	Name	2017/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
763	Cupido	10/09-10/31	717	5.6,16.5	12	6	151.1	0.1	0.24	0.02	FLOR
882	Swetlana	09/17-09/23	698	10.0,12.3	336	8	29.867	0.009	0.38	0.02	MB-O
916	America	09/24-10/03	731	13.9,10.9	16	12	37.294	0.013	0.13	0.01	MB-I
920	Rogeria	10/10-10/23	725	7.9,2.9	32	5	12.244	0.003	0.31	0.03	EUN
1182	Ilona	09/24-10/03	727	6.7,5.0	9	7	29.8553	0.0023	0.92	0.02	MB-I
1283	Komsomolia	09/24-10/09	563	9.1,4.2	19	-7	32.175	0.005	0.40	0.02	MB-O
1639	Bower	10/09-10/31	613	5.5,14.2	11	9	22.181	0.003	0.27	0.02	MB-I

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 or maximum, which is then the second of three values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

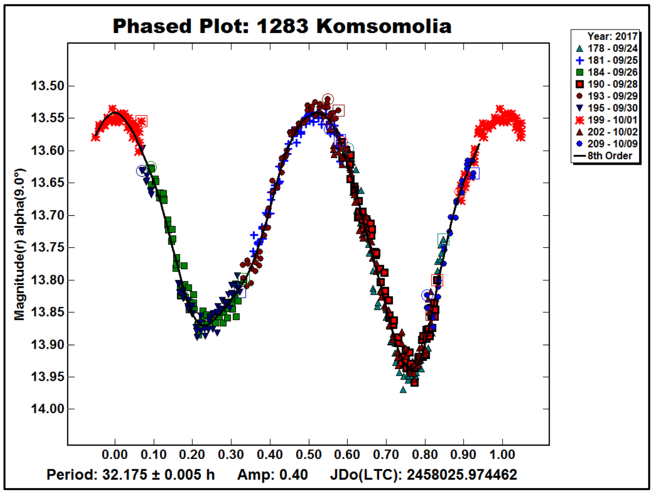
1182 Ilona is an inner-belt asteroid discovered by Karl Reinmuth in 1927 at Heidelberg. There have been three period determinations for 1182 Ilona. Behrend (2004) obtained a period of 14.938 ± 0.005 h. LeCrone (2005) computed 29.8 ± 0.1 h based on five nights of observations, while a similar result of 29.853 ± 0.0627 h was derived by Waszczak et al. (2015) using data from the Palomar Transient Factory Survey.

In 2017 September and October, 727 images of 1182 Ilona were secured. A well-defined lightcurve showing a period of 29.8553 ± 0.0023 h was computed. This value is roughly double that of Behrend's result. The RMS scatter on the 15th-order fit, which was required to capture the sharp minima, is 0.016 mag. The amplitude is 0.92 ± 0.02 mag.



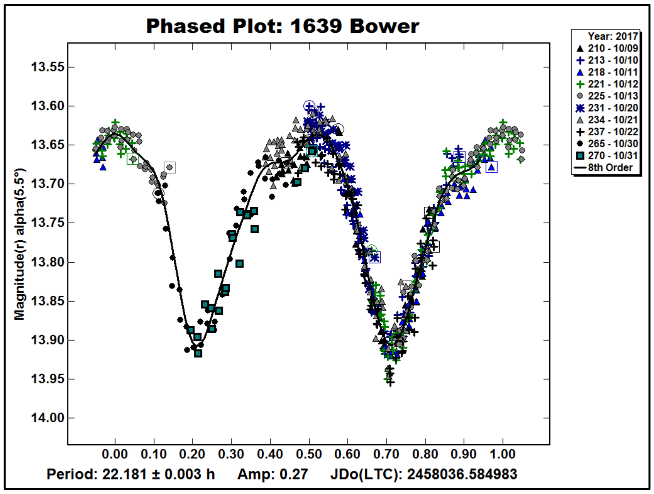
1283 Komsomolia. Vladimir Albitzkij discovered this outer-belt asteroid at Simeis in 1925. The sole rotational period in the LCDB is by Behrend (2006), who shows a result of 96 h.

Observations of 1283 Komsomolia were made on nine nights in 2017 September and October until 563 data points were acquired. The calculated period is 32.175 ± 0.005 h, approximately one-third of Behrend's period. The amplitude is 0.40 ± 0.02 mag, and the RMS error on the fit is 0.016 mag.



1639 Bower was discovered by Sylvain Arend at Uccle in 1951. Behrend (2005) gives a period of 22.4 ± 0.4 h. Robinson (2011) shows a result of 12.5 h.

During ten nights in 2017 October, 613 images were secured. A rotational period of 22.181 ± 0.003 h was determined. This agrees with the period provided by Behrend. The amplitude is 0.27 ± 0.02 mag; the RMS scatter of the fit is 0.020 mag.



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PHOTOMETRIC OBSERVATIONS OF MAIN-BELT ASTEROIDS 1637 SWINGS, 10498 BOBGENT, AND (25980) 2001 FK 53

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Photometric observations of asteroids 1637 Swings, 10498 Bobgent and (25980) 2001 FK 53 were acquired from Flarestar Observatory (MPC171) and Znith Observatory in 2017. The observations were made during a favourable apparition for each asteroid.

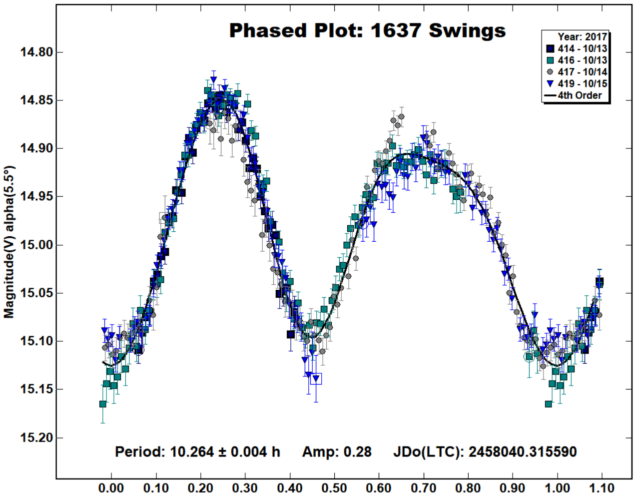
In between the months of July to November 2017, photometric observations of three main-belt asteroids were carried out from two observatories located in Malta (Europe). Observations of 1637 Swings and asteroid (25980) 2001 FK53 were obtained from Flarestar Observatory (MPC171). Observations of 10498 Bobgent were obtained from Znith Observatory through a 0.20-m *f*/10 Schmidt-Cassegrain (SCT) equipped with a Moravian G2-1600 CCD camera. Flarestar Observatory utilized a Moravian G2-1600 camera at 1x1 binning mode with a resultant pixel scale of 0.99" per pixel while Znith operated at a pixel scale of 0.17" per pixel using the same binning mode. All cameras were operated at sensor temperature of -15°C and images were dark subtracted and flat-fielded.

Both telescopes and cameras were controlled remotely from a nearby location via *Sequence Generator Pro* (Binary Star Software). Photometric reduction, lightcurve construction and analyses were derived through *MPO Canopus* software (Warner, 2017). Differential aperture photometry was utilized and photometric measurements were derived through the use of MPO Canopus, Comparison Star Selector (CSS) that utilized comparison stars of near-solar color. All measurements were taken from the MPOSC3 Catalog that is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI (Warner, 2007).

The three asteroids for this research have been selected through the CALL website as maintained by Warner (2016).

<u>1637 Swings</u> is a main-belt asteroid that was discovered on 1936 August 28 by Hunaerts, J. at the at the Royal Observatory of Belgium in Uccle, Belgium. This asteroid was named after the Belgian astronomer Pol Swings (1906–1983). 1637 Swings orbits the sun with a semi-major axis of 2.935 AU, eccentricity 0.0444, and period of 5.38 years (JPL, 2017). The JPL Small-Bodies Database Browser (JPL, 2017) lists the diameter as 53.0 km ± 0.4 km based on an absolute magnitude H = 10.4.

1637 Swings was observed from Flarestar Observatory on 4 nights starting on the night of 2017 October 12/13 at 00:10 UT and ending on the night of 2017 October 15/16. Our results yielded a synodic period of 20.998 ± 0.001h and amplitude of 0.62 ± 0.02 mag. The Lightcurve Database did not contain any references of the synodic period of this asteroid.



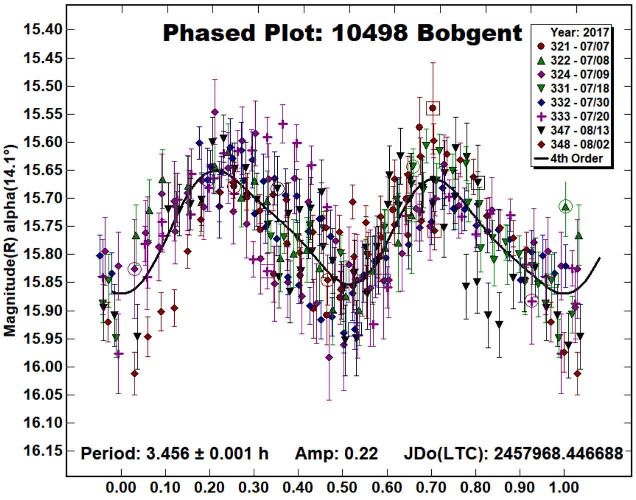
<u>10498 Bobgent</u> is a main-belt asteroid that was discovered on 1986 September 11 by E. Bowell at the Anderson Mesa Station of the Lowell Observatory. Also known as 1986 RG3, this asteroid was named in honour of Robert Gent (b. 1947), an enthusiastic amateur astronomer and International Dark-Sky Association

Number	Name	yyyy /mm/ dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Group
1637	Swings	2017 03/18-04/13	335	5.8,4.4	034	3.1	10.264	0.004	0.28	0.02	MB-O
10498	Bobgent	2017 07/07-08/02	306	14.5,8.5	301	9.4	3.456	0.001	0.22	0.05	MB-I
25980	2001 FK53	2017 09/23-10/10	166	9.8,2.5	013	-3.3	2.760	0.001	0.10	0.03	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).

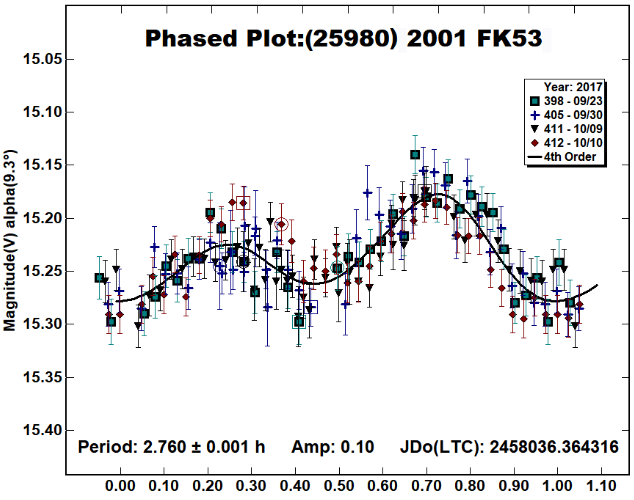
volunteer (Schmadel & Schmadel, 1992). The asteroid orbits the sun with a semi-major axis of 2.286 AU, eccentricity 0.259, and period of 3.46 years (JPL, 2017). The JPL Small-Bodies Database Browser lists the diameter of 10498 Bobgent as 2.7 km ± 0.8 km based on an absolute magnitude H = 14.6.

Observations were conducted from Znith Observatory and were carried out on 7 nights from 2017 July 7 to August 2. Results indicate a synodic period of 3.456 ± 0.001 h and amplitude of 0.22 ± 0.05 mag.



(25980) 2001 FK53 is a main-belt asteroid that was discovered on 2001 March 18 by LINEAR at Socorro. Provisionally designated as 2001 FK53, this asteroid has an absolute magnitude (H) of 13.7 and orbits the sun with a semi-major axis of 2.424 AU, eccentricity 0.2676, and period of 3.77 years (JPL, 2017).

Observations were conducted from Flarestar Observatory on 4 nights from 2017 September 23 to October 10. The derived lightcurve indicates a synodic period of 2.760 ± 0.001 h and amplitude of 0.10 ± 0.03 mag. No previous entries in the LCDB database were found for this asteroid.



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We would like to thank Brian Warner his work in the development of *MPO Canopus* and for his efforts in maintaining the CALL website. This research has made use of the JPL's Small-Body Database.

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LIGHTCURVE ANALYSIS OF MINOR PLANETS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2017 MARCH – MAY

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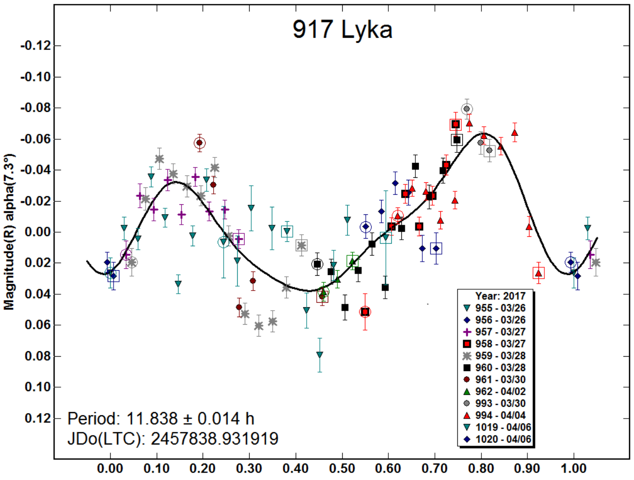
During 2017 March to May, CCD images were taken of 13 minor planets in order to determine rotation periods and lightcurves. The targeted minor planets were: 917 Lyka, 1034 Mozartia, 1118 Hanskya, 1167 Dubiago, 2847 Parvati, 2881 Meiden, 3107 Weaver, 3176 Paolicchi, 3262 Miune, 5605 Kushida, 6669 Obi, 9671 Hemera, and (23738) 1998 JZ1.

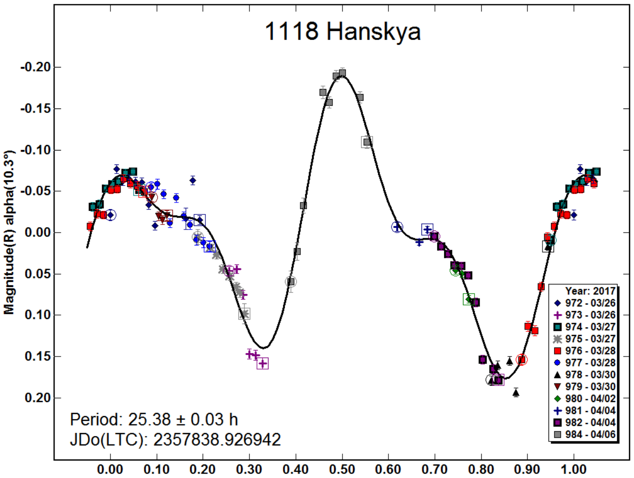
CCD images were taken at the Oakley Southern Sky Observatory in New South Wales, Australia on the nights of 2017 March 26-28, 30, April 2, 4-6, May 16-22, and 24-30. During these observing runs, we targeted 13 different minor planets: 917 Lyka, 1034 Mozartia, 1118 Hanskya, 1167 Dubiago, 2847 Parvati, 2881 Meiden, 3107 Weaver, 3176 Paolicchi, 3262 Miune, 5606 Kushida, 6669 Obi, 9671 Hemera, and (23738) 1998 JZ1. The observations were made using an *f*/6.7 0.5-m Planewave and an STX-16803 camera set for 3x3 binning. This resulted in a plate scale of 1.63 arcseconds per pixel. All images were taken with a luminance filter and calibrated using *MaxIm DL*. Photometric measurements and lightcurve generation were done with *MPO Canopus*.

Table I lists the observing circumstances as well as the rotation periods we found. Unfortunately, we were unable to recognize a repeatable pattern in our data for 1034 Mozartia, 1167 Dubiago, 2847 Parvati, 5606 Kushida, or 6669 Obi. Additional comments on individual results are given below as needed.

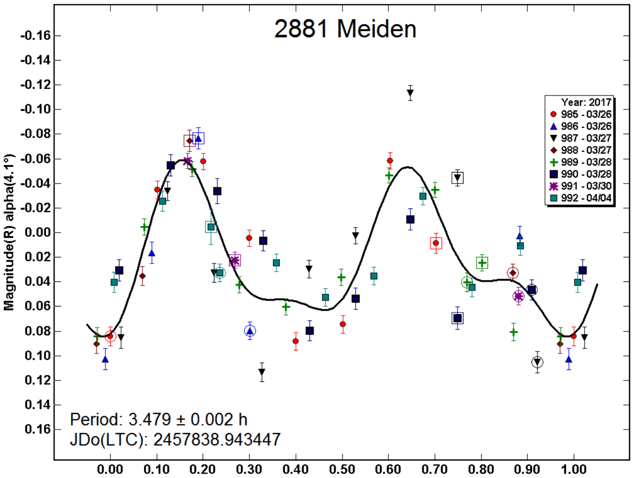
917 Lyka. While we were able fit our data with a period of 7.92 ± 0.01 h, as found by Behrend (2005), we got a better fit (lower RMS) with our period of 11.838 ± 0.014 h.



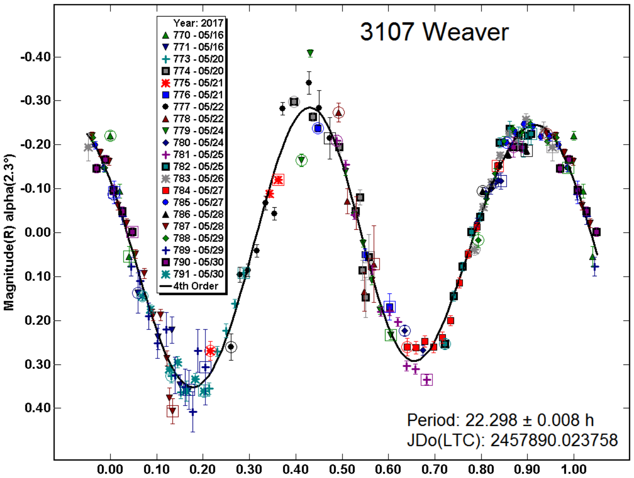
1118 Hanskya. Our data could not be fit with the period of 15.61 ± 0.01 h found by Robinson (2002). In addition, our period of 25.38 ± 0.03 h did not agree within experimental uncertainty with the period found by Behrend (2007) of 25.308 h (no uncertainty given).



2881 Meiden. Our period agrees within experimental uncertainty with the 3.48011 ± 0.00002 h found by Polakis et al. (2017).



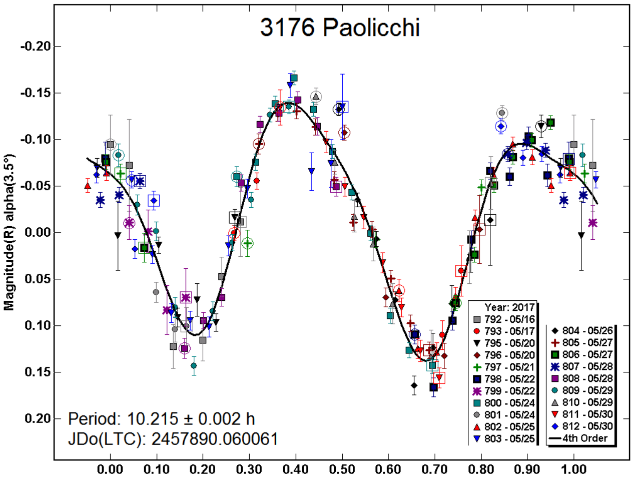
3107 Weaver. We could not fit our data to the period of 10.54 ± 0.01 h found by Tomassini et al. (2015).



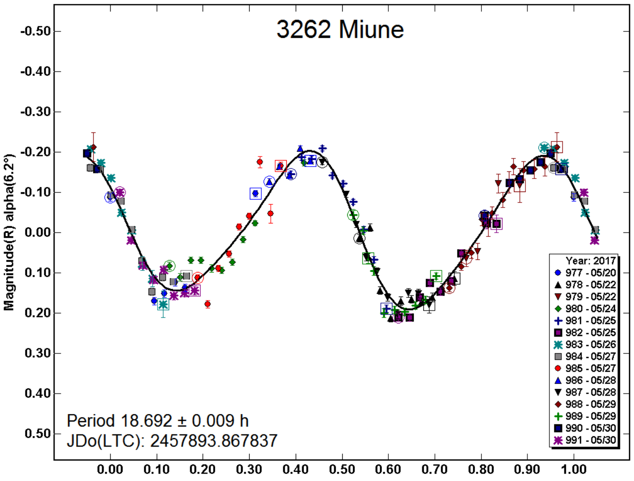
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.
917	Lyka	03/26-04/06	88	7.5,3.1	202	-4	11.838	0.014	0.10	0.03
1034	Mozartia	03/26-04/06	75	5.9,2.4	197	-5			0.10	0.03
1118	Hanskya	03/26-04/06	92	10.4,7.9	212	-16	25.38	0.03	0.35	0.05
1167	Dubiago	05/16-05/30	137	4.7,9.1	222	0			0.10	0.05
2847	Parvati	05/16-05/30	155	5.7,13.9	227	-1			0.15	0.05
2881	Meiden	03/26-04/06	59	4.3,1.5,3.0	192	2	3.479	0.002	0.13	0.03
3107	Weaver	05/16-05/30	164	2.0,10.0	232	-1	22.298	0.008	0.66	0.05
3176	Paolicchi	05/16-05/30	149	3.2,8.5	227	1	10.215	0.002	0.30	0.03
3262	Miune	05/16-05/30	130	4.6,9.3	225	5	18.692	0.009	0.38	0.03
5605	Kushida	03/26-04/06	71	3.5,0.0,3.1	191	0			0.10	0.05
6669	Obi	05/16-05/30	121	7.0, 15.2	225	0			0.15	0.05
9671	Hemera	03/26-04/06	89	9.8,3.1	197	-3	2.5318	0.0004	0.14	0.03
23738	1998 JZ1	05/16-05/30	185	2.1,11.1	235	-3	6.2883	0.0012	0.30	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.

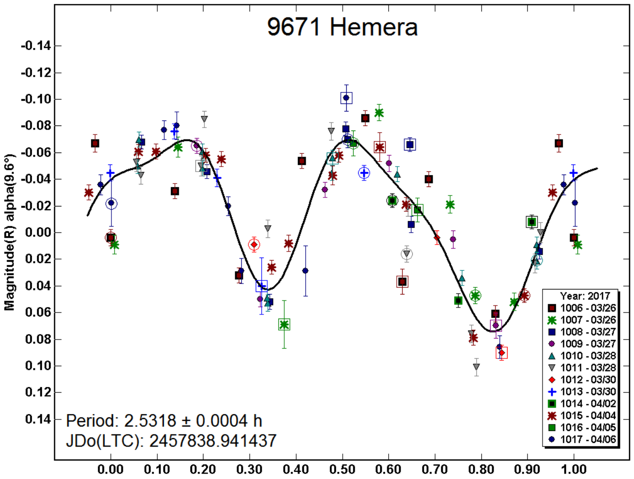
3176 Paolicchi. Our period is just half that of the 20.4 h (no uncertainty given) found by Behrend (2011).



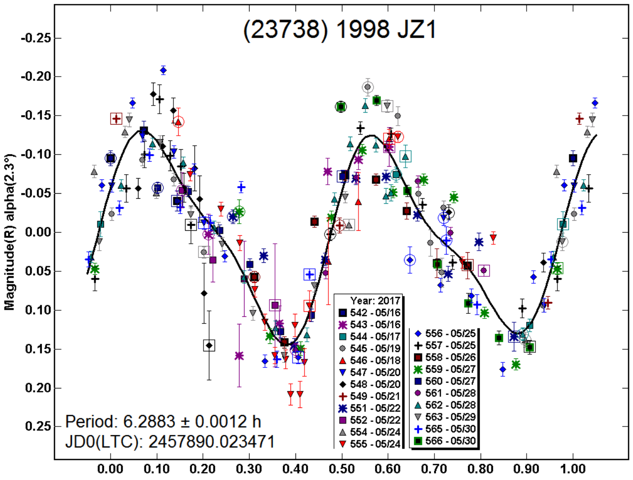
3262 Miune. We could not fit our data with the period of 19.61 h (no uncertainty given) found by Behrend (2009).



9671 Hemera. Our period agrees within experimental uncertainty with the periods of 2.532 ± 0.001 h found by Brincat (2017) and 2.53143 ± 0.00035 h found by Skiff (2017).



(23738) 1998 JZ1. Our period of 6.2883 ± 0.0012 h lies just outside the error bounds of the period of 6.295 ± 0.002 h found by Waszczak et al. (2015).



Acknowledgements

The authors would like to thank Gwang Ho Choi, Tae Won Huh, and JeongRok Kim for their assistance with calibrating and measuring three of the minor planets reported in this paper.

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LIGHTCURVE AND ROTATION PERIOD FOR MINOR PLANET 2052 TAMRIKO

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(Received: 2017 November 19)

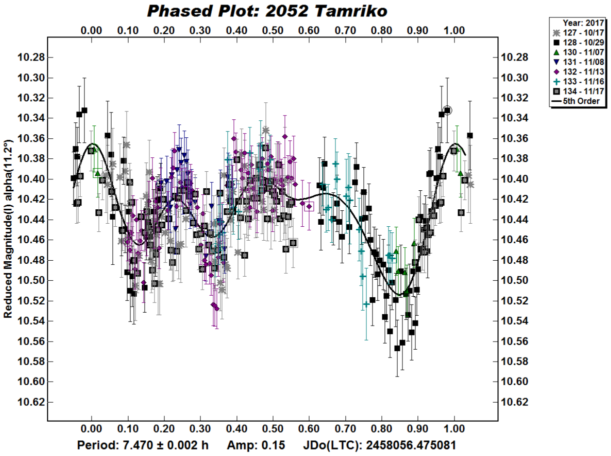
CCD photometric observations in Cousins I-band of minor planet 2052 Tamriko (1976 UN) were acquired during 2017 October and November. A rotation period of 7.470 ± 0.002 h and amplitude of $A = 0.15 \pm 0.05$ mag were determined from the five nights of observations.

The main-belt asteroid 2052 Tamriko was discovered in 1976 by Richard Martin West from ESO's La Silla observatory northern Chile. Named in honor of Tamara West, wife of the discoverer. Its orbital period is approximately 5.22 years. The absolute magnitude $H = 10.48$ is based upon IRAS (Tedesco, 2004) observations and assumed albedo of 0.158 give an estimated diameter of 26.8 km. The asteroid is a member of the Eos asteroid family with an orbital inclination of 9.5 degrees (JPL, 2017). Its taxonomic classification is of rare T-type described generally as having low albedo with featureless, moderately red spectra and having an absorption feature at wavelengths shorter than 0.85 micron.

Cherryvalley Observatory (MPC Code I83) is an amateur observatory located in eastern rural Ireland. Observations with an I-band photometric filter were conducted with a 0.2-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/11 using an SBIG STL-1301E CCD camera with a 1280x1024 array of 16-micron pixels. The resulting image scale was 1.52 arcsecond per pixel. Image acquisition was undertaken 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* v10.7.11.1. A total of 365 useful data points were used in the calculations. Table I gives the observing circumstances and results.

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 and the MPOSC3 star catalogue. 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).

2052 Tamriko was reported as a lightcurve opportunity in the *Minor planet Bulletin* (Warner *et al.,* 2017). The period solution of 7.470 ± 0.002h as determined by Cherryvalley Observatory using an order-5 fit is in close agreement with earlier published work by Sheridan (2002), Crescent Butte Observatory in which a rotation period of 7.462 ± 0.003h was determined and Warner (2012), Palmer Divide Observatory also established a rotation period of 7.470 ± 0.002h. In all cases a low amplitude variation of 0.15 mag with a lightcurve displaying three maxima and minima was found.



Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2052	Tamriko	10/17-11/17	365	11.2,1.6,2.3	51	-3	7.470	0.002	0.15	0.05	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).

Acknowledgements

This author wishes to dedicate this work in gratitude and recognition to Mr. Kevin Smith of Dunboyne Castle Observatory (Z67) for his enthusiasm and efforts in the active promotion of astronomy through public outreach events, lectures and demonstrations and for his continued service to the amateur astronomy community.

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CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar 2017 are encouraged to report them to this author on or before 2018 April 15. This will be the deadline for receipt of reports which can be included in the "General Report of Position Observations for 2017" to be published in *MPB* Vol. 45 No. 3.

3122 FLORENCE LIGHTCURVE ANALYSIS AT ASTEROIDS OBSERVERS (OBAS) – MPPD: 2017 SEP

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(Received: 2017 Nov 13)

We report on the results of photometric analysis of 3122 Florence, a near-Earth asteroid (NEA) by Asteroids 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 lightcurve results for 3122 Florence, a near-Earth asteroid 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, operated by members of the Valencia Astronomy Association (AVA) (*http://www.astroava..org*) and La Vara Observatory located in Valdés (Asturias).

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 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.

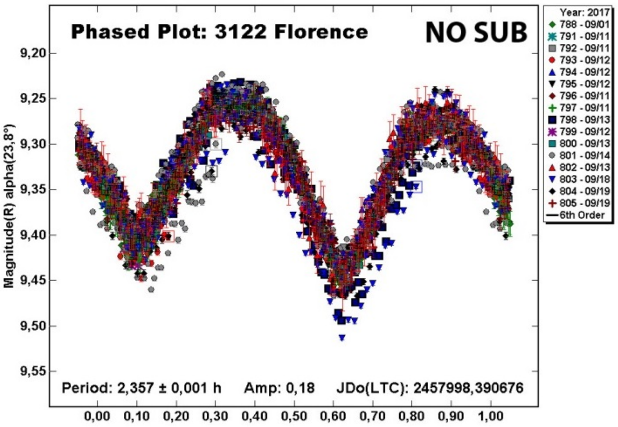
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3122	Florence	09/01-09/19	4986	23.8,78.9	328-358	7-48	2.357	0.001	0.18	0.02

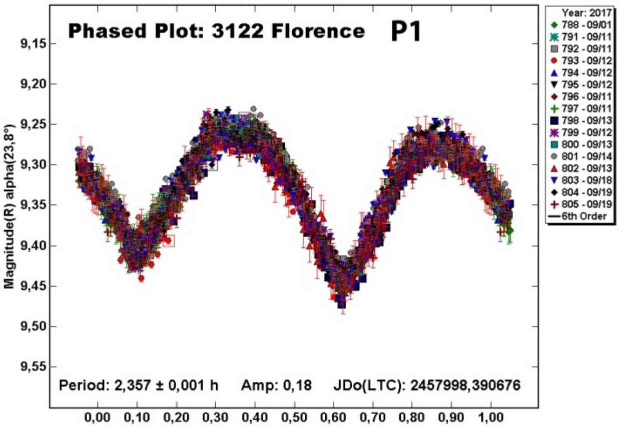
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the phase angle bisector longitude and latitude at on the first and last date of observation. (see Harris *et al.*, 1984).

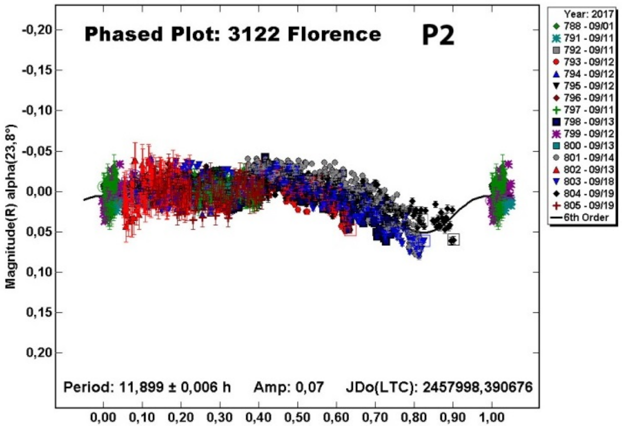
Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra	0.25 NW	Atik 414L+
La Vara	0.25 SCT	SBIG ST8-XME+AOL

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

3122 Florence is a stony trinary asteroid of the Amor group. Radar observations during the 2017 flyby showed that Florence has two moons. The rotation period measured by the Arecibo radar was 2.358 h. Warner (2016) found the same main period and a second period of 10.36 h.







We observed the asteroid for 16 nights from 2017 Sep 1-19 and obtained 4986 data points. The initial period analysis with *MPO Canopus* found a bimodal lightcurve with a period of 2.357 ± 0.001 h and amplitude of 0.18 mag. 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 = 2.357 h but the fit to the Fourier curve was much improved ("P1") after subtracting a second period of P_2 = 11.899 ± 0.006 h with an amplitude of 0.07 mag.

Acknowledgements

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

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RESULTS OF THE 2017 MEXICAN ASTEROID PHOTOMETRY CAMPAIGN – PART 1

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We report the results for the first semester of the 2017 Mexican Asteroid Photometry Campaign. Asteroid 1218 Aster (synodic period of 3.1581 ± 0.0002 h and amplitude of ~0.35 mag) was well observed and showed slight variations of its lightcurve at the end of the seven-week observing window. An uncertain, but long, period of ~93.23 ± 0.02 h and amplitude of ~0.36 mag were estimated for 2733 Hamina from sparse data. Asteroid 8443 Svecica was also well observed and yielded a period of 20.9905 ± 0.0015 h and amplitude of ~0.65 mag. Observations of NEA (143404) 2003 BD44 also resulted in an uncertain and long period of ~78.617 ± 0.009 h and amplitude of ~0.66 mag with a sparsely covered lightcurve.

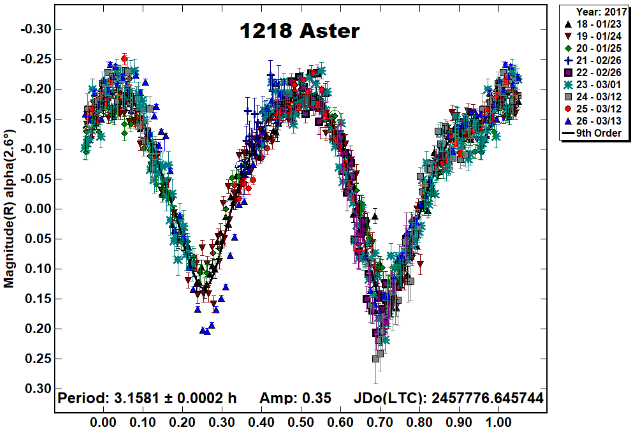
After the success of the Mexican Asteroid Photometry Campaigns in 2015 and 2016, with the observation and lightcurve characterization of seven asteroids from three different Mexican observatories (Sada et al. 2016, 2017), it was decided to continue and increase the collaboration during 2017. The eventual goal of this effort is to develop teams of coordinated observers in México capable of characterizing the lightcurves of not only of main-belt asteroids but of NEOs as well. We report here the results for the observations undertaken the first semester of the year for the 2017 Mexican Asteroid Photometry Campaign.

On this occasion, we collected 35 nights of observations from three different observatories. On four of those nights, the observing session was carried out simultaneously from two separate observatories, providing a basis for photometric comparison between them and prolonging the observing period for the target.

At the Universidad de Monterrey Observatory (UdeM; MPC 720), fitted with a Meade 0.36-m *f*/8 LX-600GPS telescope and an SBIG STL-1301E CCD, we observed all four asteroids on 18 different nights. Eighteen observing nights were also registered at the Carl Sagan Observatory belonging to the Universidad de Sonora (UNISON) in Hermosillo (Meade LX-200GPS 0.41-m *f*/10 telescope and Apogee Alta F9000 CCD). The 0.84-m *f*/15 Ritchey-Chretien telescope at the Observatorio Astronómico Nacional on the Sierra de San Pedro Mártir (OAN-SPM; MPC 679) in Baja California was also used on three nights. The observing hardware and circumstances for this year are similar to those used on last year's campaign and their descriptions can be found in Sada et al. (2017).

Images from these observatories were processed in the standard manner using dark current and flat-field files. Photometric measurements and lightcurve analysis were performed using *MPO Canopus* (version 10.7.3.0). All observations were unfiltered and differential magnitudes were calculated based on R-band stellar magnitudes.

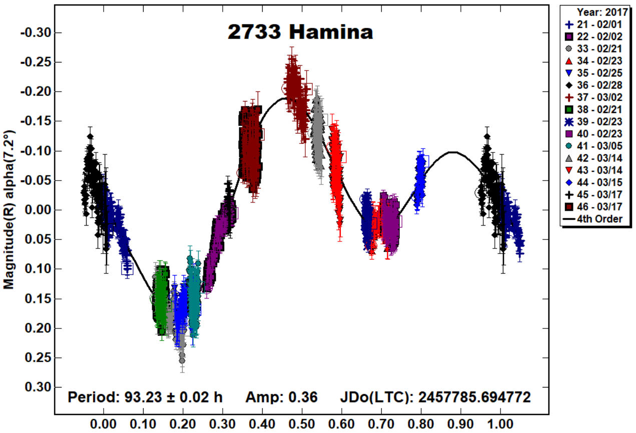
1218 Aster was discovered independently by K. Reinmuth on 1932 January 29 from Heidelberg and by M. Ferrero two days later from Turin. It was named after a flowering plant (Schmadel, 2003). This S-class asteroid from the Flora family was observed on three nights from the UdeM Observatory (2017 Jan 23-25), two nights from the UNISON Observatory (2017 Feb 26, Mar 1), and two nights at the OAN-SPM Observatory (2017 Mar 12-13). The UNISON 2017 Feb 26 and OAN-SPM 2017 Mar 12 observations were treated as two separate sessions each due to variations in the field-of-view (FOV) that required different comparison stars. We derived a relatively short rotation period of 3.1581 ± 0.0002 h with an amplitude of 0.35 mag for this asteroid. Our derived synodic rotation period is exactly the same reported by Franco et al. (2017), but we show a slightly larger amplitude in our lightcurve. The last observing night undertaken at the OAN-SPM Observatory also shows a slight variation in the shape of the lightcurve. These two differences from Franco et al. (2017) may be due to the change in observing geometry over the large seven-week observing window.



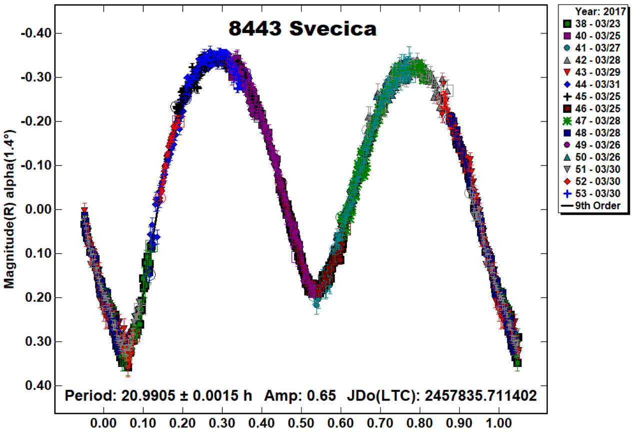
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1218	Aster	01/23-03/13	777	2.6,24.0	125	4	3.1581	0.0002	0.35	0.05	FLO
2733	Hamina	02/01-03/17	1734	7.4,17.9	144	7	93.23	0.02	0.36	0.06	MBI
8433	Svecica	03/23-03/31	1605	22.2,22.1	262	-10	20.9905	0.0015	0.65	0.04	MBO
143404	2003 BD44	03/07-04/03	1841	12.1,21.6	180	0	78.617	0.009	0.66	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).

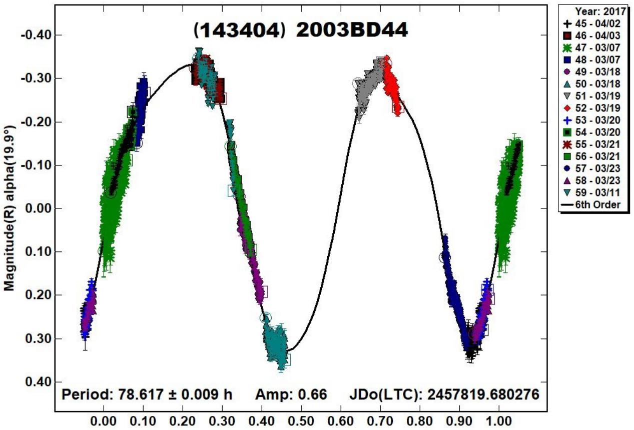
2733 Hamina was discovered on 1938 February 22 by Y. Väisälä at Turku and is named for an old Finish town (Schmadel, 2003). This S-class inner main-belt asteroid was observed at the UdeM Observatory on seven nights (2017 Feb 1, 2, 21, 23, 25, 28, and Mar 1) and at the UNISON Observatory on six (2017 Feb 21, 23 and Mar 5, 14, 15, and 17) nights. Both observatories performed simultaneous observations on the nights of 2017 Feb 21 and 23, extending each observing session due to the ~10° difference in longitude between the observatories. The UNISON observations on the nights of 2017 Feb 23 and Mar 14 and 17 were reduced as two observing sessions each due to variations in the FOV. This was a particularly difficult asteroid for which to derive a lightcurve and rotation period due to the small observed nightly magnitude variations and the limitations on performing differential photometry. The lightcurve segments could not be easily fitted into a basic shape with two maxima and two minima. After much experimentation, a very tentative and very long period of ~93.23 ±0.02 h and an amplitude of 0.36 mag stood out slightly, along with patchy lightcurve coverage. The only other report available for this asteroid, found on the Asteroid Lightcurve Database (LCDB; Warner et al., 2009), is a prepublication web report by Pravec et al. (2017) in which they report a rotation period of 93.46 ± 0.04 h and amplitude of 0.48 mag. Given the sparsity of our lightcurve coverage and our uncertainties due to our differential photometry measurements, we can only approximately confirm Pravec's reported long rotation period.



8443 Svecica. Was discovered in 1977 October 16 at Palomar Observatory and was named after the bluethroat bird (Brincat and Grech, 2017). This C-class outer main-belt asteroid was observed at the UdeM Observatory on six nights (2017 Mar 23, 25, 27-29, and 31). The asteroid was also observed on four nights from the UNISON Observatory (2017 Mar 25, 26, 28, and 30). On the nights of 2017 Feb 25 and 28, the asteroid was observed from both locations, extending the nightly observing period. All four UNISON observing nights were reduced as two or more sessions due to variations in the FOV after the central meridian telescope mount flip. The resulting lightcurve for this asteroid was very clean and had a large amplitude (~0.65 mag) that aided in the determination of a strong 20.9905 ± 0.0015 h synodic rotation period. Brincat and Grech (2017) also observed this asteroid and report a similar period of 20.998 ± 0.001 h and amplitude of 0.62 ± 0.03 mag.



(143404) 2003 BD44. This Apollo-type NEO was discovered by LONEOS and is also considered to be a potentially hazardous asteroid. On 2017 April 18, it came within 0.06 AU of Earth, allowing a good opportunity for its study. The asteroid was observed on six nights at the UNISON Observatory (2017 Mar 7, 18-21, and 23), two nights at the UdeM Observatory (2017 Apr 2 and 3), and once from the OAN-SPM Observatory (2017 Mar 11). All the UNISON observing nights were reduced as two separate sessions each because of the FOV change after the central meridian flip of the German equatorial telescope mount in use. This asteroid exhibited nightly magnitude variations that hinted at a long rotation period. After some work, a period of ~78.617 ± 0.009 h and an amplitude of 0.66 mag emerged, along with an incomplete lightcurve, as the best fit for our sparse data when assuming a simple rotation with two maxima and two minima. Warner (2017) observed this asteroid more extensively on 16 nights between 2017 Feb 25 and Apr 12 and derived a rotation period of 78.863 ± 0.003 h and amplitude of 1.05 ± 0.05 mag (although the result posted with the lightcurve figure shows a period of 78.633 ± 0.004 h and an amplitude of 0.95 mag; closer to our own results). Once again, as was the case with 2733 Hamina, given the sparsity of our lightcurve coverage and our uncertainties due to our differential photometry measurements, we can only approximately confirm Warner's reported long rotation period for this asteroid.



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LIGHTCURVE ANALYSIS OF L5 TROJAN ASTERIODS AT THE CENTER FOR SOLAR SYSTEM STUDIES 2017 SEPTEMBER TO DECEMBER

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Lightcurves for four Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2017 September to December. From observations in 2016 June, 2759 Idomeneus was found to be another candidate for the special case of very wide binaries. This would be the fifth confirmed Jovian Trojan binary asteroid.

CCD Photometric observations of four Trojan asteroids from the L_5 (Trojan) Lagrange point and one from the L_4 (Trojan) Lagrange point were obtained at the Center for Solar System Studies (CS3, MPC U81). For several years, CS3 has been conducting a study of Jovian Trojan asteroids. This is another in a series of papers reporting data being accumulated for family pole 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 and will be published at a later date.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

Telescope	Camera
0.40-m F/10 Schmidt-Cass	FLI Proline 1001E
0.35-m F/11 Schmidt-Cass	Fli Microline 1001E
0.35-m F/10 Schmidt-Cass	SBIG STL-1001E

Table I. List of telescopes and CCD cameras used at CS3.

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 (generally < ±0.05 mag) was done using field stars from the CMC-15 or APASS (Henden *et al.*, 2009) catalogs. 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 $-5*\log(r\Delta)$ 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 (e.g. Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

Targets were selected for this L_5 observing campaign based upon the availability of dense lightcurves acquired in previous years. We obtained two to four lightcurves for most of these Trojans at previous oppositions, and some data were found from the Palomar Transient Factory (Waszczak et al., 2015).

For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

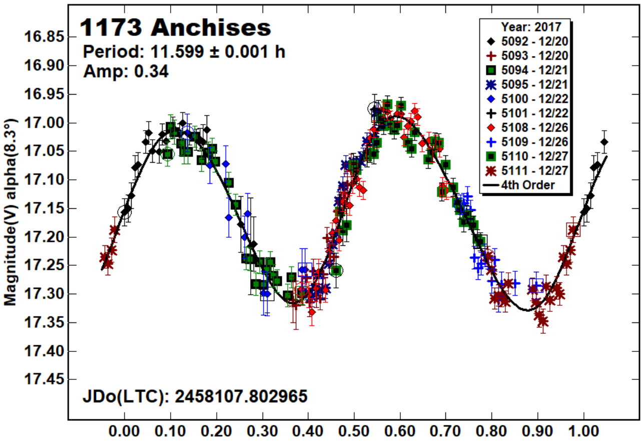
To evaluate the quality of the data obtained to determine how much more data might be needed, preliminary pole and shape models were created for all of these targets except Idomeneus. These will be published at a later date. Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (*http://hamilton.dm.unipi.it/asdys2/*). These sparse data were combined with our dense data as well as any other dense data found in the ALCDEF asteroid photometry database

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1173	Anchises	12/20-12/27	203	8.3,7.7	146	-4	11.599	0.001	0.34	0.02
2241	Alcathous	12/18-12/22	248	10.1,9.7	143	-14	7.696	0.002	0.24	0.02
2759	Idomeneus	2016/06/13-07/13	715	5.9,9.2	248	24	^{P}479	5	0.19	0.02
							32.17	0.01	0.14	0.02
2893	Peiroos	12/26-12/28	193	8.5,8.3	145	8	8.936	0.004	0.35	0.01
5130	Ilioneus	12/10-12/19	227	9.9,9.1	139	-16	14.89	0.01	0.13	0.02

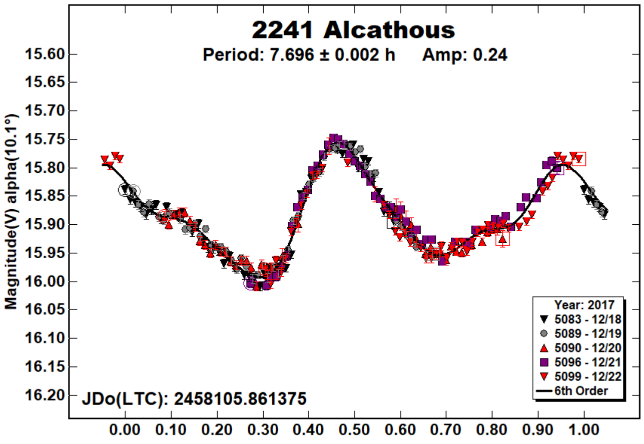
Table II. Observing circumstances and results. ^{P} in the period column indicates the period of the primary in a binary system. Pts is the number of data points. Phase is the solar phase angle for the first and last date. If there are three values, the middle value is the minimum phase angle. L_{PAB} and B_{PAB} are, respectively, the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

(*http://www.alcdef.org/*) using *MPO LCInvert*, (Bdw Publishing). This Windows-based program 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.

1173 Anchises. French (1987) found a synodic rotational of 11.60 h. Those data were combined with our data from last two years (Stephens et al. 2016a; 2017) and available sparse data to create a preliminary shape model and determine the sidereal period to be 11.609373 ± 0.000002 h.



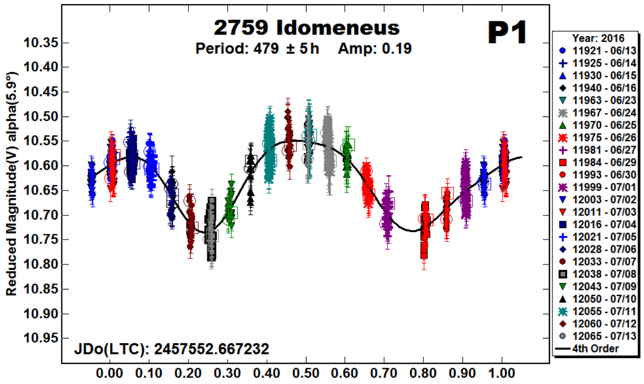
2241 Alcathous. The synodic period found in 2017 using CS3 data agrees with previous synodic results (Mottola 2011; French 2011a; Stephens 2014; 2015; 2016b; 2017). The data collected this year, when combined with our previous data and available sparse data, were used to create a preliminary shape model with a sidereal rotational period of 7.68987 ± 0.00001 h.



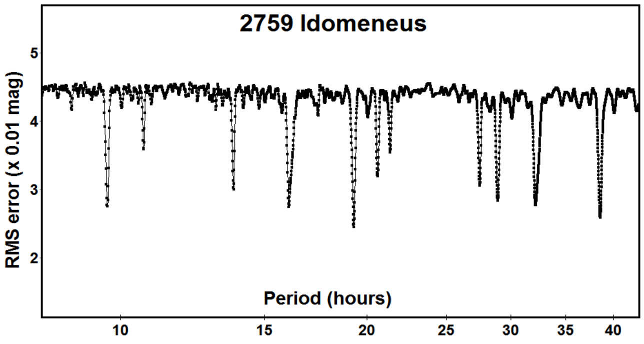
2759 Idomeneus. This 61 km diameter L_4 Trojan was observed in 2016 June and July. Mottola *et al.* (2011) observed it in 1991, 1992, and 2010. The last produced a complete lightcurve with a synodic period of around 32.4 h; the data from the first two apparitions produced incomplete lightcurves with the periods forced to be near the 2010 solution. Because of the unusual nature of the data, the findings were held back from earlier Trojan papers to obtain the Mottola data and for further analysis.

Warner started observations on 2016 June 13. Within a few nights it became apparent that despite the earlier Mottola report, it had a very long period. Night-to-night plots showed a shallow slope with first a decreasing, then increasing trend. Yet, the lightcurve trends did not always follow a typical bimodal Fourier curve as expected for a long rotational period asteroid with an amplitude of 0.19 magnitude. After sufficient data were acquired, a dual period analysis was attempted.

The dual period analysis found a primary lightcurve of P_1 = 479 ± 5 h, A_1 = 0.19 ± 0.02 mag ("P1" plot). Assuming an equatorial view of the asteroid, this leads to an a/b ratio of the asteroid's silhouette of 1.19:1.



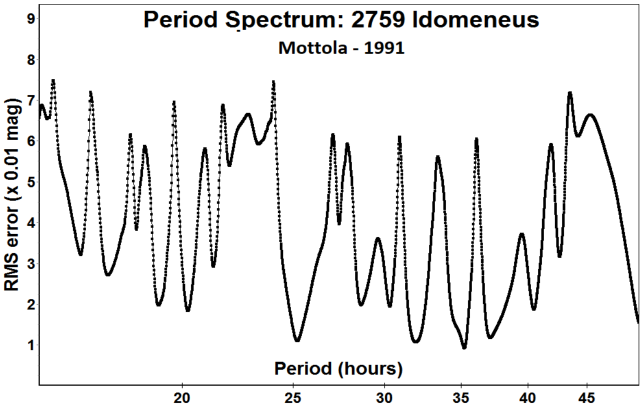
As expected, subtracting this lightcurve from the data set and doing a period search found a solution that showed no *mutual events* (occultations and/or eclipses) due to a satellite ("P2" plots).



The period spectrum of the secondary lightcurve showed that periods near 16 h, 19 h, and 32 h were equally plausible, each producing a classic bimodal shape. The 19 h solution is a bit more symmetric, but the 32 h one has a slightly larger amplitude. The other periods shown in the period spectrum were more troublesome because they created unrealistic monomodal or trimodal lightcurves

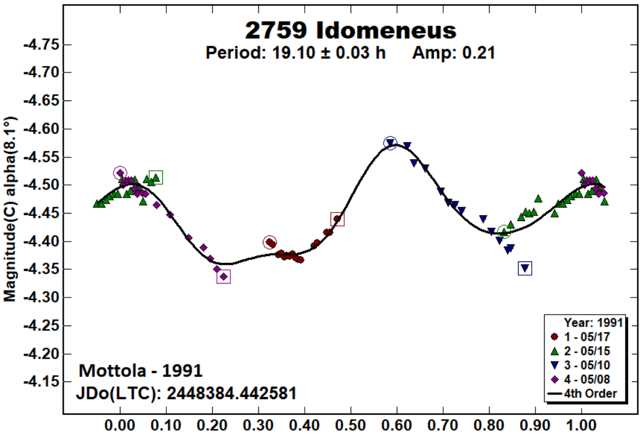
The dataset was sent to Petr Parvec for additional analysis (private communication). He indicated the 19.28 h secondary lightcurve had the strongest signal in this dataset, but was not more significant than the other solutions.

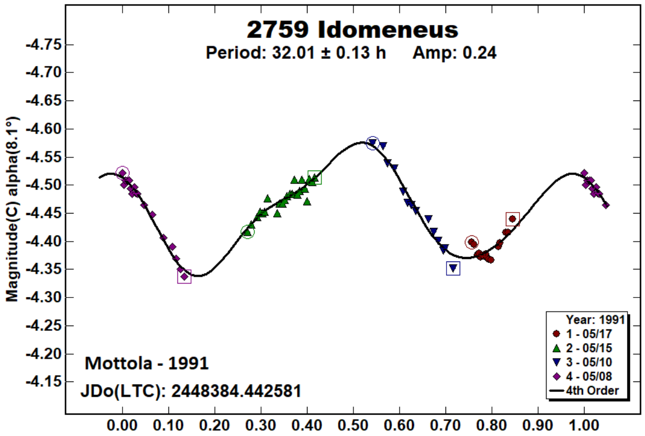
To try to break the tie, we referred to the data Mottola obtained (Mottola et al., 1991; 1992; 2010). Mottola kindly provided the original data for reanalysis. These data were somewhat sparser than what we obtained.

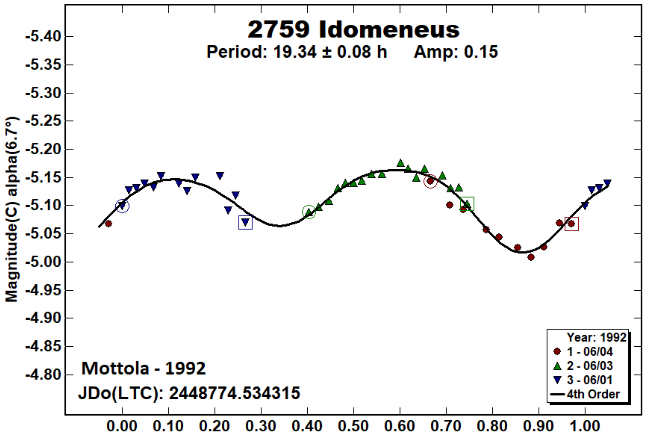


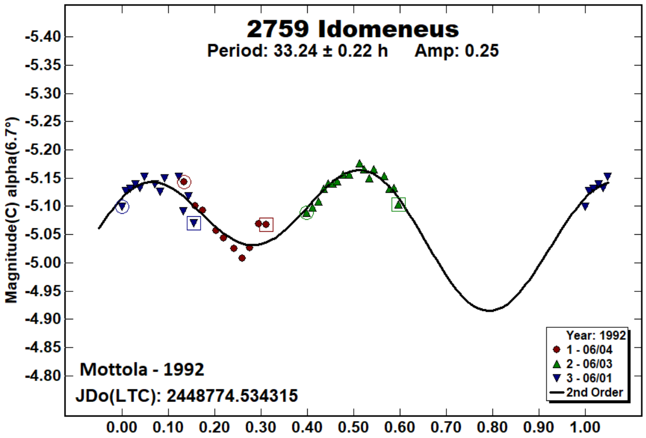
The period spectrum using only the Mottola et al. data also showed aliases near 16h, 19h, and 32h. The observing runs were not long enough to detect the 479 h period. Ultimately, the Mottola et al. data were not sufficient to determine conclusively if the P_2 period should be 19 h or 32 h, but the bimodal lightcurves from the Mottola et al. data in 1991 and 2010 suggest that the 32 h period is more likely correct.

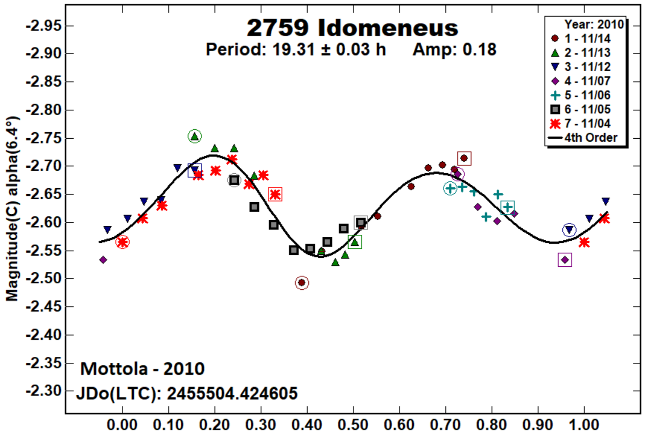
Therefore, because the Mottola data is a better fit to a 32 h period, rather than a 19 h period, we are adopting the secondary period of $P_2 = 32.17 \pm 0.01$ h, $A_2 = 0.10$ mag ("P2 - Preferred" plot). The alternative secondary period is $P_2 = 19.295 \pm 0.005$ h, $A_2 = 0.14$ mag ("P2 - Alternate" plot).

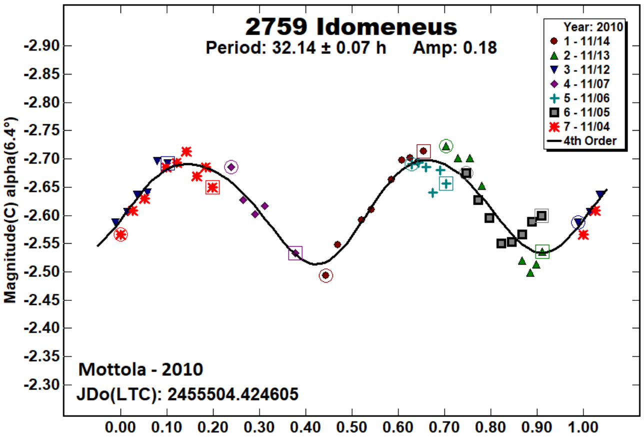


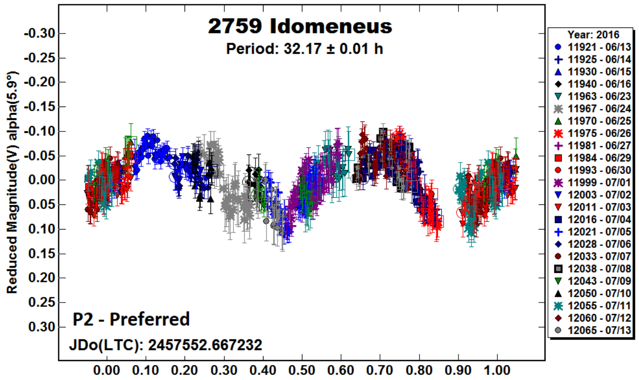


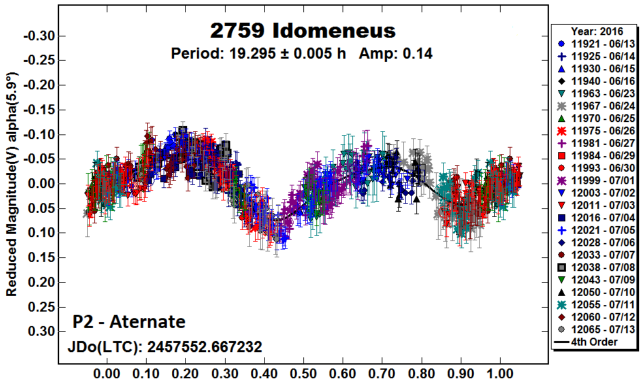










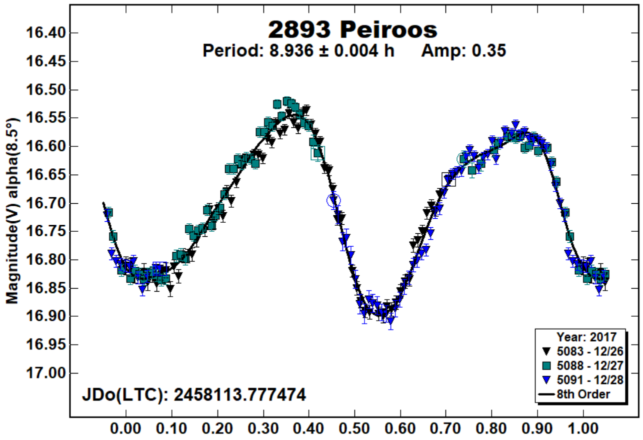


2759 Idomeneus is another possible candidate for a special case of very wide binaries (see Jacobson *et al*., 2014; Warner et al., 2016). This is where the primary period is long with a large amplitude and the secondary period is short with a low amplitude. For wide binaries, the chance of observing a *mutual event* (eclipse or occultation) would be very rare because of the long orbital period. Because of the lack of mutual events, confirmation of the nature of these asteroids will require long observing runs at future oppositions.

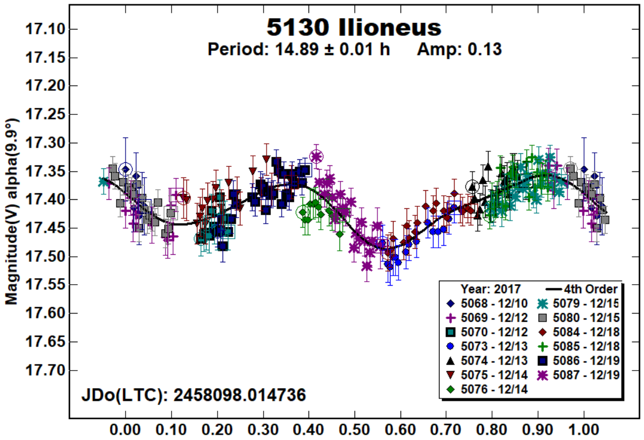
The long period (P_1) might suggest tumbling. This was rejected because of the short period and its amplitude. Black *et al.* (1999) suggest the two periods for a true tumbler should be within a factor of two of one another when one of the amplitudes is so large. A large amplitude indicates a very irregular (elongate) object, so the two tumble frequencies should be not far apart since the 'precession' frequency is essentially the moment of inertia differences (elongation or flattening of the object) times the 'rotation' frequency. For a very regularly shaped body (hence very low lightcurve amplitude), the precession frequency can be much longer than the rotation frequency. An object with a wobble frequency very different from the rotation frequency must be either close to a prolate spheroid or an oblate spheroid and the amplitude of the wobble component of the lightcurve is small, even if the amplitude of the wobble is large.

Because of the unusual nature of this Trojan, and because there are only four other known Trojan binaries, Idomeneus should be a prime candidate for future observations. It will be well placed for observations from both the northern and southern hemispheres for the next several years. With a relatively bright magnitude (V~17), it can be easily observed with small telescopes.

<u>2893 Peiroos</u>. Gonano *et al.* (1991) observed this Trojan in 1989 finding a synodic rotational period of 8.96 h. We observed it the last two years (Stephens et al. 2016a; 2017) finding synodic rotational periods of 8.99 and 8.951 h. When those data were combined with this year's data and sparse data, we were able to create a preliminary shape model with a sidereal period of 8.94892 ± 0.00001 h.



<u>5130 Ilioneus</u>. 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 in the past two years (Stephens et al. 2016a; 2017) finding synodic periods of 14.783 h and 14.799 h. The data collected this year, when combined with our previous data and available sparse data, were used to create a preliminary shape model with a sidereal rotational period of 14.81138 ± 0.00001 h.



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Work on the asteroid lightcurve database (LCDB) was 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 through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. The purchase of a FLI-1001E CCD cameras was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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ASTEROID LIGHTCURVE ANALYSIS AT TACANDE OBSERVATORY: 4650 MORI, 6779 PERRINE, AND 7996 VEDERNIKOV

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(Received: 2018 Jan 4)

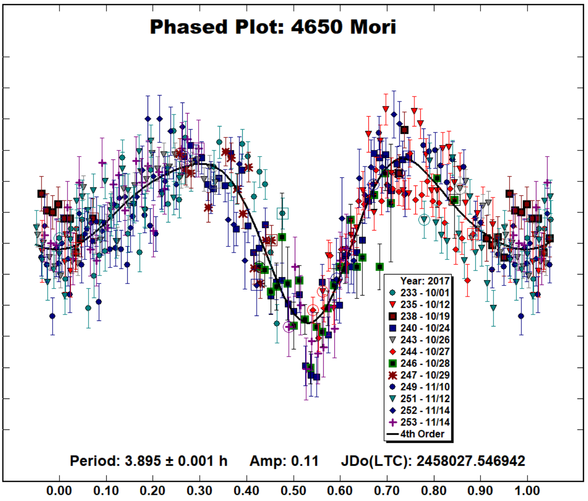
Lightcurves for three asteroids selected from the Collaborative Asteroid Lightcurve Link (CALL) website were obtained at Tacande Observatory from 2016 December to 2017 November: 4650 Mori, 6779 Perrine, and 7996 Vedernikov.

The observations reported here were 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, 2006). V magnitudes for comparison stars were extracted from the AAVSO Photometric All-Sky Survey catalog (APASS; Henden et al., 2009). Table I gives the observing circumstances and results. The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) did not contain any previously reported results for 6779 Perrine or 7996 Vedernikov.

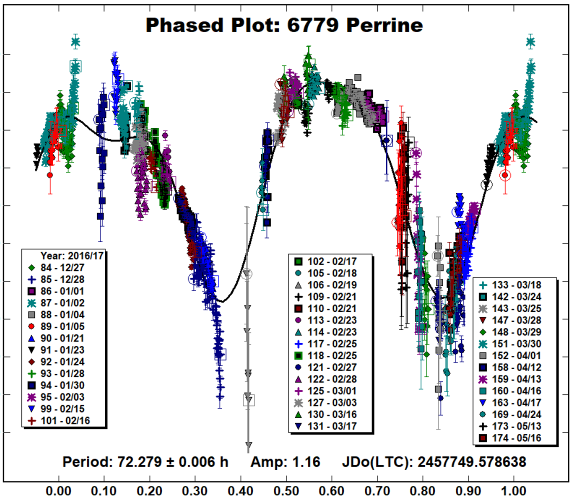
4650 Mori is a main-belt asteroid discovered by Reinmuth at Heidelberg in 1950. A total of 374 data points were obtained over 14 nights during the period 2017 Oct 1 to Nov 15. The average magnitude was 15.6 and average SNR was 103. The best-fit lightcurve shows a period of 3.895 ± 0.001 h and amplitude of 0.11 ± 0.01 mag, which suggests that the asteroid rotated 277 times during the period of observation. Pravec et al. (2017) reported a period 3.8947 h.

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4650	Mori	10/01-11/15	374	13.7,5.0,15.0	28	7	3.895	0.001	0.11	0.01	FLOR
6779	Perrine	2016/12/27-06/09	1249	15.9,1.0,27.6	131	0	72.279	0.006	1.16	0.01	FLOR
7996	Vedernikov	07/18-09/16	491	13.6,9.3,21.6	312	12	5.828	0.001	0.14	0.01	MB-O

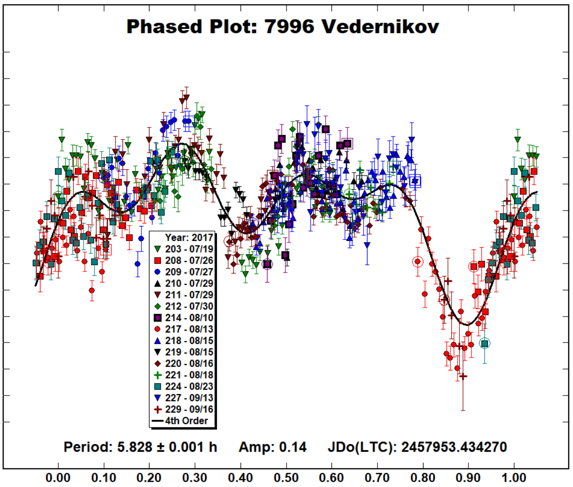
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner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



6779 Perrine is a main-belt asteroid discovered by Mrkos at Klet in 1990. A total of 1249 data points were obtained over 49 nights from 2016 Dec 27 to 2017 Jun 9. The average magnitude was 17.3 and average SNR was 53. The best-fit lightcurve shows a period of 72.279 ± 0.006 h and amplitude of 1.16 ± 0.01 mag, suggesting that the asteroid rotated 54 times during the period of observation.



7996 Vedernikov is a main-belt asteroid discovered by Karachkina at Nauchnyj in 1983. A total of 491 data points were obtained over 16 nights from 2017 Jul 18 to Sep 16. The average magnitude was 15.4 and average SNR was 135. The lightcurve shows a period of 5.828 ± 0.001 h and amplitude of 0.14 ± 0.01 mag, suggesting that the asteroid rotated 247 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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ROTATIONAL STUDY OF MARS-CROSSING ASTEROID 4435 HOLT

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A rotation period of 2.710 h ± 0.007 h and lightcurve amplitude of 0.12 mag have been derived from two nights of observations of Mars-crossing asteroid 4435 Holt.

During the nights of 2017 Dec 6 and 8 UT, a total of 74 data points were obtained of the inner main-belt asteroid 4435 Holt. Observations were made with a fork-mounted 29.4-cm SCT operating at *f*/5. The imaging train consisted of a SBIG AO-8T adaptive optics unit, FW8G-STT filter wheel, and SBIG STT 1603ME camera working at 2x2 binning; the resulting resolution was 2.2 arc sec/pix. All exposures were 300 s. The camera sensor temperature was –40° C. Due to the faintness of the target, no filters were used.

Images were reduced with dark and flat frames. *MPO Canopus* 10.7.11.1 was used for differential photometry and period analysis (see Ruthroff, 2010, for technique details). All comparison star V-R magnitudes were in the range of 0.4 to 0.7 (Warner, 2006).

A search of the Asteroid Lightcurve Database (LCDB; Warner et al., 2009), the (ADS, 2017), and the JPL Small Body Database Search Engine (JPL, 2016) did not find any results concerning the rotation period of 4435 Holt. After observations and lightcurve analysis were completed, a submission by Brian Skiff of Lowell Observatory was found on the CALL (2017) website. His observations, made on 2017 Nov 27-28 revealed a period of 2.867 ± 0.002 h and an amplitude of 0.20 ± 0.01 h. Also subsequent to the observations reported here, Stephens et al. (2018) reported that the asteroid is binary with a primary period of 2.8670 ± 0.002 h and amplitude of 0.15 mag. The orbital period is 42.65 ± 0.05 h. Some attenuations that could not be tied to the orbital period were also seen and could be indications of a third body in the system.

Acknowledgments

This research has made use of NASA's Astrophysics Data System. This paper makes use of data products from the Fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4).

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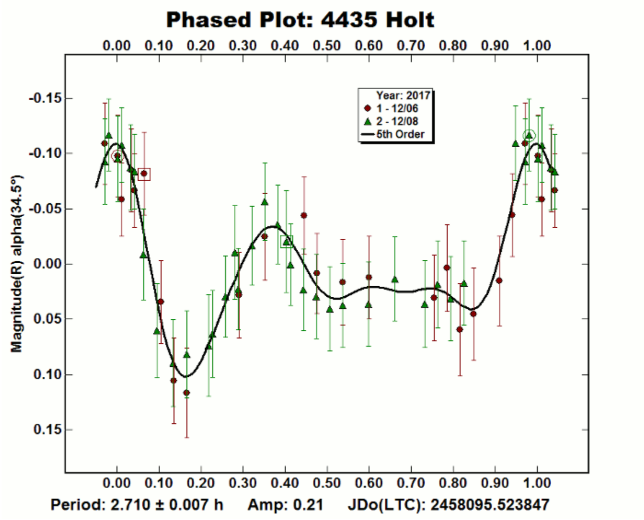

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4435	Holt	12/06-12/08	69	34.4,34.8	34	31	2.710	0.007	0.21	0.02	MC

Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The phase angle values are for the first and last date, unless a minimum (second value) was reached. LPAB and BPAB are the average phase angle bisector longitude and latitude. Period is in hours. Amp is peak-to-peak amplitude. LPAB and BPAB are the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009): MC = Mars-crosser.

PHOTOMETRY OF 3200 PHAETHON

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The close approach of 3200 Phaethon on 2017 Dec. 17 provided an opportunity for photometry from the bright-sky urban Burleith Observatory. A single night's observation confirms the rotational period 3.60 h.

3200 Phaethon (1983 TB) was discovered in 1983 by NASA's Infrared Astronomical Satellite (IRAS). Phaethon is widely considered to be the parent body for the Geminids meteor stream (Whipple 1983; Williams and Wu 1993). With a diameter of ~5 km, Phaethon is the third largest near-Earth asteroid classified as "Potentially Hazardous" after 53319 1999 JM8 (~7 km) and 4183 Cuno (~5.6 km). Phaethon has an unusually high eccentricity of 0.890 and a perihelion of 0.140 that is among the smallest known in the near-Earth asteroid population. On 2017 December 16 Phaethon approached within 0.07 AU of the Earth (Benner, 2017). The 3.6 h period has been reported several times (*e.g.* Ansdell *et al.* 2014, Warner 2015, Warner 2017a) as found in the Lightcurve Database (LCDB; Warner *et al.,* 2009), in agreement with the results reported here.

At Burleith Observatory in Washington, DC, a PlaneWave 0.32-m f/8 CDK astrograph was equipped with an SBIG STL-1001E CCD camera and an *Astrodon* Cousins Ic filter that provides a bandwidth of 700-900 nm. The unbinned image scale of 1.95 arc-seconds per pixel is well-matched to the typical 4 to 5 arcsec seeing. All exposures were guided at the rate of motion of Phaethon. Images were bias and sky flat-field corrected using CCDSoft version 5.00.217. Photometry and period analysis were performed using *MPO Canopus* version 10.7.11.1 (Warner 2017b), using "Comp Star Selection" of solar-type stars. The fast motion of Phaethon in the 33 arcmin field of view resulted in twelve separate reduction sessions, each with a new selection of comparison stars.

Acknowledgements

The author acknowledges B. D. Warner for providing the invaluable MPO Canopus photometry software.

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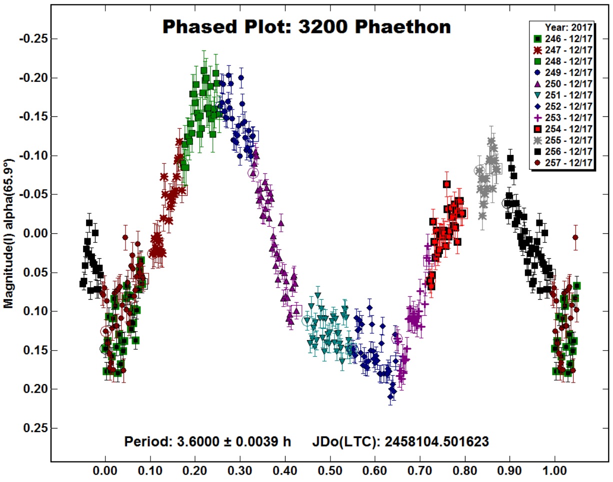

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3200	Phaethon	12/17	386	66.7	50	14	3.6000	0.0039	0.34	0.05	NEA

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).

LIGHTCURVE AND ROTATION PERIOD DETERMINATIONS FOR 1599 GIOMUS AND 1888 ZU CHONG-ZHI

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Collaborative CCD photometric observations of main-belt asteroids 1599 Giomus (1950 WA) and 1888 Zu Chong-Zhi (1964 VO1) were acquired during 2017 November and December. A rotation period of 9.53 ± 0.03 h and amplitude of A = 0.06 ± 0.05 mag were determined for 1599 Giomus and 11.053 ± 0.003 h and amplitude of A = 0.56 ± 0.05 mag were determined for 1888 Zu Chong-Zhi.

Both Cherryvalley Observatory (MPC Code I83) and Dunboyne Castle Observatory (MPC Code Z67) are amateur owned observatories located in eastern rural Ireland. Observations from Cherryvalley Observatory were taken with photometric I filter and 0.2-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/7.6 using an SBIG STL-1301E CCD camera with 1280 x 1024 array of 16-micron pixels un-binned. Observations from Dunboyne Castle Observatory were undertaken with 0.28-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/6.3 using an SBIG ST-8 CCD camera with 1534 x 1020 array of 9-micron pixels binned 2x2 and photometric V filter. In both cases the resulting image scale were 2.15 arcsec per pixel with image acquisition undertaken using Software Bisque's *TheSky6 Professional* and *CCDSoft* v5.

RMS Observatory (MPC Code W25) is located in Cincinnati, Ohio, USA. Observations were taken with a photometric V filter and 0.35-m Schmidt-Cassegrain Telescope (SCT) operating at *f*/7.6 using an ATIK One 6.0 CCD camera with a 2750 x 2200 array of 4.54-micron pixels binned 3x3 with resulting image scale 1.05 arcsec per pixel.

All light images were aligned; dark and flat-field corrected with mid-exposure time's light-time corrected using *MPO Canopus* v10.7.11.1. Table I gives the observing circumstances and results. 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 and MPOSC3 star catalogue *DerivedMags* method using I band catalog magnitudes. Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.* 1989).

1599 Giomus is a main-belt asteroid was discovered in 1950 by Boyer, L. at Algiers. Its absolute magnitude H = 11.1 and assumed albedo 0.026 give an estimated diameter of 41.3 km with an orbital inclination of 6.1 degrees and orbital period of 5.54 years (JPL, 2017). Its taxonomic classification is C-type (LCDB; Warner *et al*. 2009, version December 2017).

1599 Giomus was reported as a lightcurve opportunity in the *Minor Planet Bulletin* (Warner *et al.,* 2017) with opposition occurring on 2017 December 7. We observed 1599 Giomus on six nights spanning two weeks using photometric V and I filters which resulted in 590 useful data points before and up to opposition with the intention of improving upon its current U quality rating of 1, however we were unable to determine a secure and accurate period as our photometric errors were approximate to the values obtained for our data points due to the asteroids low 0.06 mag amplitude measured for this apparition.

Previously reported periods include 6.46 h (Clark 2010), >7.3 h (Garlitz 2013 web) and 29.1 h (Warner 2013). Recent observations from the Oakley Southern Sky Observatory, (Linville *et al* 2017) were also unable to determine a period for this asteroid because their measured magnitude variation were also too small compared to the uncertainty in the individual data points. We therefore present our lightcurve result as is using 6-order fit Fourier analysis with lowest obtained RMS value (Figure 1).

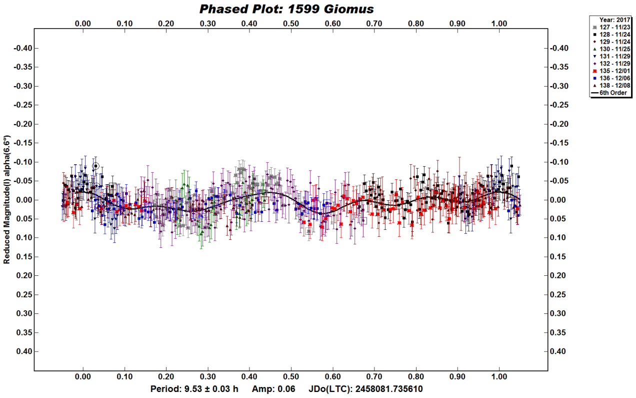

Figure 1. 1599 Giomus

1888 Zu Chong-Zhi is a main-belt asteroid was discovered in 1964 from Purple Mountain Observatory, Nanking, China. Its orbital period is 4.07 years with absolute magnitude H = 11.8 and assumed albedo of 0.274 give an estimated diameter of 11.633 km (JPL, 2017). Bus and Binzel (2002) observed 1888 Zu Chong-Zhi during Phase II of the Small Main Belt Asteroid Spectrographic Survey (SMASS II) and assigned a taxonomic classification of S-type.

1888 Zu Chong-Zhi was reported as a lightcurve opportunity in the *Minor Planet Bulletin* (Warner *et al.* 2017) with opposition occurring on 2017 December 16. We observed 1888 Zu Chong-

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1599	Giomus	11/23-12/08	590	6.6,1.8	76	4	9.53	0.03	0.06	0.05	Eos
1888	Zu Chong-Zhi	11/30-12/21	547	8.8,1.6,3.5	84	-3	11.053	0.003	0.56	0.05	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).

Zhi over six nights separated by three week time span, using photometric V and I filters. This resulted with 547 useful data points with the intention of attempting to improve upon its current U quality rating of 2.

A previously reported rotation period of 15.99 h (Behrend 2006 web) did not precisely agree with our initial observations and lightcurve fit. However, a number of period solutions stand out in the period spectrum (Figure 2) resulting in a monomodal lightcurve at 5.528 h (P/2), a trimodal lightcurve at 16.585 h (P3/2) and a quadramodal lightcurve at 22.105 h (P2). However, a bimodal period solution of 11.053 ± 0.003 h (P) using 8-order fit Fourier analysis which displayed the lowest RMS value is our proposed correct solution (Figure 3). We ruled out as improbable the monomodal, trimodal and quadramodal lightcurves due mainly to the large mag amplitude (0.56 mag) with low phase angle approach for this apparition. Harris et al. (2014) asserted that only the second harmonic of a lightcurve can exceed peak-to-peak amplitude of ~0.3 mag. In addition further supporting evidence using MPO Canopus's *split-halves* (see Harris *et al* 2014) method appears to reinforce a bimodal solution since the resulting graph is symmetrical over the two halves of the longer period within allowed photometric errors (Figure 4).

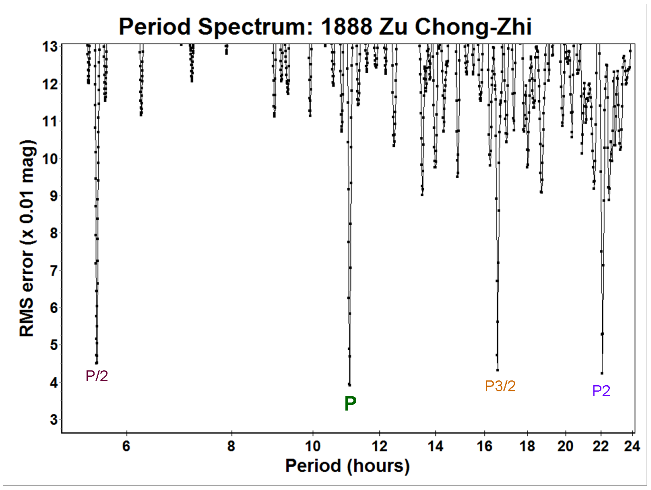

Figure 2. Period spectrum 1888 Zu Chong-Zhi

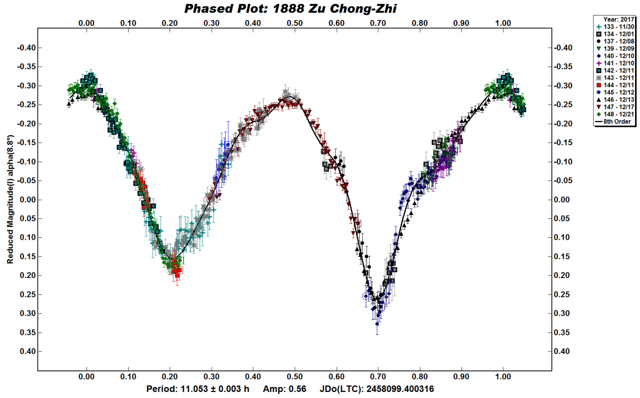

Figure 3. 1888 Zu Chong-Zhi

Acknowledgements

The authors wish to express their gratitude to Brian Warner for his help and advice in making sense of the data we obtained for asteroid 1888 Zu Chong-Zhi.

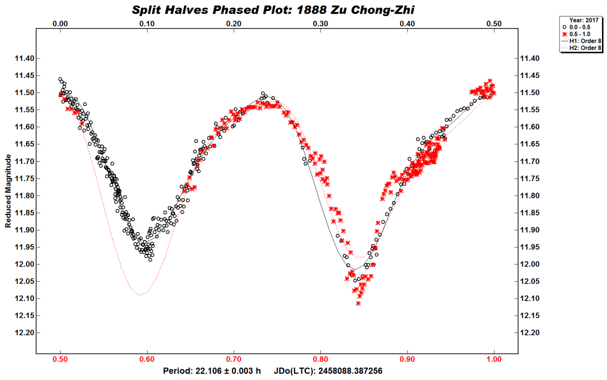

Figure 4. 1888 Zu Chong-Zhi split halves.

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A PHOTOMETRIC STUDY OF 1134 KEPLER

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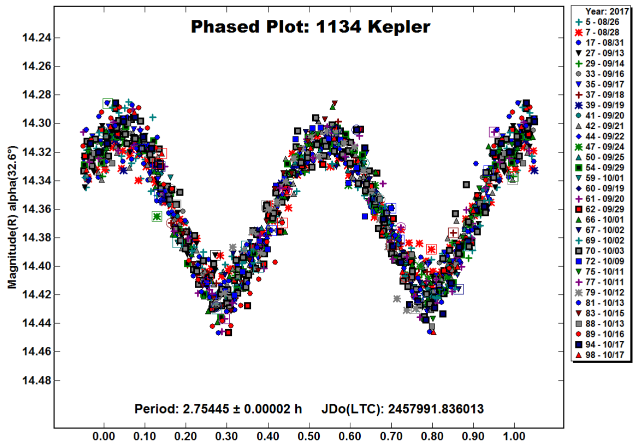
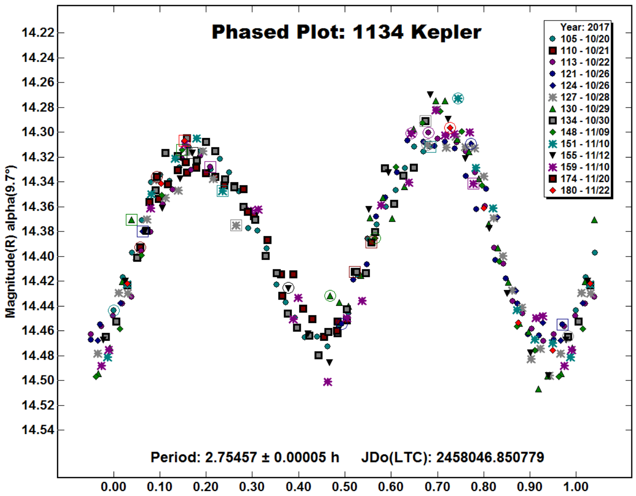
Minor planet 1134 Kepler has a synodic rotation period 2.7545 hours and amplitude increasing from 0.12 to 0.18 magnitudes in the interval 2017 Aug. 26 – Nov. 22. Superimposed upon the short rotation period is a 0.45 magnitude fading that we attribute to its movement in the sky from a more polar to a more equatorial line of sight, suggesting a somewhat flat shape for this object.

Minor Planet 1134 Kepler is a Mars crosser making its first close approach to Earth for many years. Aznar et al. (2018) published a lightcurve phased to 3.91 hours, with three maxima and minima per cycle, based on only two nights 2017 Sept. 18-19 and with considerable scatter among the data points.

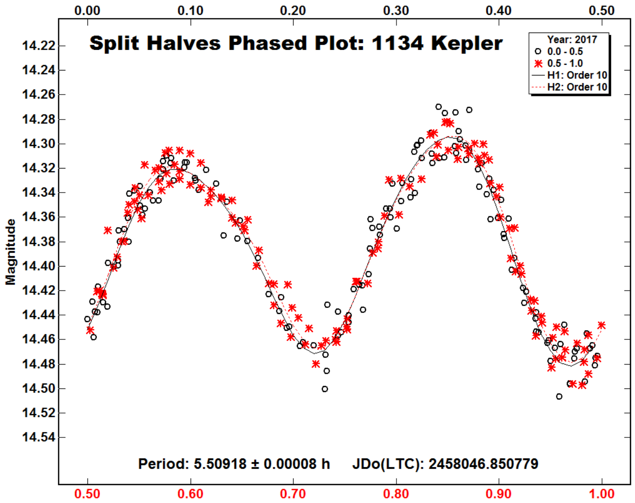
A more comprehensive study was launched 2017 Aug. 26. Pilcher at Organ Mesa observatory used a 0.35-m f/10 Meade LX200 GPS Schmidt-Cassegrain (SCT) telescope and SBIG STL-1001E CCD. Benishek at Sopot Observatory used a 0.35-m f/6.3 Meade LX200 GPS SCT and SBIG ST-8XME CCD. The exposures for both observers used a clear filter and were unguided.

First author Pilcher obtained the first session of this study on 2017 Aug. 26. The lightcurve of each subsequent session was adjusted vertically to a best fit with previous sessions. By mid-September a good fit to a well-defined period of 2.7545 hours and amplitude 0.12 was obtained. In late September second author Benishek started contributing observations. By late October an increase in both period and amplitude were noted, and the lightcurve had become less symmetric. Hence we present two lightcurves, one representing observations August 26 – October 17 and the other for observations October 20 – November 22.





Observations from August 26 – October 17 provide a good fit to a highly symmetric bimodal lightcurve with period 2.75445 ± 0.00002 hours and amplitude 0.12 ± 0.02 magnitudes. An equally good fit could be obtained to a period 3/2 and 2 times as great with 3 and 4 maxima and minima, respectively, per cycle. A lightcurve with a good fit to observations from October 20 – November 22 has period 2.75457 ± 0.00005 hours, amplitude 0.18 ± 0.02 magnitudes and is sufficiently asymmetric to rule out the 3/2 period. The half period of 1.38 hours can be rejected as shorter than the centrifugal disruption limit. A split halves plot for observations in the interval October 20 – November 22 for the double period of 5.50918 hours shows that the two halves are almost identical and rules out the double period. Hence a period of 2.7545 hours can be considered secure.

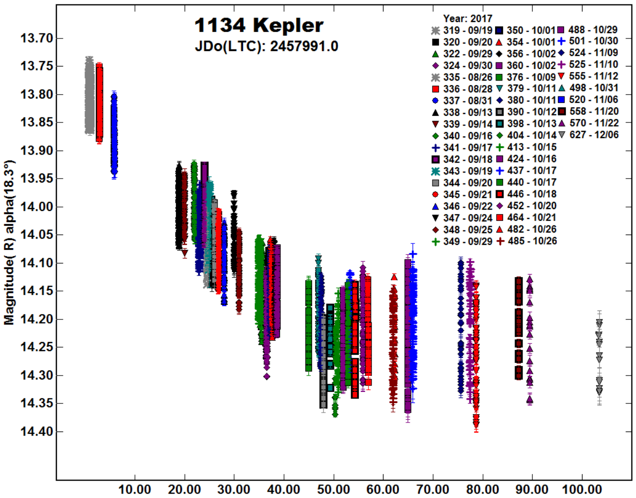


All sessions were calibrated to the R magnitudes of comparison stars from the Carlsberg Meridian Catalog 15 (CMC15). The magnitudes of these stars are usually consistent over the whole sky within 0.05, although occasionally larger discordances occur. The August 26 and 28 sessions required no magnitude adjustment to fit. For the third session August 31 an upward adjustment of 0.07 magnitude was required for best fit, larger than is usually needed for CMC15 calibration stars but occasionally found. The next session September 13 required a 0.17 magnitude upward adjustment. An overall dimming greater than the amplitude of the lightcurve had occurred. By mid-October the magnitude was 0.4

Number	Name	yyyy/mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
1134	Kepler	2017/08/25-2017/10/17	3975	32.6, 6.6, 8.3	14	0	2.75445	0.00002	0.12	0.02
1134	Kepler	2017/10/20-2017/11/22	796	9.7, 24.0	25	12	2.75457	0.00005	0.18	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).

fainter than on August 26, and by mid-November 0.45 magnitude fainter, even adjusting for the default G=0.15. To track changes in the magnitude, both observers obtained frequent additional short sessions, usually 1 to 1.5 hours, until December 6. Following conclusion of the observation campaign, delta comp magnitudes were readjusted to zero and a raw plot of all sessions is shown to illustrate the 0.45 magnitude fading. As each night's session on this plot includes the full short period amplitude range, the increase of amplitude with decreasing brightness is also displayed.



P. Pravec (personal communication) explains the 0.45 magnitude fading with a very simple argument. During the nearly three-month interval of observation, 1134 Kepler moved from RA 1h 37m, Dec -02°; to RA 0h 37m, Dec +23°, an arc of nearly 30 degrees. We define triaxial ellipse approximations to the three axes as a, b, c, in sequence from largest to smallest, and for this short period rotator expect principal axis rotation along the c axis. We suggest that at the start of observations the object was in a more polar oriented line of sight in which the rotational amplitude is smaller but a larger area close to πab is presented. The object subsequently moved into more equatorial view in which the presented area is smaller but the amplitude, dependent upon the difference between the a and b axes, has increased. The large brightness decrease suggests that c is much smaller than either a or b and that a-b<<b-c; or in other words, a somewhat flat shape for this object.

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ASTEROIDS OBSERVED FROM CS3: 2017 OCTOBER - DECEMBER

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(Received: 2018 Jan 11)

CCD photometric observations of seven main-belt asteroids were obtained from the Center for Solar System Studies from 2017 October to December.

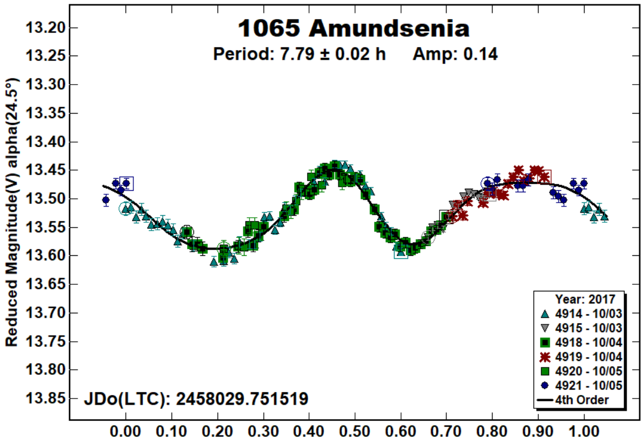
The Center for Solar System Studies "Trojan Station" (CS3, MPC U81) has two telescopes which are normally used in program asteroid family studies such as Jovian Trojans and Hildas. During the 4th quarter of 2017 the targets which are normally studied were mostly out of season, so targets of opportunity amongst the Main Belt families were selected.

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 (generally < ±0.05 mag) was done using field stars from the CMC-15 catalog. The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

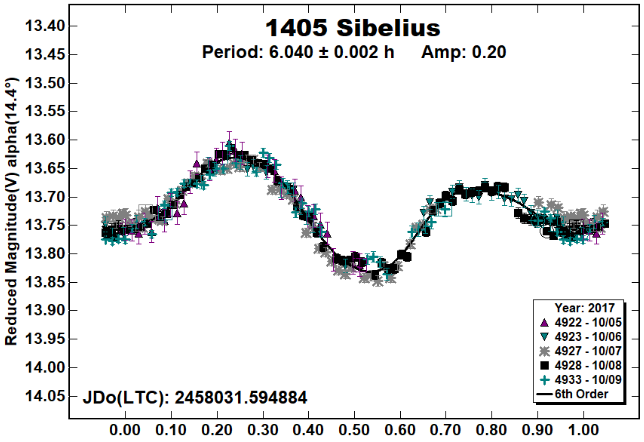
In the lightcurve plots, the "Reduced Magnitude" is Johnson V corrected to a unity distance by applying -5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses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

The amplitude indicated in the plots (e.g. Amp. 0.20) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve. For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

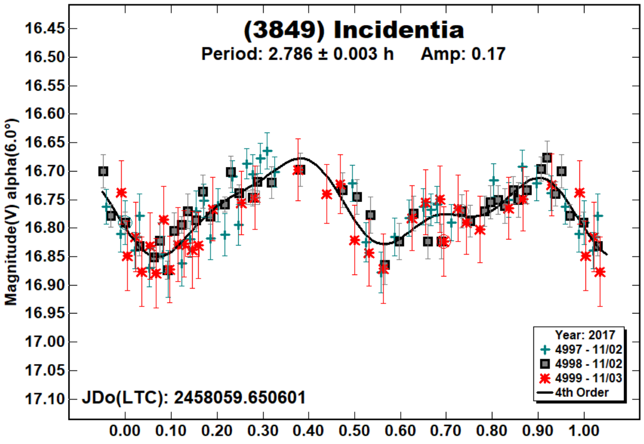
1065 Amundsenia. This outer main-belt asteroid was studied as part of the Photometric Survey for Asynchronous Binary Asteroids (Pravec 2017) which reported a rotational period of 7.7594 h. The result from this opposition is in good agreement with that result.



1405 Sibelius. This member of the Flora family was also studied as part of the. Photometric Survey for Asynchronous Binary Asteroids (Pravec 2017) which reported a rotational period of 6.051 h. The result found this year is in good agreement with that findings.

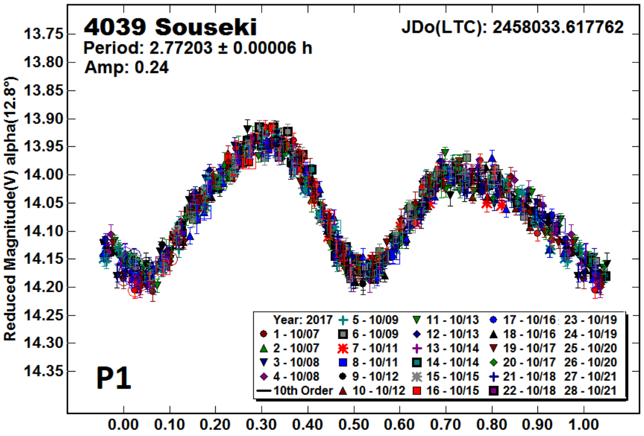


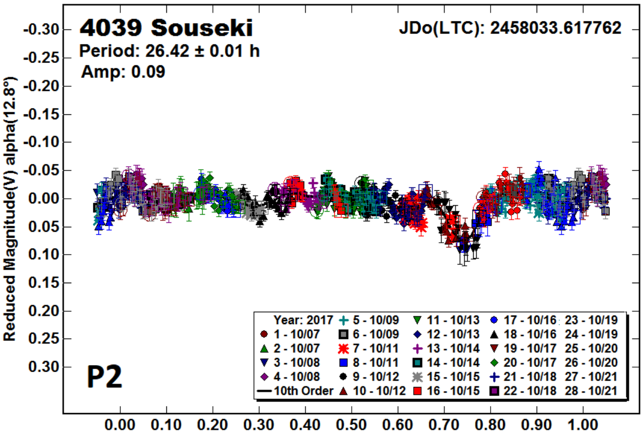
3849 Incidentia. This Vesta family member has been previously observed by Waszczak et al., (2015) using sparse data from Palomar Transient Factory Survey finding a rotational period of 2.778 h. This year's result is in good agreement with that finding.



4039 Souseki. No previous rotational periods could be found in the Lightcurve Database (Warner et al. 2009). Due to inconsistencies in the lightcurve, this Vestoid family member is suspect of being a binary system. On several nights a decline in brightness of about 0.09 magnitude was detected which would suggest a second period.

The dual period analysis found a primary lightcurve of P_1 = 2.77203 ± 0.00006 h, A_1 = 0.24 ± 0.01 mag ("P1" plot). As suspected, subtracting this lightcurve from the data set and doing a period search found a solution that showed *mutual events* (occultations and/or eclipses) due to a satellite ("P2" plot). The lightcurve has a period of P_2 = 26.42 ± 0.01 h, A_2 = 0.09 mag. At this time, due to the shallowness of the mutual events, this can only be considered a suspected binary. A good opportunity for follow up is in 2019 February. Thanks to Brian Warner for assistance in the dual period analysis.

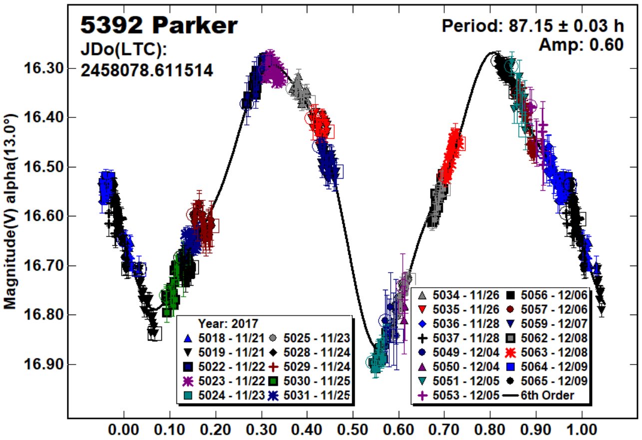




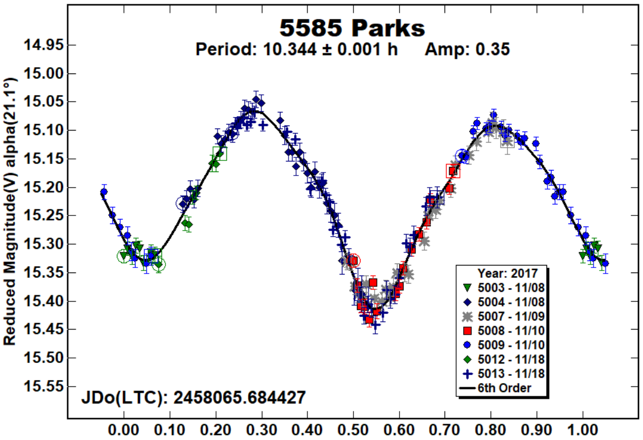
5392 Parker. No entry for this Mars crosser could be found in the Lightcurve Database (Warner et al. 2009). Because of the long rotational period, the possibility that it was tumbling (non-principal axis rotation) was considered. On a couple of nights, the slope of the individual night's observations did not agree with the slope of the Fourier for that phase of the lightcurve. However, due to the length of the rotational period, it is unlikely that a single station could get enough data to determine any additional frequencies.

Number	Name	mm\dd	Pts	Phase	LPAB	BPAB	Period	P.E.	Amp	A.E.	Grp
1065	Amundsenia	10/03-10/05	141	24.5,23.8	54	10	7.79	0.02	0.14	0.01	MC
1405	Sibelius	10/05-10/09	238	14.5,16.4	350	7	6.04	0.002	0.2	0.01	FLOR
3849	Incidentia	11/03-11/03	107	5.5,5.5	51	3	2.786	0.003	0.17	0.02	V
4039	Souseki	10/07-10/21	620	12.9,18.0	351	7	2.77203	0.00006	0.24	0.01	V
5392	Parker	11/21-12/09	524	13.1,19.7	33	-7	87.15	0.03	0.6	0.05	MC
5585	Parks	11/08-11/18	160	21.1,20.9	38	30	10.344	0.001	0.35	0.02	MC
8037	1993 HO1	10/27-11/01	215	3.7,2.6	38	3	12.98	0.03	0.09	0.02	NEA

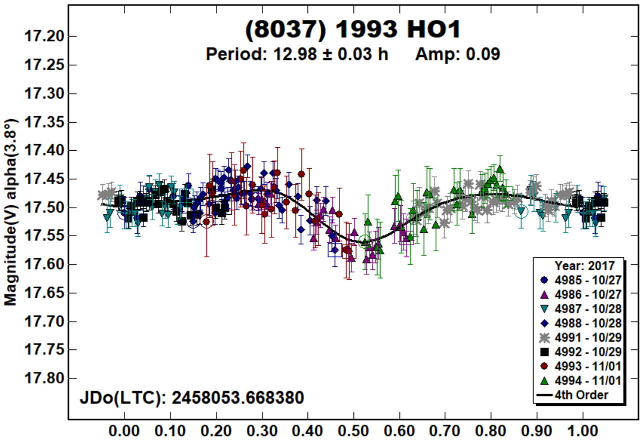
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et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



5585 Parks. Behrend (2008) reported a rotational period of 10.377 h. This result is in good agreement with that finding.



(8037) 1993 HO1. Pravec (2017) reported a rotational period of 13.04 h from the Photometric Survey for Asynchronous Binary Asteroids. This result agrees with that determination.



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

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NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2017 OCTOBER-DECEMBER

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Lightcurves for 20 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2017 October-December were analyzed for rotation period and signs of satellites or tumbling. The results for 7336 Saunders are based on data obtained in 2017 August and revise the original period of 3.36 h to 4.311 h. Preliminary shape and spin axis models are given for 1864 Daedalus and (17511) 1992 QN.

CCD photometric observations of 20 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2017 October-December. Table I lists the telescope/CCD camera combinations that were used. 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 cause a 0.1-0.3 mag 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 APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) 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).

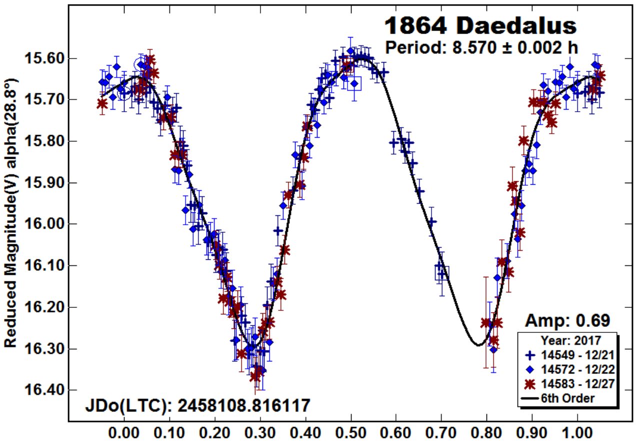
The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach > 0.1 mag. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm 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 distances by applying –5*log (rΔ) 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.

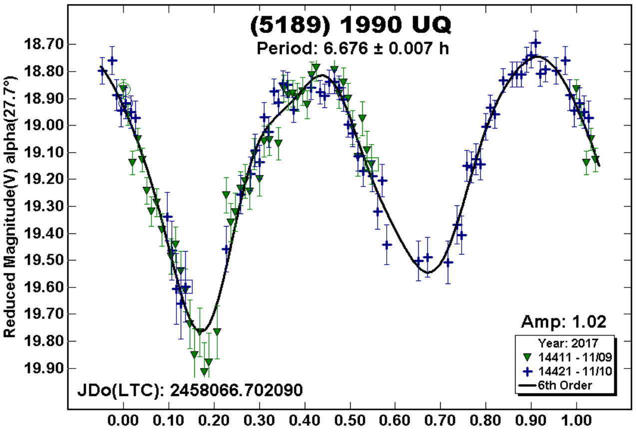
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on 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. Readers are strongly encouraged, when possible, to cross-check with the original references listed in the LCDB.

1864 Daedalus. Gehrels et al. (1971) were the first in the LCDB to have found a period for Daedalus (8.57 h). Warner (2015) found a period of 8.575 h, in good agreement with the period reported here. The data from the two apparitions observed at CS3 were combined with sparse data from surveys to find a preliminary shape and pole model (described later).

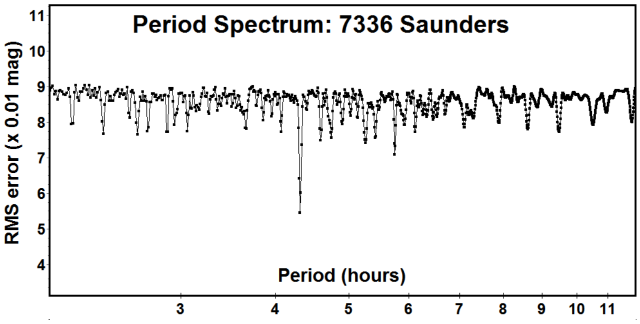


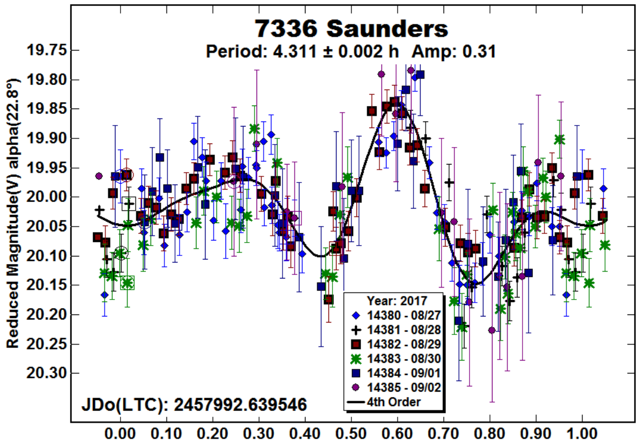
(5189) 1990 UQ. This appears to be the first reported period for this NEA, which has an estimated size of 800 meters.



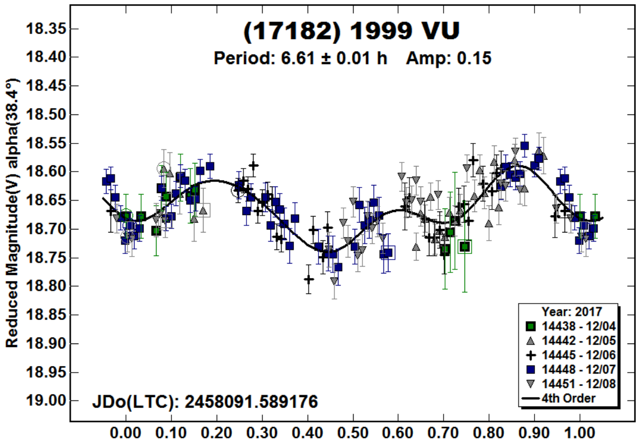
7336 Saunders. Pravec et al. (2003web) reported a period of 6.423 h, but it is rated U = 2– in the LCDB. Data obtained in 2017 August at CS3 led to a period of 3.36 h (Warner, 2018). Brian

Skiff (private communications) observed the asteroid at about the same time. Using well-calibrated high-quality data, he found a period of about 4.3 h and showed that both the Pravec et al. (2003web) and Warner (2018) solutions were not correct. This prompted a re-examination of the CS3 data that eventually found a period of 4.311 h. This revised period is now considered to be the most-likely correct despite the unusual shape of the lightcurve.

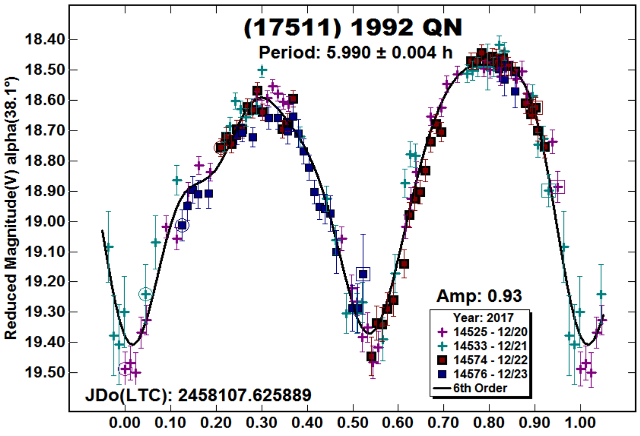




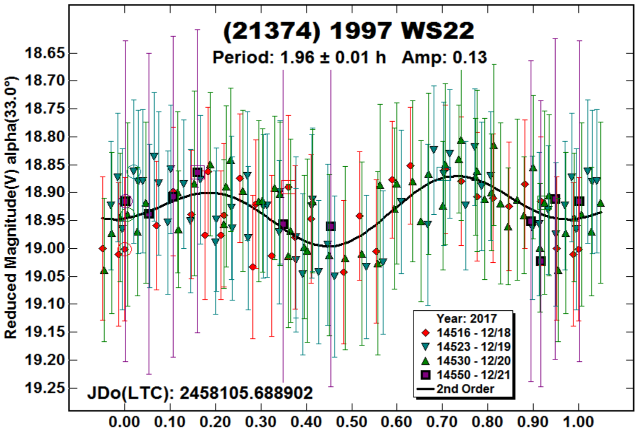
(17182) 1999 VU. There were no previously reported periods in the LCDB. The estimated size is 1.2 km, assuming an average albedo of 0.2 for NEAs.



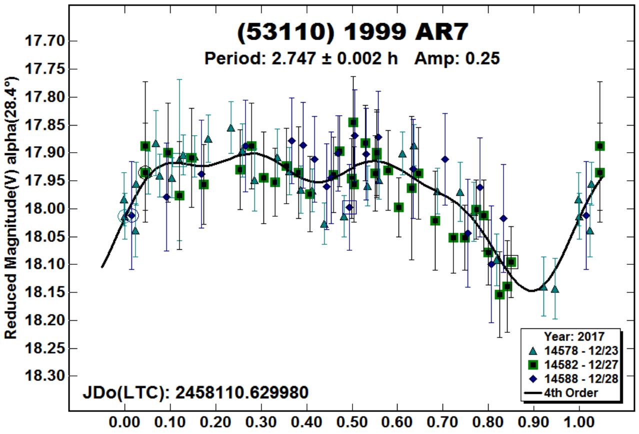
(17511) 1992 QN. Previous results include Pravec et al. (1998; 5.9902 h) and Waszczak et al. (2015; 5.988 h). The NEA was first observed at CS3 in 2013 (Warner, 2014a) when a period of 5.985 h was determined. The 2017 PDS data give almost identical results. The data from the two CS3 apparitions along with sparse data were used to model the asteroid (described later).



(21374) 1997 WS22. Previous observations at CS3 (Warner, 2014b) led to a period of 3.405 h. Carbognani (2014b) found a period of 2.292 h, while Vaduvescu et al. (2017) determined the period to be 2.4 h. The data from CS3 in 2017 were extremely noisy, so any period solution was suspect. The final result of 1.96 h is particularly so. The data can be forced to produce a bimodal solution with $P = 3.405$ h and $A = 0.08$ mag, but the result is even less convincing than the one given here. The correct solution remains as elusive.

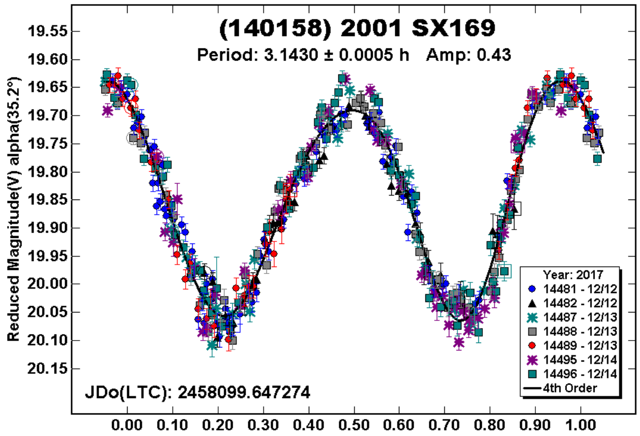


(53110) 1999 AR7. Warner (2016) reported this to be a binary asteroid based on conclusive evidence. The satellite orbital period is 31.31 h and the estimated satellite/primary effective diameter ratio is Ds/Dp = 0.40. The primary period was 2.7375 h: a result nearly echoed using the 2017 data from PDS.



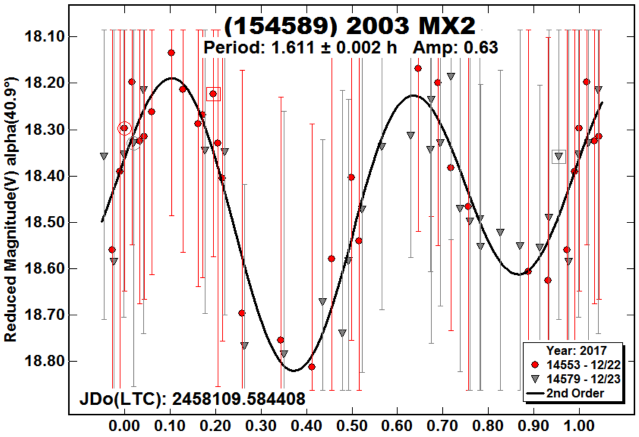
However, there were no signs of the satellite to be found. The phase angle bisector longitudes for 2016 and 2017 were, respectively, 100° and 64°. Assuming that the satellite orbit is close to the asteroid's equatorial plane, this might be enough of a difference so that the satellite passed above and below the primary and, therefore, no events were seen. Additional observations are strongly encouraged.

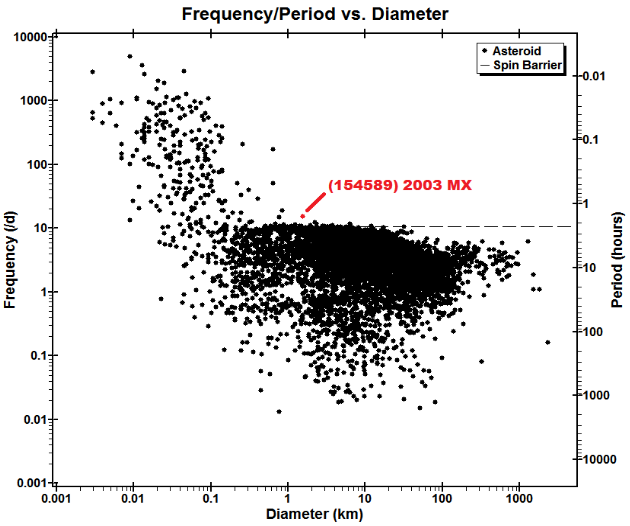
(140158) 2001 SX169. This apparition appears to be the first opportunity for period results to be reported for 2001 SX169. Vecchione et al. (2018; this issue) report confirming results. The estimated diameter is about 650 meters.



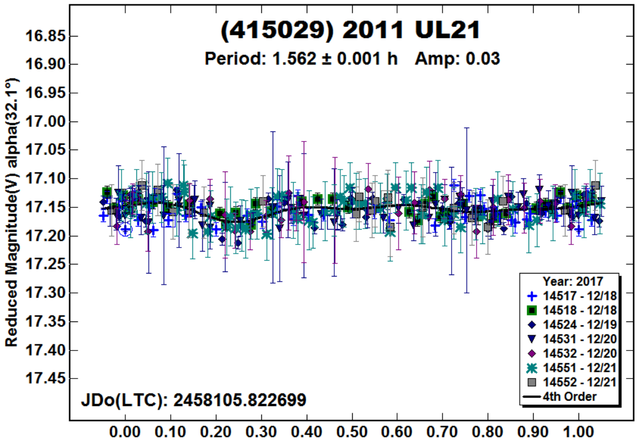
(154589) 2003 MX2. Sometimes not even an apparently large amplitude can overcome very low-quality data. Such is the case here. While the lightcurve amplitude is more than 0.6 mag, the error bars are almost as large. It's unfortunate in this case because the combination of the period and estimated diameter would place the asteroid just above the so-called "spin barrier" shown the frequency-diameter plot. The location is not so far above the barrier (which is more a fuzzy line than hard demarcation) as to be unreasonable (see Polishook et al., 2016).

In their case, they met the required standard of "extraordinary evidence" for an extraordinary claim. The evidence here is anything but extraordinary and so the result cannot even rise to the level of U = 2–; it should not be used in rotation statistical analysis. Looking ahead, the next best chance for those with modestly-sized telescopes is 2024 October-November when the asteroid will reach V ~ 15.3 at +5° declination.

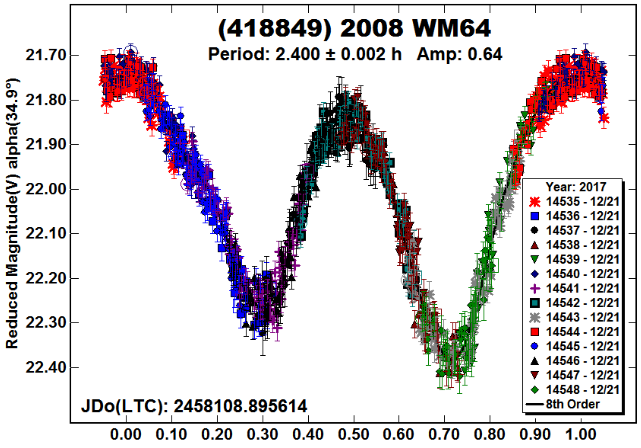


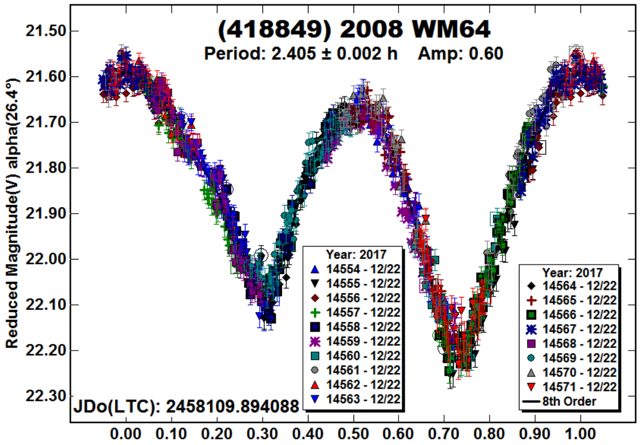


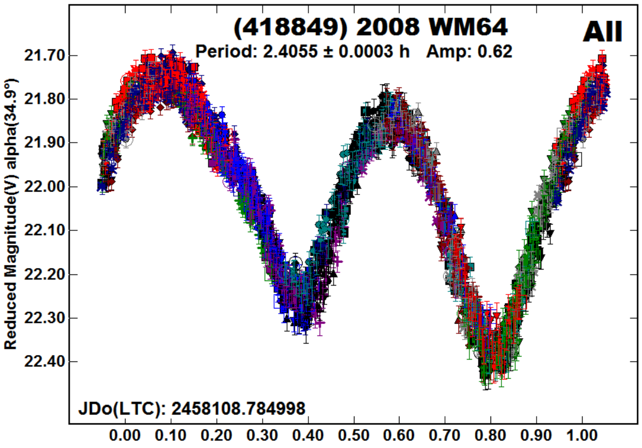
(415029) 2011 UL21. This appears to be a first-time result. Here again, it is highly-suspicious because it places the asteroid significantly above the spin barrier. There were no signs of a long period in the individual nights and so the solution may merely be the result of the Fourier analysis locking onto systematic noise.



(418849) 2008 WM64. This NEA was observed on two consecutive nights. The lightcurves have been split to show the slightly different shape and synodic period for each night.

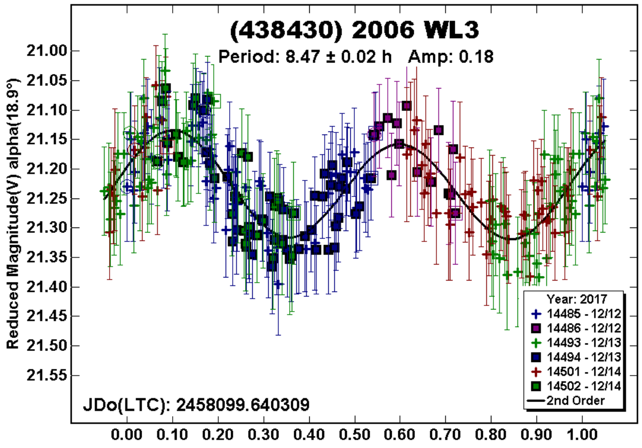


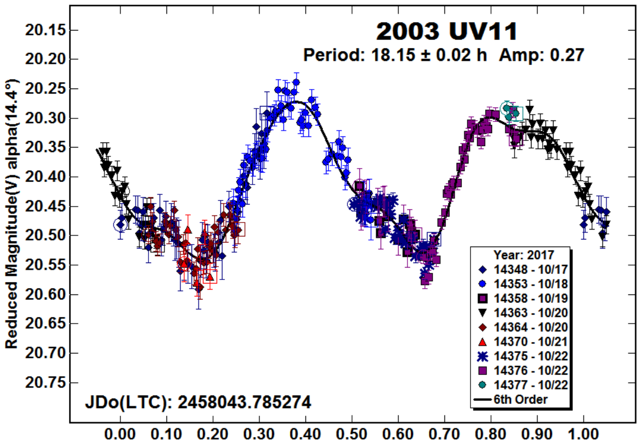


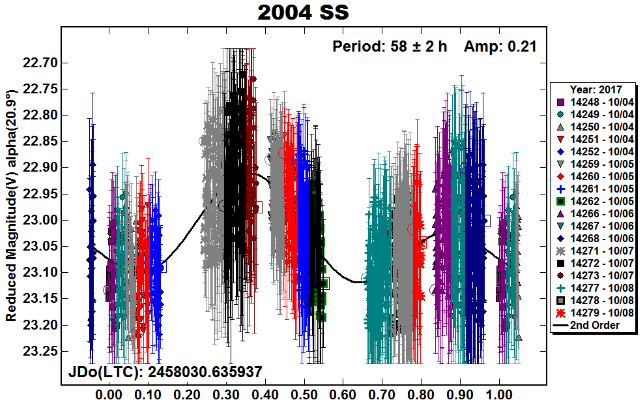


The combined data set was used to generate the "All" plot, which gave a period closer to the one for the second night.

<u>(438430) 2006 WL3, 2003 UV11, 2004 SS</u>. There were no previously reported periods found in the LCDB for these three NEAs. 2006 WL3 has an estimated diameter of 310 meters, the size for 2003 UV11 is about 250 meters, and 2004 SS comes in at only 125 meters. The first two have somewhat unusually long periods for asteroids with $D < 500$ meters. The solution for 2004 SS is highly unreliable and is a best guess based on the available data. Unfortunately, 2017 was the only time through 2050 that the asteroid was bright enough for modestly-sized telescopes (V ~ 16). From now until 2015, it will be V = 23-27 at brightest.

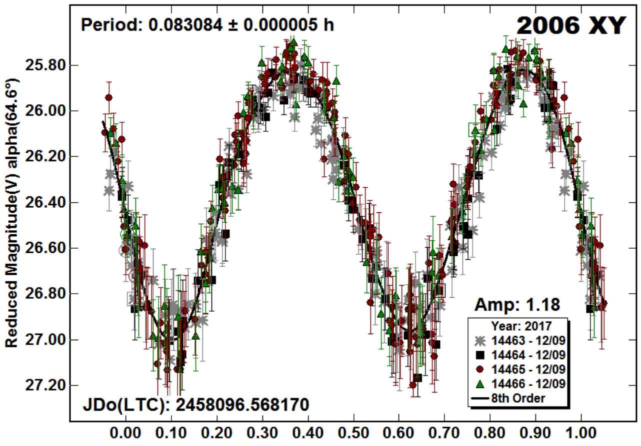


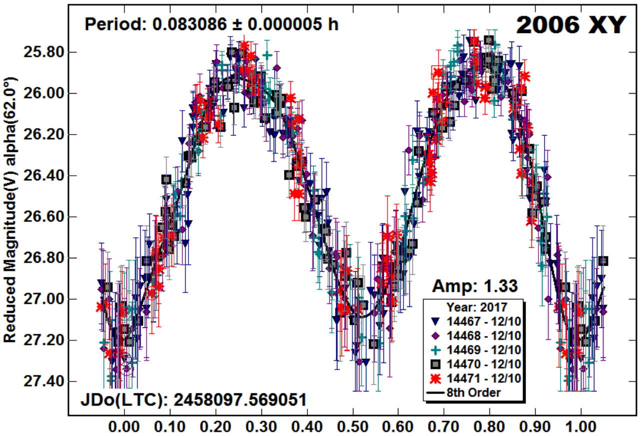


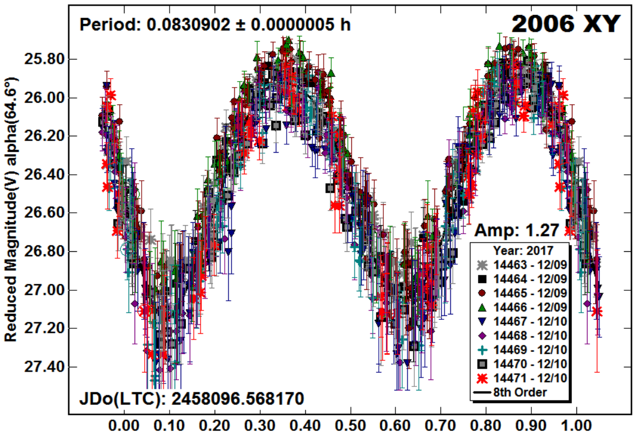


<u>2006 XY</u>. Hergenrother et al. (2009) first reported a period of 0.0830 h (about 299 seconds). Using data from 2007, Kwiatkowski et al. (2010) found 0.0832 h, or about 0.7 seconds longer. The data set from PDS over two nights gives a period of 0.0830902 h, or 299.125 seconds.

The data have been separated to show the lightcurves on each night: 2017 Dec 9 and 10. Note that the amplitude *increased* significantly on Dec 10 as the phase angle *decreased* from 65° to 62°. This is counter to the usual behavior of the amplitude increasing with *increasing* phase angle (Zappala et al., 1990). The phase angle bisector longitude changed by only 2°, so that was not likely a contributing factor.

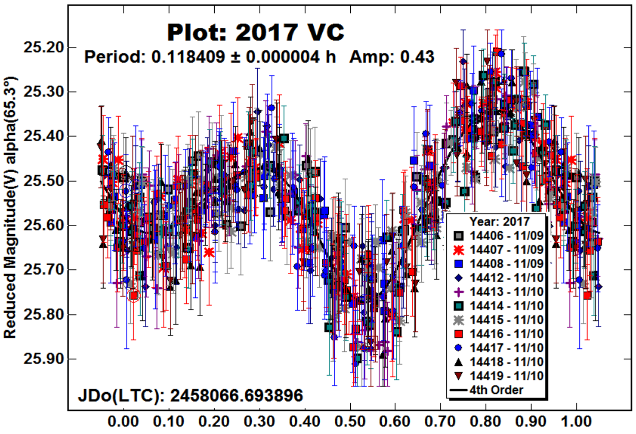


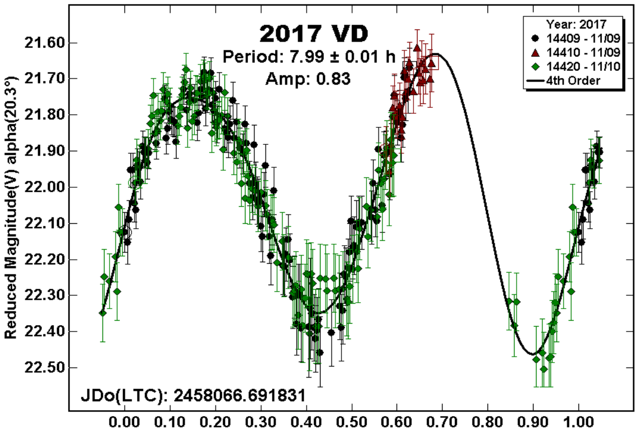




<u>2017 VC, 2017 VD</u>. Despite the somewhat noisy data, a reliable solution was found for the 75-meter 2017 VC. The result is consistent with asteroids having $D < 170$ meters, which usually "super-fast" rotators, i.e., $P < 2.2$ hours. There were no previously reported periods in the LCDB.

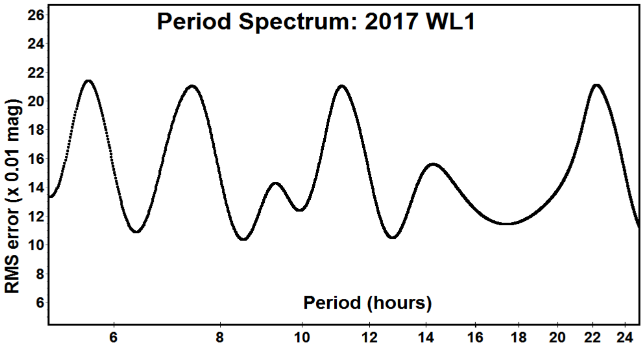
On the other hand, the estimated diameter of 2017 VD is about 200 meters, so it was less likely to have a very short period. This proved to be the case when the period was found to be 7.99 h. Given that this is close to being commensurate with an Earth day, other periods were possible, but the amplitude of 0.83 mag and somewhat low phase angle virtually assured a bimodal lightcurve that was nearly symmetrical (Harris et al., 2014). The adopted period provided the best fit under those constraints.

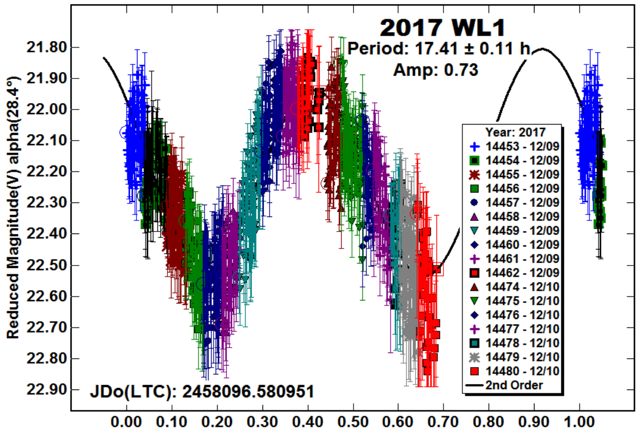


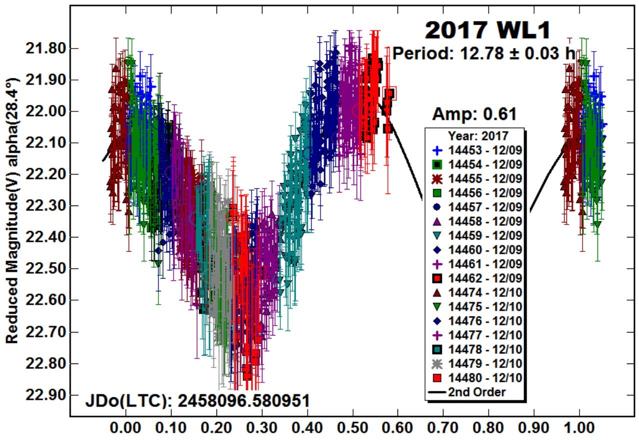


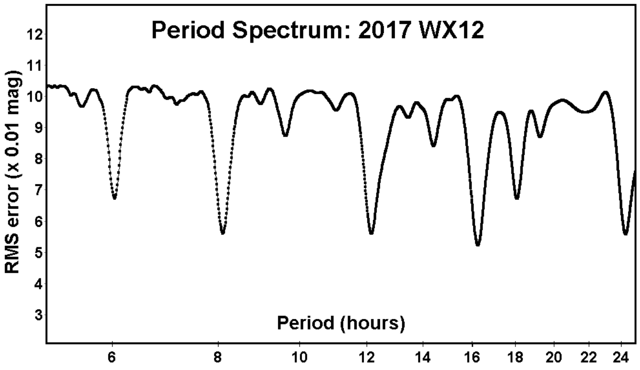
<u>2017 WL1, 2017 WX12, 2017 QQ32</u>. The period spectrum for 2017 WL1 shows a number of almost equally likely solutions. Matters were complicated by the large error bars masking any subtleties that would favor one solution over another. Here again, the amplitude and somewhat low phase angle constrained the solution to a bimodal lightcurve of nearly symmetrical shape. In the end, it's not possible to give a definitive solution. Those of 17.41 h and 12.78 h are the most probable. The longer period is adopted for this paper since its shape is slightly more symmetric within both halves.

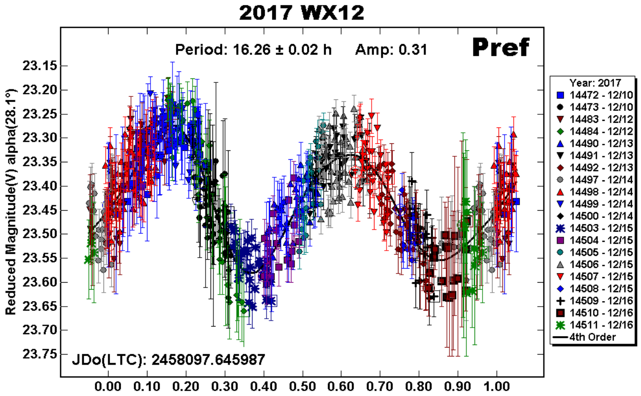
A similar conundrum appears for 2017 WX12. However, there is more confidence in the adopted period because it produces a complete lightcurve of reasonable shape. The solution of 12.16 h has a large gap, which could be the result of a *fit by exclusion*, which is when the Fourier analysis finds a local instead of global RMS minimum by minimizing the number of overlapping data points.

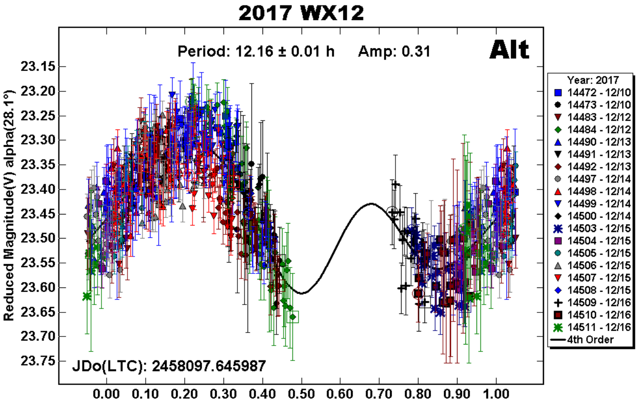




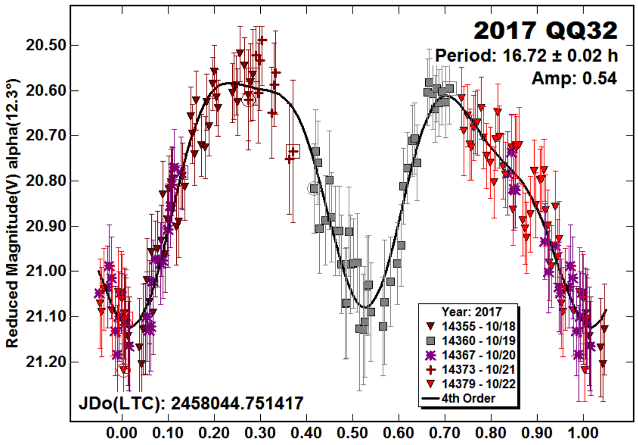








Fortunately, the solution for 2017 QQ32 is clear-cut. More than half the lightcurve has duplicate coverage and the period spectrum was dominated by the solution at 16.72 h.



Shape and Spin Axis Models

Asteroid	Pole	Period (hrs)
1864 Daedalus	(67, -80)	8.571974
(17511) 1992 QN	(120, -18)	5.986762

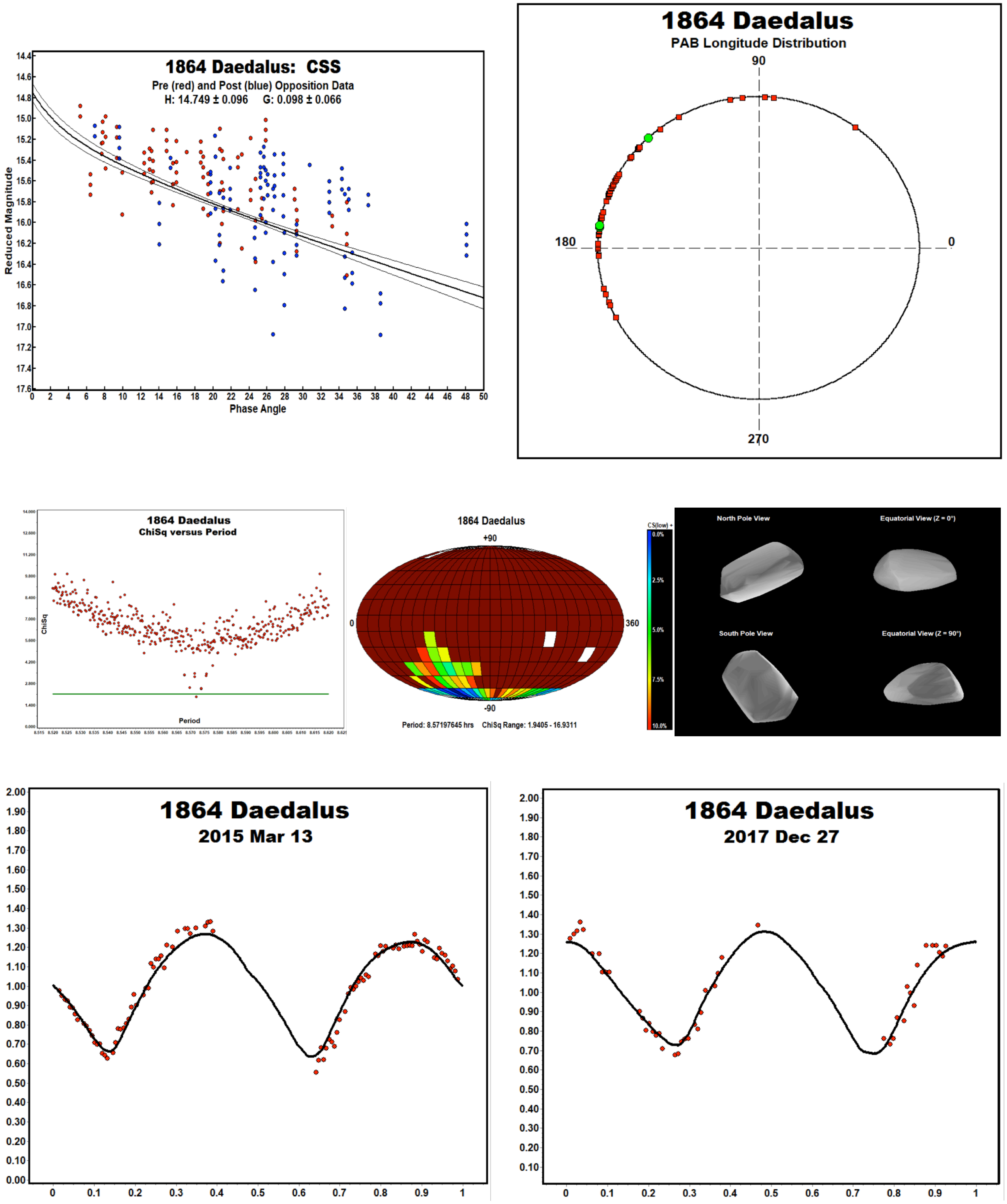
Table II. The Pole column gives the ecliptic longitude and latitude of the asteroid's north pole. The Period column gives the sidereal period, in hours.

The modeling processing using lightcurve inversion has been detailed previously (e.g., Warner et al., 2017). Briefly, the idea is to find a shape and its orientation such that its modeled lightcurves closely match the original data. It is generally "easier" to model NEAs because a single apparition can cover a wide range of phase angle bisector longitudes and phases, which is critical in finding a reliable solution. Main-belt asteroids often require data from several oppositions at different phase angle bisector longitudes before a reliable model can be developed. This is even when using sparse data from surveys, most often the Catalina Sky Survey in Arizona (*https://catalina.lpl.arizona.edu/*). All dense data used for modeling are from CS3 although additional dense data may be available.

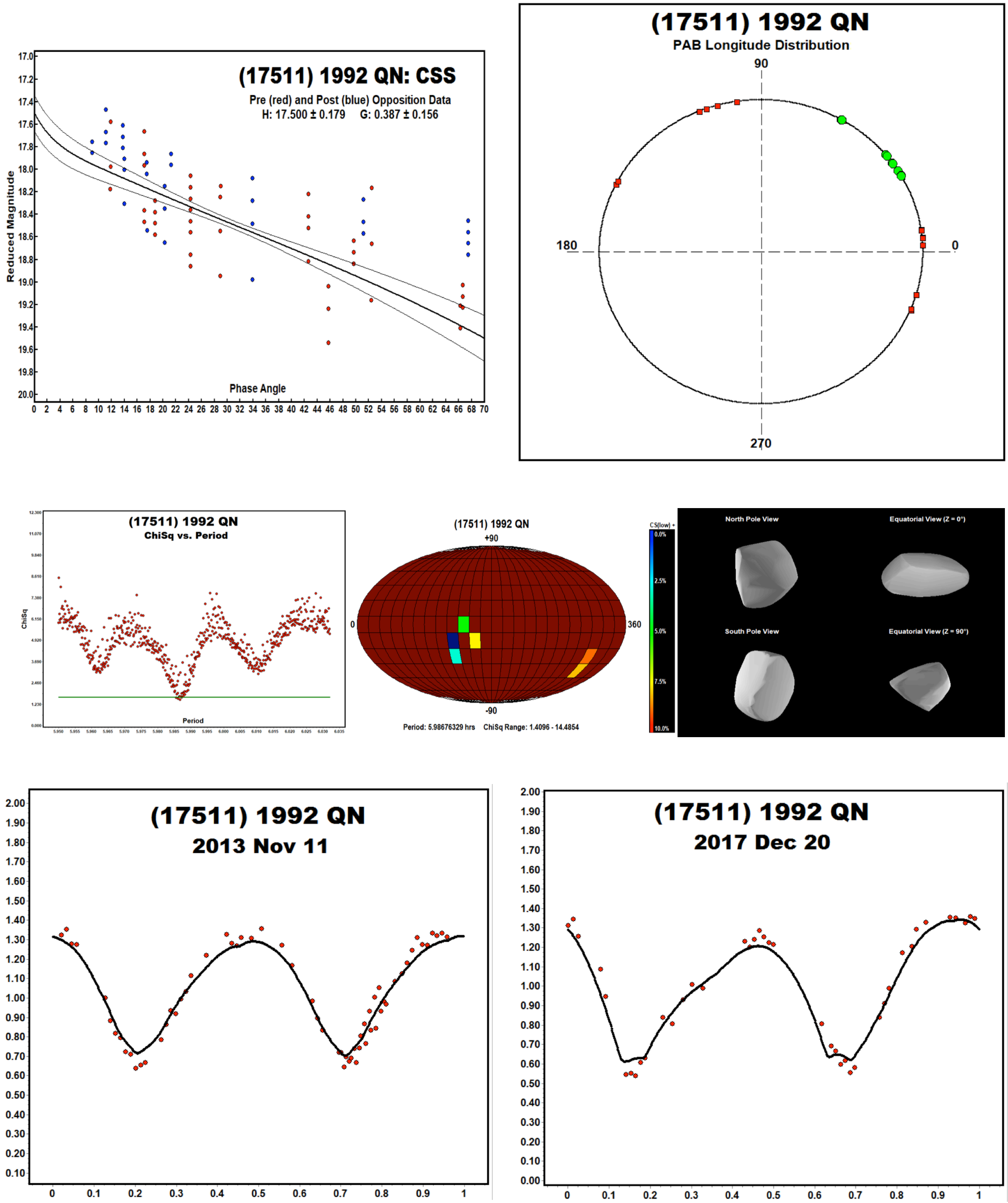
The inversion process finds a convex hull, i.e., it is akin to the shape after trying to wrap the asteroid with paper. This can result in large flat areas in the model, which are often interpreted to be concavities of one degree or another. More advanced techniques in recent years allow finding nonconvex models.

The period and pole search solutions produce a set of χ^2 values with the best solution having the lowest χ^2 value. Ideally, the second best χ^2 is at least 110% of the lowest χ^2. In the period search plot, the horizontal green line represents this 10% cutoff. In the pole solution plot, dark red (maroon) represents solutions that are more than 110% of the lowest χ^2. The best case is a single dark blue region. More typically, there are some adjacent regions ranging from light blue to bright red. The larger that "island", the less certain is the pole solution.

In both cases presented here, the period and pole solutions are fairly certain, i.e., no or very few χ^2 values within 10% of the lowest χ^2. This leads to the pole solutions having errors of about ±10 degrees in longitude and latitude and a sidereal period error on the order of two units in the last decimal place. Future data will, hopefully, prove these solutions correct and improve upon them.



Inversion modeling plots for 1864 Daedalus. In this model, there was a single data point below the 10% line in the period search plot. This gives greater confidence in the subsequent solutions for the pole and shape. The L_{PAB} distribution covers almost 180° of longitude. While covering the full circle is ideal, the second half would be mirroring the opposite pole – unless the shape significantly asymmetric along any of the axes. When modeling, there can almost never be too much data.



Inversion modeling plots for (17511) 1992 QN. The data from CSS in the H-G plot favor a higher albedo object, possibly close to a type E (see Warner et al., 2009). This is somewhat rare within the NEA population. The period solution has a well-defined minimum but is not unique since the several solutions below the 10% line. The pole solution is clear, with almost no ambiguity. See the text regarding the large flat areas in the shape model.

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1864	Daedalus	12/21-12/27	179	28.8,26.6	133	28	8.57	0.002	0.72	0.03
5189	1990 UQ	11/09-11/10	107	27.7,27.9	24	-8	6.676	0.007	1.02	0.04
7336	Saunders	08/27-09/02	125	22.9,25.1	321	8	3.36	0.01	0.28	0.03
17182	1999 VU	12/04-12/08	146	38.6,44.1	48	23	6.61	0.01	0.15	0.02
17511	1992 QN	12/20-12/23	146	38.2,40.8	60	21	5.99	0.004	0.96	0.04
21374	1997 WS22	12/18-12/21	135	33.1,34.6	52	7	1.96	0.01	0.13	0.03
53110	1999 AR7	12/23-12/28	86	28.4,31.2	64	-11	2.747	0.002	0.25	0.03
140158	2001 SX169	12/12-12/14	374	35.4,41.0	59	-10	3.143	0.0005	0.43	0.03
154589	2003 MX2	12/22-12/23	54	40.9,40.8	37	0	1.611	0.002	0.63	0.06
415029	2011 UL21	12/18-12/21	253	32.1,32.3	117	-8	1.562	0.001	0.03	0.01
418849	2008 WM64	12/21-12/22	1683	34.6,25.9	105	-4	2.4055	0.0003	0.62	0.03
438430	2006 WL3	12/12-12/14	244	19.0,20.9	68	-5	8.47	0.02	0.18	0.03
	2003 UV11	10/17-10/22	279	14.5,5.9	33	-1	18.18	0.02	0.27	0.02
	2004 SS	10/04-10/08	1220	21.1,26.1	16	13	58	2	0.21	0.05
	2006 XY	12/09-12/10	975	64.2,61.4	47	1	0.0830902	0.0000005	1.27	0.05
	2017 VC	11/09-11/10	617	64.8,60.2	18	14	0.118409	0.000004	0.43	0.04
	2017 VD	11/09-11/10	276	20.3,19.9	35	1	7.99	0.01	0.83	0.02
	2017 WL1	12/10-12/10	993	37.4,37.4	59	-10	[A]17.41	0.11	0.73	0.05
	2017 WX12	12/10-12/16	627	28.0,21.0	71	-8	16.26	0.02	0.31	0.03
	2017 QQ32	10/18-10/22	174	12.3,8.9	32	-6	16.72	0.02	0.54	0.03

Table III. Observing circumstances. [A](Period) indicates the preferred period of an ambiguous solution. 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. 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).

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/*)

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LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2017 OCTOBER-DECEMBER

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Lightcurves for 12 Hilda asteroids were obtained at the Center for Solar System Studies (CS3) from 2017 October-December. Preliminary shape and spin axis models are given for seven of the Hildas: 958 Asplinda, 1439 Vogita, 1539 Oterma, 2483 Guinevere, 3561 Devine, 4317 Garibaldi, and 17428 Charleroi. These will serve as good starting points for future modeling.

CCD photometric observations of 12 Hilda asteroids were made at the Center for Solar System Studies (CS3) from 2017 October-December. This is another installment of an on-going 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 we look to examine the degree of influence that the YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) 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 APASS (Henden et al., 2009) or CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/*) 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).

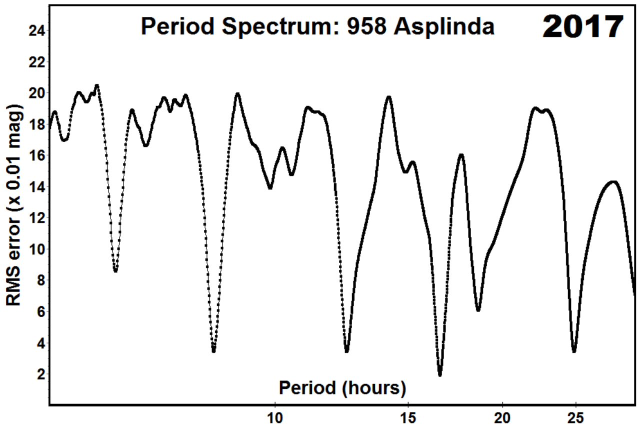
The nightly zero points for the catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach > 0.1 mag. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm 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.

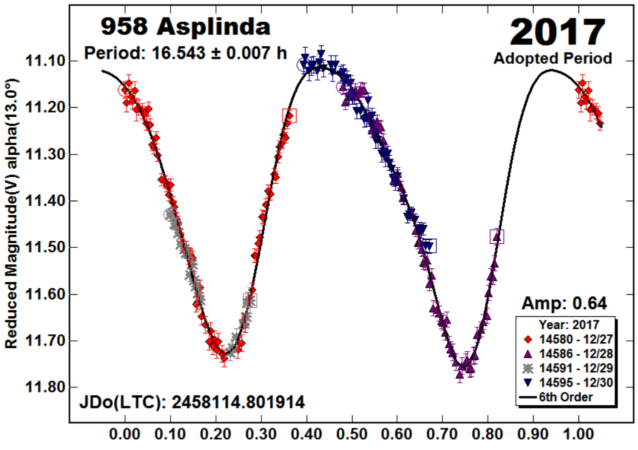
If the plot includes an amplitude, *e.g.*, “Amp: 0.65”, this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

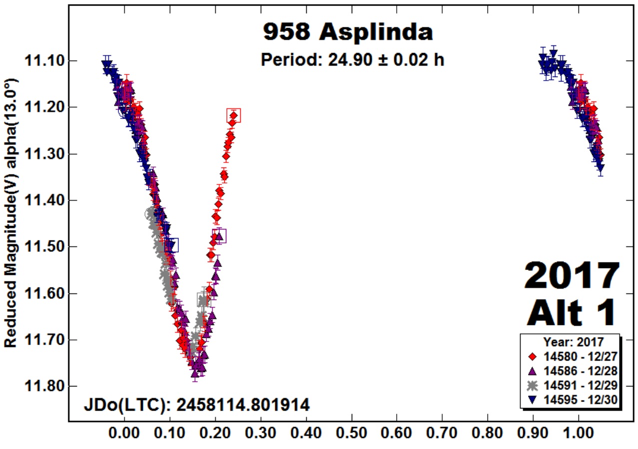
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html* 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.

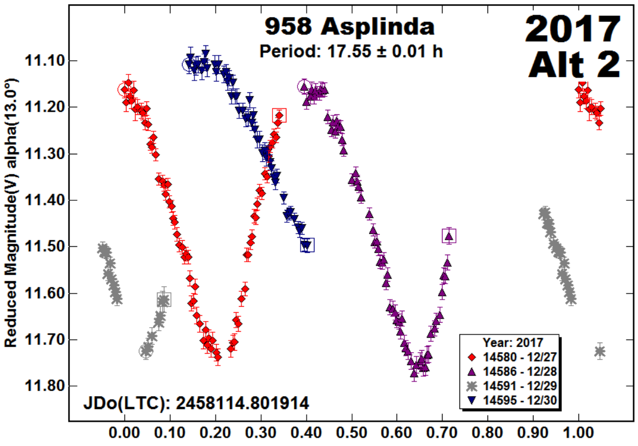
958 Asplinda. Dahlgren et al. (1998) reported a period of 25.3 h and amplitude of 0.57 mag for this 47-km Hilda. Hanus et al. (2013) modeled the asteroid using available dense and sparse data to find a sidereal period of 25.3050 h. Warner et al. (2017b) found a synodic period of 17.55 h and amplitude of 0.18 mag. The asteroid was observed again at CS3 to see if a definitive period could be found.



As the period spectrum shows, the 2017 data did not immediately lead to a unique solution. However, they did eliminate the 17.5 hour solution as seen in the “2017 Alt2” plot. A solution near 25 h was possible but, when the data were forced to fit between 25-26 h (“2017 Alt1”), the slopes of the phased lightcurve were unreasonably steep, looking more like they were part of a trimodal solution. Given the amplitude and low phase angle, this was not realistic (Harris et al., 2014).

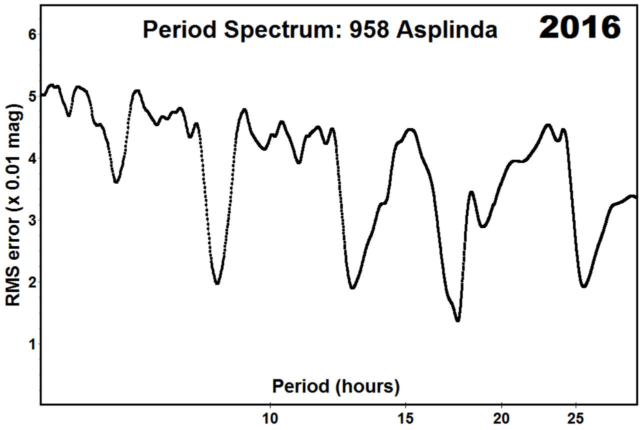


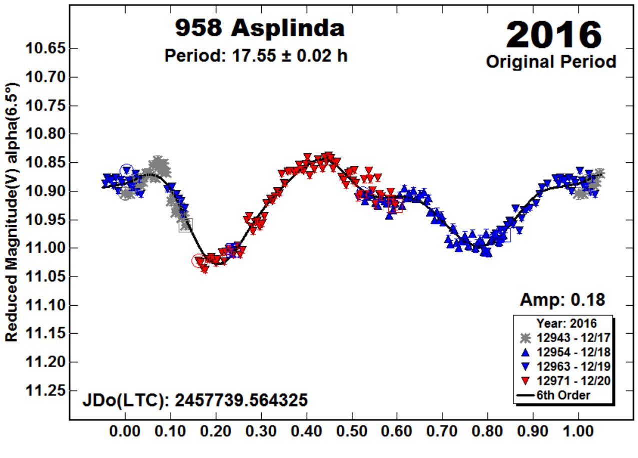


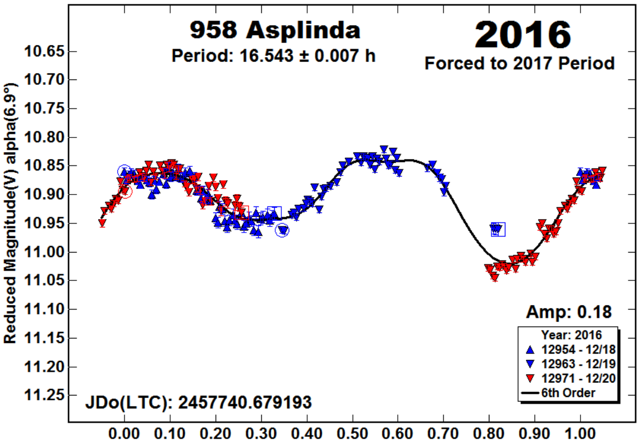


On the presumption that the period was about 16.5 h, the original data from 2016, obtained by Coley at CS3, were re-examined to see if they could be fit to the shorter period. The period spectrum, when using the original zero points, still favored 17.5 h. However, with only very minor zero point shifts (< 0.03 mag), the data could be fit to the 2017 period. The two caveats were that the session from 2016 Dec 17 was dropped because it didn’t fit the shorter period and the data covered the entire lightcurve with the original period but did not with the shorter period.

We modeled the shape and spin axis using our two dense data sets (including the 2016 Dec 17 session) and sparse data from the Catalina Sky Survey (CSS) after first doing period searches covering 16-18 h and 25.2-25.5 h. The 16.5 h solution provided a significantly lower χ^2 value.

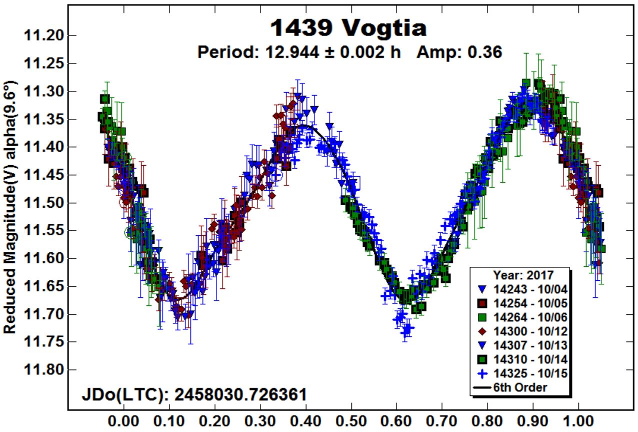






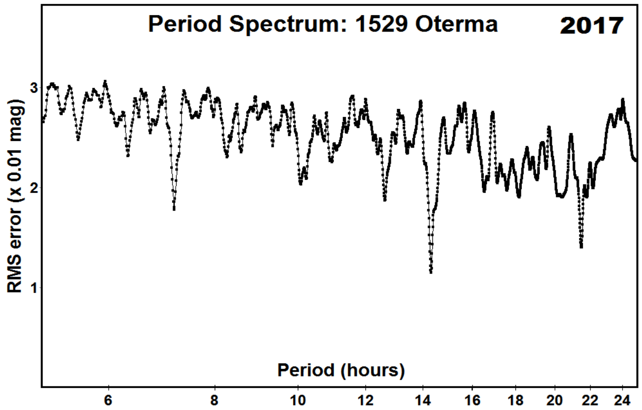
1439 Vogtia. Dahlgren et al. (1998) found a period of 12.95 h, a solution reasonably matched by Warner et al. (2017b) and the one found with our most recent data. In the three cases, the asteroid lightcurve amplitude ranged from 0.33-0.36 mag even though the phase angle bisector was significantly different at two of the apparitions. This implied that the asteroid was elongated and that its pole was nearer to an ecliptic pole than the ecliptic equator.

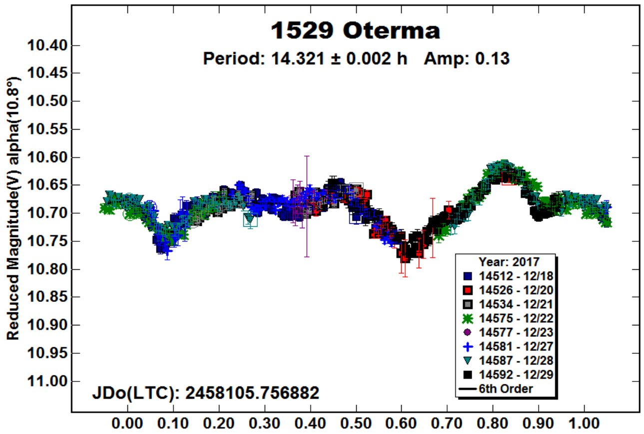
We modeled the asteroid using sparse data from USNO-Flagstaff and CSS as well as our two dense data sets from 2016 and 2017. The period search found a well-constrained solution. However, the pole latitude was near the ecliptic north pole. In such cases, there can be considerable ambiguity in the pole longitude. We found two possible poles where the longitude errors were ±20°. The latitude errors were smaller, ±10° to 15°

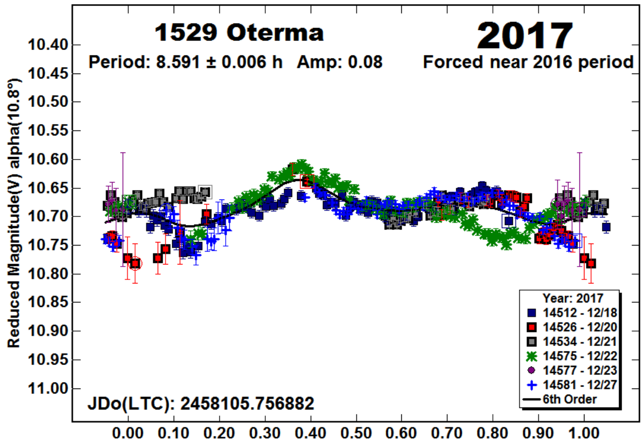


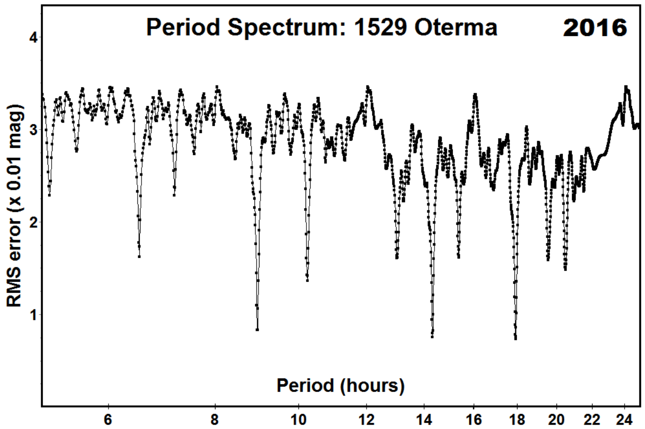
1529 Oterma. This 54-km Hilda was another case of diverging solutions. Dahlgren et al. (1998) found a period of 15.75 h while Warner et al. (2017b) found 8.956 h. The amplitudes were less than 0.2 mag, leaving the possibility that a bimodal lightcurve should not be assumed.

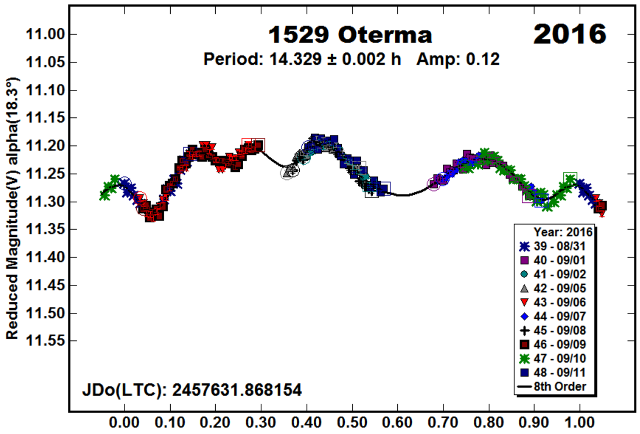
Ditteon et al. (2018) found a convincing solution at a third period: 14.298 h. This prompted a second look using the 2016 data CS3 data as well as the more recent observations. We found that the 2017 data provided a good fit to a period almost identical to Ditteon et al. (2018). The 2016 solution was not so straightforward. The period spectrum showed several possibilities, with two being the original solution of 8.96 h and the new period of 14.32 h.





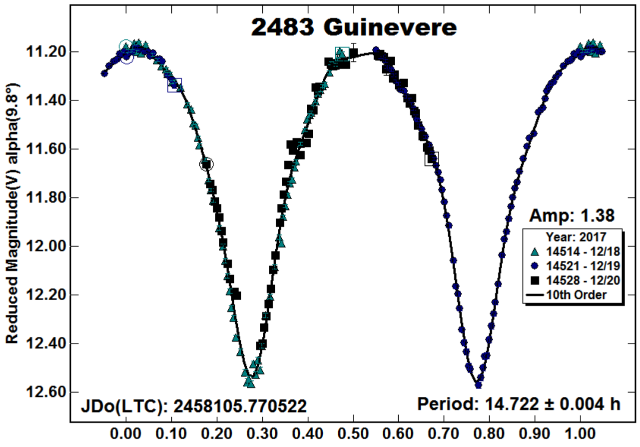






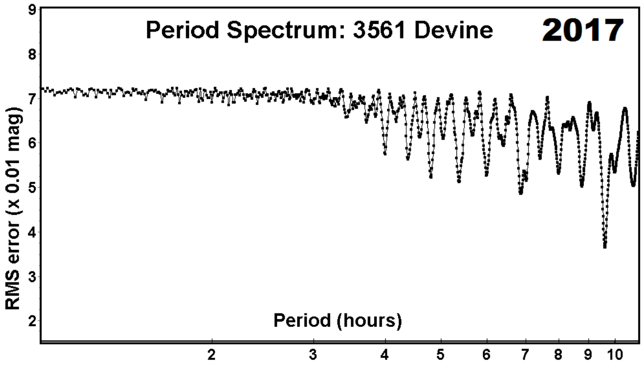
The fit the data to the longer period produces a multimodal lightcurve, which is not unreasonable given the low amplitude and phase angle (Harris et al., 2014). We modeled the asteroid after doing two searches about periods of 8.96 h and 14.32 h, eliminating the likelihood of the period found by Dahlgren et al. (1998). The period solution was weak but it still led to a strong, single pole solution with a negative latitude.

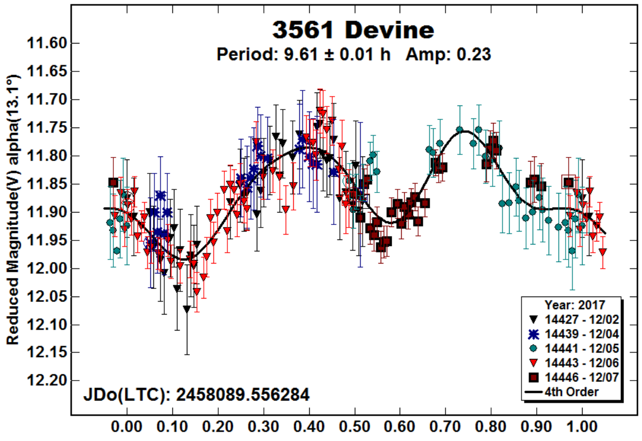
2483 Guinevere. Dahlgren et al. (1998) found *P* = 14.733 h. Durech et al. (2016) modeled the asteroid, finding a sidereal period of 14.73081 h. Our previous result (Warner et al., 2017b) and the one derived from the 2017 data are in good agreement. We used our two dense data sets along with sparse data from CSS to find a model. As shown in Table III, our single pole solution closely matches the longitude of the preferred pole found by Durech et al. (2016). However, our pole has a significantly lower latitude. Even so, ours and the Durech et al. (2016) poles indicate prograde rotation.

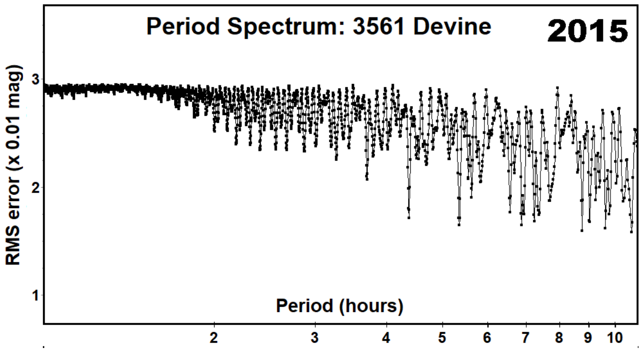


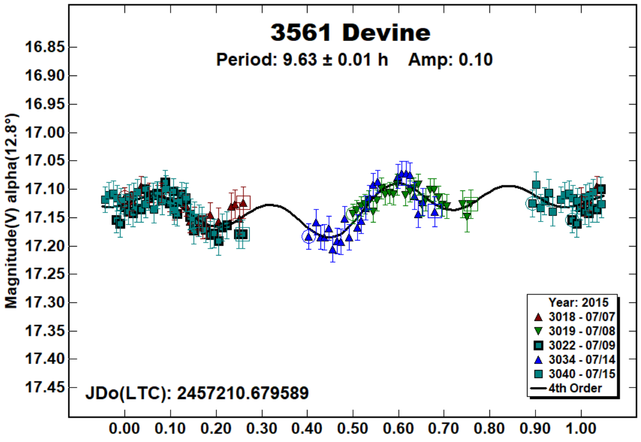
3561 Devine. Dahlgren et al. (1998) reported only that the amplitude of the lightcurve was > 0.04 mag. Stephens (2016) found an ambiguous solution that favored 4.376 h but one of 5.354 h could not be excluded. The amplitude was only 0.08 mag during his 2015 July observations. It's worth noting that the two periods differ by one rotation over 24 hours.

The 2017 data, while somewhat noisy, produced a lightcurve with an amplitude of 0.23 mag and, from the period spectrum, a unique period of 9.61 h. Stephens' 2015 data were re-examined and found to fit a period of 9.63 h, although the shape is multimodal and there are gaps. The revised 2015 period spectrum shows again that several solutions are possible.



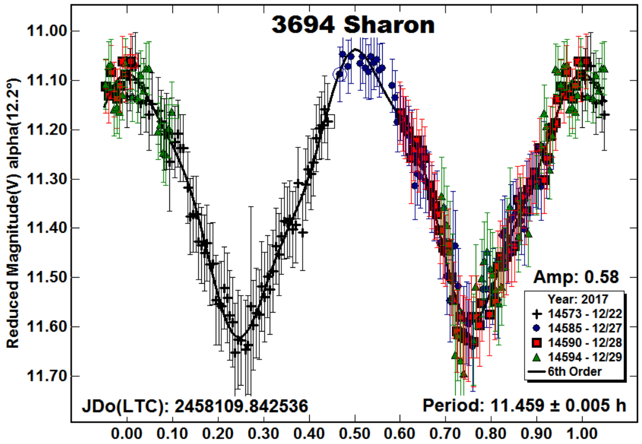




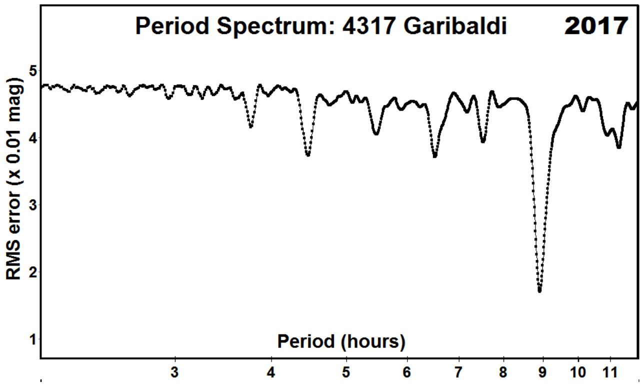


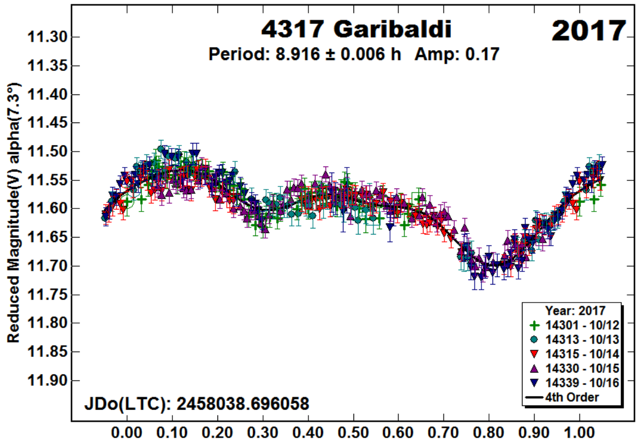
Because of the ambiguities, we modeled the asteroid after doing period searches about 4.4 h and 9.6 h. The lowest χ^2 for a 9.6 period was nearly half of the one for 4.4 h and so we have adopted a synodic period of 9.61 h for the asteroid. The pole search plot found two longitude that differed by about 180°. This is a common artifact of lightcurve inversion when dealing with objects that have low orbital inclinations. The poles have an error of about ±20°.

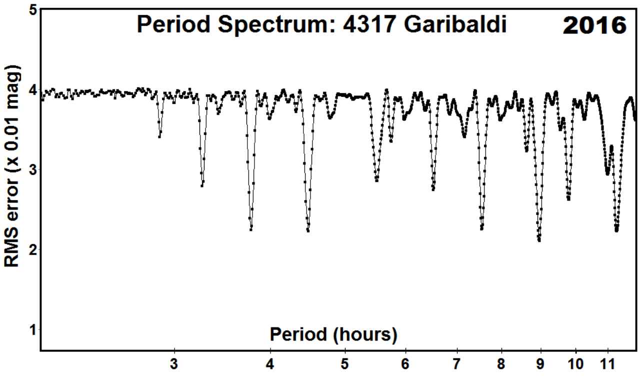
3694 Sharon. Dahlgren et al. (1998) found a period of 11.478 h for this 45-km Hilda. Our result of 11.459 h is in good agreement. There were insufficient dense data to try modeling the asteroid.

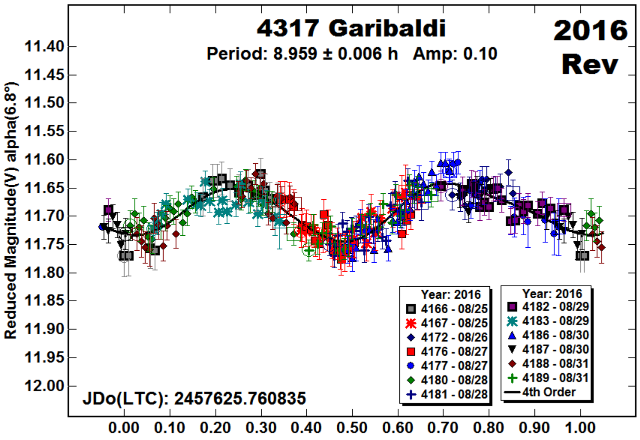


4317 Garibaldi. Dahlgren et al. (1998) reported *P* = 28.5 h, but it is rated U = 1 ("probably wrong") in the LCDB. The data from the 2017 campaign led to a period of 8.917 h, which differed from our previous result of 7.539 h from 2016 (Warner et al., 2017a). The data from both apparitions were checked to see if they would fit the opposing period. The result was that the 2016 data could be fit to the longer period but the 2017 data could not be fit to the shorter period.





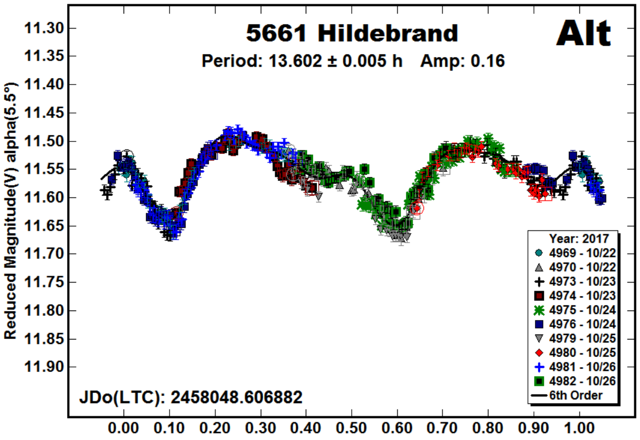


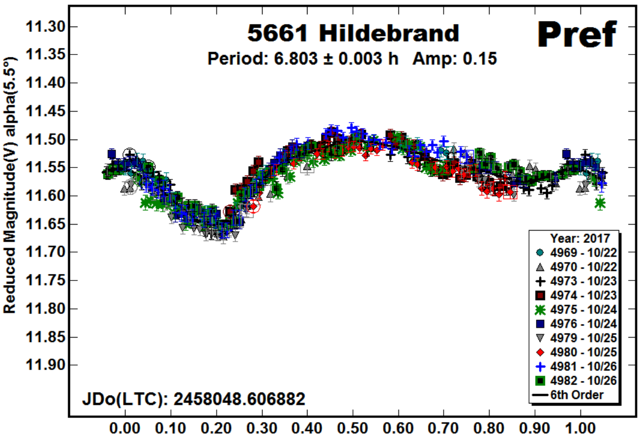


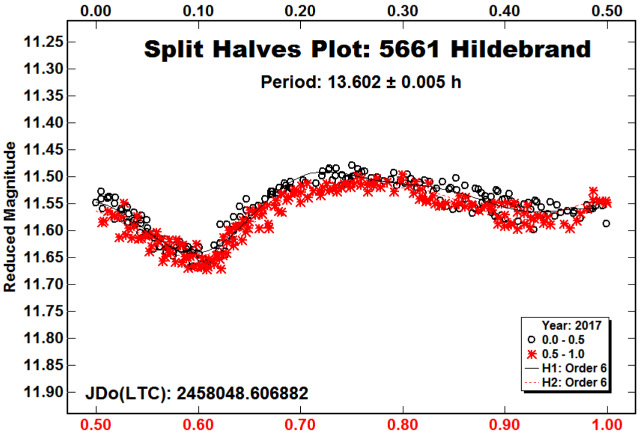
We used the 8.959 h period as the basis for modeling the asteroid. As the pole search plot shows, neither the longitude nor latitude was reliably found. During the 2018-19 apparition, Garibaldi will have a phase angle bisector longitude about 65° from the one in 2016. It's hoped that the addition of a good dense lightcurve set at that time will allow a more constrained pole solution.

5661 Hildebrand. Dahlgren et al. (1998) found a period of 13.61 h. Our 2017 data led to two possible periods, one very similar to that from Dahlgren et al. (1998). That longer period produced a lightcurve that was highly symmetric about the two halves, as seen in the split-halves plot where the second half the lightcurve is superimposed on top of the first half. This technique from Harris et al. (2014) is useful when determining if a half-period solution is possible, as demonstrated by the two halves being nearly identical. In this case, the split-halves plot was essentially the same as the lightcurve for the shorter period.

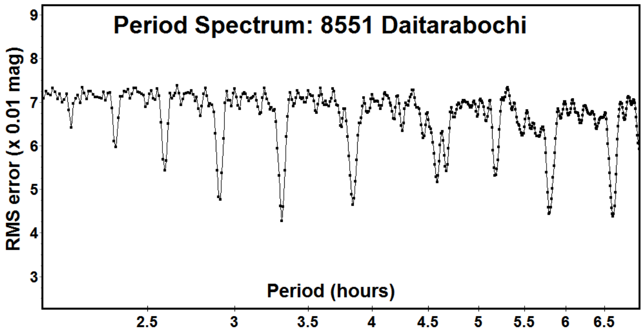
The Dahlgren et al. (1998) data set was fairly sparse and broken into two consecutive night blocks separated by almost two weeks. This makes it possible (probable) that their solution is the result of a *rotational alias*, i.e., a miscount of the number of rotations over the range of the data. Based on this and the split-halves plot, we have adopted a period of 6.803 h for this work but recognize that the double period cannot be formally excluded.

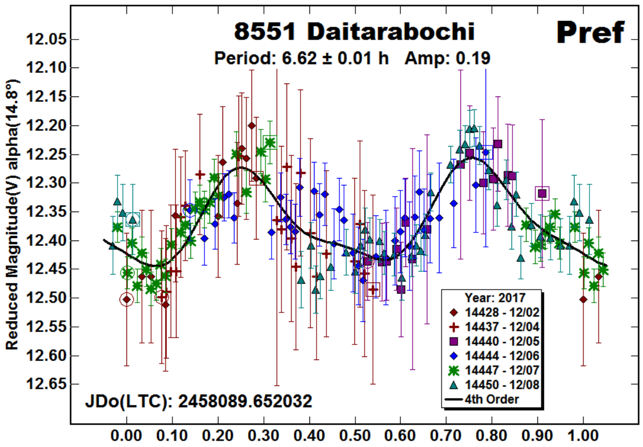


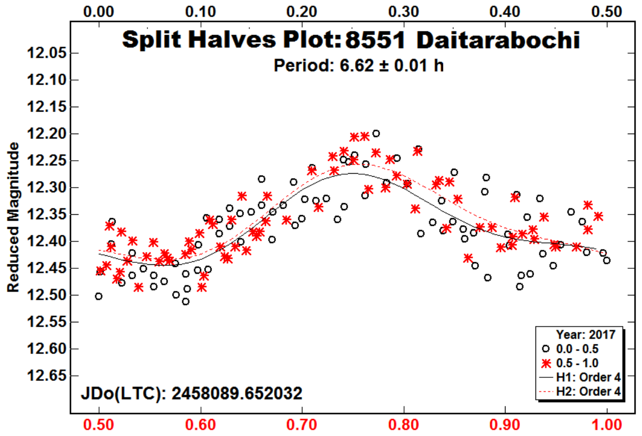


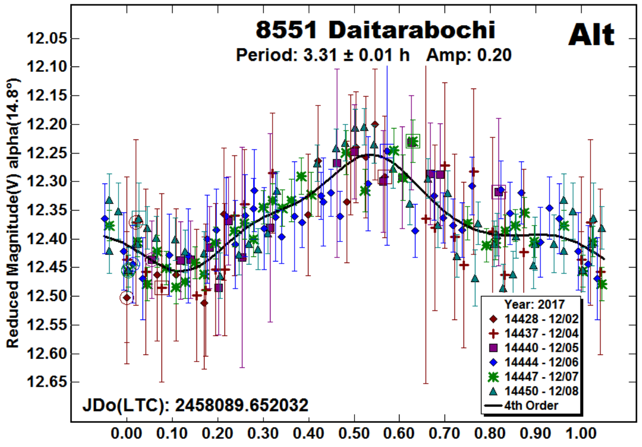


8551 Daitarabochi. This appears to be the first reported period for this 34-km Hilda. The period spectrum shows that the two more likely periods are 6.62 h or the half-period of 3.31 h.



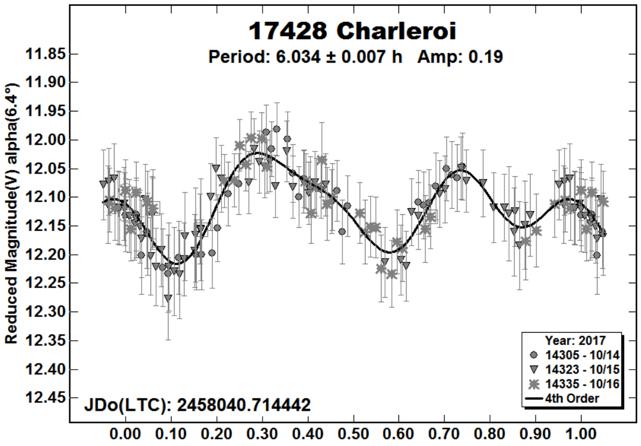




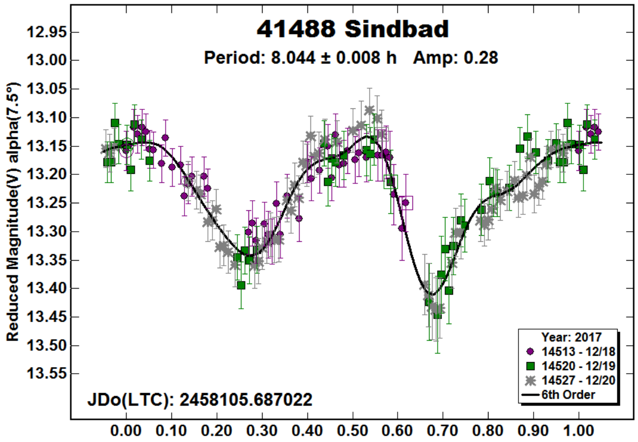


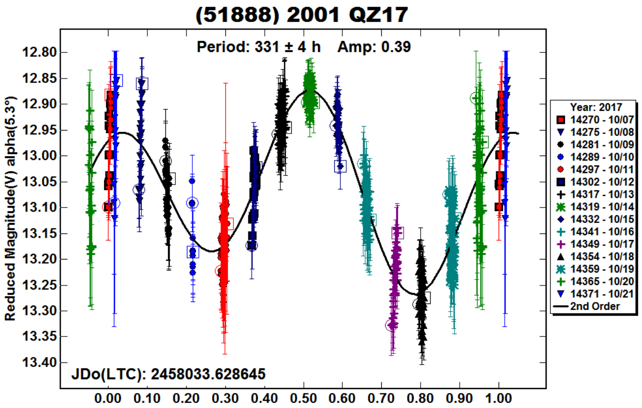
The split-halves plot seems to favor the longer period but, given the noise in the data, the differences in the two halves is not significant. We have adopted 6.62 h for the preferred period but 3.31 h cannot be formally excluded. The estimated diameter of 33 km does not help eliminate the shorter solution. As of 2018 January, there are five asteroids in the LCDB with *D* > 30 km and *P* < 3.5 h.

17428 Charleroi. The period of 6.034 h found from the 2017 data is in good agreement with our previous result of 5.990 h (Warner et al., 2017a). We used our two dense data sets and sparse data from CSS to model the asteroid. The longitude seems to be reasonably established at one of two values separated by about 180°. The latitude is not so well-determined. Our two poles have negative latitudes, indicating retrograde rotation.



41488 Sindbad, (51888) 2001 QZ17. There were no previous entries in the LCDB for either of these Hildas. Sindbad has an estimated diameter of 18 km while 2001 QZ17 is about 15 km. The period for Sindbad is considered secure. The period for 2001 QZ17 is a little less so, although it is almost certainly a very slow rotator. The period makes it a good candidate for tumbling (see Pravec et al., 2014, and references therein). There do seem to be some slight indications of tumbling in that the slope of some of the sessions does not match the slope of the Fourier model curve. However, these small differences are not enough to rate the asteroid even as a possible tumbler.





Shape and Spin Axis Models

Asteroid	Src	Pole	Period (hrs)
958 Asplinda	TW	**(228, +33)**	**16.556100**
958 Asplinda	TW	(46, +45)	16.556089
958 Asplinda	*H13*	*(41, +48)*	*25.3050*
958 Asplinda	*H13*	*(226, +35)*	*25.3050*
1439 Vogtia	TW	(255, +71)	12.934244
1439 Vogtia	TW	(76, +67)	12.934239
1529 Oterma	TW	(59, -71)	14.339108
2483 Guinevere	TW	(16, +42)	14.730644
2483 Guinevere	*D16*	*(19, +70)*	*14.73081*
3561 Devine	TW	**(95, -38)**	**9.622158**
3561 Devine	TW	(261, -28)	9.622160
4317 Garibaldi	TW	(164, +28)	8.933050
17428 Charleroi	TW	**(329, -35)**	**5.989413**
17428 Charleroi	TW	(145, -49)	5.989415

Table II. The Src column gives the source for the results: TW, this work; H13, Hanus et al., 2013; D16, Durech et al., 2016. The Pole column gives the ecliptic longitude and latitude of the asteroid's north pole. The Period column gives the sidereal period, in hours. If there is more than one solution, the preferred one is in bold text. The period error is on the order of 1-2 units in the last decimal place. For single solutions, the pole

The modeling processing using lightcurve inversion has been detailed previously (e.g., Warner et al., 2017b). Briefly, the idea is to find a shape and its orientation such that its modeled lightcurves closely match the original data. It is generally "easier" to model NEAs because a single apparition can cover a wide range of phase angle bisector longitudes and phases, which are critical in finding a reliable solution. Main-belt asteroids usually require data from at least three oppositions at different phase angle bisector longitudes before a reliable model can be developed. This is even when using sparse data from surveys such as from the Catalina Sky Survey in Arizona (*https://catalina.lpl.arizona.edu/*).

In the PAB longitude plot, green circles represent dense lightcurves while red squares represent sparse data from one or more of the surveys. The green line in the period plot lies 10% above the lowest χ^2 value. An ideal solution has a well-defined shape with only one data point below the line. In the pole plot, dark red represents a solution that is more than 10% above the lowest χ^2 value. A "perfect" solution is when there is only one dark blue region and all the others are dark red. The solid black line in the lightcurve plots is the model lightcurve and the red dots are the original data.

In most models presented here, the period solution is far from being unique, which is critical to the subsequent steps. The only way to improve the solution is to obtain data from even further back in time and/or the future so that the data cover a longer time span. This, of course, presumes data of sufficient quality. The sparse data are often the only source of extended data. Unfortunately, in some cases here, the original sparse data set showed much higher scatter than usual and so a number of observations had to be removed. This shortened the date range of observations considerably.

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Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
958	Asplinda	12/27-12/29	205	13.1,12.7	143	3	16.543	0.007	0.64	0.02
1439	Vogtia	10/04-10/15	432	9.6,7.1	48	1	12.944	0.002	0.36	0.02
1529	Oterma	12/31-12/31	250	9.6,0.0,7.1	0	0	14.329	0.002	0.12	0.01
1529	Oterma	12/18-12/29	524	10.8,8.3	127	4	14.321	0.002	0.13	0.01
2483	Guinevere	12/18-12/20	250	9.9,9.2	112	-3	14.721	0.006	1.37	0.03
3561	Devine	12/04-12/07	172	13.3,13.6	15	-10	9.61	0.01	0.23	0.02
3694	Sharon	12/22-12/29	250	12.3,11.2	144	-1	11.459	0.005	0.58	0.03
4317	Garibaldi	08/25-08/31	254	6.8,5.5	359	-8	8.959	0.006	0.1	0.01
4317	Garibaldi	10/04-10/16	357	9.1,6.3	45	1	8.917	0.005	0.17	0.01
5661	Hildebrand	10/22-10/26	386	5.5,5.1	36	15	13.6	0.005	0.16	0.01
8551	Daitarabochi	12/04-12/08	800	14.9,15.2	8	-9	6.62	0.01	0.19	0.03
17428	Charleroi	10/14-10/16	130	6.4,6.0	47	5	6.034	0.007	0.19	0.02
41488	Sindbad	12/18-12/20	147	7.5,8.1	66	-11	8.044	0.008	0.28	0.02
51888	2001 QZ17	10/07-10/21	508	5.4,9.8	216	1	331	4	0.39	0.03

Table III. Observing circumstances. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984).

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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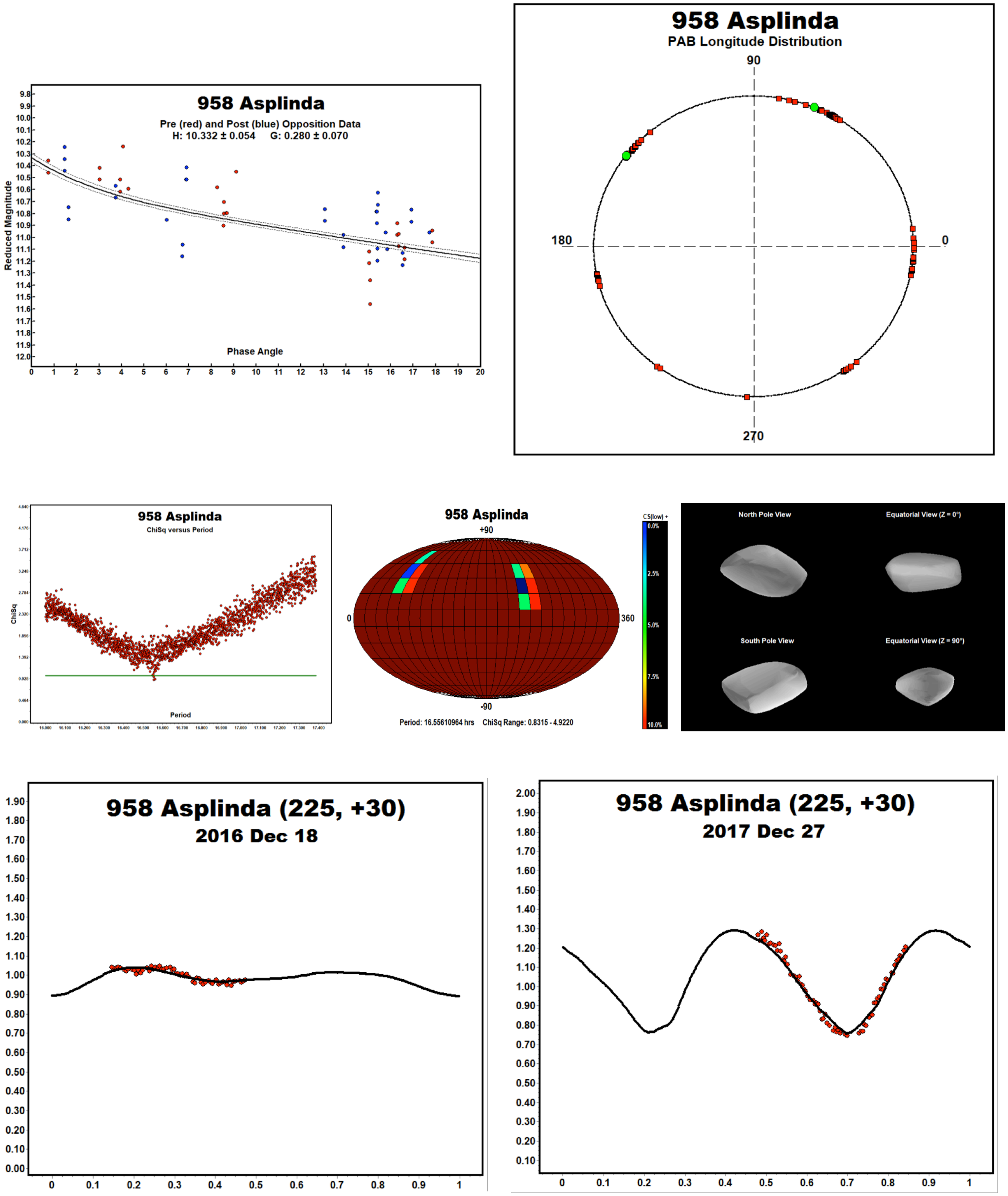
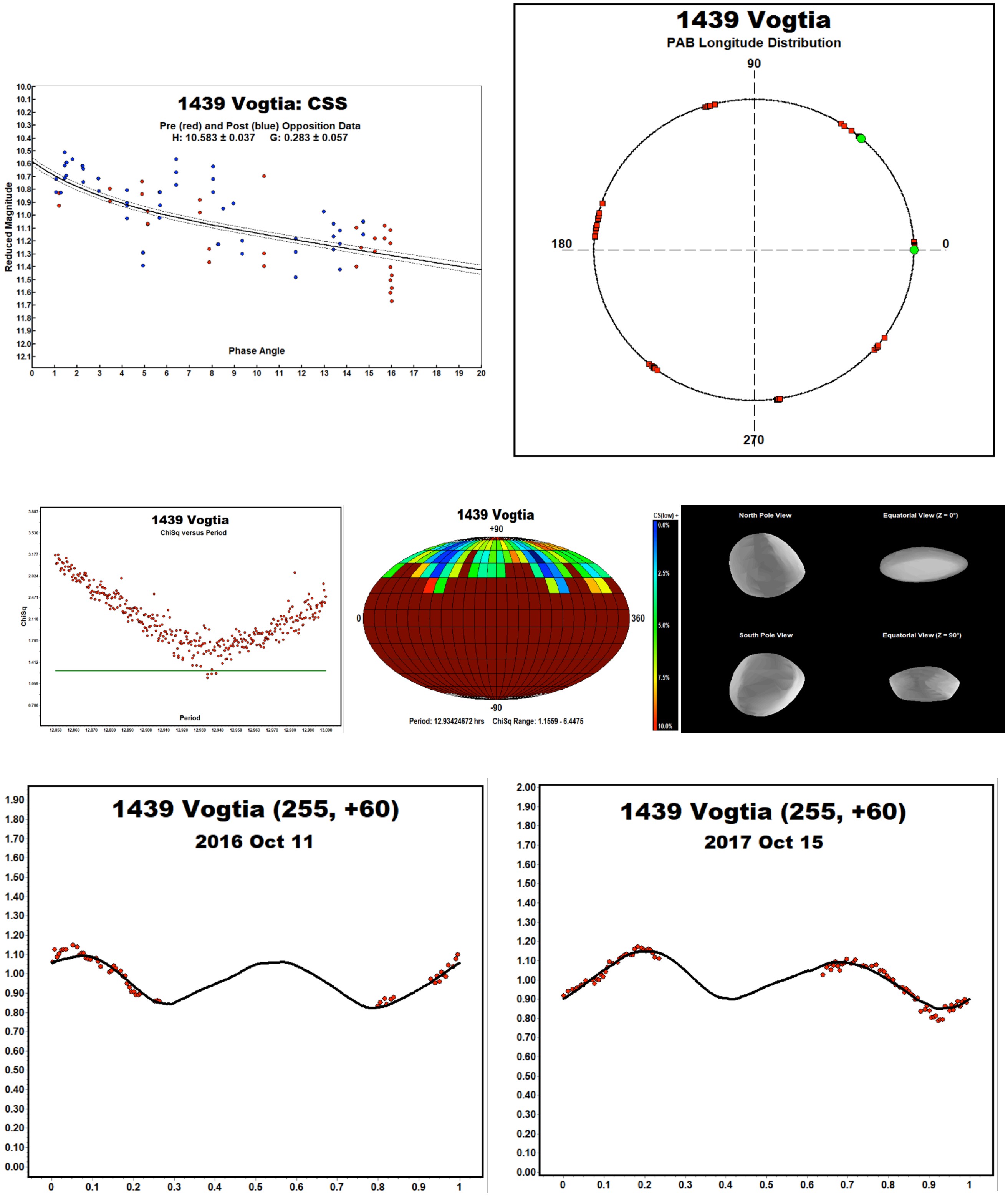
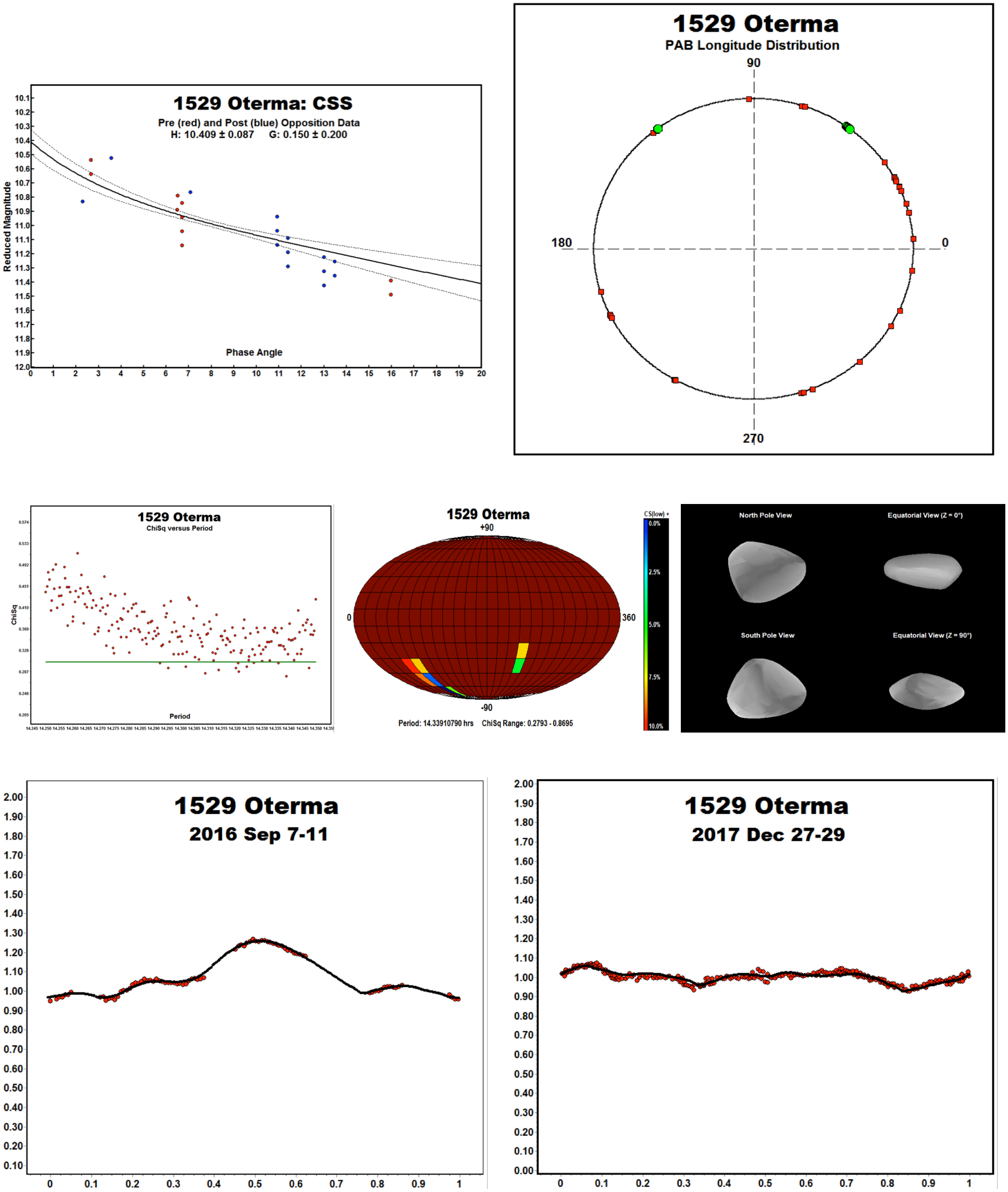


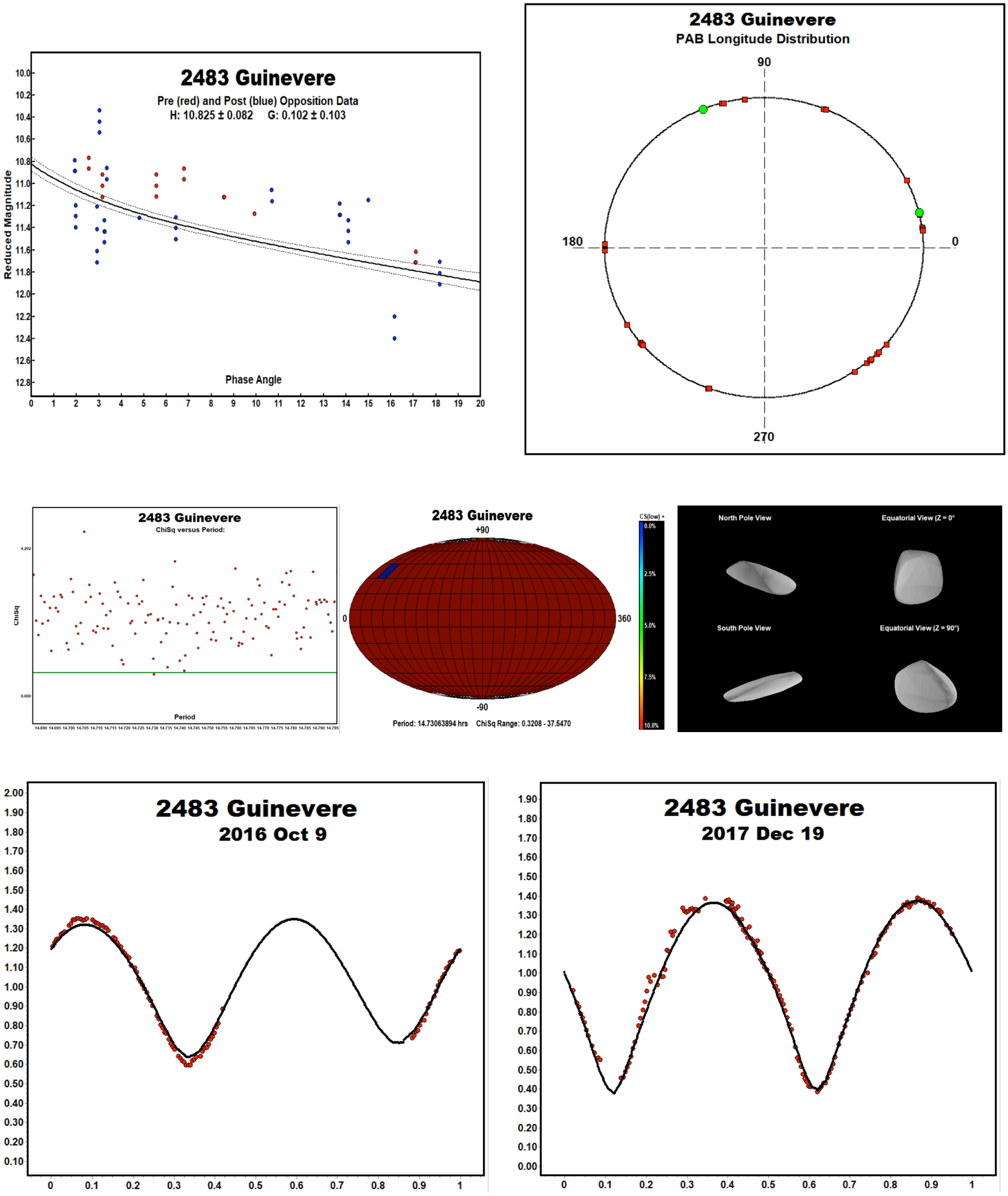
Inversion modeling plots for 958 Asplinda. This model has two likely solutions that differ mostly by about 180° ecliptic longitude. The large flat areas on the model could indicate concavities.



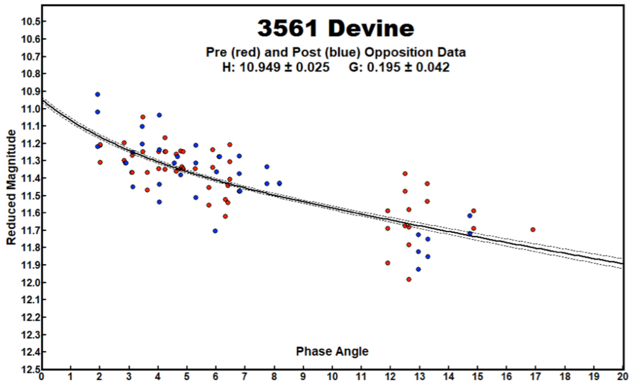
Inversion modeling plots for 1439 Vogtia. When the asteroid's pole is close to one of the ecliptic poles, it's common to have considerable ambiguity in the longitude. In this case, two solutions were favored: the one with the lowest χ^2 in the pole search is shown here.

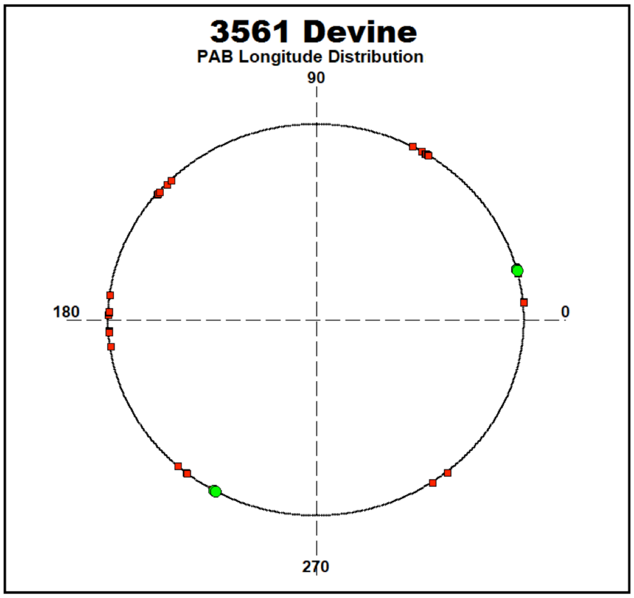


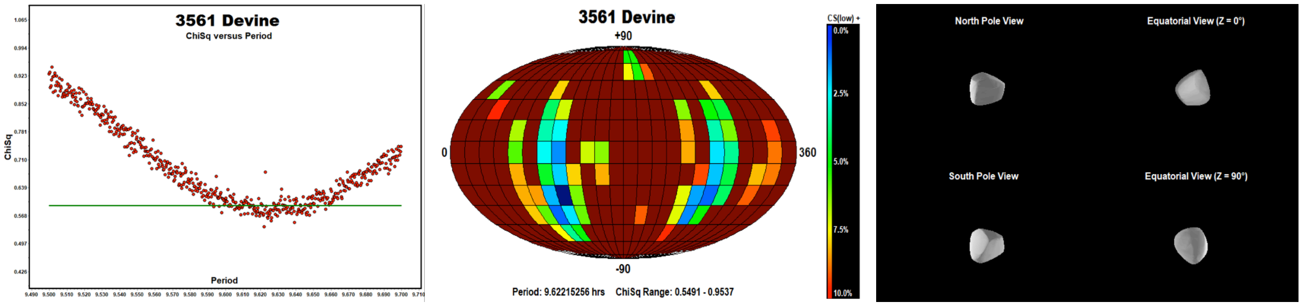
Inversion modeling plots for 1529 Oterma. The period solution is weak, mostly due to very noisy and limited sparse data. Under these circumstances, the subsequent pole solution is surprisingly unambiguous. Additional observations are strongly encourage to allow confirming and then refining the solution.

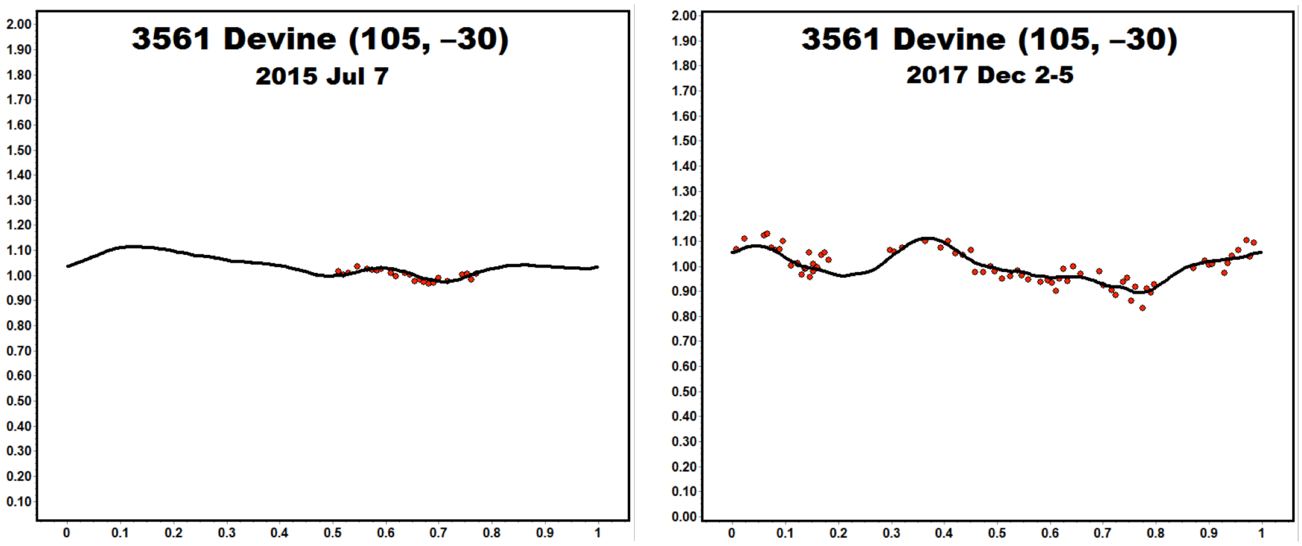


Inversion modeling plots for 2483 Guinevere. Only a small part of the range in the period search is shown so that the lowest x2 value would be visible. The entire plot at normal scale is a narrow flat line with large scatter. Despite the problems with the period, this model has one solution. The positive latitude indicates that the asteroid has a prograde rotation. The model curve for 2016 doesn't quite have enough amplitude. Here again, additional observations are needed to check these results.

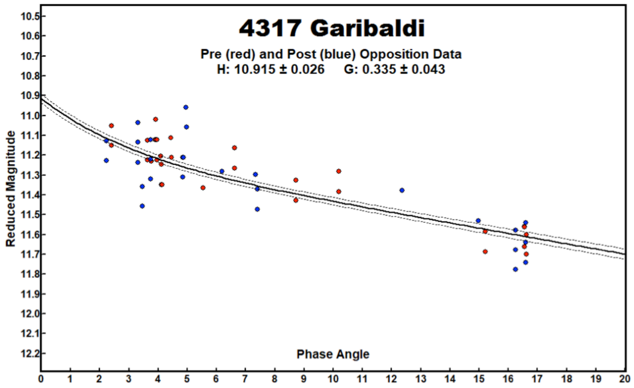


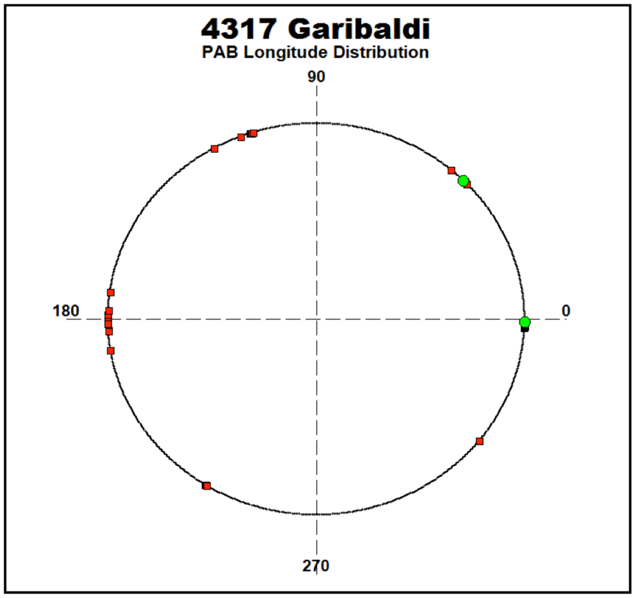


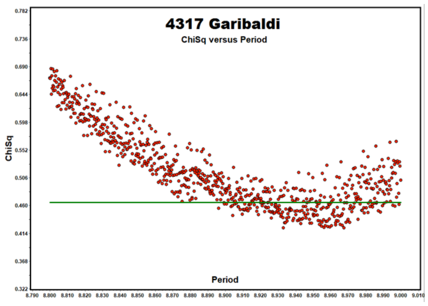


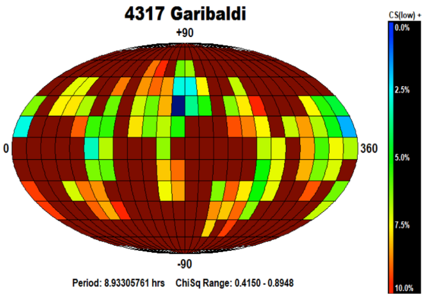


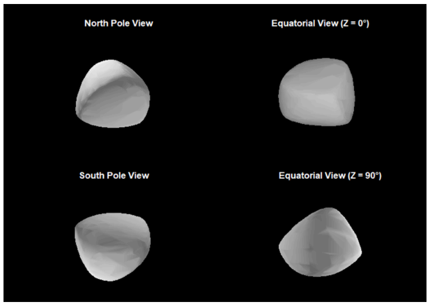
Inversion modeling plots for 3561 Devine. This model is poorly constrained in both longitude and latitude. The two adopted solutions have negative latitudes, indicating retrograde rotation. As expected, the data are not a tight fit to the model lightcurve.

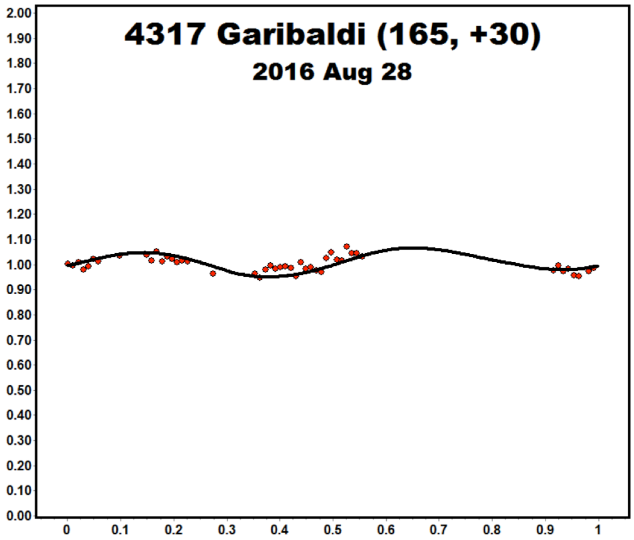


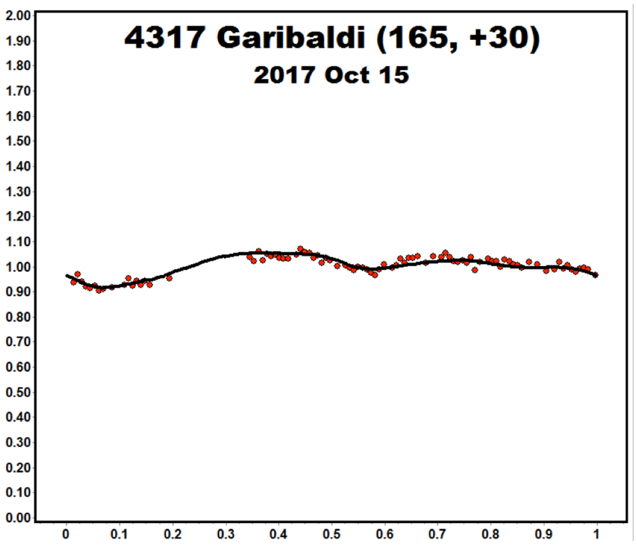




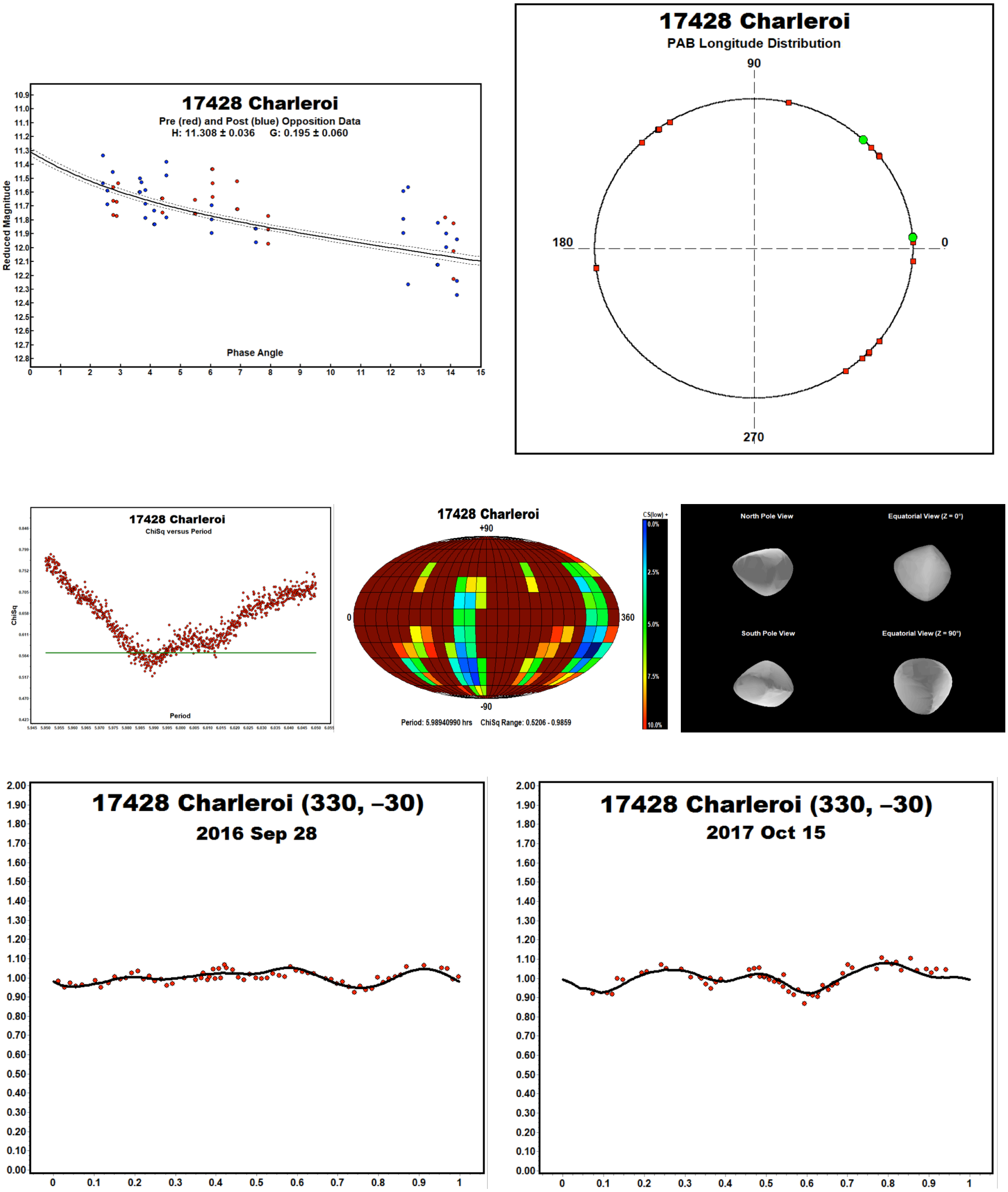








Inversion modeling plots for 4317 Garibaldi. This model is very ambiguous with no outstanding preference in period or pole longitude/latitude. The low amplitudes at each apparition do support the adopted model shape of a nearly spheroidal body.



Inversion modeling plots for 17428 Charleroi. The large number of 10% solutions in the period search show the need for more data, either further back in time or in the future. This model favors two, mirrored longitudes but the latitude is poorly constrained. The adopted solutions both have negative latitudes and so imply retrograde rotation.

ASTEROID LIGHTCURVE OBSERVATIONS AT ETSCORN OBSERVATORY

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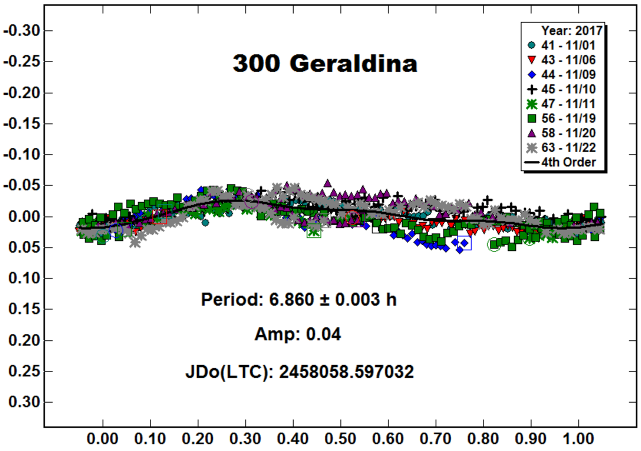
We determined the synodic rotation periods for nine asteroids. Eight are candidates for spin-shape modeling and one is a first attempt at period determination.

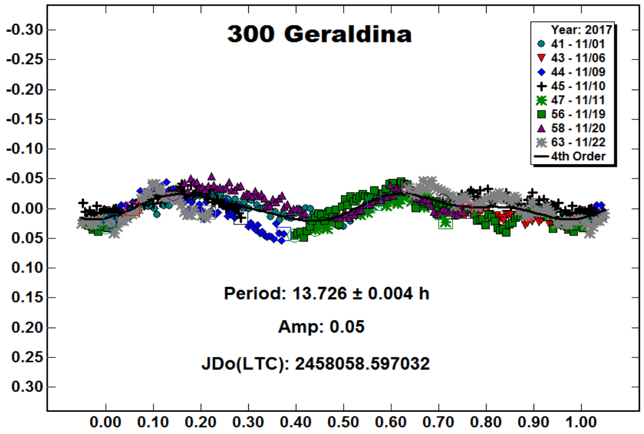
Our observations of nine minor planets were obtained with two Celestron 0.35-m telescopes and SBIG CCD STL 1001E cameras at Etscorn Campus Observatory (Klinglesmith and Franco, 2016). Eight of the asteroids: 300 Geraldine, 775 Lumiere, 1426 Riviera, 1590 Tsiolkovskaja, 1741 Gilasiolkl, 2144 Marietta, 7505 Furusho, and (46436) 2005 LH5 were suggest by Warner et al. (2017) as spin/shape model candidates. The ninth one, 4911 Rosenzqweig, was suggested by Warner et al. (2017) for period determination.

The images were processed and calibrated using *MPO Canopus* 10.7.2.0 (Warner, 2016). Exposures were between 60 and 360 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.

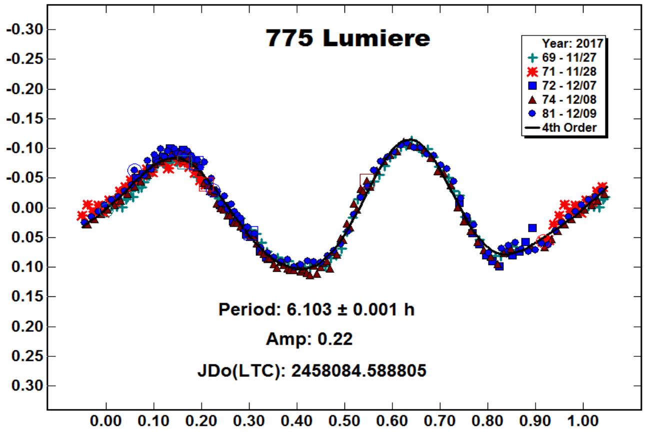
Discovery information was obtained from the JPL Small Bodies Node (JPL, 2017). Table I contains the observation circumstances and results. Table II is a compilation of the previously obtained lightcurves with their references.

300 Geraldina is a main-belt asteroid discovered by A. Charles at Nice on 1890 Oct 3. It is also known as 1933 BV, 1950 DV, 1953 PJ, 1953 RO1, 1961 AD, and A923 LB. We observed it on eight nights between 2017 Nov 1-22. It has five periods reported in the LCBD (Warner, 2009 et. al; Table II) with the adopted period of 6.8423 h and amplitude range of 0.13-0.32 mag. We found a period of 6.8459 ± 0.002 h and amplitude of 0.04 mag. This appears to be a single maximum lightcurve with low amplitude. A possible bimodal period of 13.726 ± 0.004 h and amplitude of 0.05 mag is shown in the second plot.

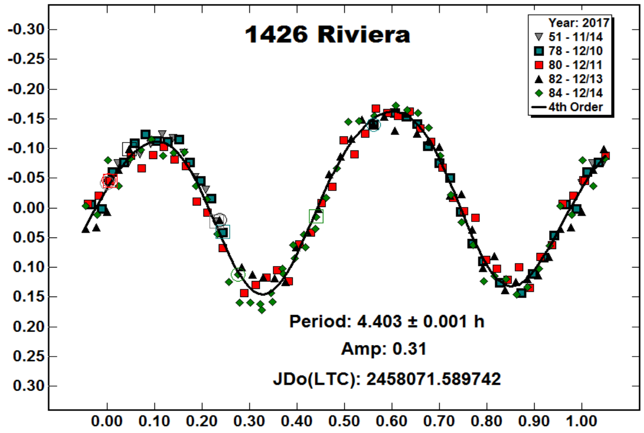




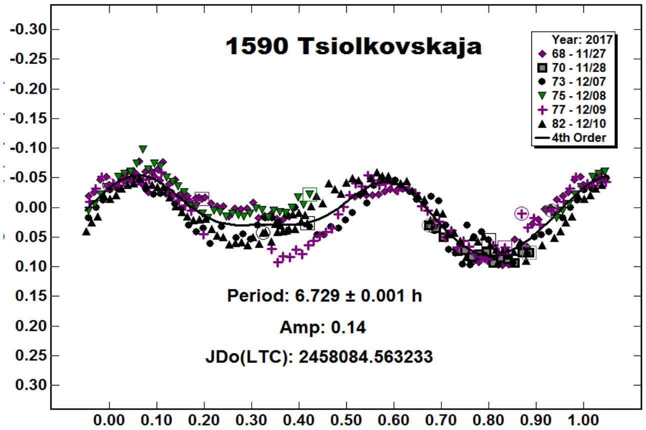
775 Lumiere is a main-belt asteroid discovered by J. Lagrula at Nice on 1914 Jan 6. It is also known as 1914 TX and A917 SB. We observed it on five nights between 2017 Nov 27 and Dec 9. We obtained a synodic period of 6.103 ± 0.001 h and amplitude of 0.22 mag.



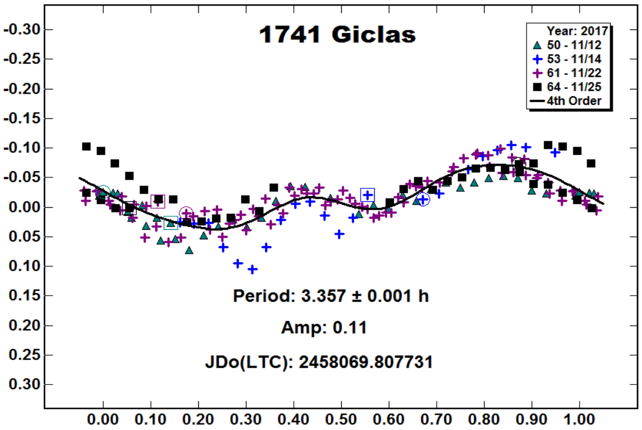
1426 Riviera is a main-belt asteroid discovered by M. Laugier at Nice on 1937 Apr 1. It is also known as 1937 GF, 1930 UD1, 1933 HJ, 1938 SN, 1949 HP, 2004 ST12, and A920 CA. We observed it on five nights between 2017 Nov 14 and Dec 14. We obtained a synodic period of 4.403 ± 0.001 and amplitude of 0.31 mag.



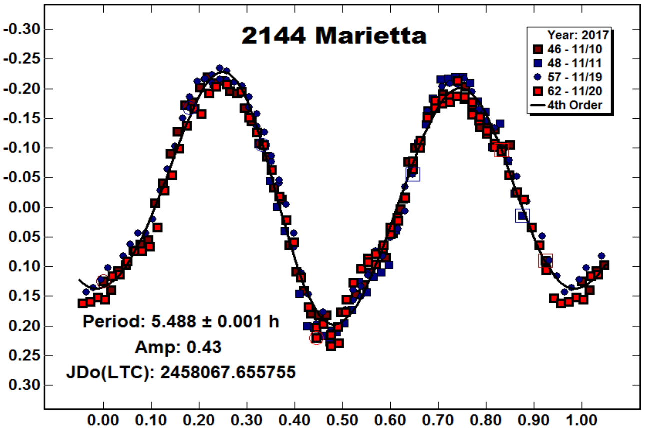
1590 Tsiolkovskaja is a main-belt asteroid discovered by G. Neujmin at Simeis on 1933 Jul 1. It is also known as 1933 NA, 1933 OU, 1936 HB, 1937 VE, 1940 RN, 1940 RX, 1943 OD, 1950 SF, A907 TB, and A913 MC. We observed it on six nights between Nov 27 and Dec 10. We obtained a synodic period of 6.729 ± 0.001 h and amplitude of 0.14 mag.



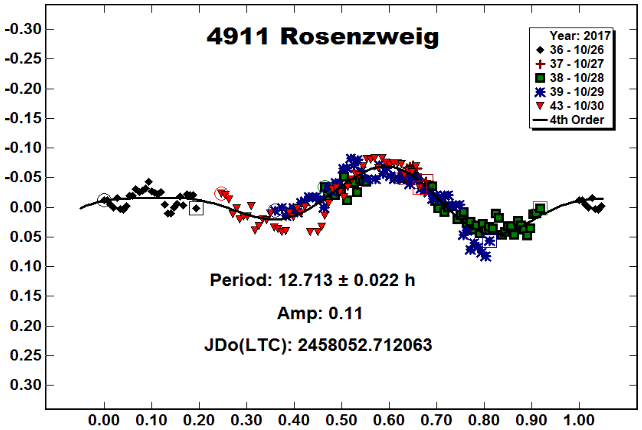
1741 Giclas is a main-belt asteroid discovered at Goethe Link Observatory at Brooklyn, Indiana, on 1960 Jan 26. It is also known as 1960 BC, 1953 UY, 1953 VH1, 1953 XN, and 1963 YD. We observed it on three nights between 2017 Nov 12-25. We obtained a synodic period of 3.219 ± 0.001 h and amplitude of 0.10 mag. Our result differs from the accepted period of 2.943 h.



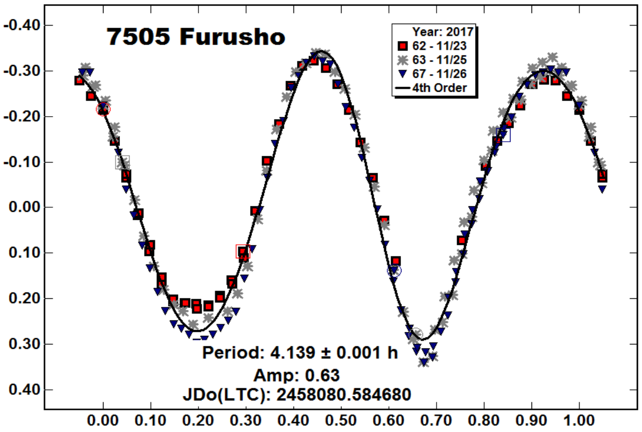
2144 Marietta is a main-belt asteroid discovered by L. I. Chernykh at the Crimean Astrophysical Observatory on 1975 Jan 18. It is also known as 1975 BC1, 1929 VB, 1947 LH, 1968 UC3, 1971 HC, 1972 NM, 1973 TA1, and 1977 NO. We observed it on four nights between 2017 Nov 10-20. We obtained a synodic period of 5.488 ± 0.001 h and amplitude of 0.43 mag.



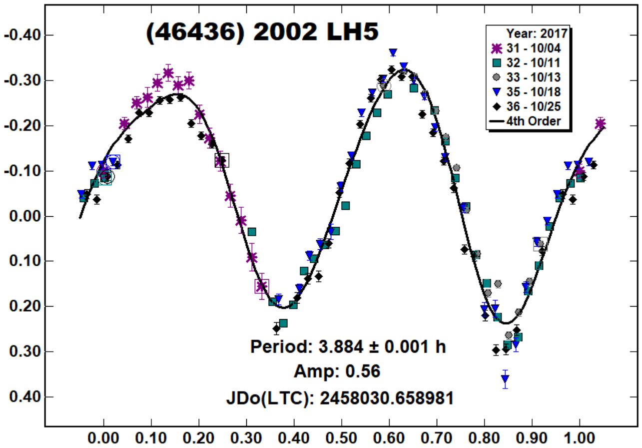
4911 Rosenzweig is a main-belt asteroid discovered at the Goethe Link Observatory at Brooklyn, Indiana, on 1953 Oct 16. It is also known as 1953 UD and 1987 SM. We observed it on six nights between 2017 Oct 26-30. We obtained a synodic period of 12.71 ± 0.02 h and amplitude of 0.11 mag. No previous period determinations were found in the LCDB (Warner et al., 2009).



7505 Furusho is a main-belt asteroid discovered by T. Kobayashi at OIzumi on 1997 Jan 3. It is also known as 1997 AM2, 1940 WC, 1944 OG, 1950 BA1, 1970 WG, and 1991 NS. We observed it on three nights between 2017 Nov 23-26. We obtained a synodic period of 4.139 ± 0.001 h and amplitude of 0.63 mag.



(46436) 2005 LH5 is a main-belt asteroid discovered by C. W. Juels and P. R. Holvorcem at Fountain Hills on 2002 Jun 6. It is also known as 2002 LH5, 1958 TX, 1987 MT, 1992 OC1, and 1994 AP15. We observed it on five nights between 2017 Oct 4-25. We obtained a synodic period of 3.884 ± 0.001 h and amplitude of 0.56 mag.



Acknowledgements

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Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
300	Geraldina	11/01-11/22	667	2.3,0.0,5.4	44	0	6.860	0.003	0.04	0.05	MB-O
775	Lumiere	11/27-12/09	331	4.0,5.3	68	9	6.103	0.001	0.22	0.03	EOS
1426	Riviera	11/14-12/14	165	10.7,17.7	26	9	4.403	0.001	0.31	0.03	MB-I
1590	Tsiolkovskaja	11/27-12/19	350	3.7,9.8	57	-1	6.729	0.001	0.14	0.05	FLOR
1741	Giclas	11/12-11/25	165	11.4,14.5	172	1	3.357	0.001	0.11	0.10	KOR
2144	Marietta	11/10-11/20	270	3.8,1.7	55	-4	5.488	0.001	0.43	0.05	KOR
4911	Rosenzweig	10/26-10/30	199	19.0,20.2	358	7	12.713	0.022	0.11	0.05	EUN
7505	Furusho	11/23-11/26	185	20.7,21.9	35	-7	4.139	0.001	0.63	0.05	MC
46436	2002 LH5	10/04-10/25	125	14.8,18.1	8	21	3.884	0.001	0.56	0.05	MB-O

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).

Number	Name	References	Date	L_{PAB}	B_{PAB}	Phase	Period	Amp
300	Geraldine	This paper	2017 Nov 11	44	0	0.0	6.860	0.04
		Chang 2014	2013 Feb 16	104	1	13.6	6.86	0.17
		Licchelli 2006	2005 Oct 04	359	-1	4.6	6.818	0.32
		Behrend 2008	2008 Mar 09	156	1	4.3	6.8423	0.26
		Waszczak 2015	2013 Feb 16	104	1	13.6	6.850	0.13
775	Lumiere	This paper	2017 Nov 08	68	9	9	6.103	0.22
		Behrend 2003	2003 Mar 24	136	-5	16.9	6.1	0.28
		Behrend 2001	2001 Sep 13	34	11	15.7	6.1035	0.28
		Binzel 1987	1983 May 14	217	-11	7.4	6.96	0.25
		Klinglesmith 2017	2016 Sep 18	339	8	6.8	6.075	0.25
		Behrend 2005	2005 Jul 07	299	0	5.2	6.1	0.20
		Behrend 2006	2006 Oct 21	16	11	6	6.103	0.19
1426	Riviera	This paper	2017 Nov 29	26	9	14.2	4.403	0.31
		Behrend 2003	2003 Mar 10	164	-3	5.5	4.4044	0.30
		Behrend 2005	2005 Jan 01	350	4	18.7	4.4	0.31
		Behrend 2007	2007 Mar 14	148	0	11.6	4.38	0.31
1590	Tsiolkovskaja	This paper	2017 Dec 04	57	-1	6.7	6.729	0.14
		Warner 2008	2007 Nov 07	57	-1	6.4	6.737	0.11
		Kryszczynska 2012	2008 Jan 15	60	-2	20.7	6.7299	0.10
		Lagerkvist 1978	1976 Apr 24	217	-1	2.0	6.7	0.40
		Carbo 2009	2009 Mar 18	166	-5	6.7	6.731	0.25
1741	Giclas	This paper	2017 Nov 18	172	1	4.6	3.357	0.11
		Behrend 2005	2005 Apr 30	225	1	2.0	2.92	0.15
		Slivan 2008	2004 Feb 18	143	4	2.6	2.943	0.10
		Warner 2008	2007 Dec 14	55	0	11.2	**2.938**	0.11
		Oey 2016	2014 Feb 20	161	4	4.1	3.107	0.12
		Oey 2017	2015 Jun 13	240	-1	8.3	2.9426	0.15
2144	Marietta	This paper	2017 Nov 15	55	-4	2.7	5.448	0.43
		Arredondo 2014	2014 Mar 14	145	1	11.1	5.489	0.40
		Behrend 2010	2010 May 22	220	4	8.1	6.26	0.43
		Slivan 2008	2004 Jan 17	121	-1	2.0		0.40
		Slivan 2008	1999 Jan 12	104	-2	1.5	5.489	0.44
7505	Furusho	This paper	2017 Nov 24	35	-7	21.3	4.139	0.63
		Stephens 2001	2000 Nov 03	70	-5	20.9	4.14	0.65
		Warner 2014	2013 Dec 21	102	2	7.6	4.140	0.52
		Waszczak 2015	2011 May 20	191	7	13.1	4.414	0.61
46436	2002 LH5	This paper	2017 Oct 14	8	21	16.3	3.884	0.56
		Clark 2008	2007 Aug 04	329	17	17.7	3.8836	0.54
		Clark 2013	2012 Sep 24	352	22	16.3	3.8832	0.62
		Vander Hagen 2008	2007 Aug 24	333	19.6	14.5	3.884	0.50
		Warner 2008	2007 Aug 18	332	19	14.9	3.884	0.46

Table II: Summation of solar bisector angles, phase angles, periods and amplitudes for the asteroids discussed in this paper.

ROTATIONAL STUDY OF ASTEROID 126 VELLEDA

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A rotation period of 5.36 h ± 0.01 h and lightcurve amplitude of 0.20 mag have been derived for asteroid 126 Velleda based on two consecutive nights (2018 Jan 3-4 UT) of CCD photometric observations.

Observations of the inner main-belt asteroid 126 Velleda were made on the nights of 2018 Jan 3 and 4 using a fork-mounted 29.4-cm Schmidt-Cassegrain telescope operating at *f*/5 and a CCD camera operating at –40° C. The pixel scale was 2.2 arcsec/pix. All exposures were 180 s and made through a Johnson V filter.

Images were reduced with dark and flat frames. *MPO Canopus* v10.7.11.1 was used for differential photometry and period analysis (see Ruthroff, 2010, for technique details). All comparison star V-R magnitudes were in the range of 0.4 to 0.7 (Warner 2006).

A search of the asteroid lightcurve database (LCDB; Warner et al., 2009), the Astrophysics Data System (ADS, 2018), and the JPL Small Body Database Search Engine (JPL, 2016) found that the rotation period of 126 Velleda is well documented: Behrend (2007, 2011), Dovgopol et al. (1992), Licchelli (2006), and Pilcher (2011). All previously published periods centered around 5.36 h.

The observations produced a data set of 162 points. Lightcurve analysis found a period of 5.36 ± 0.01 h, which is within the margin of error of previously published observers. The lightcurve amplitude was 0.20 mag. No pole position was noted in the LCDB summary table. The previous observers reported that the phase angle bisector longitude (L_{PAB}) was in the range of 144° to 341°. The observations reported here were conducted when L_{PAB} was about 75°.

Acknowledgments

This research has made use of NASA's Astrophysics Data System. This paper makes use of data products from the Fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4).

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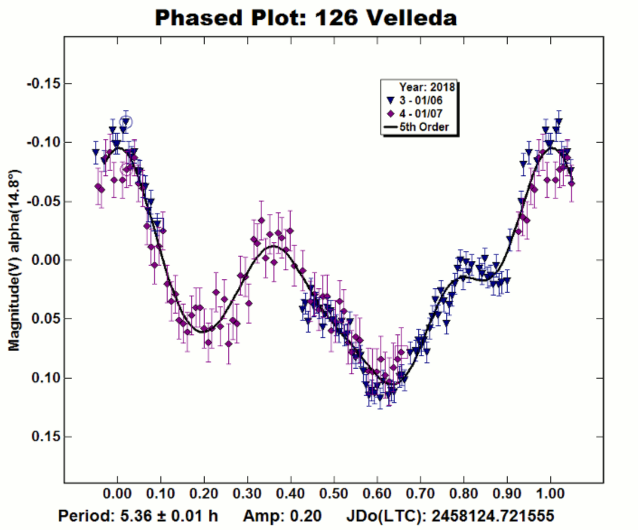

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
126	Velleda	1/06-01/07	162	14.8,15.1	75	3	5.36	0.01	0.20	0.04	MB-I

Table I. Observing circumstances and results. Pts is the number of data points used in the analysis. The phase angle values are for the first and last date, unless a minimum (second value) was reached. LPAB and BPAB are the average phase angle bisector longitude and latitude. Period is in hours. Amp is peak-to-peak amplitude. LPAB and BPAB are the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). MB-I: Inner main-belt.

PERIOD DETERMINATION FOR (69315) 1992 UR2

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Photometric observations of the main-belt asteroid (69315) 1992 UR2 were conducted from a group of observers in order to determine its synodic rotation period. This asteroid turned out to be a slow rotator with a period of 106.25h ± 0.01 and an amplitude of 1.50 mag.

(69315) 1992 UR2 is a main-belt asteroid discovered on 1992 Nov 20 by H. E. Holt at Palomar. For this asteroid the JPL Small-Body Database Browser (JPL, 2017) reports an absolute magnitude of 13.8 mag, an albedo 0.310 ± 0.077 and a diameter of 4.5 km ± 0.4. Collaborative CCD photometric observations of this main-belt asteroid were carried out on 15 nights between 2017 Nov 10 and Dec 24. All the observatories and the instruments involved in this study are listed in Table I. Data processing and analysis were made with *MPO Canopus* (Warner, 2017). All the images, acquired with clear filter, were calibrated with dark and flat-field frames and converted to R magnitudes using solar-colored field stars from a version of the CMC-15 catalogue distributed with MPO Canopus. Table II shows the observing circumstances and results.

No previously reported period was found in the asteroid lightcurve database (LCDB; Warner et al. 2009). The period analysis shows a bimodal lightcurve with a synodic period of P = 106.25 h ± 0.01 and a large amplitude A = 1.50 mag ± 0.05. The characteristic V-shape of the primary minimum and the large amplitude of the lightcurve had us to suspect it was a rare binary synchronous asteroid. We asked Petr Pravec to get his opinion, but the observed data did not justify the binary hypothesis and so it was discarded. By the lightcurve amplitude we can derive the lower limit to the axis ratio of the triaxial ellipsoid (a/b) = 10^(A/2.5) = 4, so (69315) 1992 UR2 is an elongated asteroid.

Acknowledgements

The authors want to thank here some students of the course in Physics and Advanced Technologies at the Department of Physical Sciences, Earth and Environment (DSFTA, 2017), who looked after the collection of data during her internship activities at the Astronomical Observatory of the University of Siena: Leonardo Angeli, Eleonora Bernardi, Edoardo Bucalo, Antonio Buono, Denise Cocchiarella, Roberto Gambelli, Vincenzo Iannelli, Bianca Nardi, Saverio Palazzi, Leonardo Passaponti, Matilde Predella, Antonio Santacesaria, Leonella Filippa Saya, Daniele Tomei.

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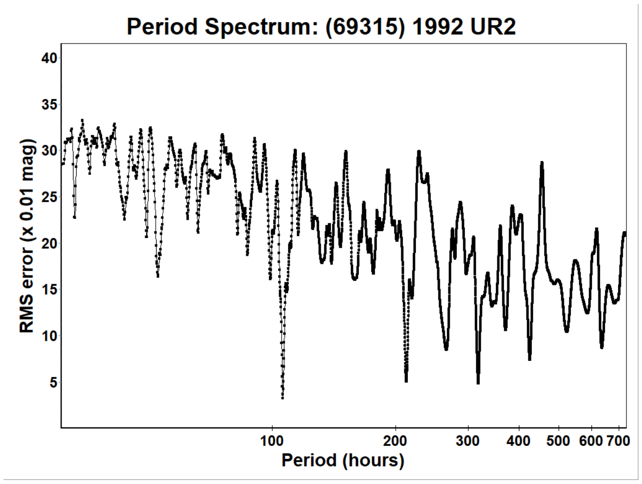
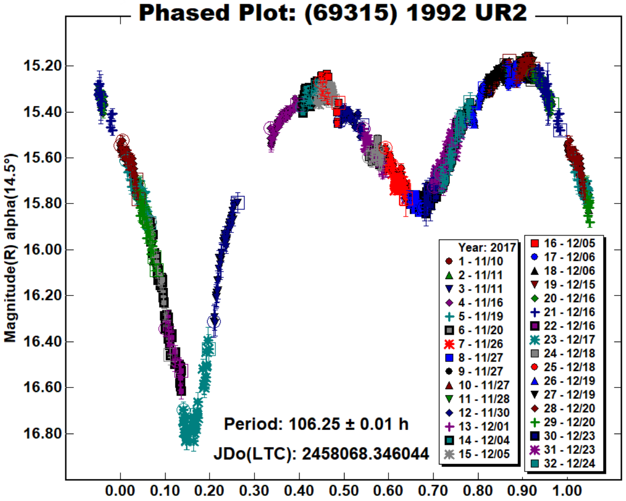
Observatory (MPC code)	**Telescope**	**CCD**
Cherryvalley (I83)	0.20-m SCT f/7.6	SBIG STL-1301E
M57 (K38)	0.30-m RCT f/5.8	SBIG STT-1603
Aurunco	0.28-m SCT f/10	Magzero MZ-9M
Salvatore di Giacomo(L07)	0.50-m RCT f/8	FLI-PL4240
WBRO (K49)	0.235-m SCT f/10	SBIG ST8-XME
San Marcello Pistoiese(104)	0.60-m NRT f/4	Apogee Alta
BS-CR (K47)	0.25-m SCT f/5.4	Seti 245 NCC
Canis Mayor	0.30-m SCT f/6.3	SBIG ST8-XME
Univ. Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e (bin 2x2)

Table I. Observing Instrumentations. MCT: Maksutov-Cassegrain, NRT: Newtonian Reflector, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain.

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
69315	1992 UR2	11/10-12/24	1575	14.5,20.2	69	14	106.25	0.01	1.50	0.05

Table II. 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).





A SHAPE AND SPIN AXIS MODEL FOR 607 JENNY

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A combination of dense lightcurves obtained by the authors over several apparitions and sparse data was used to model the outer main-belt asteroid 607 Jenny. A reasonably reliable spin axis with ecliptic coordinates of (220°, –40°, 8.52234 h) was found, although one of (35°, –17°, 8.52234 h) cannot be formally excluded.

Despite having dense lightcurves from a small number of apparitions (see Slivan, 2013) for the outer main-belt asteroid 607 Jenny, we attempted to use lightcurve inversion (see, e.g., Hanus and Durech, 2012, and references therein) to try to derive at least a preliminary spin axis model, i.e., determine the ecliptic coordinates of the asteroid's north pole. A natural consequence of this process is to derive a shape for the asteroid and a model lightcurve. The latter can be used to compare against actual data to help determine the quality of the solution.

Aside from obtaining the dense lightcurves over the past few years, the first step for each asteroid was to obtain raw sparse data observations from various surveys by using the AstDyS-2 site (*http://hamilton.dm.unipi.it/astdys2/*). From these, only data from the Catalina Sky Survey and USNO-Flagstaff were extracted since they are considered among the more reliable (internally consistent) data available (Hanus *et al.*, 2011). The data were further filtered by plotting them in reduced magnitude versus phase angle plot (Figure 4) where obvious outliers were removed. This is somewhat arbitrary in the case of large amplitude objects since the large variations from a general solution may be real and not just random scatter. The degree of scatter is also affected by forcing the value for the phase slope parameter (*G*) to the default of 0.15, or allowing the solution to float and find a "true" value for *G*. In this case, we used the results from allowing the solution to float.

Once the sparse data set was ready, it was combined with our dense lightcurves using *MPO LCInvert*, a Windows-based program developed by Warner that incorporates the algorithms developed by Kaasalainen *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. Ideally, the lowest χ^2 value should be at least 10% lower than the second lowest value, e.g., 1.0 versus 1.15. This is not often the case, especially when data set covers only a few years and/or a small number of apparitions. Figure 5 shows the χ^2 vs. period plot in our search.

After a period is found, a search for the spin axis pole is made by using the period corresponding to the lowest χ^2 (χ^2_{min}) and forcing the pole solution to one of 315 distinct longitude-latitude pairs. The period, however, is allowed to "float". This leads to a plot similar to Figure 6, which is an equal area projection of the ecliptic sphere. The colors range from deep blue to bright red (1.0-1.10 χ^2_{min}). Any dark red (maroon) area was > 1.10 χ^2_{min}.

In a perfect solution, in Figure 6 there would be a single small island of blue in a sea of greens to reds. However, the lightcurve inversion process inherently provides an ambiguous solution, especially for objects with low orbital inclinations. Often there are two solutions that differ by 180° in longitude, meaning that it's not certain when the viewing aspect at a given time is looking at the north or the south pole. Sometimes the ambiguity is in latitude only, and so it it's not possible to determine if the asteroid is in prograde or retrograde rotation. In some cases, there is a double mirroring, meaning four solutions that differ by 180° in longitude and are equally above or below the ecliptic plane. The worst case is a plot of nearly all the same color, indicating a wholly indeterminate solution.

A final search for a spin axis is made using the lowest value in each island (assuming it's possible to define one or more islands). Here the longitude and latitude are allowed to float as well as the period. The spin axis parameters are then used to generate a final shape and spin axis model. Figure 7 shows an example of what is called the "4-vane" shape model, which shows the asteroid as viewed from its two poles and in its equatorial planes at different rotations about the Z-axis. It's important to note that, unless using well-calibrated (absolute) data throughout, the lightcurve inversion process poorly constrains the height (Z-axis) of the asteroid. Therefore, the asteroid could actually be flatter or more spheroidal than shown in the 4-vane image. Figures 8, 9, and 10 show the model lightcurve (black) for specific dates versus the actual lightcurve (red). Naturally, the two lightcurves for any given data should closely match.

Warner (2011) reported a synodic period of 8.526 h based on observations in 2002. The phase angle bisector longitude (L_{PAB}; see Harris *et al*., 1984) at the time was approximately 340° and the amplitude 0.12 mag. He worked it again in 2007 (Warner, 2007) finding a rotational period of 8.524 h (Figure 1). Stephens (2014) observed the asteroid in 2013, finding a period of 8.521 h (Figure 2) with an amplitude of 0.25 mag. The L_{PAB} was about 91° at the time. At the 2017 opposition, Stephens found a synodic rotational period of 8.514 h with an amplitude of 0.16 mag (Figure 3). The L_{PAB} was about 24° in 2017.

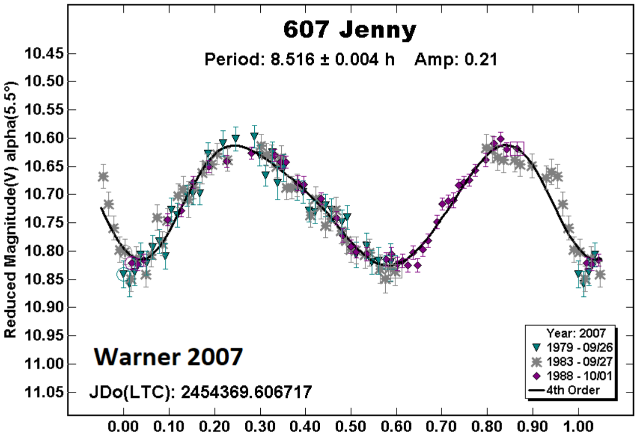

Figure 1. The amplitude of the lightcurve for 607 Jenny from observations by Warner at the 2007 opposition was 0.25 mag at L_{PAB} ~ 355° and α ~ 6°.

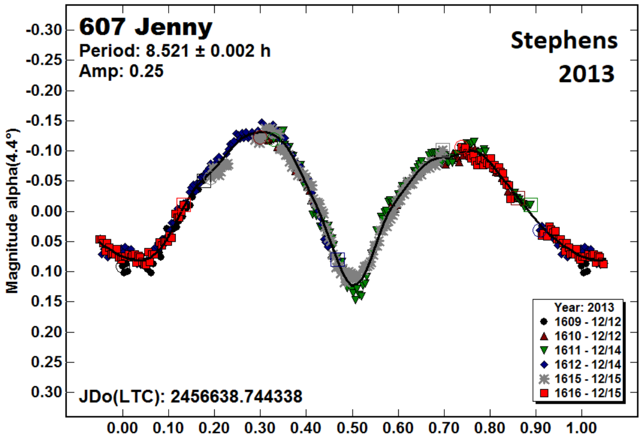

Figure 2. The amplitude of the lightcurve for 607 Jenny from 2013 September observations by Stephens was 0.25 mag at L_{PAB} ~ 91° and α ~ 4°.

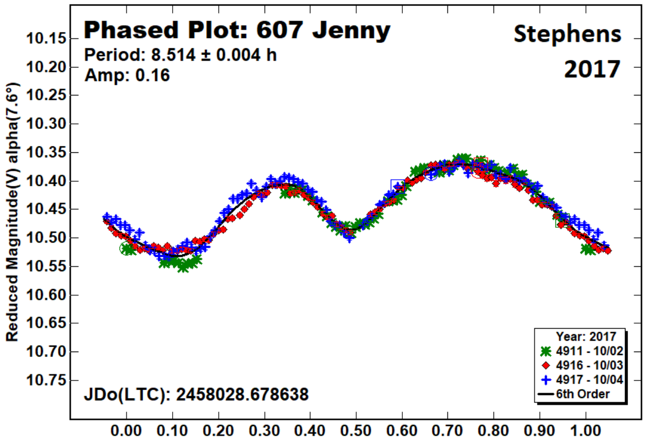

Figure 3. At L_{PAB} ~ 24° and α ~ 8°, the amplitude of the lightcurve for 607 Jenny from 2017 October observations by Stephens was 0.16 mag.

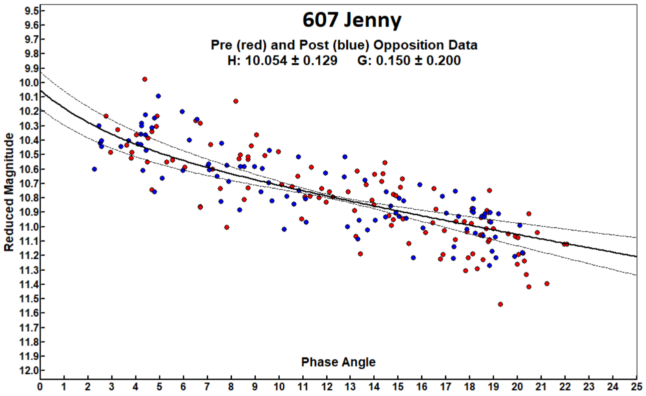

Figure 4. A reduced magnitude vs. phase angle plot for 607 Jenny using data from the USNO.

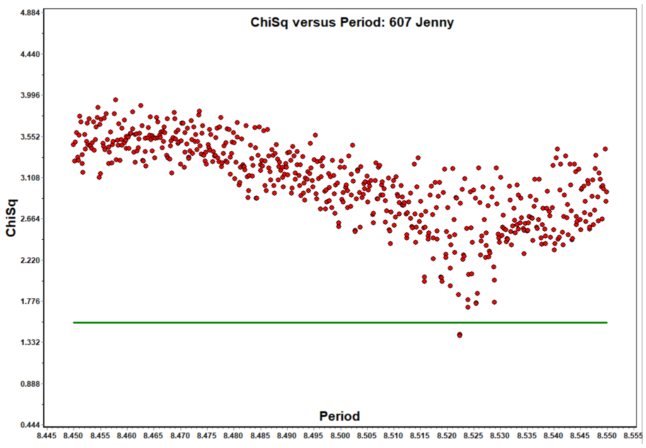

Figure 5. A plot of χ^2 versus period for 607 Jenny.

Having only a single point below the green line (10%) in Figure 5 gives added confidence to the period associated with χ^2_{min}.

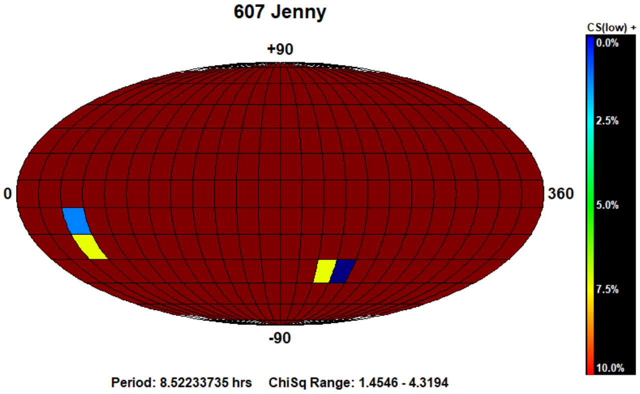

Figure 6. A pole search plot for 607 Jenny shows two "islands" that represent likely solutions.

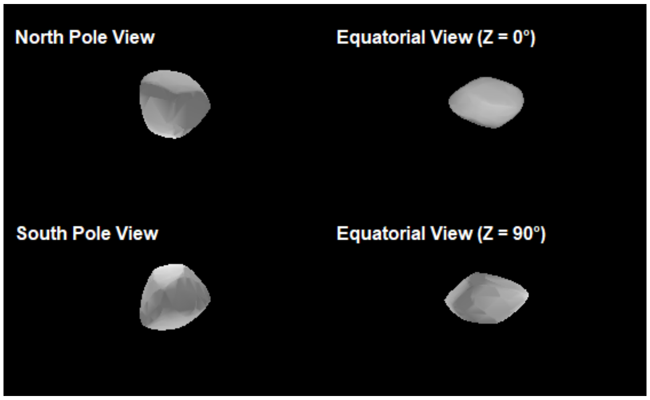

Figure 7. Four views of 607 Jenny. On the left are views from the north and south poles. On the right are views in the asteroid's equatorial plane, one at 0° rotation and the other at 90° rotation about the Z-axis. The elongated shape is expected given the lightcurve amplitude of 0.25 mag in 2013.

The model curves in Figures 8, 9, and 10 are from the solution for ecliptic coordinates (210°, –40°, 8.52234 h) although the fits to the model based on (35°, –17°, 8.52234 h) are essentially identical. In both cases, the estimated error for the pole is a circle of about 10° radius and 0.00002 h for the period.

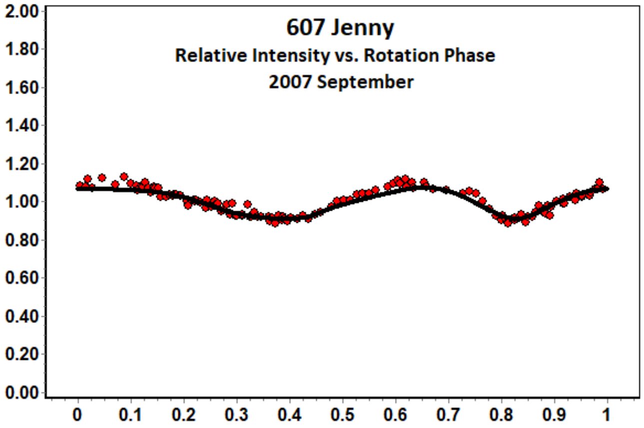

Figure 8. The model lightcurve (black) for 607 Jenny versus the data (red) in 2007 September. The vertical axis gives the relative intensity of the data points, not the magnitude.

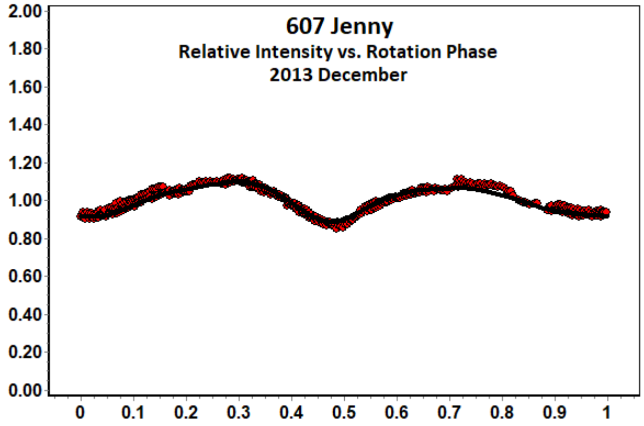

Figure 9. The model lightcurve (black) for 607 Jenny versus the data (red) in 2013 December. The vertical axis gives the relative intensity of the data points, not the magnitude.

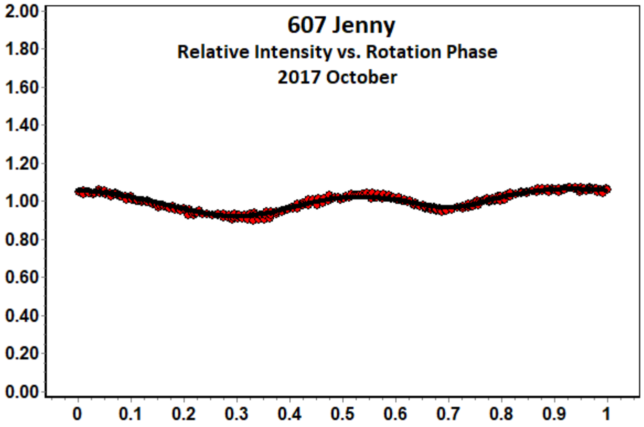

Figure 10. The intensity versus phase from 2017 October is even flatter than in 2007.

In the end, we chose (210°, –40°, 8.52234 h) based on the fact that the lightcurve amplitude changed significantly with L_{PAB}. If the asteroid's pole were closer to one of the ecliptic poles, the variation due to different viewing aspects would not be as great as when the asteroid pole was closer to the ecliptic plane. In the first case, the viewing aspect would be somewhat equatorial for all viewing aspects (values of L_{PAB}) while, in the second case, the viewing aspect would range from nearly pole-on to nearly equatorial and so a wider range of lightcurve amplitudes. Despite these arguments, the other solution cannot be formally excluded and data from future apparitions are required to resolve the ambiguity.

A general warning coming from this analysis is that when observing an asteroid close to pole-on, the solution loses sensitivity to rotational phase. Thus the period and the pole orientation become highly correlated, and the uncertainty in either quantity is larger than the uncorrelated error bars. Put another way, if a pole longitude solution is also near the L_{PAB} of a given data set and the amplitude is about the same as one with another aspect that is close to a right angle with the first, then either the asteroid is nearly spheroidal or the solution is likely wrong. For example, if the amplitude of the lightcurves in 2013 and 2017 had been similar, the adopted solution for the pole would be suspect, especially since the asteroid is known not to be nearly spheroidal.

Conclusions

This case cries out for "more data!" to better refine the distinction between the two pole solutions. The next favorable opposition for 607 Jenny is 2019 January; Southern Hemisphere observers will get a favorable opposition in 2020 April.

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LIGHTCURVE AND ROTATION PERIOD DETERMINATION FOR 2578 SAINT-EXUPERY, 4297 EICHHORN, 10132 LUMMELUNDA AND (21766) 1999 RW208

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(Received: 2018 Jan 13)

Photometric observations of the main-belt asteroids 2578 Saint-Exupery, 4297 Eichhorn, 10132 Lummelunda and (21766) 1999 RW208 performed by the authors from June to December 2017, revealed the bimodal light curves phased to 8.146 ± 0.001 h for 2578 Saint-Exupery, 4.105 ± 0.003 h for 4297 Eichhorn, 2.51 ± 0.03 h for 10132 Lummellunda and 5.841 ± 0.001 h for (21766) 1999 RW208 as the most likely solutions representing the synodic rotation periods for these asteroids.

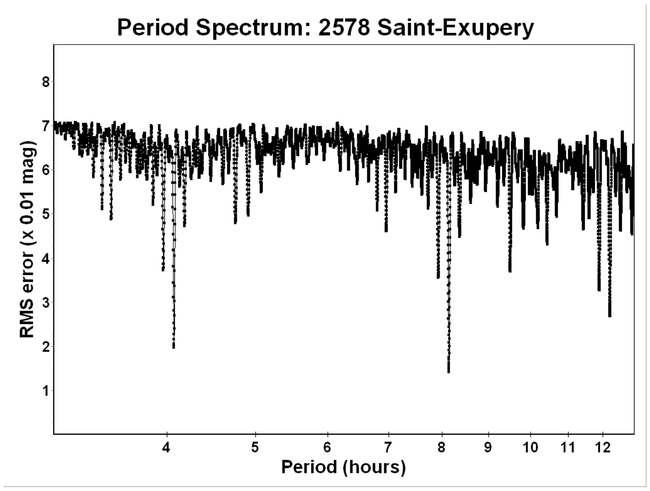
Lightcurve analysis was performed using images taken at the Astronomical Observatory of the University of Siena (Italy) and at the Wild Boar Remote Observatory (K49).

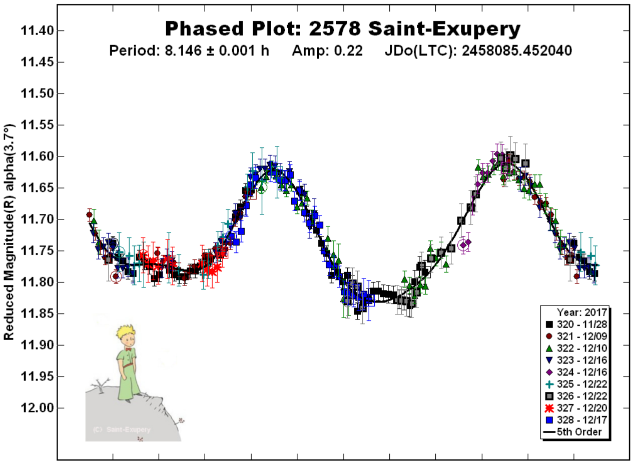
At the Astronomical Observatory of the University of Siena, a facility of the Department of Physical Sciences, Earth and Environment (DSFTA, 2017), data were obtained with 0.30-m f/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E NABG CCD camera and clear filter; the pixel scale was 2.26 arcsec in binning 2x2. Exposures were set to 300 seconds. At the Wild Boar Remote Observatory (K49) data were obtained with a 0.235-m f/10 (SCT) telescope, SBIG ST8-XME NABG CCD camera, unfiltered; the pixel scale was 1.6 arcsec in binning 2x2. Exposure were set to 300 seconds.

A search through the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) indicates that our results may be the first reported lightcurve observations and results for these objects. MPO Canopus (Warner, 2017) was used to measure the images, do Fourier analysis, and produce the lightcurves. Table I lists the asteroids that were observed as well as the period associated with the analysis and the number of data points in the analysis. Orbital data and discovery circumstances were taken from the JPL Small Bodies Node (JPL, 2017).

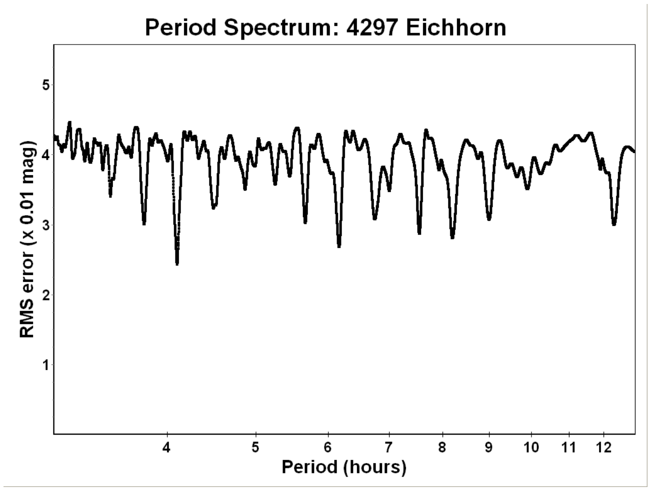
2578 Saint-Exupery (1975 VW3) is a main-belt asteroid discovered on November, 02 1975 by Smirnova T. at Nauchnyj. It's named in memory of the French writer Antoine de Saint-Exupery (1900-1944). It's a typical main-belt asteroid in an orbit with a semi-major axis of about 3.00 AU, eccentricity 0.097, and orbital period of about 5.19 years. We observed this asteroid in

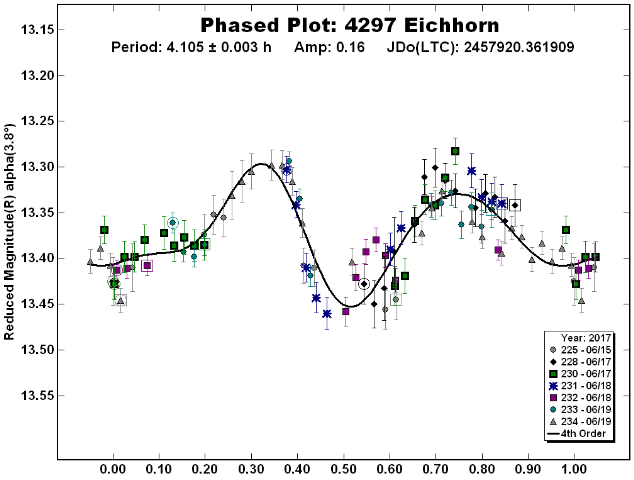
2017 from November, 28 to December, 23. The collaborative observations resulted in 7 sessions with a total of 249 data points. The result for the synodic period for 2578 Saint-Exupery is associated with the established trimodal lightcurve phased to 8.146 ± 0.001 h with an amplitude of 0.22 ± 0.02 mag.





4297 Eichhorn (1938 HE) is a main-belt asteroid discovered on April, 19 1938 by Dieckvoss W. at Bergedorf. It's a typical main-belt asteroid in an orbit with a semi-major axis of about 2.34 AU, eccentricity 0.192, and orbital period of about 3.57 years. We observed this asteroid in June, 15 to 19, 2017. The collaborative observations resulted in 4 sessions with a total of 97 data points. The result for the synodic period for 4297 Eichhorn is associated with the established bimodal lightcurve phased to 4.105 ± 0.003 h with an amplitude of 0.16 ± 0.03 mag.

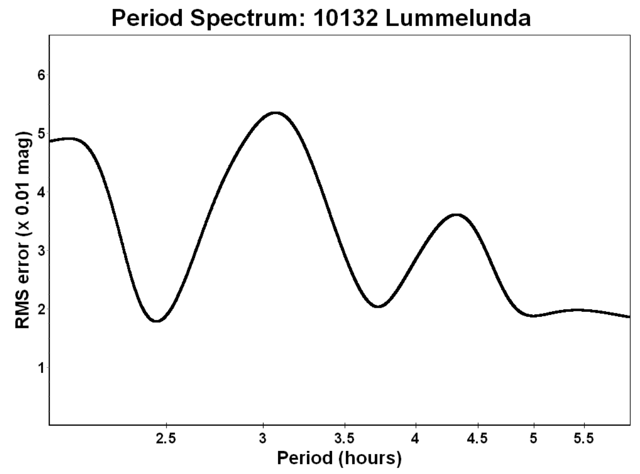


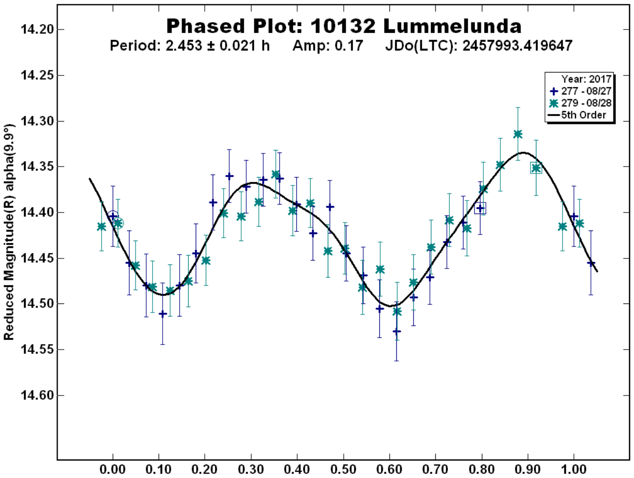


10132 Lummelunda (1993 FL84) is a main-belt asteroid discovered on March, 20 1993 at ESO. It's a typical main-belt asteroid in an orbit with a semi-major axis of about 2.22 AU, eccentricity 0.165, and orbital period of about 3.30 years. We observed this asteroid on 2017 August, 27. The collaborative observations resulted in one sessions with a total of 49 data points. The result for the synodic period for 10132 Lummelunda is associated with the established bimodal lightcurve phased to 2.510 ± 0.001 h with an amplitude of 0.17 ± 0.02 mag. This minor planet was revealed as a binary through the CBET 4440 (Benishek *et al.*, 2017) with a primary period of 2.5099 ± 0.0001 h, perfectly comparable with our result.

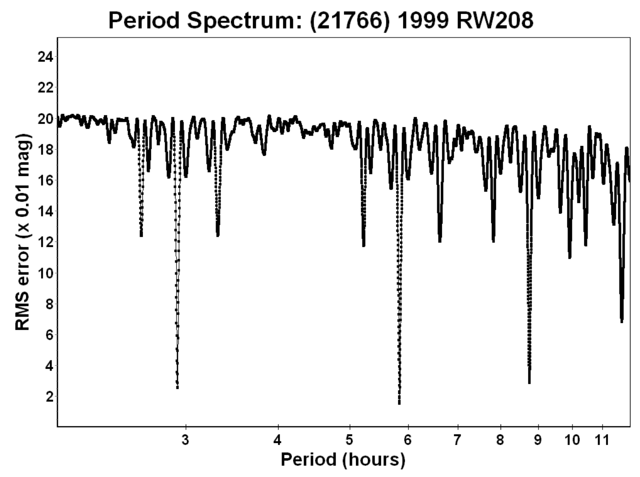
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
2578	Saint-Exupery	11/28-12/23	249	3.8,7.6	74	5	8.146	0.001	0.22	0.02
4297	Eichhorn	06/15-06/19	97	3.8,3.8,4.3	265	5	4.105	0.003	0.16	0.03
10132	Lummelunda	08/27	49	10.5	347	5	2.510	0.001	0.17	0.02
21766	1999 RW208	10/13-10/20	290	12.2,8.7	40	3	5.841	0.001	0.63	0.01

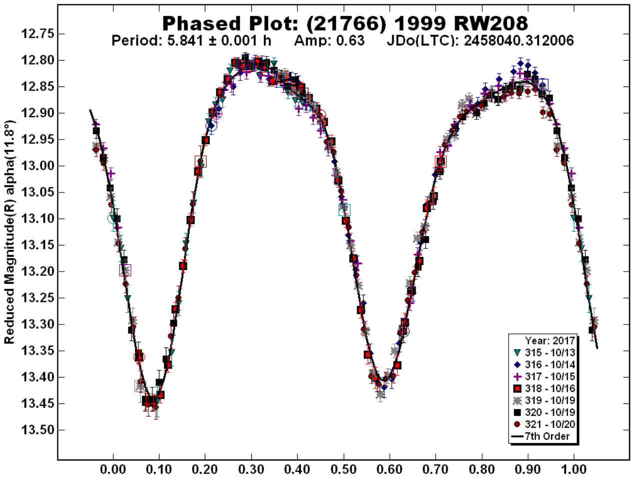
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).





<u>(21766) 1999 RW208</u> is a main-belt asteroid discovered on September, 08 1999 by LINEAR. It's a typical main-belt asteroid in an orbit with a semi-major axis of about 2.71 AU, eccentricity 0.219, and orbital period of about 4.46 years. We observed this asteroid in October 2017, from 13 to 20. The collaborative observations resulted in one sessions with a total of 290 data points. The result for the synodic period for (21766) 1999 RW208 is associated with the established bimodal lightcurve phased to 5.841 ± 0.001 h with an amplitude of 0.63 ± 0.01 mag.





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3122 FLORENCE: LIGHTCURVE ANALYSIS AND PRELIMINARY MODEL

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Photometric observations of 3122 Florence were carried out on 12 nights between 2017 Aug 30 and Oct 6. This allowed us to determine a synodic period range from P = 2.3568 h ± 0.0002 to 2.3576 h ± 0.0002 with amplitude ranging from A = 0.22 to 0.16 mag. Multi-band photometric sessions and low resolution visible spectrum analysis shows a taxonomic class S, according to the SMASS II classification. Using lightcurve inversion method we also obtained a preliminary shape and spin axis model of (λ = 164° ± 15, β = -86° ± 5) with a sidereal period Psid = 2.3583 h ± 0.0005.

3122 Florence is an Amor NEA (PHA) discovered on 1981 Mar 2 by J.S. Bus at Siding Spring in Australia. Collaborative observations were made over twelve nights inside the UAI (Italian Amateur Astronomers Union) group in order to observe this asteroid during its close approach to the Earth in the early of September 2017. The CCD observations were carried out between 2017 Aug 30 and Oct 6, covering wide variations in the phase angle and in the viewing geometries. The instrumentation is described in the Table I. Lightcurve analysis was made at the Balzaretto Observatory with *MPO Canopus v.10.7.7.0* (BDW Publishing, 2016). All the images were calibrated with dark and flat frames and converted to standard magnitude system using solar colored field stars from APASS catalogue. For the Rc and the Ic photometric bands were used the transformations by Munari (Munari, 2012), while for the B and V photometric bands were used the magnitude values of the catalog without any transformation. Table II shows the observing circumstances and results. Multi-band photometric sessions, acquired at Balzaretto Observatory on 2017 Aug 30 and at University of Siena (DSFTA, 2017) on 2017 Sept 4, let us determine the color indexes reported on table III and in Fig 1. These color indexes are consistent with a medium albedo S-type taxonomic class (Shevchenko and Lupishko, 1998).

There are many previously published rotation periods reported into lightcurve database (LCDB; Warner et al., 2009). The period analysis shows variations of the synodic periods and lightcurves amplitude as a consequence of the wide variations of the viewing geometry. The synodic period ranging from P = 2.3568 h ± 0.0002 to 2.3576 h ± 0.0002 and the amplitude ranging from A = 0.22 to 0.16 mag (Fig. 2). Moreover, the observed synodic period decrease respect the daily change rate of PAB Longitude (Fig. 3). This trend suggests a retrograde rotation for 3122 Florence. In addition, the intercept of the stationary point (ΔPABL/day=0) with the regression line is consistent (within the errors) with the sidereal period derived from the lightcurve inversion process.

Reflectance spectrum

Low resolution visible spectrum was observed at Balzaretto Observatory on 2017 Aug 30 with the diffraction grating SA-200 (Paton Hawksley Education) mounted inside the filter wheel, obtaining in this configuration a spectral resolution R~100. In order to increase the signal-to-noise ratio, we acquired and stacked 45 frames, each with a 30 second exposure time. In the same session we also acquired, at the same air-mass of the asteroid, the spectra of the stars HD 203893 (A0V type) and HD 203311 (solar-like G2V type), respectively for wavelength calibration and for solar reference to derive the reflectance spectrum. This was achieved by dividing the asteroid spectrum with the solar-like star and then normalized to the unity at the standard wavelength of 0.55 μm (center of the photometric V band). The resulting asteroid reflectance spectrum was compared with the SMASS II single-letter taxonomy classes (Bus and Binzel, 2002). The best fit of the 3122 Florence reflectance spectrum was achieved for the S-type taxonomic class (Fig. 4), according to the SMASS II taxonomy classification (Bus and Binzel, 2002). Moreover, a more rigorous taxonomy classification was done using the PCA analysis technique. First, we computed the principal component scores (PC1, PC2) and eigenvectors coefficients for the SMASS II single-letter taxomomy classes at discrete wavelengths (0.44, 0.50, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85 μm; Bus and Binzel, 2002). We fit the normalized spectrum of 3122 Florence using a 4th order polynomial function and computed the two component scores (PC1, PC2) with the previously determined eigenvectors. Figure 5 compare the position of 3122 Florence respect single-letter taxonomy classes in the PC1, PC2 space. The taxonomy class of 3122 Florence is close to that of S-type asteroids.

Lightcurve inversion

The lightcurve inversion process requires at least 2-3 apparitions data and a wide range of the viewing angles in order to determine the asteroid spin axis vector. In this apparition, the wide variations of the viewing geometry let us to attempt a preliminary shape and spin axis model. For this purpose, we used only the best lightcurves, that cover the entire observing geometries of our complete sample (Fig. 6). Lightcurve inversion was performed using *MPO LCInvert v.11.7.5.1* (BDW Publishing, 2016). For a description of the modeling process see LCInvert Operating Instructions Manual and Warner et al. (2017). The search for sidereal period was started around the synodic periods found in the period analysis. For this search the "dark facet" weighting factor was set to 0.3 and the number of iterations was set to 300. We found three sidereal periods with nearly lower chi-square value below the 10% limit, where the first two produce prograde pole solutions at (λ = 224, β = 89), (λ = 269, β = 82) and the third produce a retrograde pole solution at (λ = 164, β = -86). This last one have a lower chi-square value and it is consistent with PAB calculations, so we prefer this last one (Fig. 7).

For the pole search we used the “medium” search option with the previously found sidereal period set to “float”. The “dark facet” weighting factor was set to 0.3 and the number of iterations was set to 50. Data analysis shows a rough solution with lower chi-square value at λ = 180°, β = -90°. The subsequent “fine” search, centered on this position, allowed us to further refine the position of the pole (Fig. 8). The analysis does not find a well-isolated solution for the pole position with lowest chi-square below the 3% limit, but a wide distribution of the ecliptic longitude (lambda) and a more restricted distribution for the ecliptic latitude (beta). A preliminary solution, with lowest chi-square, is located at λ = 164° ± 15 β = -86° ± 5, with a sidereal period Psid = 2.3583 h ± 0.0005. The uncertainty in the sidereal period has been evaluated as a rotational error of 30° over the total timespan of the observations. Figure 9 shows the shape model with the fit between the model (black line) and the observed lightcurves (red points). The asteroid shape is nearly spheroidal in agreement with the observed low amplitude lightcurves and with the radar observations obtained on 2017 Sept 4 from Arecibo (CNEOS, 2017; Fig. 10).

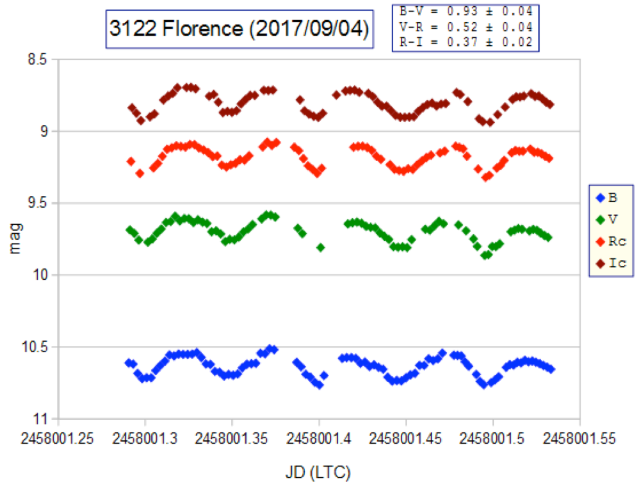

Fig. 1: Multi-band photometric lightcurves acquired on 2017 Sep 4 at DSFTA Observatory.

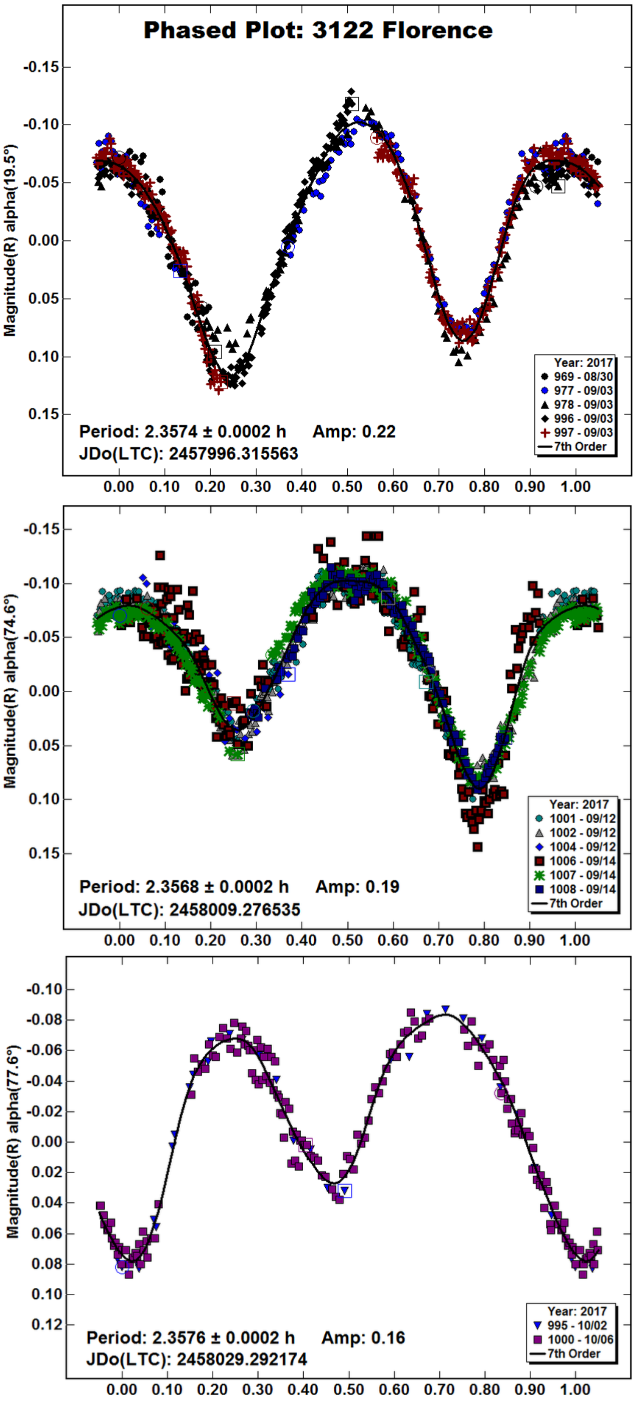

Fig. 2: 3122 Florence. The acquired lightcurves show variations in the synodic period and amplitude.

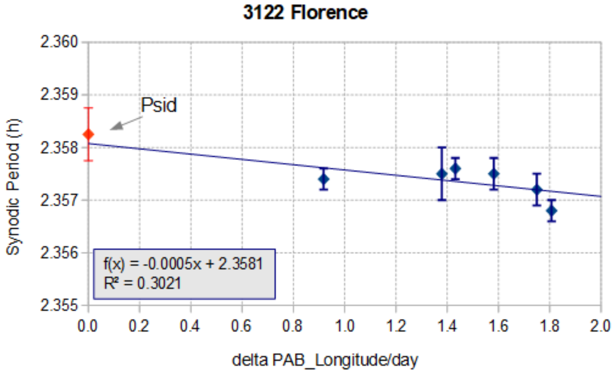

Fig. 3: The observed synodic period decreases, respect the daily change rate of the PAB Longitude, suggesting a retrograde rotation for 3122 Florence.

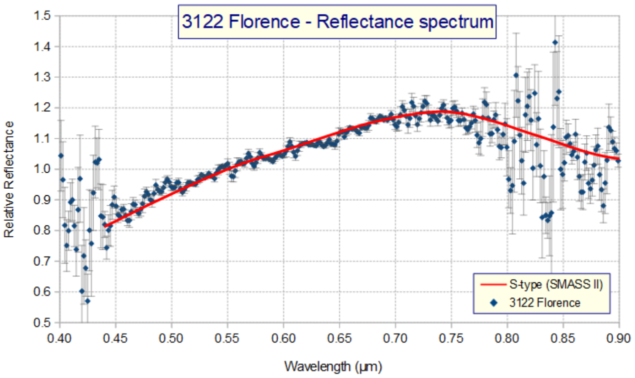

Fig. 4: The reflectance spectrum of 3122 Florence compared with S-type taxonomic class (SMASS II).

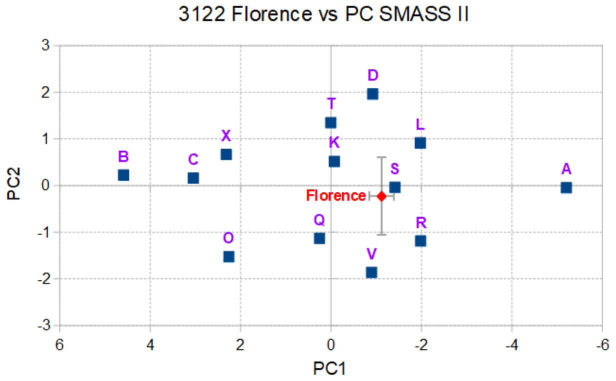

Fig. 5: The position of 3122 Florence respect single-letter taxonomy classes in the PC1, PC2 space. The error bars indicate the 1-sigma uncertainty.

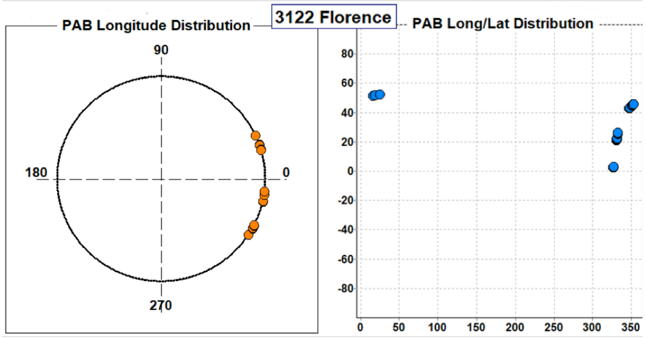

Fig. 6: Phase angle bisector (PAB) longitude/latitude distribution of the data used for the lightcurve inversion model.

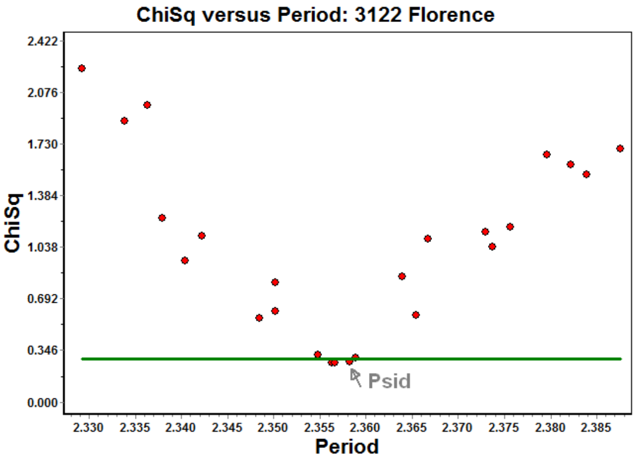

Fig. 7: The period search do not find a unique solution with lowest chi-square, but three solutions with a similar low chi-square reside below the 10% limit (green line).

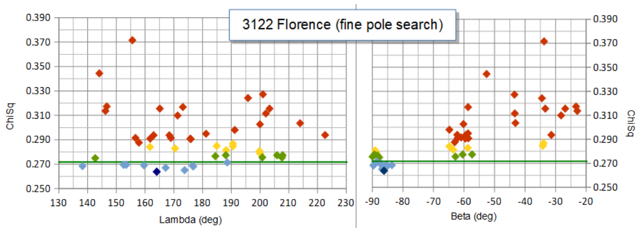

Fig. 8: The “fine” pole search shows a distribution of the ecliptic coordinates. The colors from dark blue to maroon indicates the better solutions (lower chi-square) and the worst ones. The better solutions are located below the 3% limit (green line).

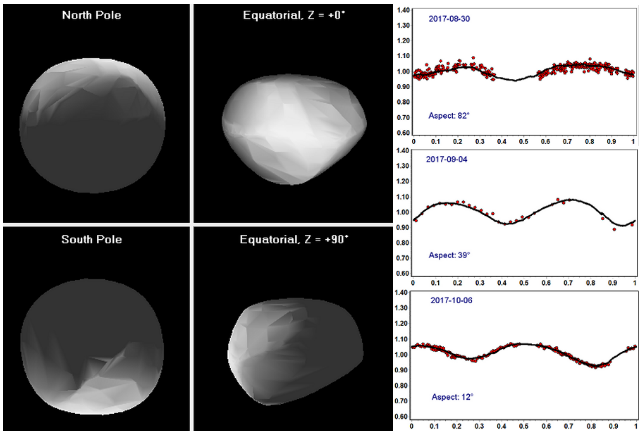

Fig. 9: The shape model for 3122 Florence (λ = 164°, β = -86°) and the fit between the model (black line) and the observed lightcurves (red points).

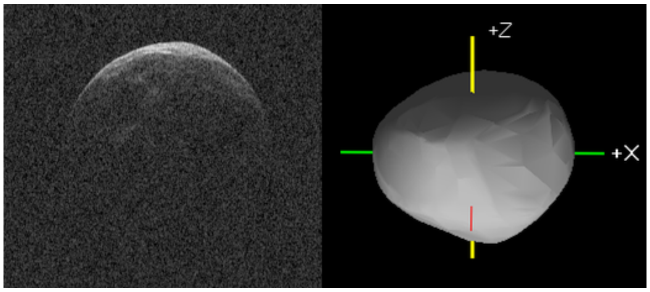

Fig. 10: Comparison between the radar image obtained on 2017 Sept 4 from Arecibo and the model obtained from lightcurve inversion process.

Observatory (MPC code)	Telescope	CCD	Filter
M57 (K38)	0.30-m RCT f/5.8	SBIG STT-1603	Rc
Balzaretto (A81)	0.20-m SCT f/5.5	SBIG ST7-XME	V,Rc
GiaGa (203)	0.28-m SCT f/10	SBIG ST8XME	Rc
Eurac (C62)	0.30-m NRT f/4	QHY9	Rc
Univ.Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e (2x2)	B, V, Rc,Ic
Salvatore di Giacomo(L07)	0.50-m RCT f/8	FLI-PL4240	Rc
AAB	0.40-m SCT f/10	KAF 1603 ME	C
San Marcello Pistoiese (104)	0.60-m NRT f/4	Apogee Alta	C

Table I. Observing Instrumentations. MCT: Maksutov-Cassegrain, NRT: Newtonian Reflector, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain.

Date (MPC code)	Color Indexes
2017 Aug 30 (A81)	(V-Rc) = 0.48 ± 0.05
2017 Sept 4 (K54)	(B-V) = 0.93 ± 0.04
	(V-Rc) = 0.52 ± 0.04
	(Rc-Ic) = 0.37 ± 0.02

Table III. The color indexes acquired for asteroid 3122 Florence.

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Number	Name	2017 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
3122	Florence	08/30-09/03	723	19.5,43.2	329	12	2.3574	0.0002	0.22	0.03
3122	Florence	09/12-09/14	1156	74.5,76.8	349	44	2.3568	0.0002	0.19	0.03
3122	Florence	10/02-10/06	186	77.5,76.0	22	52	2.3576	0.0002	0.16	0.03

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).

LIGHTCURVE ANALYSIS FOR FOUR NEAR-EARTH ASTEROIDS

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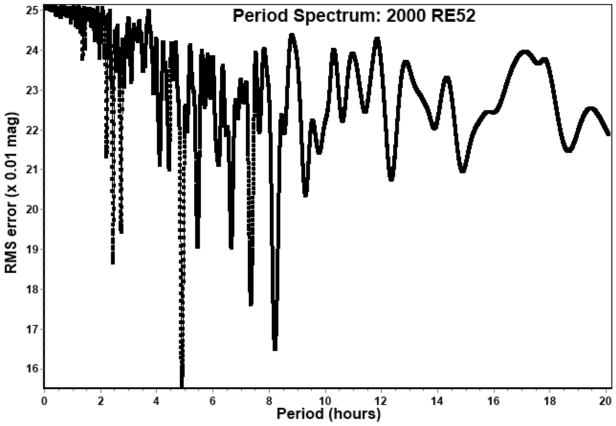
Lightcurves are reported for four near-Earth asteroids observed from Great Shefford Observatory during close approaches between 2010 January and 2017 November: 2000 RE52, 2008 YZ32, 2017 UK8, and 2017 VD. 2008 YZ32 is a large superfast rotator.

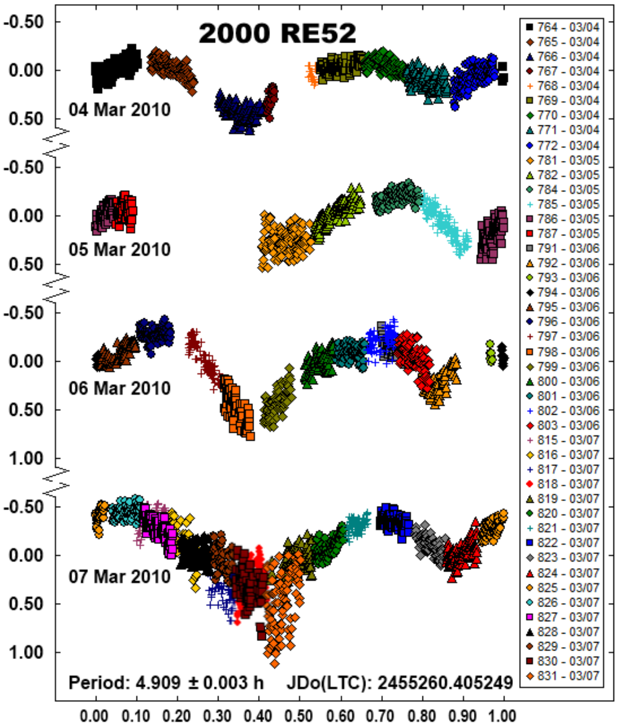
Photometric observations of near-Earth asteroids during close approaches to Earth were made at Great Shefford Observatory between 2010 January and 2017 November using a 0.40-m Schmidt-Cassegrain and Apogee Alta U47+ CCD camera. All observations were made unfiltered and with the telescope operating with a focal reducer at *f*/6. The 1Kx1K, 13-micron CCD was binned 2x2 resulting in an image scale of 2.16 arc seconds/pixel. Except where noted, *Astrometrica* (Raab, 2017) was used to measure photometry using APASS Johnson V band data from the UCAC4 catalogue and *MPO Canopus* (Warner 2017), incorporating the Fourier algorithm developed by Harris (Harris et al., 1989) was used for lightcurve analysis.

2000 RE52 = 2010 EK2. Discovered as a 16th mag object on 2010 Mar 4 by the Catalina Sky Survey (Hill et al., 2010), it was then linked to 2000 RE52 by Francesco Manca the next day (Manca and Spahr, 2010). It reached its closest to Earth on 2010 Mar 8 at a distance of 0.0347 AU. The 2000 apparition had been less favourable, reaching only mag +18.5. A search of the Asteroid Lightcurve Database (LCDB; Warner et al., 2009) and wider searches do not reveal any previously reported lightcurve results. Photometry was obtained on 2010 Mar 4 (for 4h 49m), Mar 5 (4h 48m), Mar 6 (5h 29m) and Mar 7 (6h 53m). *MPO Canopus* (Warner, 2010) was used for image measurement using differential aperture photometry and for lightcurve analysis and using all four dates a period of 4.909 h derived.

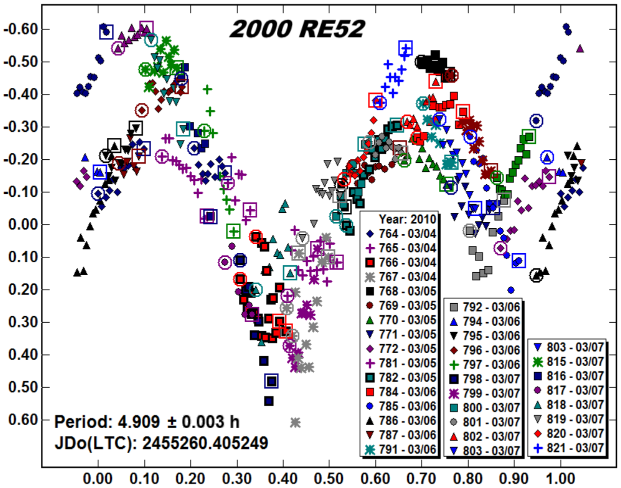
However, there are night-to-night variations in the lightcurve shape and amplitude. A period spectrum shows a second RMS minimum at 8.2 h but this tri-modal solution gives a much less satisfactory fit than the 4.9 h period.



A phased plot of relative magnitude is given showing all four nights arranged vertically.



Another plot combining all four nights, but binning up to 9 individual measurements into single points if separated by no more than 9 minutes of time, allows the variation in the curves between nights to be seen more clearly.



The maximum amplitude of ~0.9 mag occurred on Mar 6. The shape and amplitude changes may indicate that 2000 RE52 is tumbling but this is not resolved conclusively, so it is expected to be rated as PAR = –1 (Non-Principal Axis rotation possible, but not conclusively) on the scale of Pravec et. al. (2005).

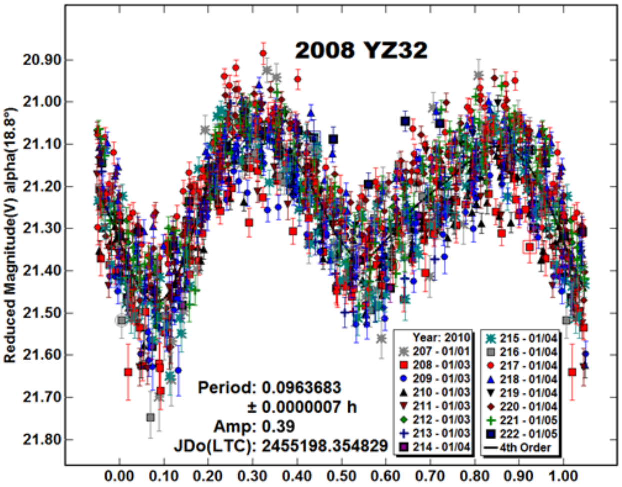
2008 YZ32. Observations of this Apollo asteroid were made on the nights of 2010 January 1, 3, and 4 during a close approach to Earth. There was significant light pollution from the full Moon, only 30 degrees away on the first date, but this diminished rapidly on the following nights. A search of the LCDB and wider searches do not reveal any previously reported lightcurve results but 2008

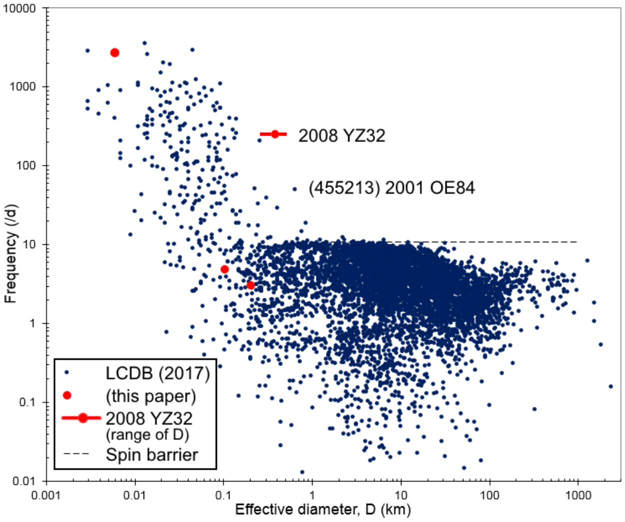
YZ32 was observed by the NEOWISE Post-Cryogenic Survey (Mainzer et al. 2012) in 2011 January, resulting in estimates for diameter and visual albedo.

A period spectrum using all observations favours a bimodal solution and the 0.39 magnitude amplitude also suggests a bimodal solution is to be preferred (Harris et al., 2014). Reductions from Jan 1, 3, and 4 produce very similar lightcurves with rotation periods 346.4, 346.9, and 347.0 seconds respectively. An estimate of the likely error in number of rotations ΔN when propagating a calculated period with its associated error to another time is derived from Eq (3) in Kwiatkowski et al. (2010) as:

$$\Delta N \approx \Delta t \, \Delta P / P^2. \qquad (1)$$

where Δt is the time interval separating two individual lightcurves, P is the period from one of the individual solutions and ΔP is the maximum period uncertainty, in practice taken here to be 3σ and Δt, ΔP, and P in the same units. For a bimodal curve, ΔN < 0.25 implies a maximum (or minimum) can be matched unambiguously, less than ¼ cycle from reality. Using the period calculated for Jan 3 and matching back to Jan 1 gave an unsatisfactory ΔN = 0.25 but matching forward to Jan 4, ΔN = 0.10 allowing Jan 3 and 4 to be combined, resulting in revised values for P and ΔP. This then allowed matching back unambiguously to Jan 1 with ΔN = 0.05 and a period calculated from all three nights of P = 0.0963683 ± 0.0000007 h. 795 revolutions occurred between the first and last measurements.





During the period of observation, the phase angle bisector was changing at a rate of 2°/day and, according to Warner et al. (2009), the expected difference between the sidereal period and synodic period is estimated to be 0.0000017 h, slightly larger than the estimated error on the calculated synodic period derived using all three nights.

The MPCORB database (MPC, 2017a) gives values of H = 20.1 and G = 0.15; the NEOWISE survey used H = 20.1 to find a geometric albedo of $p_V = 0.111 \pm 0.102$ and diameter $D = 0.382 \pm 0.133$ km. This range of D for 2008 YZ32 is plotted on a standard frequency-diameter diagram.

For comparison, (455213) 2001 OE84 is labelled; it is the largest, fastest rotating object in the LCDB that breaks the 2.2 h spin rate barrier (e.g., Polishook et al., 2017). It is noted that 2008 YZ32 is probably about half the diameter of 2001 OE84 but rotating five times faster.

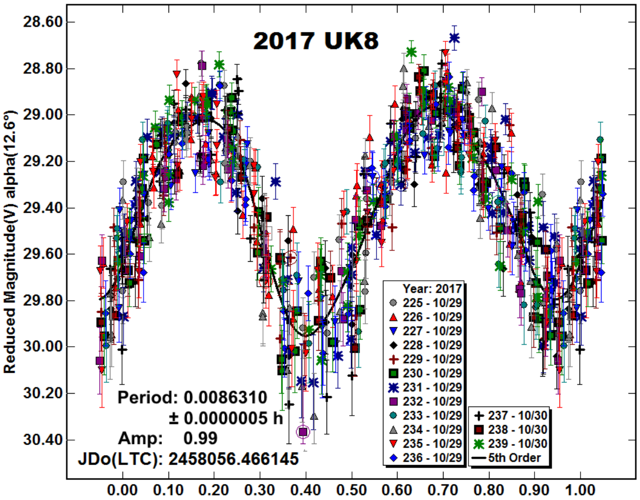
2017 UK8. This was a one-night only target of opportunity, discovered by the Catalina Sky Survey on 2017 Oct 29 and passing Earth at 0.6 lunar distances 26 hours later. A search of the LCDB and wider web searches has not revealed any previously reported lightcurve results. Four separate imaging runs were completed (Table I).

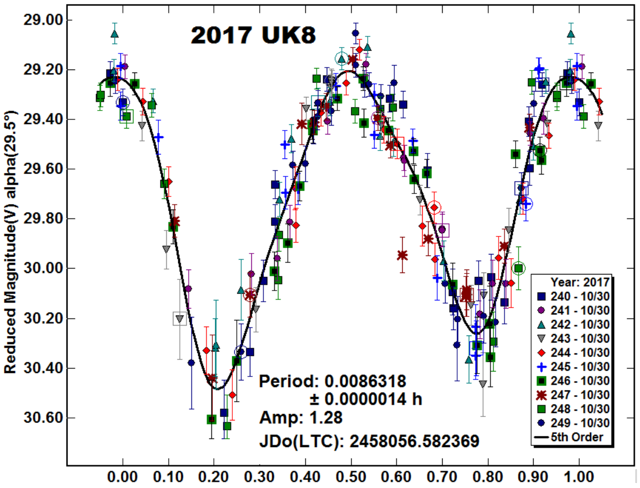
Run	2017 Oct dd hh:mm	Fields/ Points	Phase range	Exp
1	29 18:56-29 19:06	2/90	3.6-3.5	2
2	29 23:11-30 00:13	15/630	12.4-17.4	1
3	30 01:59-30 02:20	10/183	29.2-32.2	1
4	30 02:23-30 02:29	3/72	32.7-33.6	0.4

Table I. Summary of observing runs for 2017 UK8. The start and end times of images used is given. Fields/Points gives the number of times the telescope was repositioned to different fields during the run together with the number of data points used in the analysis. Phase range gives the phase at start and end of each run. Note the phase was decreasing during run 1 and increasing in runs 2-4. Exp is the exposure time in seconds.

The initial 10-minute run provided astrometry to the NEO Confirmation Page (MPC, 2017b). Large variations in brightness were evident in consecutive exposures. The remaining runs were specifically to collect photometry but with the object rapidly accelerating (to 550 arcsec/min by the end of run 4), exposures were reduced to keep trailing short. Images from runs 2 and 3 were suitable for individual measurement. The target was visible in every exposure, though only faintly at some of the minima. Trailing was limited to 8 arc seconds or less with the 1 second exposures. An aperture radius of 3 pixels was used for measurement, this equating to 13 arc seconds diameter and allowing the trails to be kept well within the measurement annulus at all times. 2017 UK8 was not recorded strongly enough for individual images to be consistently measured from runs 1 and 4. Lightcurves generated independently from runs 2 and 3 are given, both favouring a very short bi-modal rotation period of 31 s with amplitude >1 mag. There is less noise in the later diagram as the apparent magnitude had brightened by ~0.3 magnitudes. As expected, with increasing phase angle the amplitude also increased, from 1.0 to 1.3 mags.

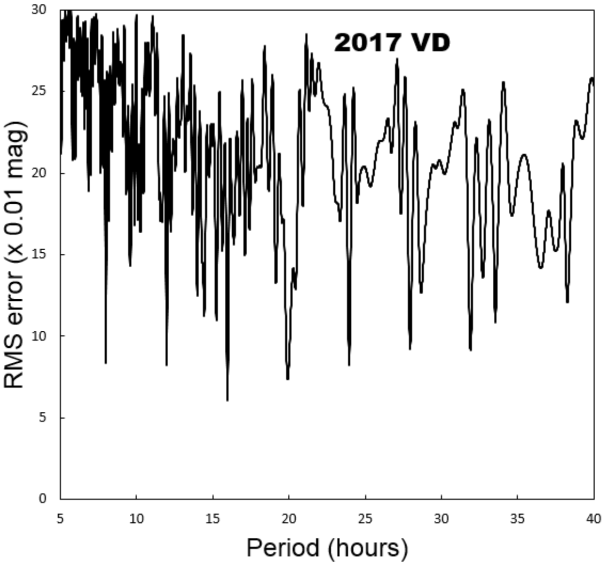
Using the period of 0.0086310 ± 0.0000005 h determined from run 2 and propagating that error to the start of run 3 with Eq. 1 gives ΔN = 0.012, indicating the two runs could be combined unambiguously, with resulting $P = 0.0086309 \pm 0.0000001$ h and indicating 364 revolutions occurred in the 3 h 8 m between the first and last measurements of runs 2 and 3. The phase angle bisector was changing at a rate of 68°/day. According to Warner et al. (2009), the magnitude of the expected difference between the sidereal period and synodic period is 0.0000006 h, somewhat larger than the estimated error on the calculated synodic period.

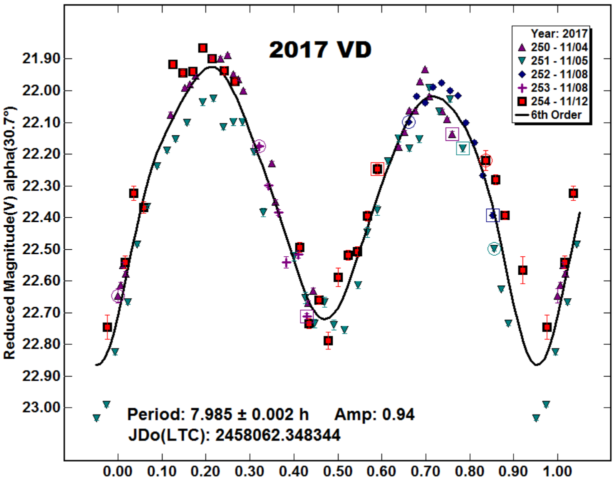




2017 VD. This was another target of opportunity, discovered by ATLAS-MLO on 2017 November 4.4 UT with the first observations from Great Shefford starting about 11 hours later. 2017 VD was mag +16 and moving at 22 arcsec/minute; the full moon was 43° distant. The asteroid was followed for 6 h on Nov 4, 7.5 h on Nov 5, 1.75 h Nov 8.1, 1 h on Nov 8.9, and 6 h on Nov 12. A search of the LCDB and wider web searches has not revealed any previously reported lightcurve results. Exposure lengths ranged from 6-30 seconds. The images were stacked using *Astrometrica* to increase SNR. A maximum of 28 images were stacked for each photometric measurement, representing a maximum effective exposure length of 13 m 43 s. Since this was 0.029 of the derived period, it caused negligible smearing of the lightcurve (Pravec et al., 2000).

The 0.9 magnitude amplitude implies a bimodal solution (Harris et al., 2014) and therefore the 8 h solution is adopted rather than other slightly lower minima in the period spectrum for aliases at 12, 16, 20 and 24 hours. Discrepancies in the lightcurve, especially between sessions from Nov 5 and Nov 12, are expected due to the phase reducing from 32° to 20°.





Acknowledgments

The author is grateful to Dr. Petr Pravec for his advice and help, especially with the interpretation of the lightcurves for 2000 RE52, and to Alan Harris for discussions on 2017 UK8.

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Name	Intg. time	Intg. / Period	Min a/b
2000 RE52	10	0.001	1.3
2008 YZ32	24	0.069	1.6
2017 UK8	2	0.064	1.9
2017 VD	823	0.029	1.5

Table II. Ancillary information, listing the longest integration time used (seconds), the fraction of the period represented by the integration time (see Pravec *et al.,* 2000) and the calculated minimum elongation of the asteroid.

Number	Name	yyyy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
	2000 RE52	2010/03/04-03/08	4072	14.3,33.0	155	-5	4.909	0.001	0.9	0.1
	2008 YZ32	2010/01/01-01/05	1250	18.9,17.4,18.0	94	-6	0.0963683	0.0000007	0.39	0.05
	2017 UK8	2017/10/29-10/30	813	12.4,32.2	43	7	0.0086309	0.0000001	1.3	0.2
	2017 VD	2017/11/04-11/13	106	31.6,19.9	34	1	7.985	0.002	0.9	0.1

Table III. Observing circumstances. Pts is the number of data points. 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 approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

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ROTATION PERIOD DETERMINATIONS FOR 59 ELPIS AND 295 THERESIA

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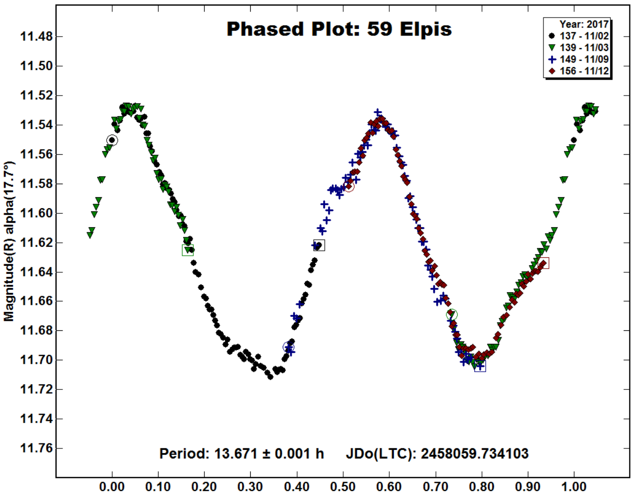
Synodic rotation periods and amplitudes are found for two asteroids: 59 Elpis 13.671 ± 0.001 hours, 0.18 ± 0.01 magnitudes; 295 Theresia 10.702 ± 0.001 hours, 0.14 ± 0.01 magnitudes.

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.

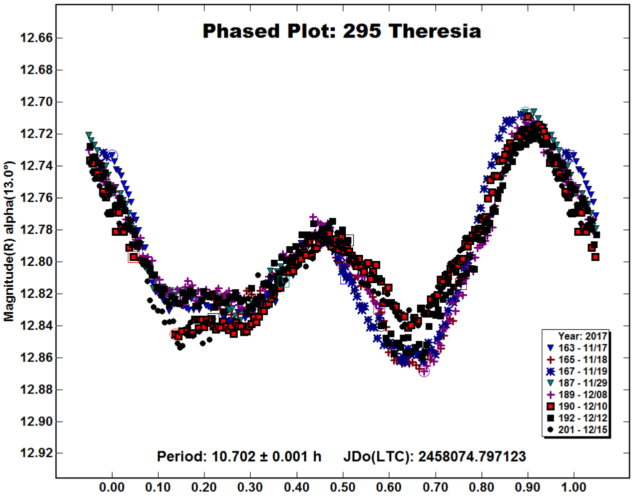
59 Elpis. Previously published period determinations are by Debehogne et al. (1978), 13.69 hours; Shevchenko et al. (1996), 13.68 hours; Behrend (2006), 13.69 hours; Behrend (2009), 13.69 hours; Behrend (2011), 14. hours; Behrend (2016), 13.69 hours. New observations on four nights 2017 Nov. 2-12 provide a good fit to a period of 13.671 ± 0.001 hours, amplitude 0.18 ± 0.01 magnitudes. This is compatible with all previous period determinations.

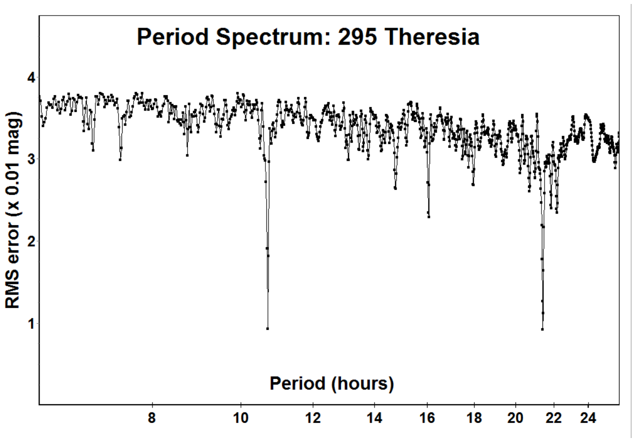
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
59	Elpis	11/02-11/12	1093	17.7, 14.6	80	-11	13.671	0.001	0.18	0.01
295	Theresia	11/17-12/15	2880	13.0, 0.9	81	1	10.702	0.001	0.14	0.01

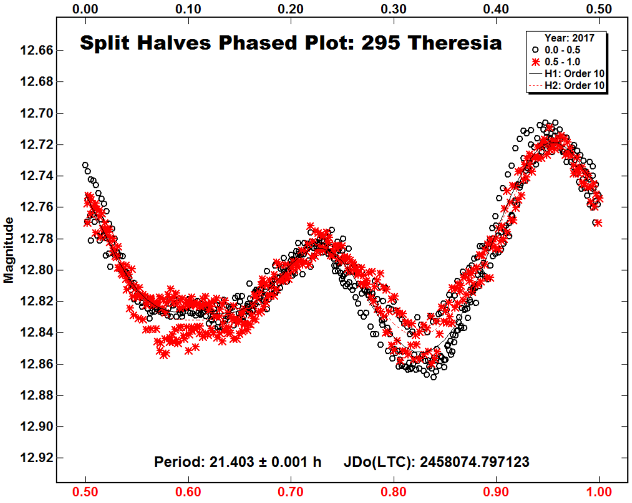
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date, unless a minimum (second value) was reached. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al*.,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



<u>295 Theresia.</u> Previously published period determations are by Behrend (2003), 10.706 hours; Menke (2005), 10.70 hours; Behrend (2007), 10.72 hours; Behrend (2009), 10.730 hours; Pligge et al. (2011), 10.87 hours. New observations were made on 8 nights 2017 Nov. 17-Dec. 15. When fitted to a lightcurve with period 10.702 ± 0.001 hours, significant changes in lightcurve shape resulting from changes of phase angle are noted. A period spectrum between 6 hours and 26 hours shows that all periods except 10.702 hours and the double period can be rejected. A split halves plot of the double period shows that changes in lightcurve shape with each half are larger than differences between the two halves of the lightcurve. The double period can therefore be rejected safely, and a period of 10.702 ± 0.001 hours may be considered secure. Previous period determinations are compatible with the new result.







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LIGHTCURVE ANALYSIS AND ROTATION PERIOD FOR (140158) 2001 SX169

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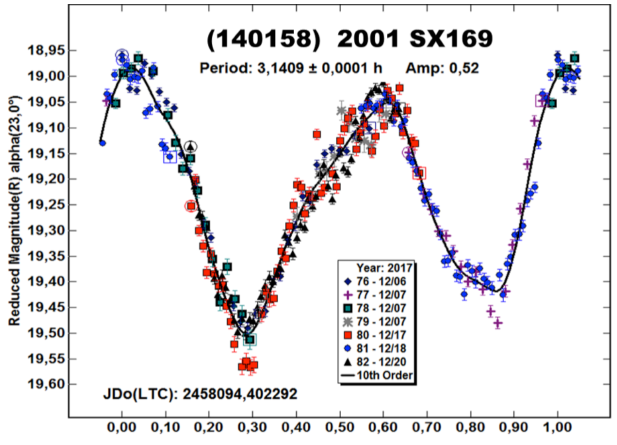
From 2017 December 6th to 2017 December 20th, CCD images were taken with the aim to measure the rotation period of (140158) 2001 SX169. The data analysis gives a light curve with a rotation period of 3.1409 ± 0.0001 h.

(140158) 2001 SX169 is a near-Earth asteroid (potentially hazardous) discovered by LINEAR - Lincoln Laboratory ETS, New Mexico on September 19th, 2001. Its H magnitude is 18.3 and diameter is estimated from 580 to 1300 meters. The orbital period is approximately 571 days and the geometric albedo is 0.289 (from JPL Small Body database - JPL, 2018).

CCD photometric observations of (140158) 2001 SX169 asteroid were performed at the Osservatorio Salvatore di Giacomo, Agerola (L07) from 2017 December 6th to 2017 December 20th to estimate the lightcurve and rotation period since there were no entries in the LCDB (Warner et al., 2009) for this asteroid at the time of the observations. Photometric measurements were carried out by means of 0.50-m Ritchen-Chretien telescope operating at f/8 using an unfiltered FLI-PL4240 CCD camera with 2048x2048 array of 13.5 micron pixels. Table I lists the telescope/CCD camera combination used to collect the data.

A total of 252 lightcurve data points were collected in 7 observing sessions with exposure times ranging from 90 s to 120 s. All images were astrometrically aligned, and dark and flat-field corrected. MPO Canopus (Warner, 2016) was used to measure the magnitudes, perform Fourier analysis, and produce the final lightcurve. In particular, data were reduced in MPO Canopus using differential photometry. Night-to-night zero point calibration was accomplished by selecting up to five comparison stars with near-solar colors using the “comp star selector” feature. The MPOSC3 (Warner, 2007) star catalog was used for determining the comparison star magnitudes. The “StarBGone” routine within MPO Canopus was used to subtract stars that occasionally merged with the asteroid during the observations. MPO Canopus was also used for rotation period analysis. The software employs a FALC Fourier analysis algorithm developed by Harris (Harris, 1989). After accumulating seven sessions, we found a period of 3.1409 ± 0.0001 h. The data shown indicate a light curve with an amplitude change of 0.52 magnitudes. Table II gives the observing circumstances and results.

The period spectrum provided shows that other solutions are possible. Even if other periods cannot be rejected, the suggested one is corresponding to a bimodal shape lightcurve. These results call for further investigations in the next future. Warner (2018; this issue) independently reports confirming results.



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Site	Ap (m)	Type	f/	Camera	Array	Filter
Agerola (NA),Italy	0.500-m	RC	8.0	FLI-PL4240	2048x2048x13.5µ	clear

Table I. List of telescope/camera combinations. RC=Ritchen-Chretien

Number	Name	20yy mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Exp
140158	2001 SX169	17/12/06-17/12/20	252	23.0-63.1	59.0	-9.6	3.1409	0.001	0.52	0.02	90-120

Table II. Observing circumstances and results. 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 exposure range, seconds.

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CCD PHOTOMETRIC OBSERVATIONS OF ASTEROIDS 1953 RUPERTWILDT, 4576 YANOTOYOHIKO, 4692 SIMBAD, 16852 NUREDDUNA, (19743) 2000 AF164, (21766) 1999 RW208, (24388) 2000 AB175, AND (29564) 1998 ED6

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CCD photometric observations of asteroids 1953 Rupertwildt, 4576 Yanotoyohiko, 4692 SIMBAD, 16852 Nuredduna, (19743) 2000 AF164, (21766) 1999 RW208, (24388) 2000 AB175, and (29564) 1998 ED6 were conducted from the George West ISD Mobile Observatory. The following rotational periods and lightcurve amplitudes were found: 1953 Rupertwildt, 4.39 ± 0.01 h, 0.16 mag; 4576 Yanotoyohiko 9.40 ± 0.04 h, 0.27 mag; 4692 SIMBAD, 5.44 ± 0.01 h, 0.14 mag; 16852 Nuredduna, 6.252 ± 0.015 h, 0.27 mag; (19743) 2000 AF164, 3.463 ± 0.002 h, 0.23 mag; (21766) 1999 RW208, 5.82 ± 0.01 h, 0.68 mag; (24388) 2000 AB175, 6.972 ± 0.01 h, 0.26 mag; and (29564) 1998 ED6, 8.40 ± 0.02 h, 0.58 mag.

The photometric observations described in this paper were conducted from the George West ISD Mobile Observatory, which is located at a dark sky site 19 kilometers south of the town of George West, Texas. This research was conducted as part of an educational program of the George West Independent School District and was conducted during the fall semester of the 2017-2018 school year.

Throughout this research program, a Meade 0.35-meter LX600 Schmidt Cassegrain telescope was used. The telescope is housed within a converted eight by sixteen foot Wells Cargo trailer with a hinged roof. This sets upon concrete blocks supported by a thick concrete slab to minimize vibrations. From 2017 March to September, an SBIG STF-402M thermoelectrically cooled CCD camera was used to record the images. Beginning in 2017 October, that camera was replaced with the larger format SBIG STXL 6303 camera. The photometric exposures ranged from 60 to 120 seconds and were dark subtracted and flat fielded. To preserve the maximum light intensity of the objects observed, no filters were placed in the optical path during the observations.

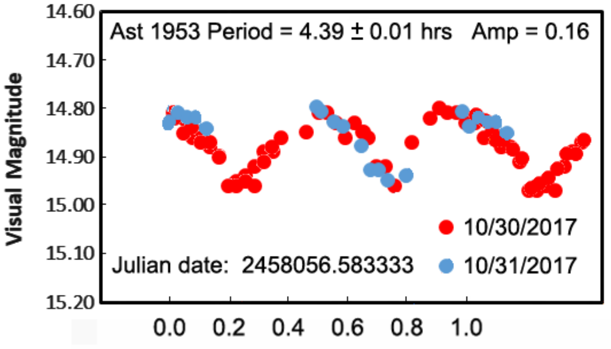
The brightness of the asteroid was compared to that of a comparison star in the same CCD frame. Two additional stars were also measured in each frame to act as check stars to assess the precision of the observations and confirm that the comparison star was not variable. When using the SBIG STF-402M camera, the brightness of the comparison and check stars along with the asteroid were determined by measuring a 49 pixel (7x7 pixel) sample surrounding the asteroid or star in question. This corresponded to a 13.65x13.65 arcsec box centered upon the object. When using the SBIG STXL-6303 camera, target brightness was determined by measuring a 169 pixel (13x13 pixel) sample surrounding the asteroid or star in question. This corresponded to an 8.45x8.45 arcsec box. When possible, the same comparison and check star were used during consecutive nights of observation. The coordinates of the asteroid were obtained from the online MinorPlanet.Info website. To compensate for the effect of the asteroid's ever-changing distance from the Sun and Earth on its visual magnitude, the following equation was used to vertically align the photometric data points from different nights in the construction of a composite lightcurve:

$$\Delta m = -2.5 \log_{10}((e_2^2/e_1^2)\,(r_2^2/r_1^2))$$

where Δm is the magnitude correction between nights 1 and 2, e_1 and e_2 are the Earth-asteroid distances on nights 1 and 2, and r_1 and r_2 are the Sun-asteroid distances on nights 1 and 2.

Orbital information was taken from the JPL web site (JPL, 2017). Targets were selected from quarterly photometric opportunity articles in the *Minor Planet Bulletin* (Warner et al., 2017a, 2017b, 2017c). The asteroid lightcurve database (LCDB; Warner et al., 2009) was checked for previous results. Ephemerides were generated using the Lowell Observatory web site (Lowell, 2017).

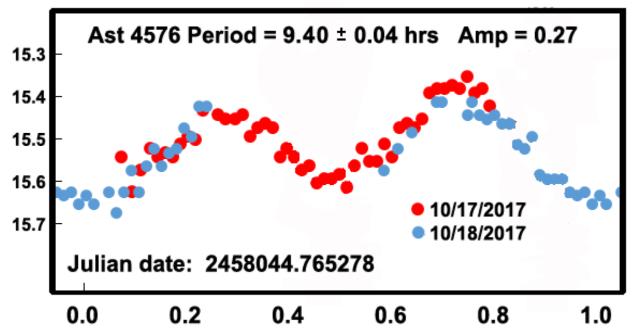
1953 Rupertwildt is an asteroid in the outer region of the main-belt, approximately 22 kilometers in diameter. It was discovered on 1951 October 29 by the Indiana Asteroid Program of Indiana University at its Goethe Link Observatory. It was named after astronomer Rupert Wilde. This asteroid was observed on the nights of 2017 October 30 and 31. A composite lightcurve with a period of 4.39 ± 0.01 h best fits the available data. The lightcurve has an amplitude of 0.16 magnitudes and displays two maxima and two minima per rotational cycle.



The two maxima appear to be of equal magnitude, as do the minima. A search of the asteroid lightcurve database (LCDB; Warner et al., 2009) revealed that this asteroid did not currently have a published rotational period.

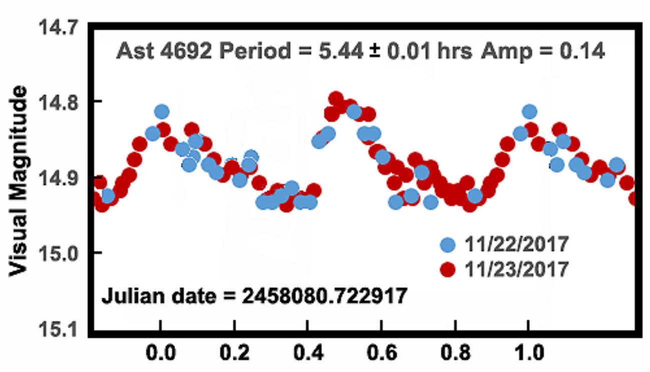
4576 Yanotoyohiko was discovered by Takuo Kojima at the YGCO Chiyoda Station in Japan on 1988 February 10. It is named after Toyohiko Yano, a materials scientist at the Tokyo Institute of

Technology and an acquaintance of the discoverer. It was observed on the nights of 2017 October 17 and 18.



A rotational period of 9.40 ± 0.04 h best fits the data. The lightcurve is characterized by two maxima and two minima per rotational cycle. The first minimum and maximum are approximately 0.06 magnitudes fainter than the second ones. The brightness variation between the brighter of the two maxima and the fainter of the two minima is approximately 0.27 magnitudes. According to the LCDB, this asteroid did not have a previously published rotational period.

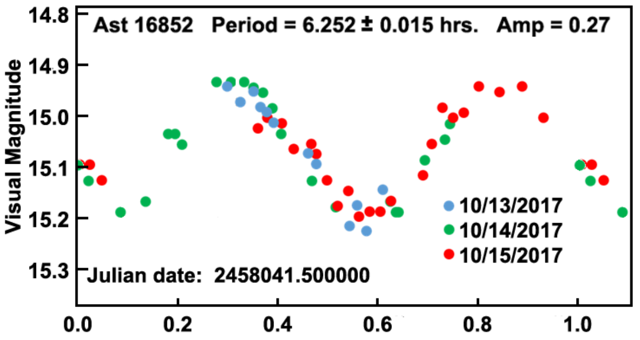
4692 SIMBAD was discovered on 1983 November 4 by Brian Skiff at Lowell Observatory in Flagstaff, Arizona. It is named after the SIMBAD extrasolar planet survey. It is located in the inner part of the main-belt, with a semi-major axis of 2.256 AU. It was observed during the nights of 2017 November 22 and 23. A composite lightcurve based upon a rotational period of 5.44 ± 0.01 h best fits the data.



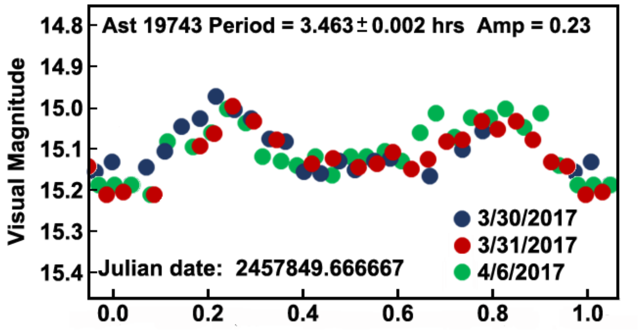
The lightcurve is characterized by two essentially identical maxima and two minima per rotational period. The asteroid transitions from minimum brightness to maximum brightness very quickly then slowly fades to the next minimum. Based on a review of the literature, it would appear that this determination of the asteroid's rotational period is the first published.

16852 Nuredduna was discovered on 1997 December 21 by Angel Lopez and Rafael Pacheco. It is located in the inner main-belt, with a semi-major axis of 2.259 AU. We observed this asteroid on the nights of 2017 October 13-15.

The lightcurve is characterized by two maxima and two minima per rotational cycle. A rotational period of 6.252 ± 0.015 h and amplitude of 0.27 mag best fits the data. The LCDB revealed no previously published lightcurves for this asteroid.



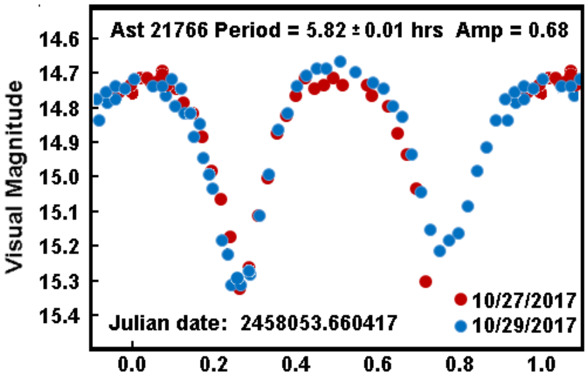
(19743) 2000 AF164 was discovered on 2000 January 5 by the LINEAR telescope outside of Socorro, New Mexico. Its orbit has a semi-major axis of 2.585 AU. It was observed on the nights of 2017 March 30-31 and April 6.



A synodic rotational period of 3.463 ± 0.002 h with an amplitude of 0.23 mag was determined. The lightcurve displays two maxima and two minima per rotational cycle. One minimum is approximately 0.06 magnitudes fainter than the other. In addition, the shallower minimum displays a flattened shape while the other is curved. The two maxima appear approximately the same. The LCDB had no previously published rotational periods for this asteroid.

(21766) 1999 RW208 was discovered on 1999 September 8 by the LINEAR telescope. It has an orbit with a semi-major axis of 2.709 AU. It was observed on the nights of 2017 October 27 and 29. The composite lightcurve is based on a synodic rotational period of 5.82 ± 0.01 h and has an amplitude of 0.68 mag.

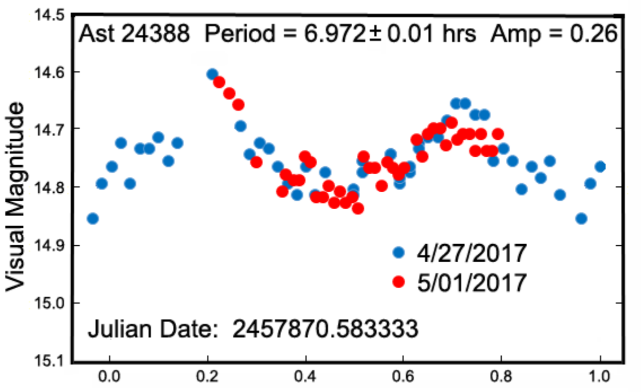
The lightcurve displays two maxima and two minima per rotational cycle. The maxima are rather broad, while the minima are deep but brief. The LCDB had no listed previously reported periods.



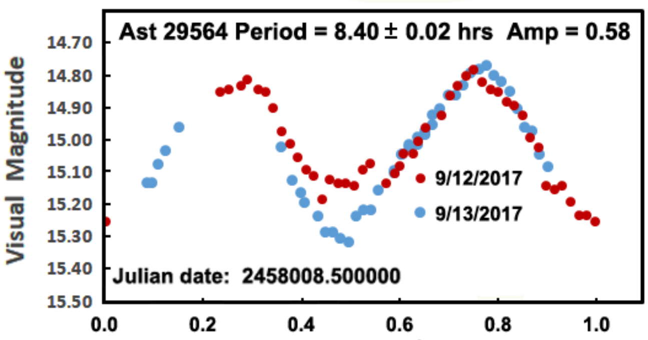
Number	Name	2017 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1953	Rupertwiltd	10/30-10/31	0.9,0.9	37	-2	4.39	0.01	0.16	0.01	THM
4576	Yanotoyohiko	10/17-10/18	3.8,3.8	24	-8	9.40	0.04	0.27	0.02	EOS
4692	SIMBAD	11/22-11/23	0.8,0.3	61	-1	5.44	0.01	0.14	0.01	FLOR
16852	Nuredduna	10/13-10/15	3.8,2.5	25	0	6.252	0.015	0.27	0.02	BAP
19743	2000 AF164	03/30-04/06	8.6,9.8	188	15	3.463	0.002	0.23	0.02	EUN
21766	1999 RW208	10/27-10/29	4.9,3.8	41	2	5.82	0.01	0.68	0.03	MB-O
24388	2000 AB175	04/27-05/01	4.2,3.3	222	-7	6.972	0.010	0.26	0.03	MB-O
29564	1998 ED6	09/12-09/13	7.7,7.7	351	15	8.40	0.02	0.58	0.03	MB-O

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). THM: Themis; FLOR: Flora; BAP: Baptistina; EUN: Eunomia; MB-O: outer main-belt.

(24388) 2000 AB175 was discovered on 2000 January 7 by the LINEAR telescope. With a semi-major axis of 3.042 AU, it is located in the middle of the main belt. This asteroid was observed on the nights of 2017 April 27 and May 1. A composite lightcurve with a period of 6.972 ± 0.01 h and amplitude of 0.26 mag best fit the available data. The lightcurve displays two maxima and two minima per rotational cycle. The LCDB did not have a previously reported period.



(29564) 1998 ED6 was discovered on 1998 March 2 by amateur astronomer Yoshisada Shimizu from the Nachi-Katsuura Observatory in Japan. With a semi-major axis of 3.010 AU and eccentricity of 0.212, it is located in the middle of the main belt. This asteroid was near perihelion when it was observed on the nights of 2017 September 12-13. A composite lightcurve with a period of 8.40 ± 0.02 h best fits the available data. It has an amplitude of 0.58 mag and displays two maxima and two minima per rotational cycle.



One troubling aspect of the data is a discrepancy in the depth of the minimum between the first and second night, which is approximately 0.18 magnitudes. The LCDB had no prior listing for a period.

Acknowledgments

This research effort represents an effort to introduce high school level students to real astronomical research. Our thanks go to the McCarthey Dressman Educational Foundation and the George West Education Foundation for their continuing support.

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EDITOR'S NOTE: Congratulations to Mr. Zeigler and all the students of the George West Independent School District on their early career scientific contributions !

LIGHTCURVE AND ROTATION PERIOD DETERMINATIONS FOR 8 ASTEROIDS

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(Received: 2018 Jan 15)

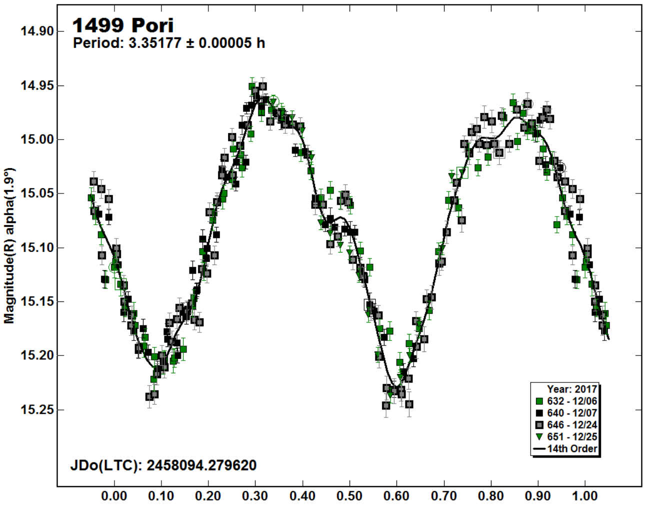
CCD photometric observations of 8 asteroids were conducted from 2017 October through December. A summary of the results obtained for synodic rotation periods as well as the lightcurves established is presented here.

Photometric observations of eight asteroids were conducted at Sopot Astronomical Observatory (SAO) between 2017 October-December in order to determine the asteroids' synodic rotation periods. For this purpose, two 0.35-m *f*/6.3 Meade LX200GPS Schmidt-Cassegrain telescopes were employed. The telescopes are equipped with a SBIG ST-8 XME CCD camera and an old SBIG ST-8 parallel port anti-blooming gate (ABG) chip CCD camera in temporary use. To avoid the non-linear response of the ABG camera, the target and comparison stars were kept below 50% saturation. This compromise reflected in reduced signal-to-noise ratio for those asteroids observed using the ABG camera. The exposures were unfiltered and unguided for all targets. Both cameras were operated in 2x2 binning mode, which an image scale of 1.66 arcsec/pixel. Prior to measurements, all images were corrected using dark and flat field frames.

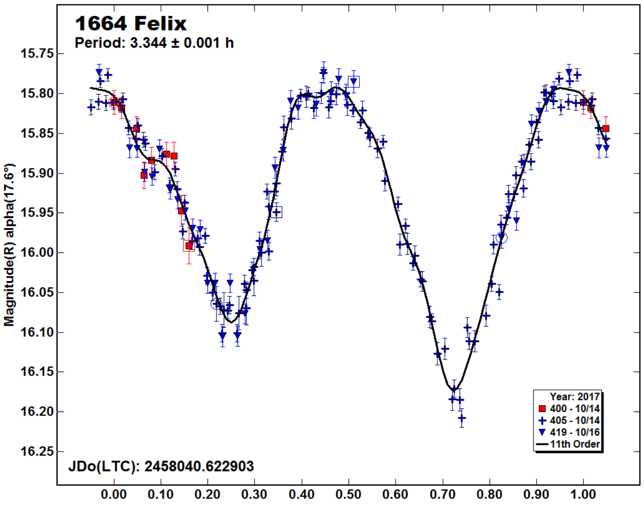
Photometric reduction, lightcurve construction, and period analysis were conducted using *MPO Canopus* (Warner, 2016). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq B\text{-}V \leq 0.9$) was performed using the Comparison Star Selector (CSS) utility. This helped ensure a satisfactory quality level of night-to-night zero point calibrations and correlation of the measurements within the standard magnitude framework. Field comparison stars were calibrated using standard Cousins R magnitudes derived from the Carlsberg Meridian Catalog 15 (VizieR, 2017) Sloan r' magnitudes using the formula $R = r' - 0.22$. In some cases, 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 gives the observing circumstances and results.

1499 Pori. Several previous rotation period determination results of differently assessed reliability were found for this Eunomia family asteroid in the asteroid lightcurve database (LCDB; Warner et al. 2009): Behrend (2003, 2008; 3.36 h), Stephens (2004; 3.36 h) and Behrend (2016; 3.3557 h). The SAO observations carried out over 4 nights in 2017 December led to a period result (P = 3.35177 ± 0.00005 h) fully consistent with those previously found.



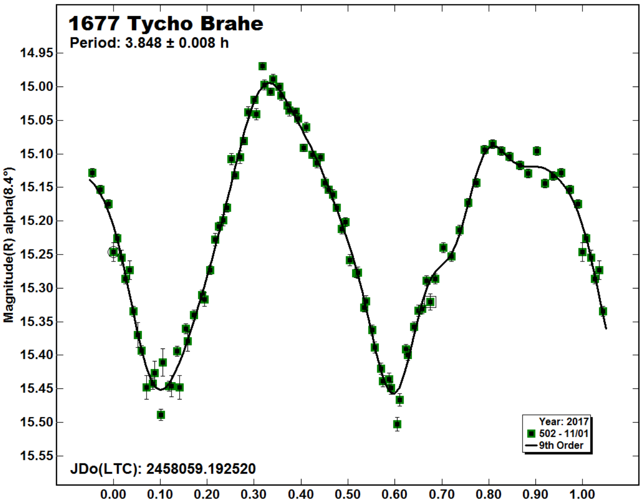
1664 Felix. The only previous rotation period determination result by Higgins et al. (2008; 3.3454 h) is in full agreement with the value obtained from the SAO observations conducted over 3 consecutive nights in 2017 October: P = 3.344 ± 0.001 h. The amplitude of the corresponding bimodal lightcurve is 0.38 mag.



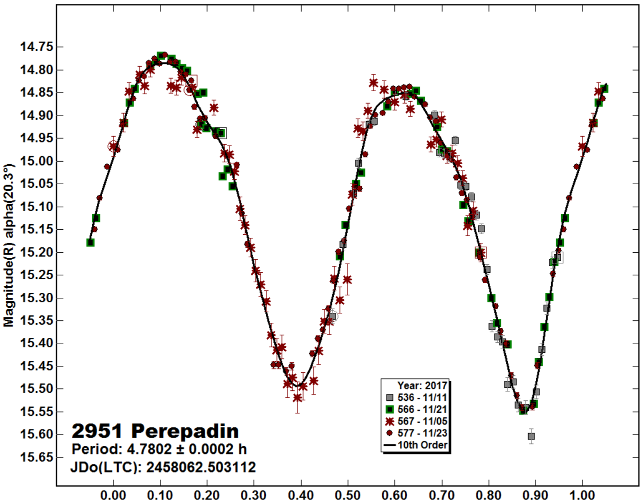
Number	Name	2017/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1499	Pori	12/06-12/25	245	1.9,1.8,7.6	76	-5	3.35177	0.00005	0.27	0.02	EUN
1664	Felix	10/14-10/16	155	17.7,17.0	57	1	3.344	0.001	0.38	0.01	FLOR
1677	Tycho Brahe	11/01	93	8.4	44	18	3.848	0.008	0.46	0.01	EUN
2951	Perepadin	11/05-11/23	201	20.5,19.7	121	16	4.7802	0.0002	0.76	0.02	MB-O
3737	Beckman	12/25-12/26	180	12.8,12.7	116	-1	3.125	0.003	0.07	0.03	MC
5049	Sherlock	10/17-10/21	233	17.2,15.0	49	-1	5.4915	0.0008	0.89	0.02	FLOR
8256	Shenzhou	12/24-12/26	176	9.0,8.5	99	9	3.394	0.001	0.32	0.01	MC
8484	1988 VM2	10/17-10/27	123	12.4,6.6	40	6	2.8496	0.0002	0.16	0.03	MB-I

Table I. Observing circumstances and results. Pts is the number of data points. Phase is the solar phase angle given at the start and end of the date range, the middle value is the minimum solar phase angle. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude. Grp is the asteroid family/group (Warner *et al.*, 2009): EUN = Eunomia, FLOR = Flora, MB-I/O = main-belt inner/outer, MC = Mars Crosser.

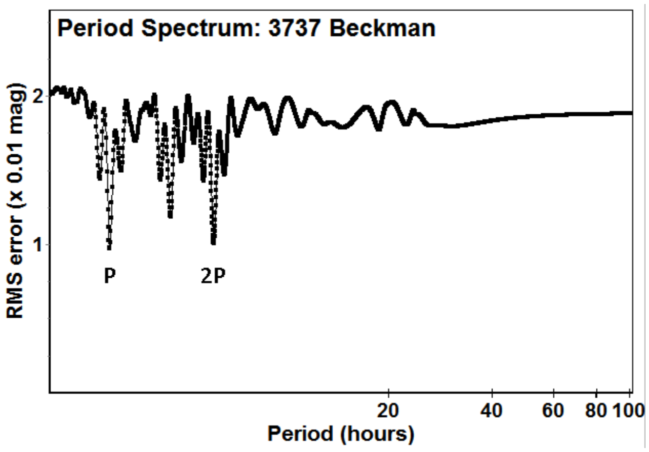
1677 Tycho Brahe. Violante and Leake (2012) found a rotation period of 3.89 h for this Eunomia family asteroid. Photometric observations conducted during nearly 6.5 hours over a single night at SAO on 2017 November 1 at low phase angle of 8.4 degrees yielded a bimodal lightcurve phased to a period of P = 3.848 ± 0.008 h. Fairly high lightcurve amplitude of 0.46 mag. as well as densely sampled data ensure high degree of plausibility of the lightcurve and period solution.

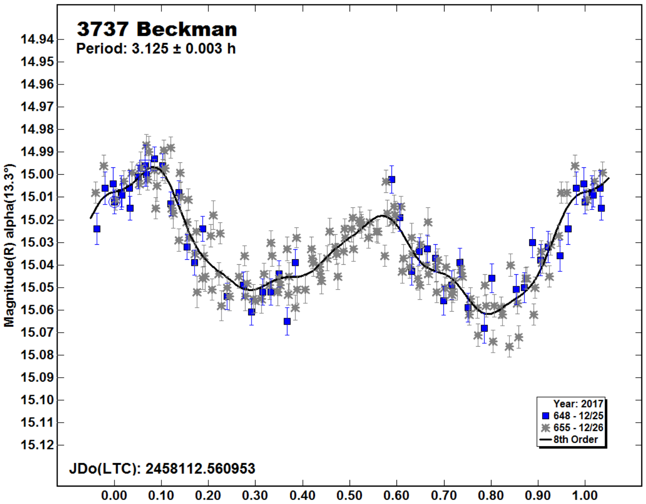


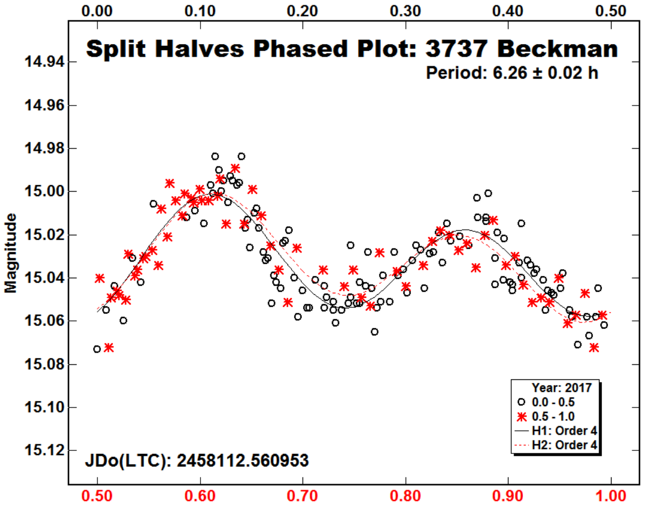
2951 Perepadin. Photometric observations were made at SAO over 4 nights in 2017 November. The bimodal period solution of 4.7802 ± 0.0002 h found for this main-belt asteroid is fully consistent with the previously determined period values, e.g. by Warner (2006; 4.7808 h) and Behrend (2007; 4.7809 h).



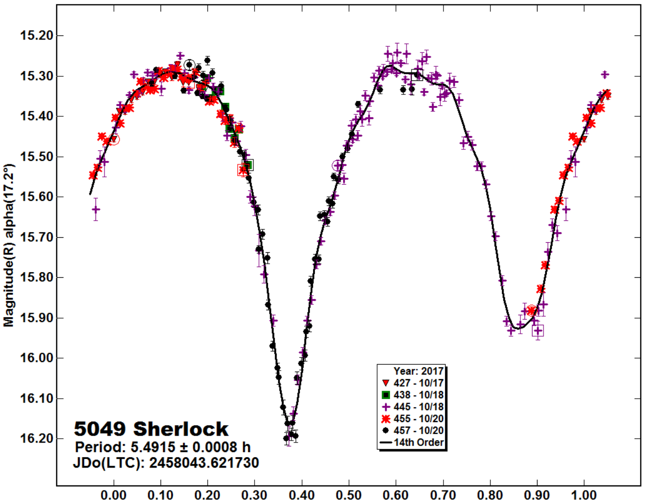
3737 Beckman. This Mars crossing minor planet was observed over two consecutive nights in 2017 December. Although the obtained lightcurve has fairly small amplitude of 0.07 mag. the bimodal solution for period of P = 3.125 ± 0.003 h can be considered as a quite reliable one as a value with clearly distinguished low RMS error in the period spectrum relative to other values in a broad period range. Harmonically related solution with twice bimodal period P should not be formally rejected even though the split halves test with the available data shows that the two halves of the resulting quadramodal lightcurve are almost identical. Found bimodal solution for period is also in very good agreement with the values previously found by Wisniewski (1991; 3.124 h) and Klinglesmith (2014; 3.130 h).



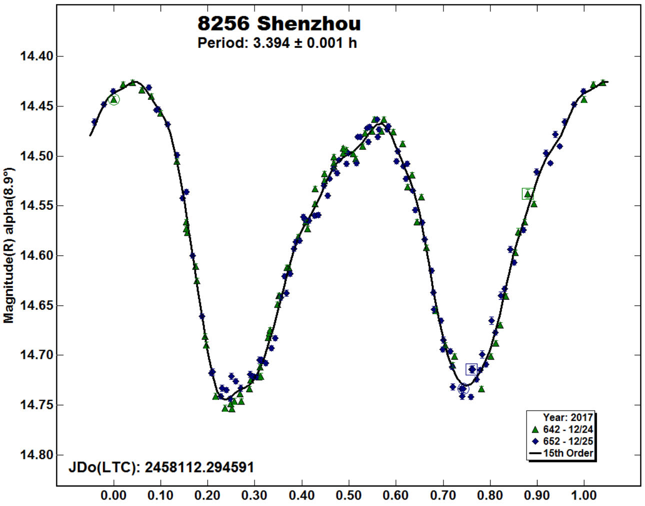




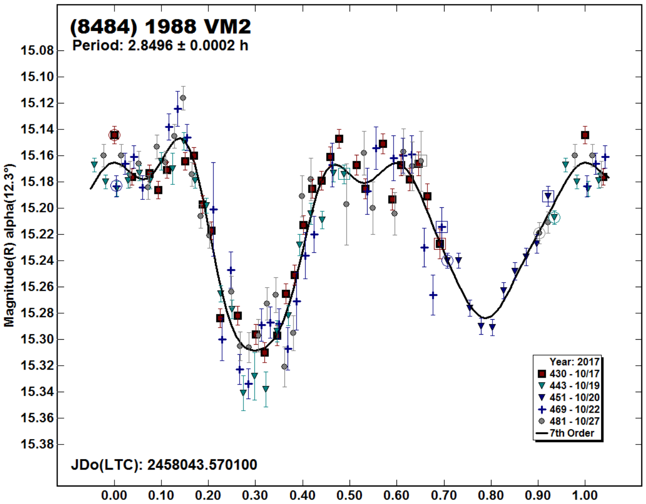
5049 Sherlock. No previous period determinations were known for this Flora family asteroid. Period analysis conducted upon the photometric data collected at SAO over 5 consecutive nights from 2017 October 17 through October 21 led to an unequivocal bimodal solution for period of P = 5.4915 ± 0.0008 h. The amplitude of the corresponding lightcurve is 0.89 mag.



8256 Shenzhou. This Mars crossing target that was observed exclusively at SAO over 2 nights in 2017 December within the framework of the Photometric Survey for Asynchronous Binary Asteroids (Pravec, 2017). Period analysis founds an ambiguous period of 3.394 ± 0.001 h, which virtually coincides with the result found by Pravec from the same data (3.3943 ± 0.0005 h). The found result is consistent with the previously determined values as well, e.g. Crawford (2008; 3.395 h).



(8484) 1988 VM2. The only previous period result of 2.548 h was found from the sparsely-sampled data within the Palomar Transient Factory Survey (Waszczak, 2015). Period analysis conducted upon the dense photometric SAO data obtained at low phase angles over 5 nights in 2017 October point out to the bimodal solution for period different from the one previously obtained. The new value for period derived from the SAO data is: 2.8496 ± 0.0002 h.



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ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2017 OCTOBER-DECEMBER

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(Received: 2018 Jan 8)

Lightcurves for 18 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2017 October-December. All but one of the asteroids were *targets of opportunity,* i.e., in the field of planned targets, which demonstrates a good reason for data mining images.

CCD photometric observations of 18 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2017 October-December. Table I lists the telescope/CCD camera combinations that were used. All the cameras use the KAF-1001E blue-enhanced CCD chip 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 cause a 0.1-0.3 mag 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 APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) 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).

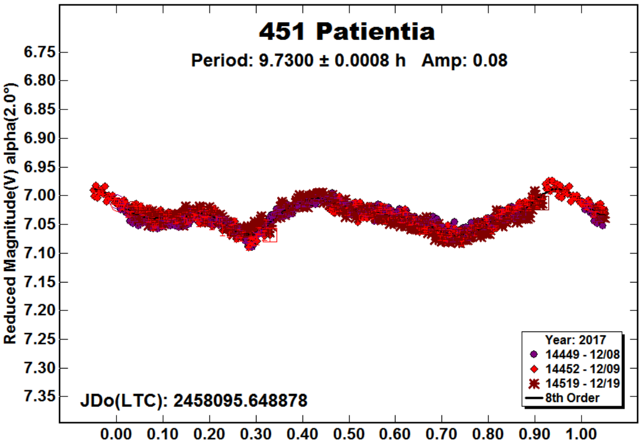
The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach > 0.1 mag. There is a systematic offset among the catalogs so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989).

In the lightcurves 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 (rΔ) 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.

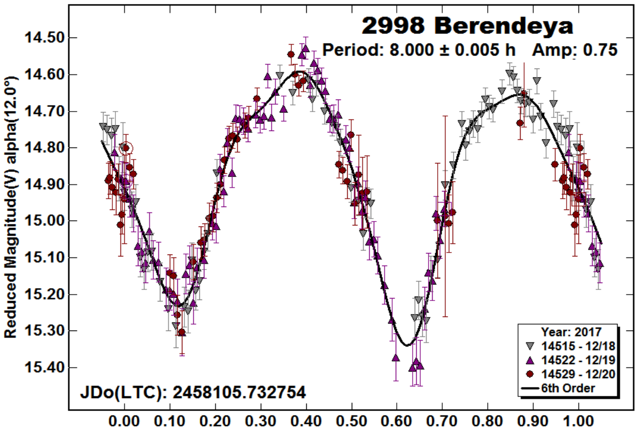
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

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.*,* 2009a). 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, when possible, to cross-check with the original references listed in the LCDB.

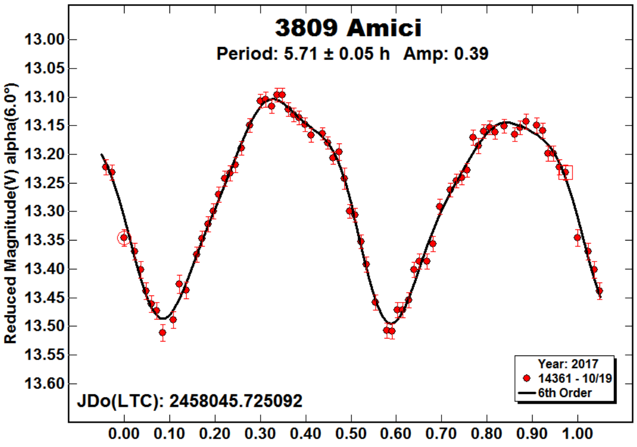
451 Patientia. Previous results for this outer main-belt asteroid have almost all been near 9.73 h; For example: Harris and Young (1983) and Behrend (2006, 2014). The results presented here, obtained to help with shape and spin axis modeling by Josef Hanus (private communications), are in good agreement. This and all previous lightcurves showed a low-amplitude lightcurve, $A \leq 0.10$ mag, which often implies a nearly spheroidal shape.



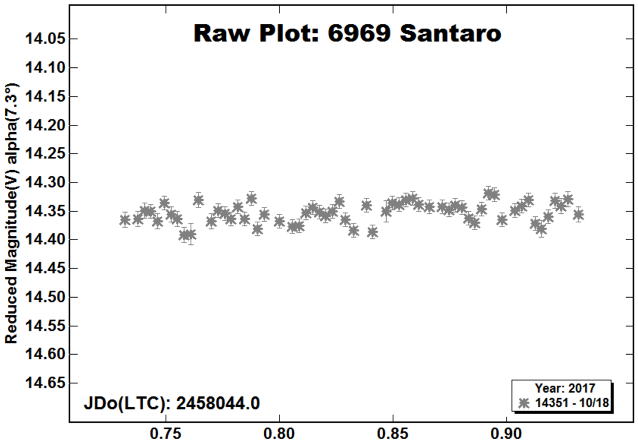
2998 Berendeya. Waszczak et al. (2017) reported a period of 6.833 h based on semi-dense data. The data from PDS could not be fit to that period but instead led to a period of 8.000 h. It's worth noting that the two periods differ by one-half rotation over 24-hours. It's likely that *rotational aliasing*, i.e., a miscount of the number of rotations over the range of the observations, led to the shorter period.



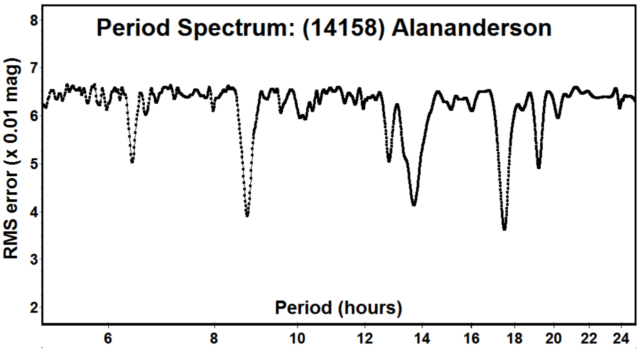
3809 Amici. There were no periods found in the LCDB for this middle main-belt asteroid with a diameter of about 13 km. While it was observed for only one night, the period is considered secure based on the amplitude and coverage of more than one cycle.

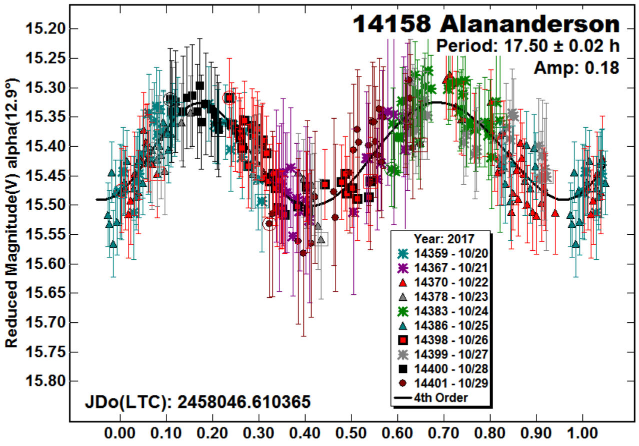


6969 Santaro. In the field for only one night, the 6-km Flora member Santaro showed a flat lightcurve, possibly with a 0.02 mag increase. Given the number of targets in the queue and the poor probability of finding a period, the asteroid was abandoned, and so added to the observational bias within the CS3 survey.

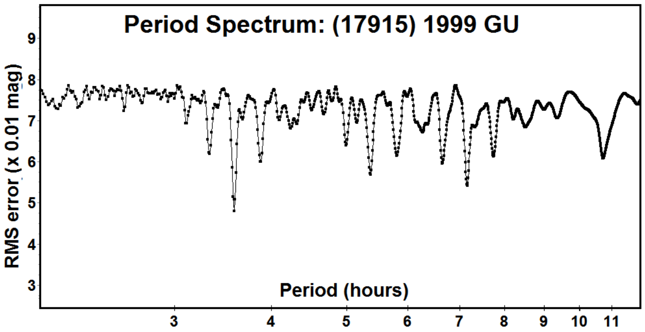


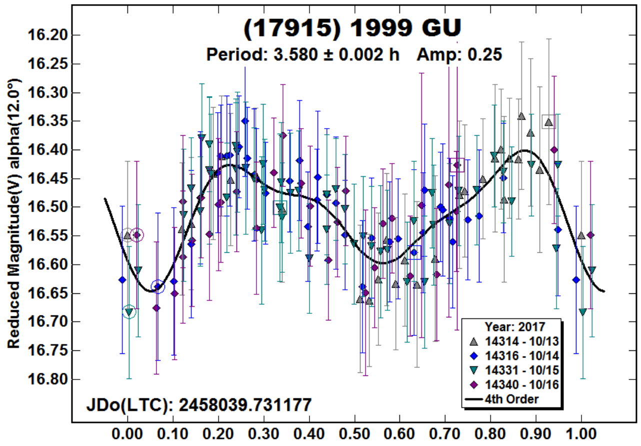
14158 Alananderson. This appears to be the first reported period for Anderson, a 5-km Vestoid. As the period spectrum shows, the data did not give a unique solution. On the presumption of a bimodal lightcurve being more likely but not guaranteed (see Harris et al., 2014), a period of 17.50 h is adopted for this work.



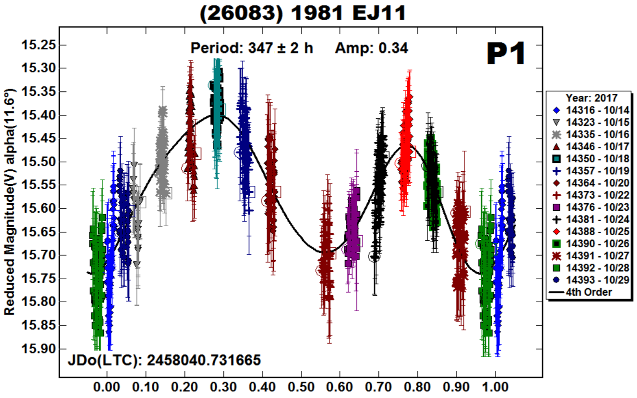


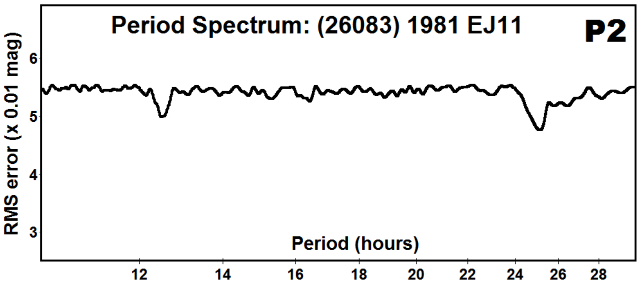
(17915) 1999 GU. The period spectrum gives confidence in the adopted period of 3.580 h. However, since that the error bars rival the amplitude of the lightcurve and the lightcurve has an unusual bimodal shape, the period cannot be considered fully secure. There were no previous lightcurve entries in the LCDB for the 2-km inner main-belt asteroid.

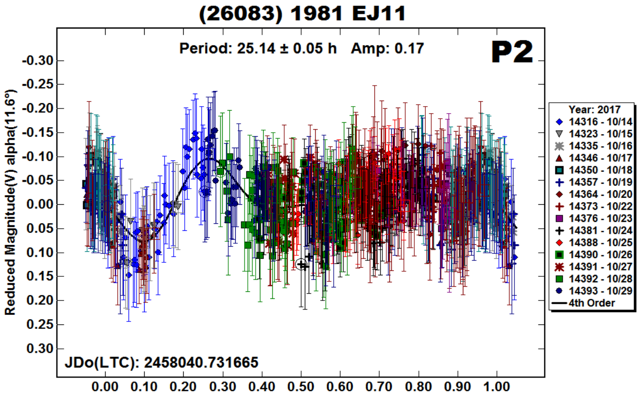




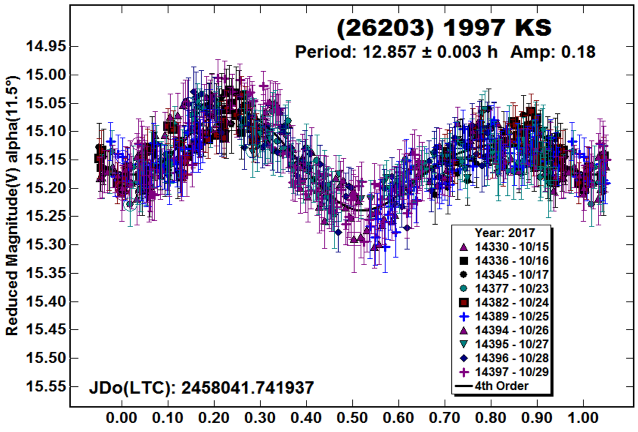
(26083) 1981 EJ11. Waszczak et al. (2015) found a period of 336 hours for 1981 EJ11, a 3-km Nysa member. The data from PDS give a similar period of 347 h. However, the individual nights seemed to show a shorter period, despite the large errors bars. Some long period asteroids have been shown to have a secondary period (Warner, B.D., 2016) and so the dual period search of *MPO Canopus* was used. A possible, but still very doubtful, solution is a bimodal lightcurve with a period of 25.14 h and amplitude of 0.17 mag, which fits with some of the previous wide-binary results. The period ratio isn't a simple integral multiple, so *harmonic aliasing* seems to be excluded.



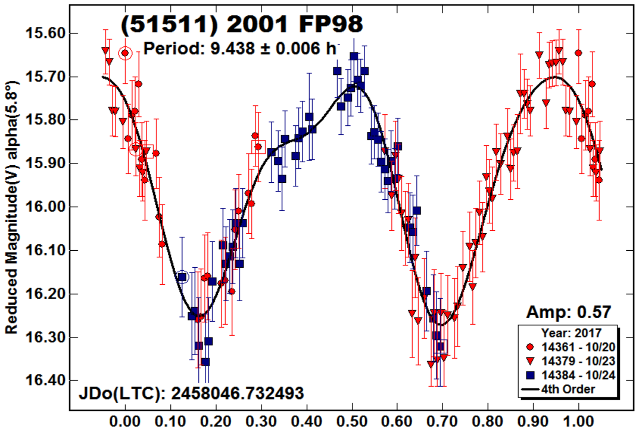




(26203) 1997 KS. The period derived from the PDS data is in good agreement with the one reported by Waszczak et al. (2015). The estimated diameter for the Vestoid is 3.7 km.

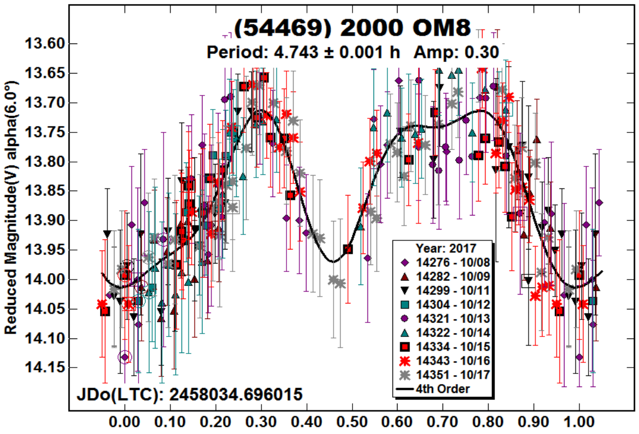


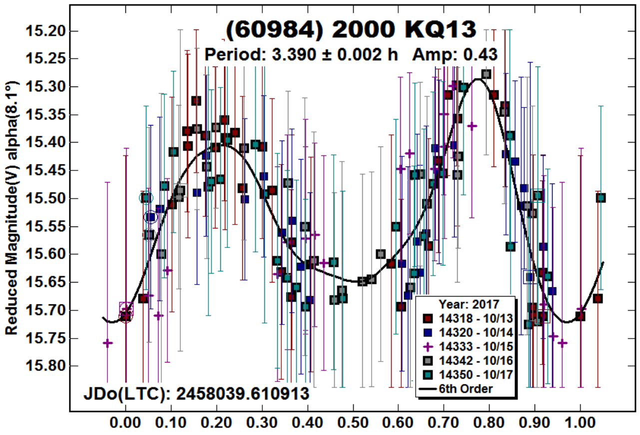
(51511) 2001 FP98. There were no previous periods found in the LCDB for this 2.6-km Vestoid. The large amplitude assures a bimodal solution (Harris et al., 2014).



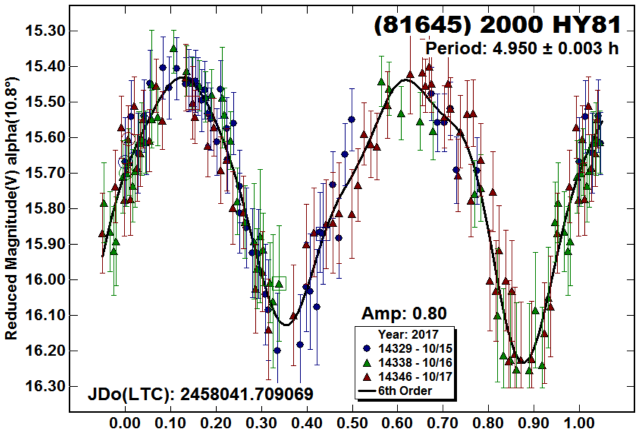
(54469) 2000 OM8, (60984) 2000 KQ13. Here again, the large error bars make the proposed periods less than fully secure. There were no periods reported in the LCDB for either one.

Being an outer main-belt asteroid, 2000 OM8 is presumed to have a low albedo (0.057; Warner et al., 2009), which leads to a diameter of about 8 km. However the WISE survey (Mainzer et al., 2011), found an albedo of 0.2013, which gives a diameter of about 4.9 km. On the other hand, Mainzer et al. (2011) found an expected albedo of 0.0325 for 2000 KQ13, also an outer main-belt asteroid, and a diameter of 5.3 km.

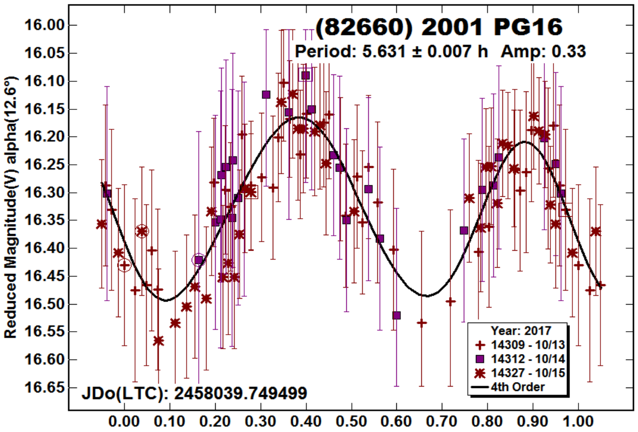




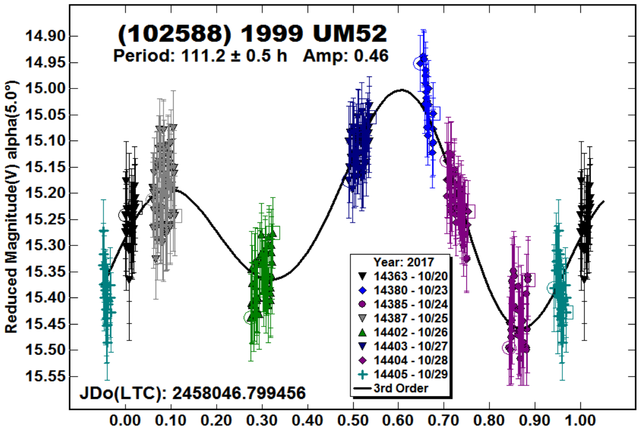
(81645) 2000 HY81. The large amplitude of 0.8 mag and low phase angle assure a bimodal lightcurve (Harris et al., 2014), and so the period, apparently the first one reported, is secure.



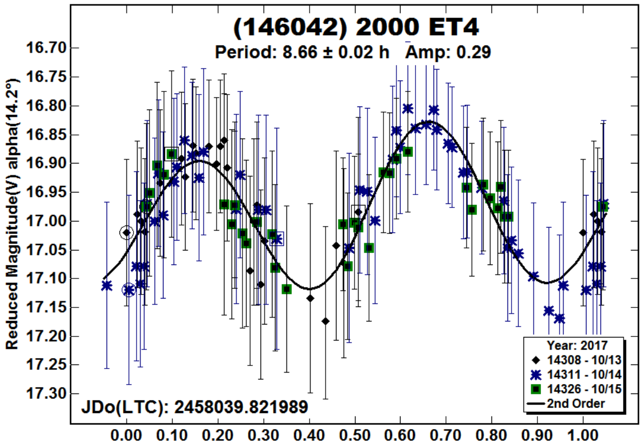
(82660) 2001 PG16. Waszczak et al. (2015) found a period of 68.3 hours with and amplitude of 0.95 mag. The PDS data from 2017, although having substantial error bars, showed no trend on individual nights that would indicate a period of nearly three days. The data do fit a period of 5.631 h with a lightcurve amplitude of 0.33 mag. The true solution has yet to be determined.



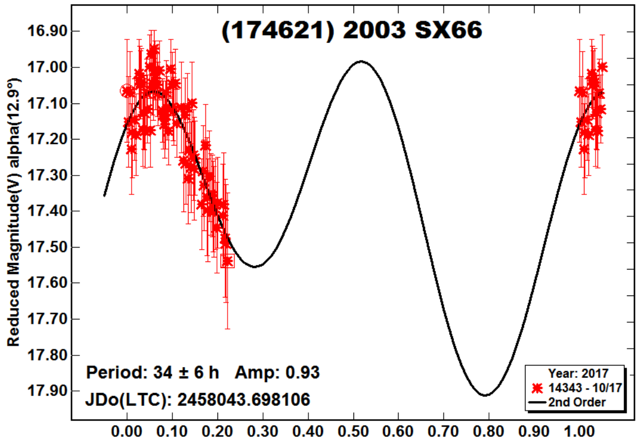
(102588) 1999 UM52. This is another case where WISE (Mainzer et al., 2011) found an albedo significantly higher that the LCDB default based on the position in the main belt. They found a diameter of 4 km using $p_V = 0.2012$, whereas the default albedo (0.057) gives about 7 km. This holds even if adjusting the WISE diameter using the MPCORB $H = 14.5$ instead of $H = 14.3$ used by Mainzer et al. (see Harris and Harris, 1997).



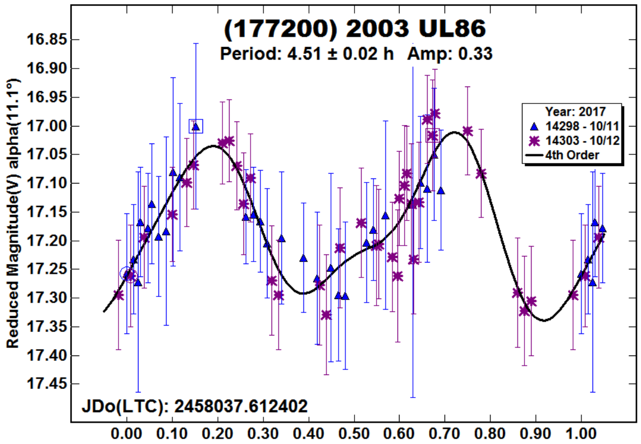
(146042) 2000 ET4. This inner main-belt asteroid with an estimated diameter of 1.7 km had no previously reported period in the LCDB. Despite the large error bars, the period seems reasonably established but, of course, not firmly secure.



(174621) 2003 SX66. The adopted period of 34 ± 6 h is based on a trial half-period solution. The results are given here only to put on the record that some observations of the asteroid exist.



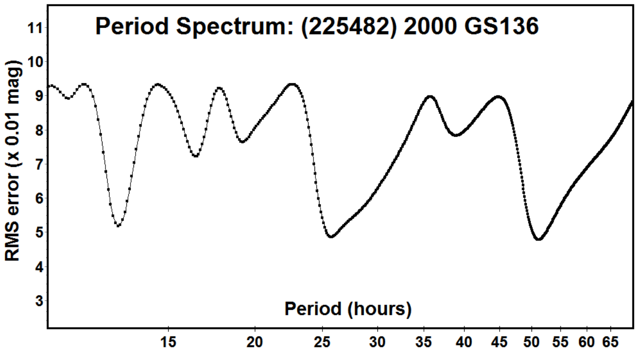
(177200) 2003 UL86. Waszczak et al. (2015) found a period of 8.14 h but with an amplitude of 0.09 mag. The larger amplitude of the PDS solution makes the period of 4.51 h more likely but still with some doubt.

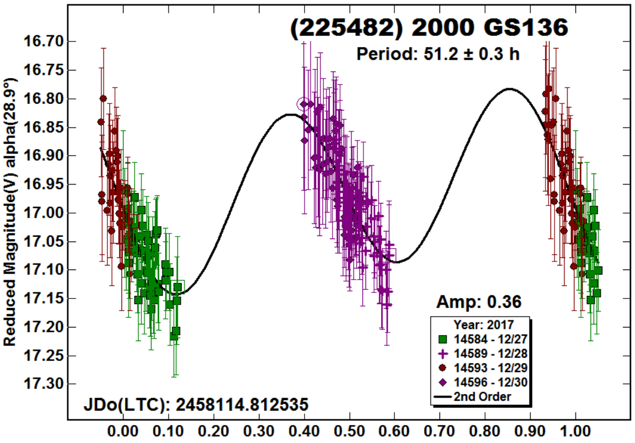


Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Group
451	Patientia	12/08-12/19	917	2.1,3.5	79	-3	9.73	0.0008	0.08	0.01	MB-O
2998	Berendeya	12/18-12/20	184	12.0,11.2	111	-3	8	0.005	0.75	0.03	NYSA
3809	Amici	10/19-10/19	69	6.0,6.0	34	-9	5.71	0.05	0.39	0.02	MB-M
6969	Santaro	10/18-10/18	62	7.3,7.3	33	-9	flat		flat		FLOR
14158	Alananderson	10/21-10/29	290	13.3,16.5	2	1	17.5	0.02	0.18	0.03	V
17915	1999 GU	10/13-10/16	143	12.0,10.6	43	1	3.58	0.002	0.25	0.03	MB-I
26083	1981 EJ11	10/14-10/29	776	11.6,4.9	44	5	347	2	0.34	0.05	NYSA
26203	1997 KS	10/15-10/29	650	11.5,5.1	46	0	12.857	0.003	0.18	0.02	V
51511	2001 FP98	10/20-10/24	122	5.7,4.7	34	-8	9.438	0.006	0.57	0.04	V
54469	2000 OM8	10/08-10/17	217	6.1,9.2	357	0	4.743	0.001	0.3	0.04	MB-O
60984	2000 KQ13	10/13-10/17	129	8.1,9.5	0	1	3.39	0.002	0.43	0.04	MB-O
81645	2000 HY81	10/15-10/17	159	10.8,10.0	46	1	4.95	0.003	0.8	0.04	MB-O
82660	2001 PG16	10/13-10/15	99	12.6,11.7	112	3	5.631	0.007	0.33	0.03	V
102588	1999 UM52	10/20-10/29	304	5.0,4.0,4.1	34	-9	111.2	0.5	0.46	0.05	MB-O
146042	2000 ET4	10/13-10/15	100	14.2,13.2	45	1	8.66	0.02	0.29	0.03	MB-I
174621	2003 SX66	10/17-10/17	72	12.9,12.9	45	1	34	12	0.6	0.1	MB-I
177200	2003 UL86	10/11-10/12	64	11.1,11.7	2	1	4.51	0.02	0.33	0.03	FLOR
225482	2000 GS136	12/27-12/29	195	28.9,28.6	132	27	51.2	0.3	0.36	0.04	PHO

Table II. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. 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*., 2009a). FLOR: Flora; MB-I/M/O: main-belt inner/middle/outer; PHO: Phocaea; V: Vestoid

<u>(225482) 2000 GS136</u>. A period search from 5 to 70 hours first found a period of about 25 h. This was for a monomodal lightcurve. The adopted period of 51.2 h leads to a bimodal lightcurve with reasonable slopes and amplitude.





Acknowledgements

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PERIOD DETERMINATION FOR 5049 SHERLOCK, 16852 NUREDDUNA AND (16943) 1998 HP42

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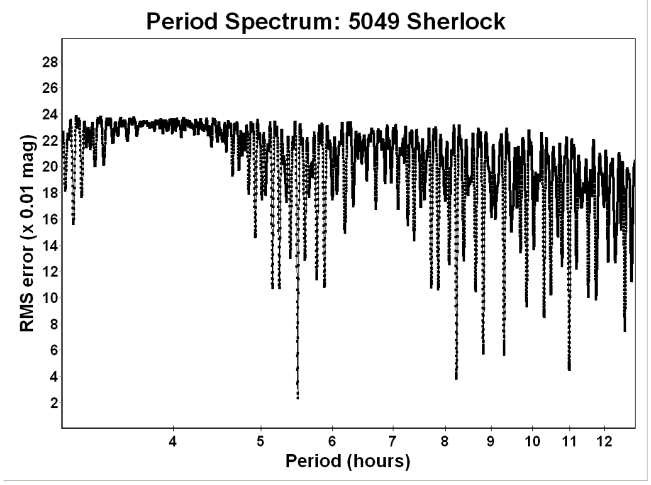
Photometric observations of three main-belt asteroids were conducted from the Astronomical Observatory of the University of Siena (Italy) in order to determine their synodic rotation periods. For 5049 Sherlock we found a period of 5.492 ± 0.001 h with an amplitude of 0.79 mag, for 16852 Nuredduna a period of 6.299 ± 0.002 h with an amplitude of 0.30 mag and for (16943) 1998 HP42 a period of 16.764 ± 0.006 h with an amplitude of 0.67 mag.

CCD photometric observations of three main-belt asteroids were carried on 2017 October – 2018 January at the Astronomical Observatory of the University of Siena (K54). We used a 0.30-m f/5.6 Maksutov-Cassegrain telescope, a SBIG STL-6303E CCD camera, and clear filter. The pixel scale was 2.30 arcsec when binned at 2x2 pixels. All exposures were 300 sec. Data processing and analysis were made with MPO Canopus (Warner, 2017). All the images were calibrated with dark and flat-field frames and converted to R magnitudes using solar-colored field stars from a version of the CMC-15 catalogue distributed with MPO Canopus. Table I shows the observing circumstances and results.

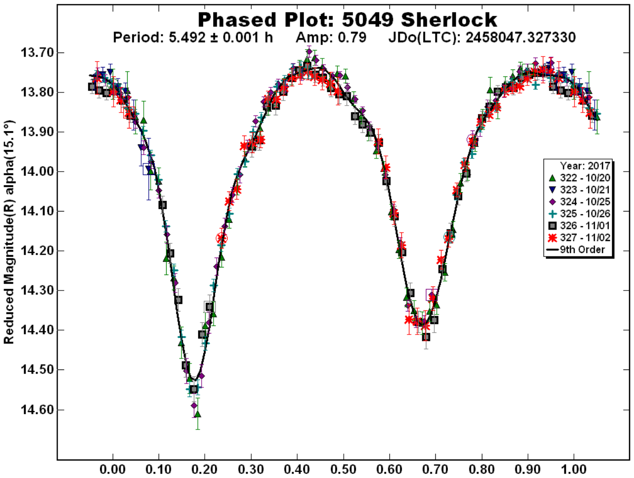
A search through the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) indicates that our results may be the first reported lightcurve observations and results for these objects. 5049 Sherlock and 16852 Nuredduna were reported as lightcurve photometry opportunities for 2017 October-December in the Minor Planet Bulletin (Warner *et al.*, 2017).

5049 Sherlock was discovered on November 2, 1981 at Flagstaff by E. Bowell, and it was named for Sherlock Holmes, the famous detective in the stories by Sir Arthur Conan Doyle, despite his ignorance of the Copernican Theory and of the composition of the solar system (MPC 22506). It is a main-belt asteroid with the semi-major axis of 2.199 AU, eccentricity 0.161, inclination 2.94 degrees and an orbital period of 3.26 years. Its absolute magnitude is H = 13.6 (JPL, 2017; MPC, 2017). The WISE satellite infrared survey (Masiero *et al.*, 2011) found an optical albedo of p_V = 0.303 ± 0.059, which, in accordance of absolute magnitude H = 13.4, derive a diameter D = 5.0 ± 0.2 km. Observations of this asteroid were conducted on three nights, collecting 249 data points. The period analysis shows a clear bimodal solution for the rotational period P = 5.492 ± 0.001 hours with an amplitude A = 0.79 ± 0.02 magnitudes.

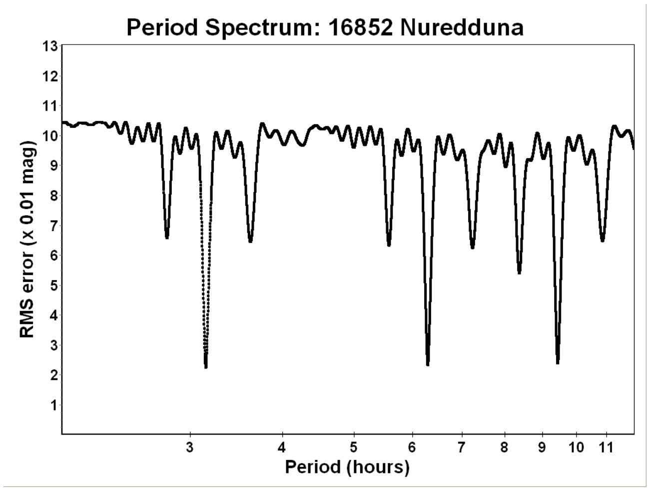


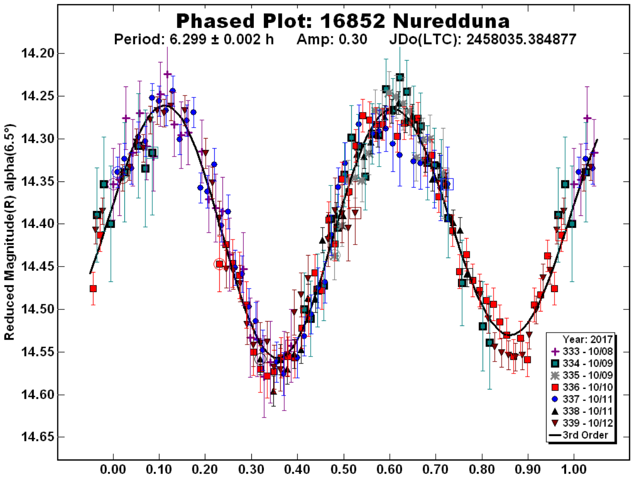
Number	Name	20yy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
5049	Sherlock	17/10/20-17/11/02	249	15.2,7.7	50	0	5.492	0.001	0.79	0.02
16852	Nuredduna	17/10/08-17/10/12	239	6.6,4.4	25	1	6.299	0.002	0.30	0.03
16943	1998 HP42	17/12/20-18/01/03	169	4.2,4.1,8.0	91	8	16.764	0.006	0.67	0.04

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).

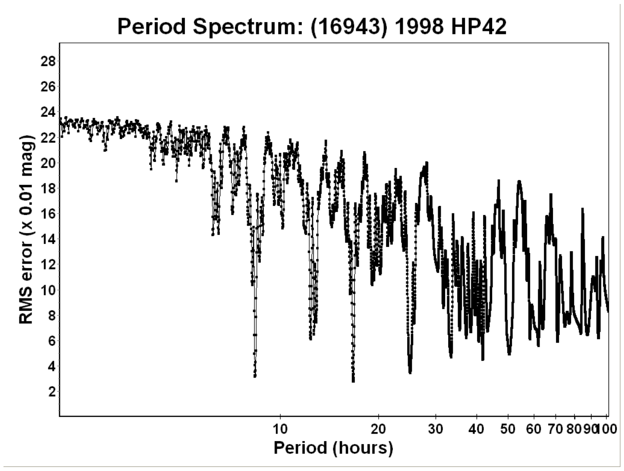


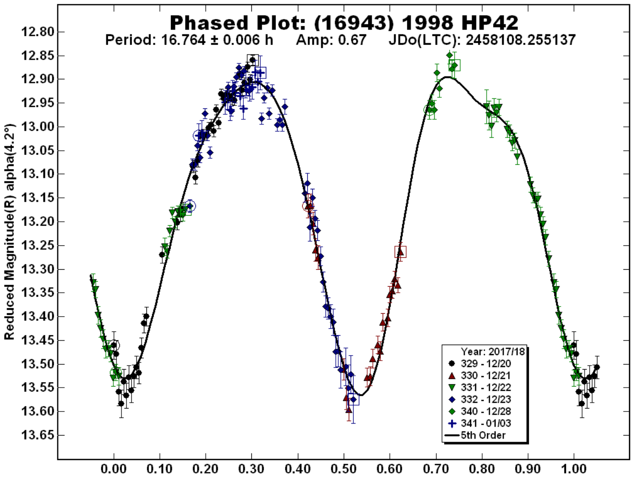
16852 Nuredduna, discovered on December 21, 1997 by A. Lopez and R. Pacheco at Mallorca, was named for Nuredduna, a great visionary priestess created by Majorcan poet Miquel Costa y Llobera, who belonged to a primitive nation that built many megalithic monuments called Talaiots that even nowadays are present in the Balearic islands (MPC 43046). It's a typical main-belt asteroid with the semi-major axis of 2.259 AU, eccentricity 0.187, inclination 4.13 degrees and an orbital period of 3.39 years. Its absolute magnitude is H = 14.0 (JPL, 2017; MPC, 2017). The WISE survey (Masiero *et al.*, 2011) found an optical albedo of p_V = 0.23 ± 0.03; with an absolute magnitude H = 14.3 a diameter of D = 3.7 ± 0.1 km is derived. Observations of this asteroid were conducted on four nights, collecting 239 data points. The period analysis shows a bimodal solution for the rotational period P = 6.299 ± 0.002 h with an amplitude A = 0.30 ± 0.03 magnitudes.





(16943) 1998 HP42 was discovered on April 23, 1998 by JPL/GEODSS NEAT at Haleakala. It is a main-belt asteroid with a semi-major axis of 2.597 AU, eccentricity 0.178, inclination 14.21 degrees and an orbital period of 4.18 years. Its absolute magnitude is H = 12.6 (JPL, MPC, 2017). In 2014 the WISE/NEOWISE near-infrared survey (Masiero *et al.*, 2014) found an optical albedo of p_V = 0.227 ± 0.027; with an absolute magnitude H = 12.7, a diameter D = 8.1 ± 0.1 is derived. Observations of this asteroid were conducted on five nights collecting 169 data points. The analysis suggests a bimodal solution for the rotational period P = 16.764 ± 0.006 h with an amplitude A = 0.67 ± 0.04 magnitudes.





Acknowledgements

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ROTATIONAL PERIODS OF ASTEROIDS 184 DEJOPEJA, 435 ELLA AND 5049 SHERLOCK

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We report on photometric observations of three main-belt asteroids, 184 Dejopeja, 435 Ella and 5049 Sherlock, made in Nov. and Dec. 2017. We find synodic rotation periods and amplitudes of 6.4416 ± 0.0004 h and 0.22 mag (184 Dejopeja), 4.621 ± 0.009 h and 0.38 mag (435 Ella) and 5.4914 ± 0.0005 h and 0.75 mag (5049 Sherlock).

All observations reported here were made through Johnson V filter with the instruments listed in table I. All raw images were calibrated with median darks in sets with same exposure time as the raw images and then normalized with a median flat. Photometric reduction and period analyses where done by KL using MPO Canopus 10.4.3.21 (Warner, 2014). Differential photometry using the MPOSC3 star catalog supplied with MPO Canopus, were used to analyze all sessions and up to five solar like comparison stars were selected if possible. Observing circumstances and results are summarized in table II.

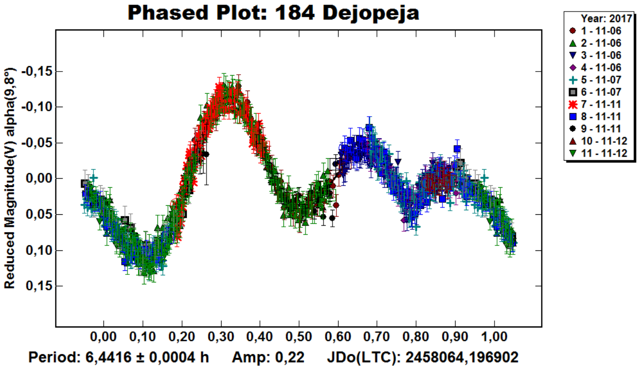
Obs	Telescope	CCD Camera
Jacobsen	0.36-m f/7 SCT	Moravian G2-1600
Kristensen	0.28-m f/6.3 SCT	Atik 428EXM
Larsen	0.30-m f/10 ACF	SBIG ST-8XME

Table I. Equipment used by observers. SCT: Schmidt-Cassegrain; ACF: Meade Advanced Coma Free.

184 Dejopeja was discovered by Johann Palisa in February of 1878 when he was director of the observatory in Pola, Russia. Dejopeja was named after the fairest of the 14 Nymphs (*Schmadel, J.D., Dictionary of Minor Planet Names. 2nd Ed. (1993).* The asteroid Dejopeja is situated in the outer main belt and has a diameter of 62 km. This asteroid was selected from *the Low Phase Angle Opportunities* list in MPB 44-4 and observed by JJ and LHK in November 2017 past its opposition on October 7th.

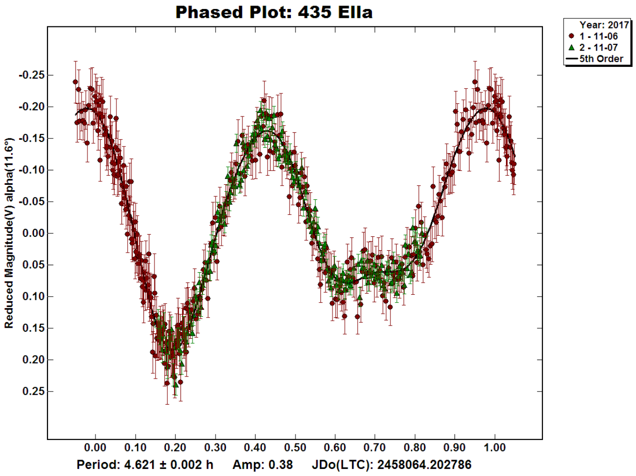
Number Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
184 Dejopeja	11/06-11/12	927	9.8, 11.4	14	1	6.4416	0.0004	0.22	0.03	MB-O
435 Ella	11/06-11/07	502	11.5, 12.0	25	0	4.621	0.009	0.38	0.05	Nysa
5049 Sherlock	11/13-12/03	302	0.2, 12.2	52	1	5.4915	0.0005	0.75	0.05	MB-I

Table II. 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).

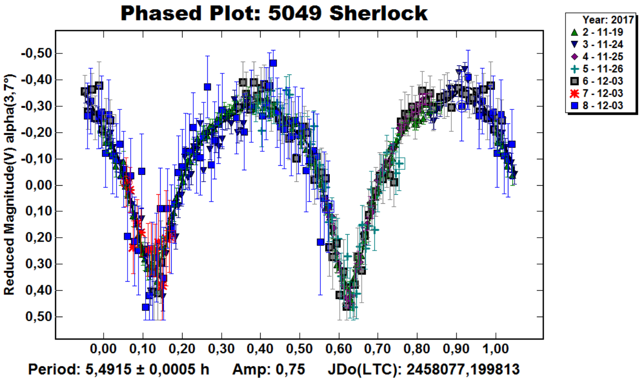


The lightcurve is trimodal with an amplitude of 0.22 magitudes and a synodic period of 6.4416 ±0.0004 h. A search of the LCDB (LCDB; Warner *et al.*, 2009) finds numerous studies including Gill-Hutton (1995b) with P = 6.455 h and Hanus (2013b) with P = 6.44111 h. This study supports their conclusions.

435 Ella was in opposition on October 16. 2017 and selected from the *Low Phase Angle Opportunities* list of MPB 44-4. 435 Ella is a member of the Nysa family and has a diameter of 41.5 ± 1.5 km (SIMPS). Earlier reported synodic periods of 435 Ella include Behrend (2006web) of 4.6233 ± 0.0002 h. Amplitude of lightcurves of 435 Ella found in the LCDB are between 0.30 and 0.60 magnitudes. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009) and the on-line version at *http://www.minorplanet.info/lightcurvedatabase.html.* All 502 images were recorded by JJ and the analysis finds a period of 4.621 ± 0.009 h and amplitude of 0.38 mag and thus in good agreement with previous results.



5049 Sherlock was discovered by Bowell, E. at Flagstaff on November 2nd 1981. This asteroid is 5 km in diameter and is part of the inner main belt. It has a fairly high albedo of 0.329. 5049 Sherlock was observed by JJ, FRL and LHK. The analysis finds a synodic period of 5.4915 ± 0.0005 h and amplitude of 0.75 magnitudes. As discussed in Harris et al. (2014) amplitudes exceeding approx. 0.4 magnitudes at low phase angles suggest a unique period dominated by the second harmonic. A search in the LCDB did not find any references to 5049 Sherlock.



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LIGHTCURVE ANALYSIS FOR ELEVEN MAIN-BELT ASTEROIDS

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Synodic rotation periods were determined for eleven main-belt asteroids: 300 Geraldina, 6.847 ± 0.012 h; 597 Bandusia, 7.6636 ± 0.0008 h; 868 Lova, 41.118 ± 0.011 h; 904 Rockefellia, 6.826 ± 0.004 h; 964 Subamara, 6.8695 ± 0.0012 h; 965 Angelica, 26.752 ± 0.035 h; 1105 Fragaria, 5.4312 ± 0.0008 h; 1181 Lilith, 15.033 ± 0.003 h; 1197 Rhodesia, 16.060 ± 0.006 h; 1255 Schilowa, 76.275 ± 0.041 h; and 1883 Rimito, 6.475 ± 0.008 h. All the data have submitted to the ALCDEF database.

CCD photometric observations of eleven main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe. Images at V02 were taken using a 0.32-m *f*/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a ‘clear’ glass filter. Exposure time for all the images was 2 minutes. The image scale after 2x2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results.

Images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel. Image calibration and alignment were performed using *MaxIm DL* software.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2017). The 45x30 arcmin field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of 0.5 < B-V < 0.95 to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. The *MPO Canopus* internal star catalogue was useful in selecting comp stars of suitable color and brightness.

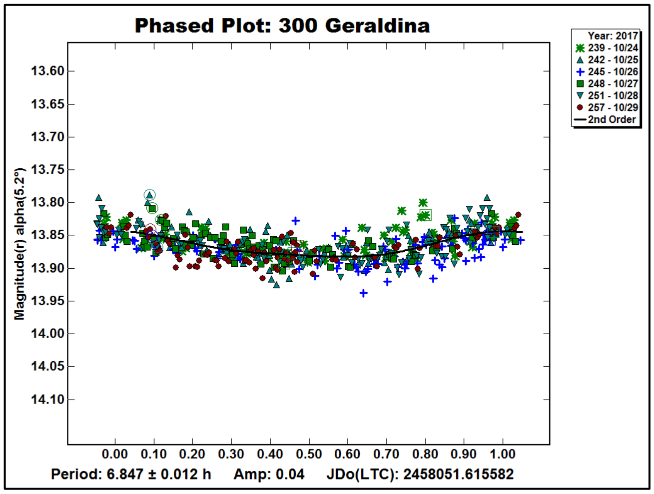
Comp star magnitudes were derived from a combination of CMC15 (Muiñoz et al. 2014), APASS DR9 (Munari et al. 2015), and GAIA1 G (Sloan r´ = G + 0.066 for stars of asteroidal color) catalogues to set the zero-points each night. In most regions the Sloan r´ data sources for brighter stars yielded very similar magnitudes (within about 0.05 mag total range), so mean values rounded to 0.01 mag precision were used.

This careful adjustment of the comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required, or shifts of only a few hundredths of a magnitude in a series.

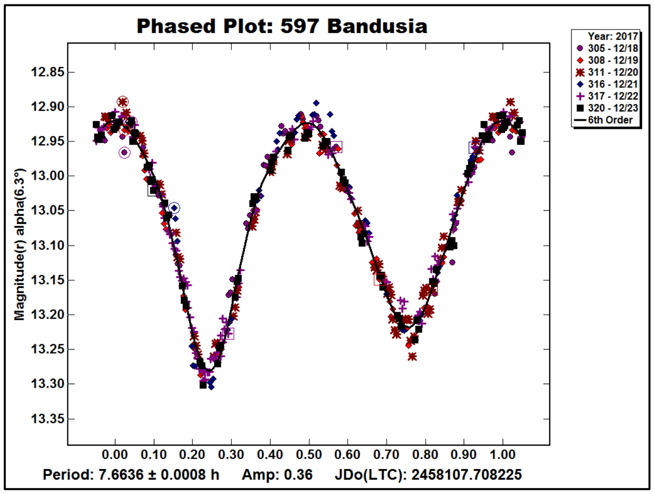
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comp stars, the asteroid itself, and the period-fit. Period determination was done using the *MPO Canopus* Fourier-type FALC fitting method (cf. Harris et al., 1989).

In most cases, asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude greater than 14.5 and quality of results, U < 3–. The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All of the new data for these eleven asteroids may be found in the ALCDEF database.

300 Geraldina is a main-belt asteroid that was discovered in 1890 by Auguste Charlois at Nice. Five consistent periods, all between 6.81 h and 6.86 h were found in the LCDB. The most recent of these is 6.850 ± 0.0041 h, determined by Waszczak et al. (2015). In 2017 October, 518 observations on six nights were obtained to determine the rotation period of 6.847 ± 0.012 h, which agreed with the previously published results. The amplitude is only 0.04 ± 0.02 mag; the RMS scatter on the fit shown in the phased plot is 0.018 mag.



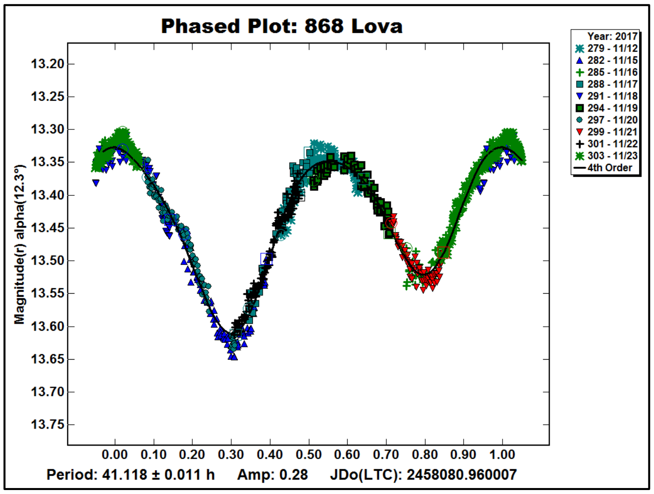
597 Bandusia. Max Wolf discovered this Eunomia-family asteroid in 1906 at Heidelberg. Two periods were found: Behrend (2002) shows 11.50 h, and Garlitz (2013) computed 15.340 h.



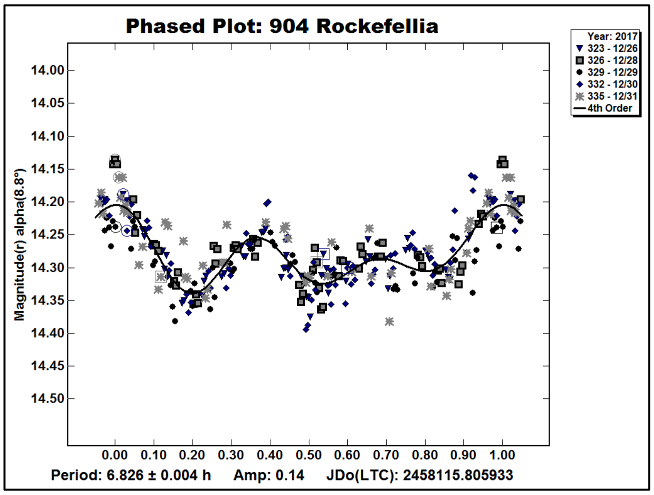
A total of 454 images were gathered during six nights in 2017 December, producing a rotational period of 7.6636 ± 0.0008 h. This result disagrees with Behrend’s period and is roughly half of

Garlitz's result. The amplitude is 0.36 ± 0.02 mag. The RMS scatter on the fit is 0.016 mag.

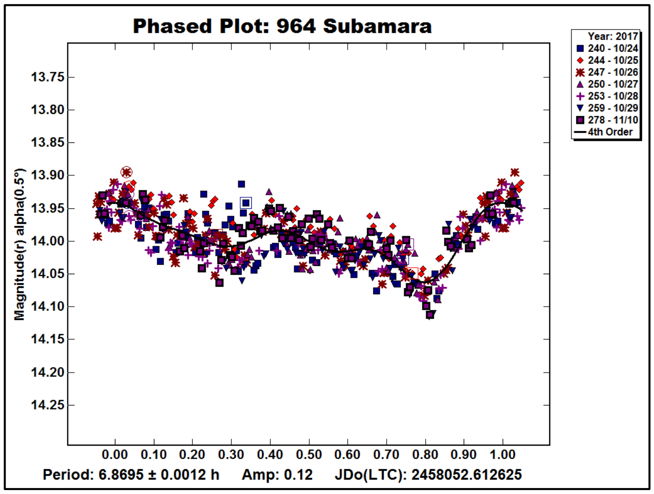
868 Lova was discovered by Max Wolf at Heidelberg in 1917. Three entries for the period were found in the LCDB. Warner (2001) and Warner (2006) both show a period of >24 h. Behrend (2005) computed 41.3 h. A total of 857 observations during ten nights in 2017 November were made to produce a lightcurve for 868 Lova. The resulting rotational period is 41.118 ± 0.011 h, which agrees well with Behrend's result. The full amplitude is 0.28 ± 0.01 mag; the RMS scatter of the fit is 0.014 mag.



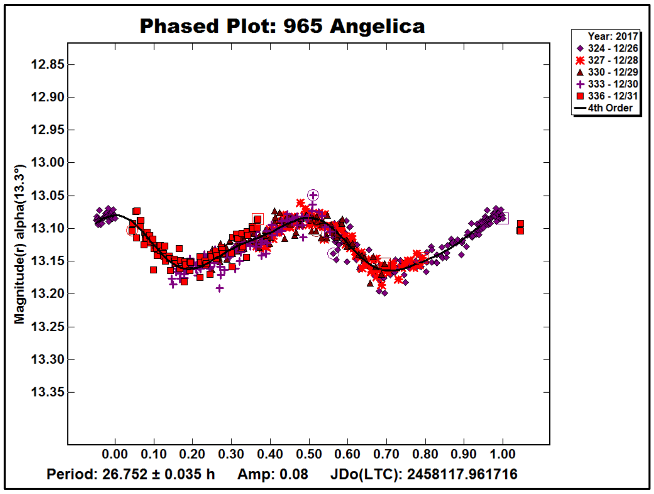
904 Rockefellia. Max Wolf at Heidelberg discovered this outer-belt asteroid in 1918. Fauvaud (2013) determined a period of 5.82 ± 0.01 h and Behrend (2014) computed 12.72 ± 0.03 h. Five nights in 2017 December and 285 observations were sufficient to determine a rotational period of 6.826 ± 0.004 h, disagreeing with previously published results. The amplitude is 0.14 ± 0.03 mag, and the RMS error on the fit is 0.030 mag.



964 Subamara. This outer-belt asteroid was discovered in 1921 by Johann Palisa at Vienna. *Two periods have been documented. Folberth et al. (2012) obtained a period of 6.864* ± 0.004 h and Alkema (2013) computed 6.868 ± 0.001 h. On seven nights in 2017 October and November, 555 images of 964 Subamara were secured. The lightcurve shows a period of 6.8695 ± 0.0012 h, in accordance with the two published period solutions. The RMS scatter on the fit is 0.025 mag. The amplitude is 0.12 ± 0.03 mag.



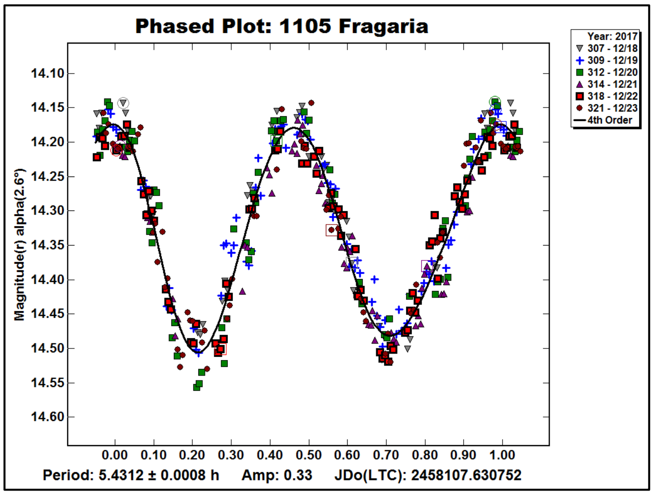
965 Angelica is an outer-belt asteroid with high eccentricity discovered by Johannes Hartman at La Plata in 1921. Its high inclination brought it to a declination of greater than +50° during the observing interval. The only published rotational period is that of Behrend (2006), who shows a result of 17.772 ± 0.007 h. Observations of 965 Angelica were made on five nights in 2017 December, until 530 data points were acquired. The double-mode period is 26.752 ± 0.035 h, which is larger than Behrend's determination by a 3/2 ratio. The amplitude is 0.08 ± 0.01 mag, and the RMS error on the fit is 0.012 mag. The "split halves" feature in *MPO Canopus* was used to assess the validity of the single-mode solution of 13.335 h. The mismatch in the phased halves illustrated that the double-mode period is the preferred solution.



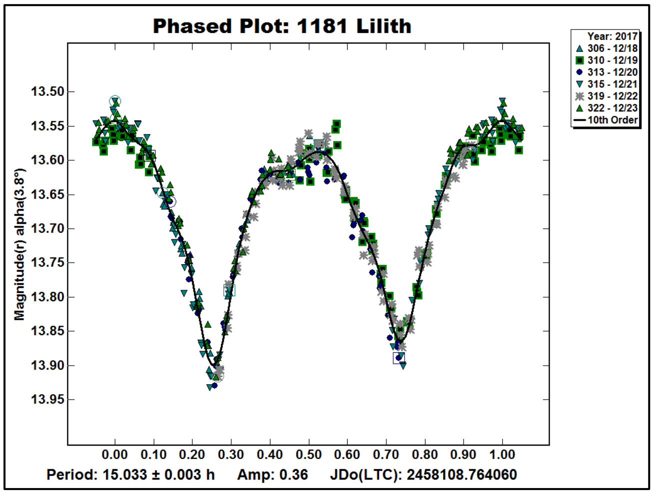
1105 Fragaria is an Eoan asteroid that was discovered in 1929 by Karl Reinmuth at Heidelberg. Only one period is found in the LCDB, that of Barucci et al. (1994) who computed 10.88 h. A total of 385 images were obtained during six nights in 2017 December. These data produced a rotational period of 5.4312 ± 0.0008 h. This period is roughly half of Barucci's result. The amplitude is 0.33 ± 0.03 mag., and the RMS scatter of the fit is 0.029 mag.

Number	Name	2017/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
300	Geraldina	10/24-10/29	518	5.2,3.3	44	0	6.847	0.012	0.04	0.02	MB-O
597	Bandusia	12/18-12/23	454	6.4,5.9	92	13	7.6636	0.0008	0.36	0.02	EUN
868	Lova	11/12-11/23	857	12.3,7.3	73	-6	41.118	0.011	0.28	0.01	MB-O
904	Rockefellia	12/26-12/31	285	8.8,8.3	103	-19	6.826	0.004	0.14	0.03	MB-O
964	Subamara	10/24-11/10	555	0.5,0.1,6.9	32	1	6.8695	0.0012	0.12	0.03	MB-O
965	Angelica	12/26-12/31	530	13.3,13.2	101	25	26.752	0.035	0.08	0.01	MB-O
1105	Fragaria	12/18-12/23	385	2.6,3.0	87	-7	5.4312	0.0008	0.33	0.03	EOS
1181	Lilith	12/18-12/23	447	3.8,6.5	80	0	15.033	0.003	0.36	0.02	MB-M
1197	Rhodesia	12/26-12/31	359	2.5,4.0	93	-5	16.060	0.006	0.27	0.01	MB-O
1255	Schilowa	11/12-11/23	880	1.3,0.4,3.6	53	1	76.275	0.041	0.26	0.01	MB-O
1883	Rimito	11/12-11/19	331	12.7,9.3	60	-13	6.475	0.008	0.04	0.02	MB-I

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 or maximum, which is then the second of three values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



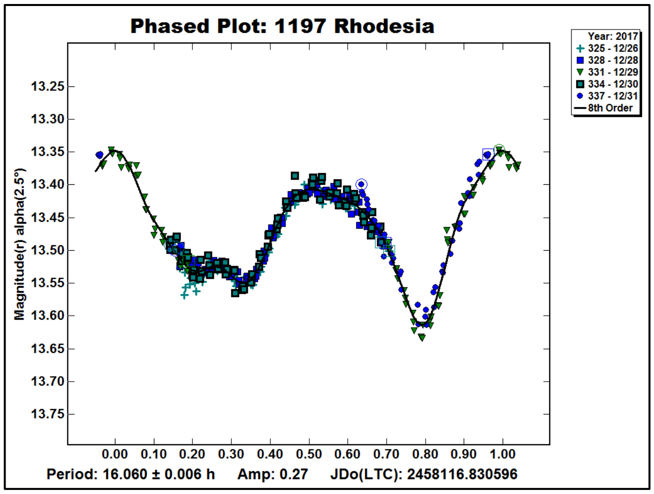
1181 Lilith was discovered by Benjamin Jekhovsky at Algiers in 1927. The only rotational period that has been published is that of Ferrero (2014), who found 15.04 ± 0.01 h.



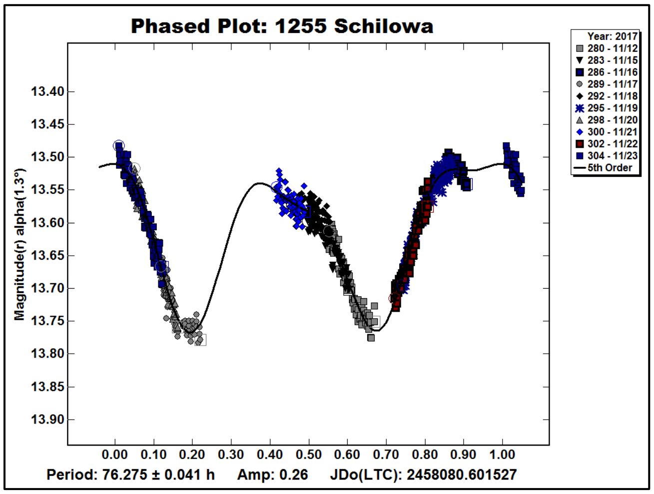
Observations of 1181 Lilith were made on six nights in 2017 December, and 447 data points were obtained. Due to the sharp minima, a 10th-order curve fit was used. The resulting period is 15.033 ± 0.003 h, in accordance with Ferrero's determination. The amplitude of the lightcurve is 0.36 ± 0.02 mag. The fit has an RMS scatter of 0.017 mag.

1197 Rhodesia Cyril Jackson discovered this outer-belt asteroid in 1931 at Johannesburg in 1931. Two period determinations have been performed. Binzel (1987) found a period of 15.89 h while Behrend (2005) obtained 16.062 ± 0.003 h.

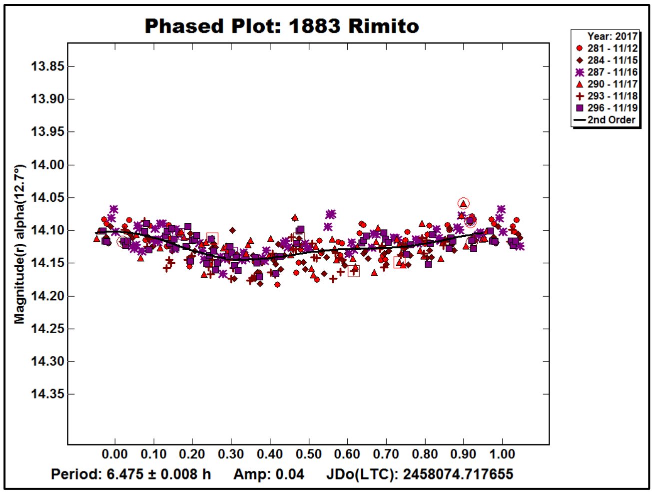
Due mostly to clouds and proximity of the moon, observations were limited to only five nights in late 2017 December, during which 359 images were gathered. As a result of the brief observation interval and the commensurate nature of the period, the lightcurve has less coverage than desired. The period of 16.060 ± 0.006 h agrees with previous determinations. A lightcurve amplitude of 0.27 ± 0.01 mag and an RMS scatter of 0.012 mag were computed.



1255 Schilowa was discovered in 1932 by Grigory Neujmin at Simeis. The most recent period determination of Behrend (2006) is 29.7 ± 0.1 h. This asteroid's long period required a significant observation interval. On ten nights in 2017 November, 880 data points were captured to produce a rotational period of 76.275 ± 0.041 h., disagreeing with Behrend's result. The amplitude is 0.26 ± 0.01, and RMS scatter of the fit is 0.013 mag.



1883 Rimito. This inner-belt asteroid has both high inclination and eccentricity. It was discovered in 1942 at Turku by Yrjö Väisälä. The LCB shows no entries for this asteroid. On six nights in 2017 November, 331 images of 1883 Rimito were obtained. The very low amplitude initially led to an indeterminate period solution. Brian Skiff (private communications) used the 0.7-m *f*/8 telescope at the Lowell Observatory Anderson Mesa Station (MPC 688) to gather 85 data points on three consecutive nights, also in 2017 November. His analysis produced a period of 6.492 ± 0.013 h, with an RMS scatter on the fit of 0.005 mag. Revisiting the data from the six nights at V02, a similar rotational period of 6.475 ± 0.008 h was computed. The amplitude is 0.05 ± 0.02 mag. RMS scatter of the fit is 0.019 mag., which is significant relative to the amplitude.



Acknowledgments

The author would like to express his gratitude to Brian Skiff for his indispensable mentoring in data acquisition and reduction. Thanks also go out to Brian Warner for support of his *MPO Canopus* software package.

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LIGHTCURVE ANALYSIS OF TEN ASTEROIDS FROM RMS OBSERVATORY

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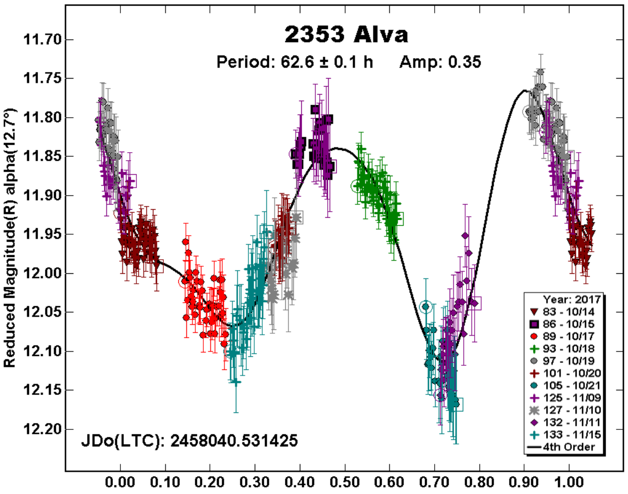
CCD images of ten asteroids were taken from 2017 August 24 to November 14 for the purpose of determining the asteroids’ synodic rotation periods: 2353 Alva, 2440 Educatio, 2633 Bishop, 4911 Rosenzweig, (6490) 1991 NR2, (6693) 1986 CC2, (11745) 1999 NH3, (20885) 2000 WD2, (33982) 2000 NQ23, and (171576) 1999 VP11.

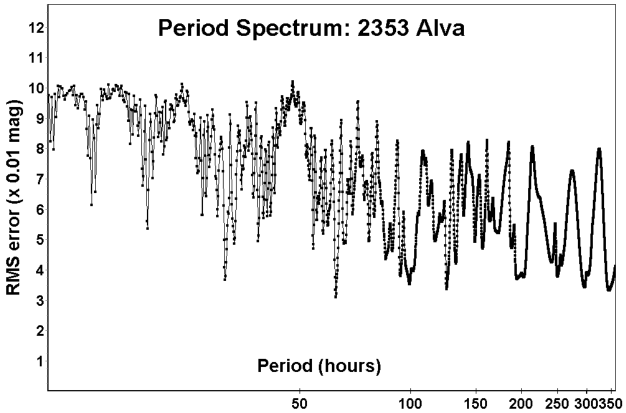
CCD photometric observations of ten asteroids were made from the RMS Observatory (W25) from 2017 August 24 to November 14. The observations were made with a 0.35-m Schmidt-Cassegrain operating at *f*/7.6 and Atik One 6.0 CCD. The camera was binned 3x3, which gave an image scale of 1.05 arcseconds per pixel. Exposures were unfiltered and varied from 30 to 240 s.

The images were calibrated (bias, dark, and flat) with *AstroImageJ* (Collins and Kielkopf, 2013). Differential photometry measurements were made in *MPO Canopus* (Warner, 2017) using the FALC routine (Harris *et al*., 1989) to derive the asteroid synodic periods. The StarBGone utility in *MPO Canopus* was applied to measure images when asteroids where located in the vicinity of stars. The *MPO Canopus* Comp Star Selector utility was employed to select comparison stars of near solar-color for differential photometry for all asteroids. R band magnitudes were taken from the CMC-15 catalog (Munos, 2017) and were chosen to best match the unfiltered CCD measurements.

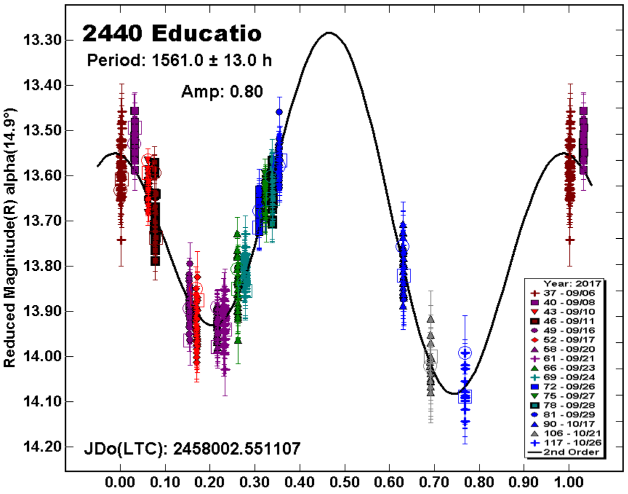
Table I lists the observing circumstances and the analysis results.

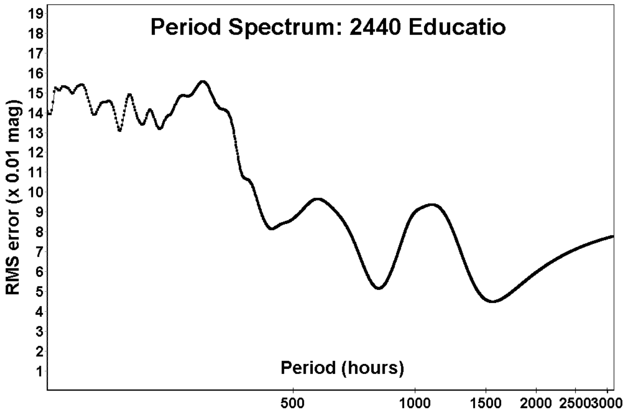
2353 Alva. This main belt asteroid was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the asteroid lightcurve database (LCDB; Warner *et al.* 2009) did not find any previous period. Analysis showed a bimodal period of 62.6 h. A monomodal solution of 31.3 h is indicated in the period spectrum plot, but this is probably an alias.



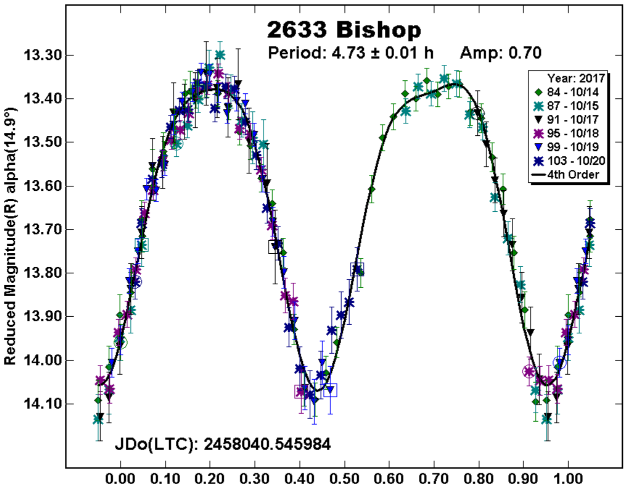


2440 Educatio. This member of the Flora group was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the LCDB (Warner et al., 2009) did not find any previous period; however, this asteroid was a target for the Photometric Survey for Asynchronous Binary Asteroids (Pravec, 2017). Those observations had some overlap in observation dates with this report. That study indicated a slow rotation with a period of about 1200 h and amplitude of 0.6 mag. Those results and those reported here seem to somewhat agree. It is clear this object is a slow rotator with a large lightcurve amplitude.

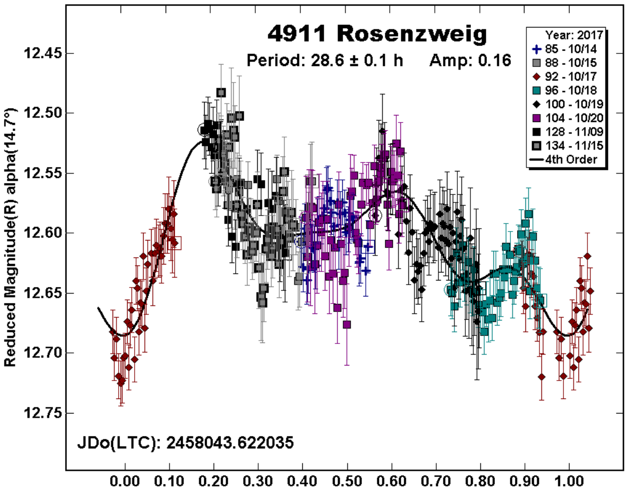


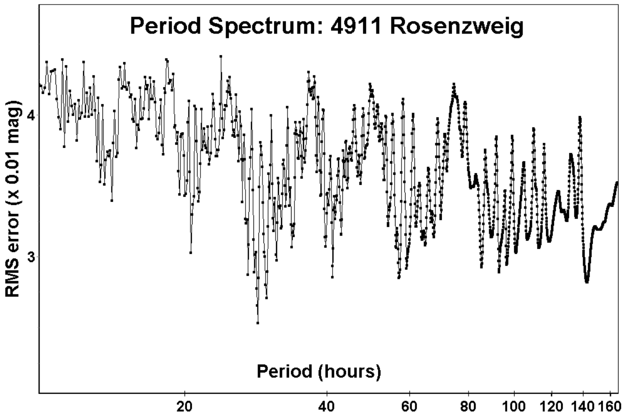


2633 Bishop. This member of the Flora group was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the LCDB (Warner et al., 2009) did not find any previous period. Analysis showed well a defined bimodal lightcurve with a period of 4.73 h.

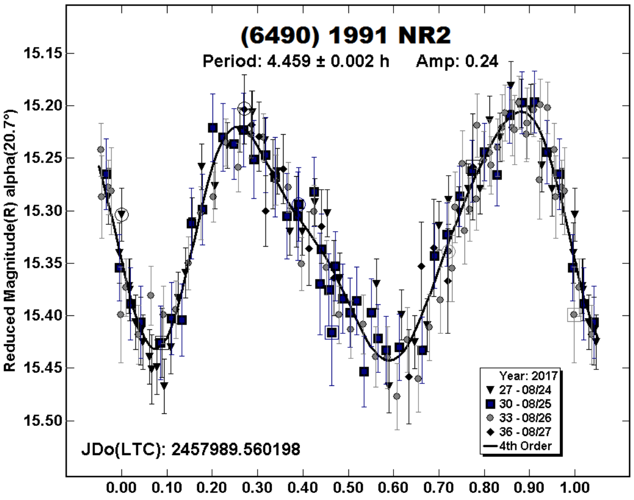


4911 Rosenzweig. This member of the Eunomia group was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the LCDB (Warner et al., 2009) did not find any previous period. The reported period of 28.6 h provides the best fit to the data; however, it also indicates a trimodal solution.

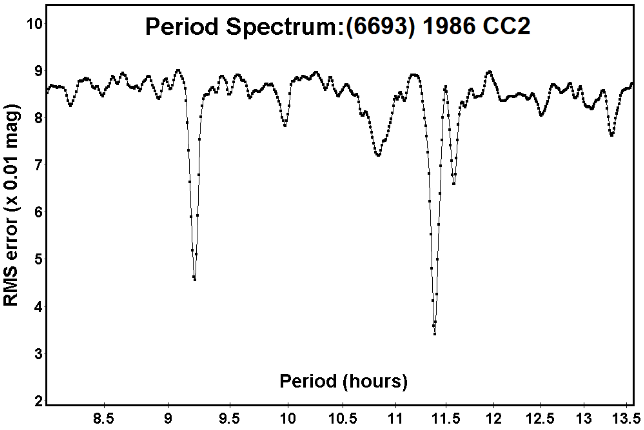


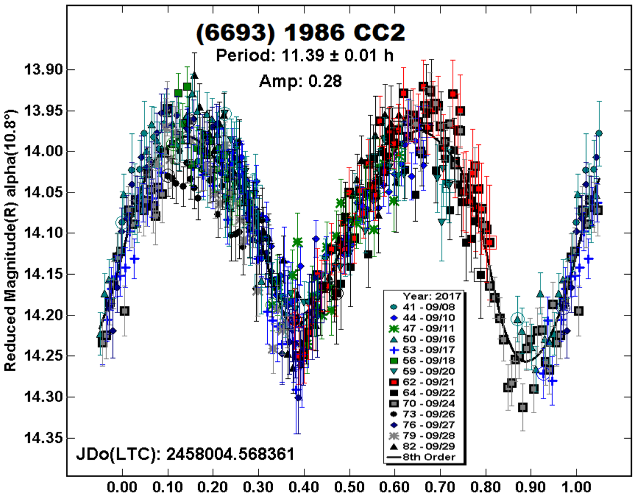


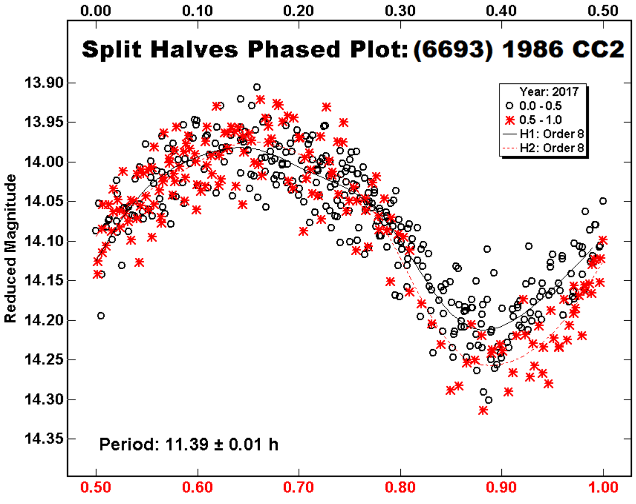
(6490) 1991 NR2. Previous work on this main-belt asteroid gave a period of 4.468 h (Warner, 2005). The result found this year is in good agreement with those findings.

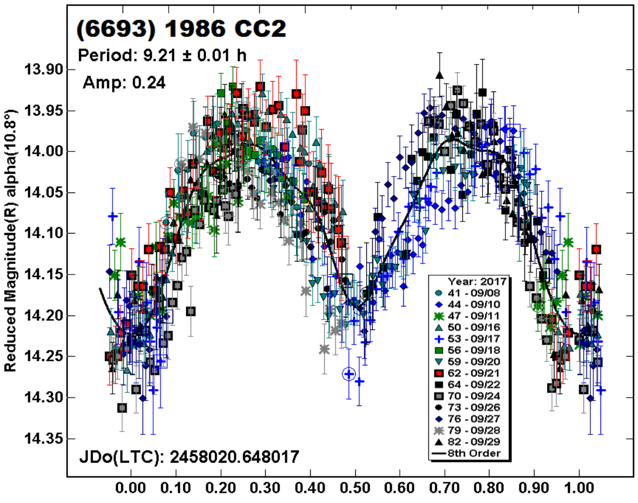


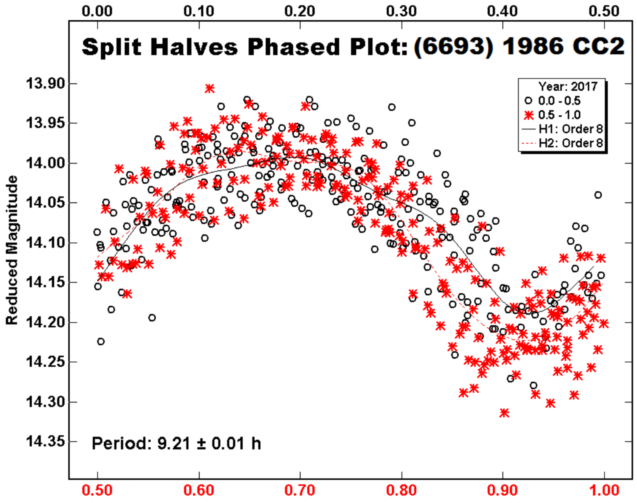
(6693) 1986 CC2. This main-belt asteroid was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the LCDB (Warner et al., 2009) did not find any previous period. Analysis indicated two possible bimodal periods: 11.39 h and 9.21 h. The 11.39 h period is favored.



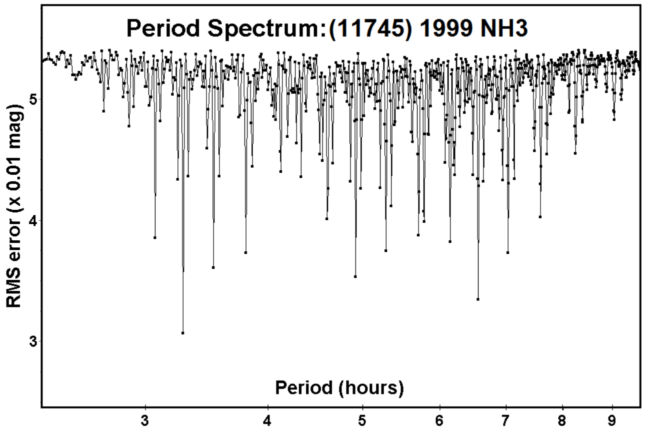


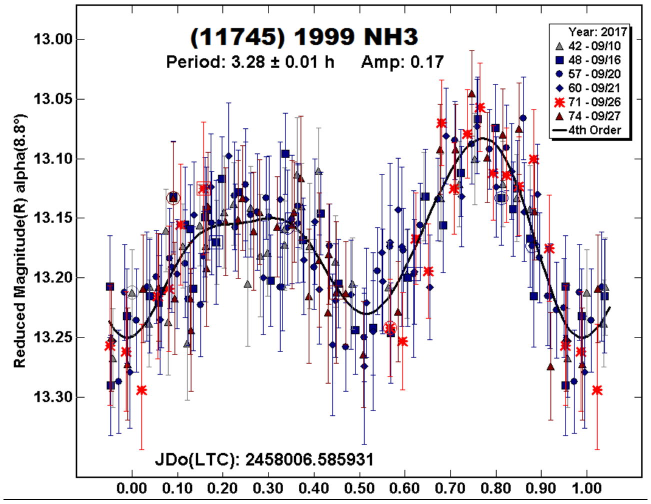




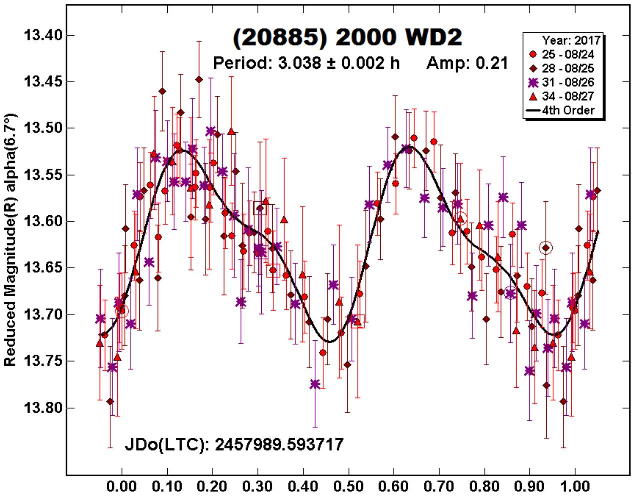


<u>(11745) 1999 NH3</u>. This member of the Eunomia group was listed as a lightcurve photometery opportunity (Warner et al., 2017a). A search of the LCDB (Warner et al., 2009) did not find any previous period. A period of 3.28 h is reported.

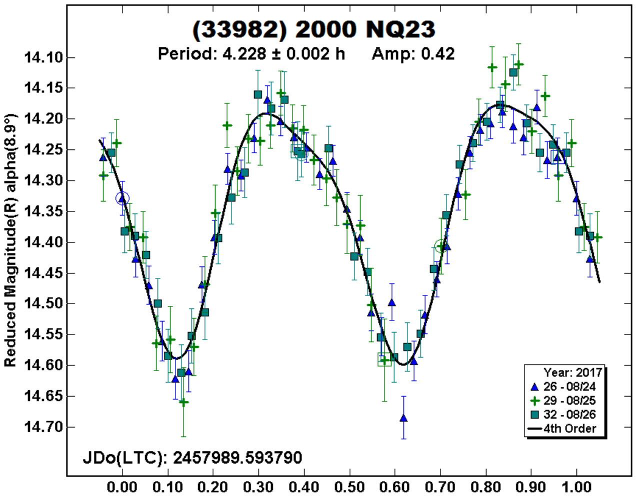




<u>(20885) 2000 WD2</u>. Previous work on this main-belt asteroid indicated a period of 3.07 h (Chang et al., 2016) and 2.696 h (Waszczak et al., 2015). The result found this year is in good agreement with Chang et al. (2016).



(33982) 2000 NQ23. Previous work on this main-belt asteroid indicated a period of 4.227 h (Waszczak *et al.* 2015). The result found this year is in good agreement with those findings.



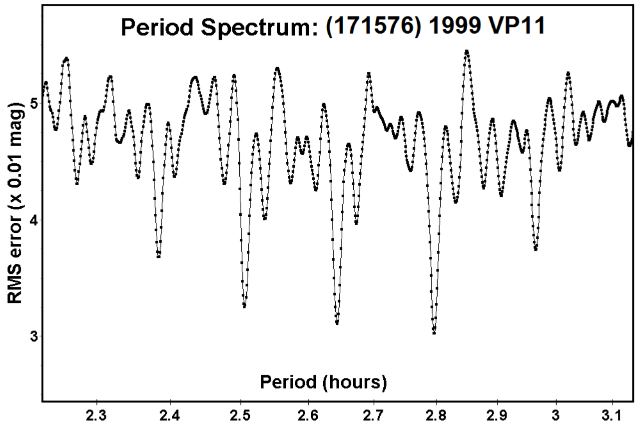
(171576) 1999 VP11. This NEA was listed as a radar target at Goldstone (Warner et al., 2017b). A search of the LCDB (Warner et al., 2009) did not find any previous period.

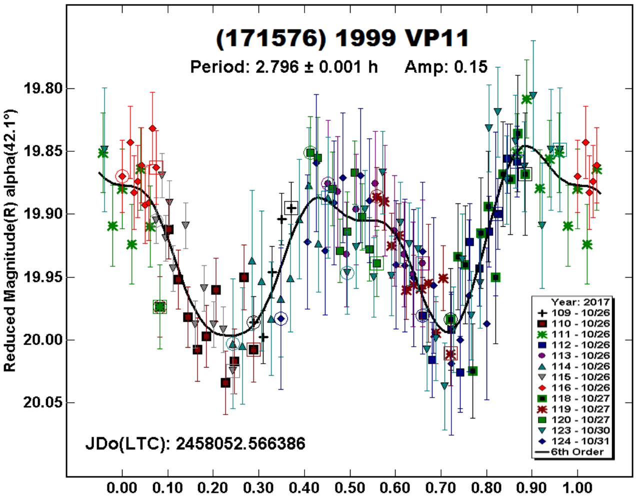
The rapid motion of this target required several sessions of observations per night. The single-night sessions were tied together by using at least one identical comparison star in consecutive sessions, when possible.

Since 1999 VP11 was a radar target, analysis was immediately sent to Lance Benner at JPL. Benner (private communication) found radar measurements on 2017 October 24-25 indicated a rounded object roughly 500 m in diameter with a possible indication of a satellite. This information was then forwarded to Petr Pravec, who made measurements on 2017 November 12-14 with the 1.54 m telescope at La Silla. Those observations indicated a period of 2.6457 ± 0.0008 h, but he found no sign of a binary in the lightcurve (private communication).

Authors note: this was my first collaboration with professional astronomers and I am very grateful for their guidance, encouragement, and sharing their results.

EDITOR'S NOTE: Congratulations and welcome !





Acknowledgements

The author would like to acknowledge the help of several people with my first attempts at asteroid lightcurve analysis. Brian Warner was extremely helpful learning *MPO Canopus* and analysis of 2440 Educatio. Vladimir Benishek was very helpful with analysis of 2440 Educatio. Petr Pravec was very helpful with analysis of 1999 VP11 and exchanging data in ALCDEF format.

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Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2353	Alva	10/14-11/14	358	12.5,20.4	355	-2	62.6	0.1	0.35	0.03	MB
2440	Educatio	09/06-10/26	575	14.8,29.3	329	5	1561	13	0.80	0.04	FLOR
2633	Bishop	10/14-10/21	171	14.7,17.9	359	-4	4.73	0.01	0.70	0.03	FLOR
4911	Rosenzweig	10/14-11/14	345	14.6,23.9	358	6	28.6	0.1	0.16	0.03	EUN
6490	1991 NR2	08/24-08/27	160	20.6,21.8	317	19	4.459	0.002	0.24	0.02	MB
6693	1986 CC2	09/06-09/24	511	6.9,4.1	191	10	11.39	0.01	0.28	0.03	MB
11745	1999 NH3	09/08-09/29	203	7.7,17.0	333	0	3.28	0.01	0.17	0.03	EUN
20885	2000 WD2	08/24-08/27	129	6.6,8.0	321	5	3.038	0.002	0.21	0.04	MB
33982	2000 NQ23	08/24-08/27	104	8.8,10.6	319	3	4.228	0.002	0.42	0.04	MB
171576	1999 VP11	10/26-10/31	152	43.1,35.8	16	-11	2.796	0.001	0.15	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. The definitions and values are those used in the LCDB (Warner *et al.* 2009).

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Warner, B.D., Harris, A.W., Durech, J., Benner, L.A.M. (2017b) "Radar-Optical Opportunities 2017 October - December". *Minor Planet Bulletin* **44, 357-361.**

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." *Astron. J.* **150**, A75.

CALL FOR NASA MISSION SUPPORTING OBSERVATIONS

Richard P. Binzel
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NASA *Psyche* Mission to Asteroid 16 Psyche
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Lightcurve observations are requested to support NASA missions planned for launch to study main-belt and Trojan asteroids. In some cases, the rotations of the target asteroids are unknown. In other cases, the periods are well established and ongoing measurements will deliver the precision needed to deduce the rotation phase at the time of encounter more than a decade away.

NASA has announced two new asteroid missions that have been selected to move forward toward flight. The *Lucy* mission, planned for launch in 2021, will perform flyby studies of Jupiter Trojan asteroids with at least one main-belt asteroid flyby. Given that Trojan asteroids are thought to be remnant "fossils" trapped at Jupiter's Lagrange points in the early formation of our solar system, the mission name derives from the Australopithecus fossil discovered by Donald Johanson in 1971.

Asteroid 16 Psyche is the destination for the eponymous *Psyche* orbiter mission planned for launch in 2022. Asteroid Psyche is thought to be a surviving metallic core of a once larger protoplanet whose overlying layers were stripped by one or more catastrophic collisions.

The table lists 2018 observing opportunities for each mission target; all are *Lucy* targets except (of course) 16 Psyche. "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base documentation for an explanation of the U code:

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

The final column of the table indicates the year of the anticipated *Lucy* flyby or *Psyche* orbiter arrival. Observers should note that 617 Patroclus is a known binary system currently undergoing mutual transits and occultations with its large satellite Menoetius. Detailed predictions on these mutual events are available at the *Lucy* mission's observation coordination website. You are also encouraged to communicate your *Lucy* target observing plans and outcomes on that mission's coordination website:

https://lucyebo.space.swri.edu

For asteroid Psyche measurements, as well as *Lucy* target results, observers themselves are encouraged to publish their results as they become available. It is not the intention of the missions to publish measurements collected by others. You are encouraged to consider submitting your raw data to the ALCDEF web site:

http://alcdef.org

The author serves as the Earth-Based Observations Coordinator and conveys to all observers the thanks of the NASA mission teams for considering these objects in your observing program.

		Brightest			LCDB Data			
Number	Name	Date	Mag	Dec	Period	Amp	U	Year
16	Psyche	05 09	10.4	-13	4.196	0.3	3	2026
617	Patroclus	03 08	15.9	26	102.8	0.07	3	2033
3548	Eurybates	08 03	16.7	-27	8.711	0.2	3	2027
11351	Leucus	08 07	17.8	-04	445.	0.5	2	2028
15094	Polymele	08 01	18.8	-33				2027
21900	Orus	07 12	16.9	-16	13.45	0.2	2	2028
52246	Donaldjohanson	04 19	18.1	-17				2025

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2018 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 2018 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 database (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 ≤ 18.0 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 database. This can be accessed for uploading and downloading data at

http://www.alcdef.org

Containing almost 3.15 million observations for more than 13300 objects, we believe this to be the largest publicly available database of raw asteroid time-series lightcurve data.

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 and 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.

An entry in bold italics is a near-Earth asteroid (NEA).

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
12914	1998 SJ141	04 03.0	15.5	-1			
9931	Herbhauptman	04 12.6	15.5	-5	4.44	0.15-0.21	2
3747	Belinskij	04 14.0	15.1	+0	14.6	0.08	2
3394	Banno	04 14.9	14.6	-7			
9899	1996 EH	04 18.5	15.3	-20			
9369	1993 DB1	04 19.1	15.1	-11	54.335	0.17-0.43	2
86401	2000 AF143	04 20.5	15.4	-22			
10500	Nishi-koen	04 20.7	15.1	-5	44.552	0.27	2
2703	Rodari	04 21.8	15.3	-8	5.5	0.20	1
6868	Seiyauyeda	04 22.5	15.4	-6			
31205	1998 BW	04 23.9	15.5	-35	20.907	0.66	2
5351	Diderot	04 24.2	15.3	-4			
3617	Eicher	04 25.3	15.4	+0	5.81	0.21	2
2206	Gabrova	04 26.0	15.2	-6			
3563	Canterbury	04 26.9	15.5	-22	15.553	0.61	2
5291	Yuuko	04 26.9	15.0	-13			
242643	***2005 NZ6***	***04 26.9***	***15.0***	***-24***			
3390	Demanet	04 28.0	15.1	-19			
5952	Davemonet	04 28.0	15.5	-22			

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
3776	Vartiovuori	04 28.1	14.7	-12	7.7	0.09-0.12	2-
444193	***2005 SE71***	***04 28.9***	***13.6***	***+9***			
450648	***2006 UC63***	***04 29.8***	***15.2***	***-15***			
2369	Chekhov	04 30.0	15.3	-14			
2685	Masursky	04 30.4	15.0	-13		0.10	
11200	1999 CV121	04 30.8	14.8	-8			
5468	Hamatonbetsu	05 01.1	15.1	+5	42.02	0.43	2
5278	Polly	05 02.2	15.3	-16			
7834	1993 JL	05 02.6	15.1	+1	15.707	0.31	2
8053	Kleist	05 05.6	15.4	-19	4.172	0.73	2
821	Fanny	05 06.0	14.1	-14	5.44	0.01	1
388945	***2008 TZ3***	***05 07.4***	***12.9***	***-28***	***44.2***	***0.56***	***2***
29989	1999 XS204	05 11.9	15.5	-22			
6426	Vanysek	05 12.2	15.2	-19			
3877	Braes	05 12.9	14.4	-19			
27064	1998 SY63	05 13.0	14.9	-18			
1793	Zoya	05 14.0	13.9	-18	5.753	0.40	2+
4291	Kodaihasu	05 14.4	15.5	-23			
1849	Kresak	05 16.0	15.5	-20	19.101	0.19	2
16975	Delamere	05 16.5	15.5	-36			
16976	1999 AC2	05 18.0	15.3	-17			
4992	Kalman	05 19.4	15.5	-18			
42701	1998 MD13	05 19.4	15.1	-4			
5147	Maruyama	05 19.5	14.7	-34			
4426	Roerich	05 19.7	15.3	-20			
39609	1993 TN34	05 19.8	15.5	-20			
2149	Schwambraniya	05 20.0	14.2	-19	5.07	0.24	2
10682	1980 KK	05 20.4	15.3	-18		0.23	
1881	Shao	05 23.0	15.4	-15	7.452	0.11-0.15	2
6152	Empedocles	05 23.3	14.9	-29			
15754	1992 EP	05 24.9	15.3	-19			
4639	Minox	05 26.6	15.3	-29	12.993	0.40	2
5547	Acadiau	05 26.9	14.8	-19			
3403	Tammy	05 27.1	15.0	-15	11.85	0.10	1
10358	Kirchhoff	05 28.9	15.4	-16			
12344	1993 FB1	05 29.0	15.2	-22			
33903	2000 KH68	05 29.7	14.6	-22		0.3	
4990	Trombka	05 30.2	15.5	-30	4.927	0.61	2
68347	***2001 KB67***	***05 31.3***	***14.8***	***+35***			
3300	McGlasson	06 02.2	14.0	-43	22.91	0.16	2
5387	Casleo	06 02.8	15.0	-21			
1782	Schneller	06 03.7	15.1	-20	11.86	0.71	1
2955	Newburn	06 05.3	14.8	-28			
1315	Bronislawa	06 05.9	14.0	-19	9.565	0.16-0.24	2
10031	Vladarnolda	06 06.0	15.1	-23			
4535	Adamcarolla	06 08.8	15.3	-11	10.211	0.35-0.83	2
5217	Chaozhou	06 09.1	15.4	-19	11.3	0.55-0.56	2
4478	Blanco	06 10.2	15.5	-24			
3139	Shantou	06 10.6	15.1	-19	8.33	0.34	2
1512	Oulu	06 11.1	14.4	-32	132.3	0.33	2+
27995	1997 WL2	06 11.8	15.3	-25		1.34	
26391	1999 VN9	06 12.0	15.3	-21			
7747	Michalowski	06 13.0	14.8	-28	4.5	0.44-0.51	2
6232	Zubitskia	06 13.7	15.4	-35			
5016	Migirenko	06 19.6	15.3	-16	4.8	0.3	1
896	Sphinx	06 19.9	13.1	-19	26.27	0.08	1
1753	Mieke	06 19.9	14.8	-32	8.8	0.2	2
3788	Steyaert	06 20.2	15.3	-12			

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 to get more details about a specific asteroid.

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

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). It will be some years before H-G_{12} becomes the standard. Furthermore, it still needs refinement. That can be done mostly by having data for more asteroids, but only if at very low and moderate phase angles. We strongly encourage obtaining data every degree between 0° to 7°, the non-linear part of the curve that is due to the opposition effect. At angles $\alpha > 7°$, well-calibrated data every 2° or so out to about 25-30°, if possible, should be sufficient. Coverage beyond about 50° is not generally helpful since the H-G system is best defined with data from 0-30°.

Num	Name	Date	α	V	Dec	Period	Amp	U
586	Thekla	04 09.3	0.41	13.2	-09	13.670	0.24-0.30	3
932	Hooveria	04 09.3	0.40	13.1	-08	39.1	0.20-0.22	2+
74	Galatea	04 10.7	0.14	13.3	-08	17.268	0.08-0.16	3
215	Oenone	04 12.1	0.10	13.1	-08	27.937	0.1 -0.20	3
158	Koronis	04 16.1	0.48	13.2	-11	14.218	0.28-0.43	3
496	Gryphia	04 23.7	0.33	13.9	-12	18.0	0.05	1
393	Lampetia	04 24.5	0.33	11.3	-12	38.7	0.12-0.14	2-
379	Huenna	04 25.0	0.45	13.7	-12	14.141	0.07-0.12	3
62	Erato	04 28.9	0.84	13.8	-11	9.221	0.12-0.17	3
1421	Esperanto	05 01.0	0.23	14.0	-14	21.982	0.15	3-
33	Polyhymnia	05 01.1	0.46	12.8	-16	18.608	0.13-0.20	3
180	Garumna	05 12.6	0.50	13.8	-19	23.866	0.27-0.6	3
1793	Zoya	05 14.0	0.18	14.0	-18	5.753	0.40	2+
570	Kythera	05 19.5	0.20	13.9	-19	8.120	0.12-0.20	2
342	Endymion	05 22.0	0.57	13.9	-19	6.319	0.15-0.23	3
182	Elsa	05 30.2	0.69	12.8	-20	80.088	0.60-0.72	3
150	Nuwa	05 31.7	0.75	12.4	-20	8.135	0.08-0.31	3
243	Ida	06 01.3	0.56	13.9	-24	4.634	0.45-0.86	3
245	Vera	06 06.9	0.55	12.6	-25	14.38	0.26	3
940	Kordula	06 07.0	0.47	14.0	-24	15.57	0.36	3
966	Muschi	06 07.5	0.82	12.6	-25	5.355	0.31-0.44	3
792	Metcalfia	06 09.4	0.60	13.9	-25	9.17	0.15-0.76	3
240	Vanadis	06 09.8	0.59	13.3	-21	10.64	0.08-0.34	3
348	May	06 10.9	0.84	13.8	-20	7.381	0.14-0.16	3
9	Metis	06 16.8	0.97	9.7	-26	5.079	0.05-0.32	3
395	Delia	06 22.1	0.43	13.4	-22	19.71	0.15-0.25	2
268	Adorea	06 26.0	0.57	12.2	-22	7.80	0.15-0.20	3
1147	Stavropolis	06 27.1	0.94	12.2	-22	5.661	0.32-0.42	3
1097	Vicia	06 29.9	0.99	13.4	-21	26.5	0.08	1

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.

Favorable apparitions are in bold text. NEAs are in italics.

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
461	Saskia	04 02.0	14.6	-4	7.348	0.25-0.36	3
759	Vinifera	04 04.6	14.9	-27	14.229	0.36-0.40	3
1777	Gehrels	04 04.6	14.8	-9	2.8355	0.21-0.27	3
2080	Jihlava	04 05.3	15.3	-5	2.7088	0.15-0.27	3-
5427	Jensmartin	04 08.5	15.5	-21	5.81	0.44-0.64	3
586	Thekla	04 09.2	13.2	-9	13.67	0.24-0.30	3
74	Galatea	04 10.7	13.3	-8	17.268	0.08-0.16	3
323	Brucia	04 11.5	14.6	+23	9.463	0.19-0.36	3
177	Irma	04 12.8	14.2	-10	13.856	0.24-0.37	3
754	Malabar	04 21.0	13.6	+7	11.74	0.19-0.38	3
4029	Bridges	04 21.1	15.0	-12	3.5746	0.18-0.29	3
266	Aline	04 21.7	13.4	-19	13.018	0.05-0.10	3
255	Oppavia	04 23.5	13.7	-18	19.499	0.14-0.16	3
232	**Russia**	**04 23.7**	**12.5**	**-3**	**21.905**	**0.14-0.31**	**3**
956	Elisa	04 24.1	14.7	-9	16.492	0.35-0.37	3
206	Hersilia	04 25.2	12.4	-8	11.122	0.13-0.20	3
713	Luscinia	04 26.1	14.1	-14	9.9143	0.09-0.40	3
235	Carolina	04 26.5	12.6	-6	17.61	0.25-0.38	3
4713	Steel	04 27.9	15.5	+30	5.199	0.28-0.44	3
517	Edith	04 28.2	14.5	-18	9.2747	0.08-0.18	3
380	Fiducia	04 28.8	13.2	-6	13.69	0.04-0.32	3
504	Cora	04 28.9	14.5	+3	7.588	0.15- 0.4	3-
4666	**Dietz**	**04 29.1**	**14.8**	**-25**	**2.9524**	**0.21-0.26**	**3**
947	Monterosa	04 29.2	14.5	-13	5.164	0.15-0.23	3-
373	Melusina	04 30.3	14.0	-27	12.97	0.20-0.25	3
33	Polyhymnia	05 01.3	12.8	-16	18.608	0.13-0.20	3
2486	Metsahovi	05 06.7	15.4	-27	4.4518	0.04-0.13	3
618	Elfriede	05 08.4	13.1	+5	14.791	0.11-0.17	3
2253	Espinette	05 08.7	15.1	-10	7.442	0.18-0.48	3
1520	Imatra	05 09.6	15.1	-26	18.635	0.27-0.35	3-
289	Nenetta	05 11.5	14.1	-11	6.902	0.18-0.19	3
143	Adria	05 13.2	12.7	-36	22.005	0.07-0.10	3
463	Lola	05 14.2	15.3	-24	6.206	0.20-0.22	3
3800	Karayusuf	05 14.7	15.4	+14	2.2319	0.15-0.19	3
1171	Rusthawelia	05 17.2	15.2	-16	10.98	0.26-0.31	3
252	Clementina	05 18.0	14.3	-11	10.864	0.32-0.44	3
472	Roma	05 20.1	13.0	+3	9.8007	0.27-0.46	3
975	Perseverantia	05 20.1	14.2	-21	7.267	0.17-0.23	3
3028	Zhangguoxi	05 21.4	14.9	-9	4.826	0.12-0.25	3
3121	**Tamines**	**05 22.0**	**15.4**	**-9**	**4.043**	**0.04-0.19**	**3**
635	Vundtia	05 23.2	13.9	-7	11.79	0.15-0.27	3
1999	Hirayama	05 25.6	15.5	-3	15.63	0.45-0.57	3-
1117	Reginita	05 27.2	13.4	-12	2.946	0.10-0.33	3
971	Alsatia	05 28.0	14.2	-15	9.614	0.17-0.29	3
12008	Kandrup	05 29.8	14.8	-36	32.9034	0.4 -0.85	3
1563	Noel	05 30.0	14.5	-25	3.5495	0.14-0.18	3
333	Badenia	06 01.2	14.2	-27	9.862	0.20-0.33	3
1115	Sabauda	06 04.8	14.1	-23	6.718	0.16-0.27	3
240	Vanadis	06 09.9	13.3	-21	10.64	0.08-0.34	3
348	May	06 10.8	13.7	-20	7.3812	0.14-0.16	3
712	Boliviana	06 13.4	12.8	+19	11.7426	0.10-0.12	3
2294	Andronikov	06 15.6	14.6	-28	3.1529	0.35-0.42	3
1152	Pawona	06 17.2	13.9	-31	3.4154	0.16-0.26	3
1806	Derice	06 19.2	14.8	-24	3.224	0.07-0.19	3
2448	Sholokhov	06 19.5	14.4	-3	10.059	0.21-0.63	3
888	Parysatis	06 21.6	14.0	-12	5.9314	0.22-0.26	3
2911	Miahelena	06 24.0	15.2	-10	4.201	0.56-0.69	3
25916	***2001 CP44***	***06 24.2***	***12.8***	***-13***	***4.19***	***0.28-0.37***	***3***
1186	Turnera	06 27.6	13.2	-37	12.085	0.20-0.34	3
6249	Jennifer	06 28.0	15.5	+23	4.9566	0.06-0.49	3
2650	Elinor	06 29.0	14.5	-43	2.762	0.02-0.18	3

Radar-Optical Opportunities

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

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 or their Facebook or Twitter accounts) 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 seeing an immediate change, the data are still important. This is why observing asteroids that already have well-known periods is still a valuable use of telescope time. It is even more so when considering the BYORP (binary-YORP) effect among binary asteroids that 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.

To help focus efforts in YORP detection, Table I gives a quick summary of this quarter's radar-optical targets. The family or group for the asteroid is given under the number name. Also under the name will be additional flags such as "PHA" for Potentially Hazardous Asteroid, "Bin" to indicate the asteroid is a binary (or m ultiple) system, or NPAR for a tumbler. If followed by "?" it means that the asteroid is a suspect but not confirmed binary. The period is in hours and, in the case of binary, for the primary. The Amp column gives the known range of lightcurve amplitudes. 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 "R SNR" column indicates the estimated radar SNR using the tool at *http://www.naic.edu/~eriverav/scripts/index.php*

The "A" is for Arecibo and "G" is for Goldstone. Note that this calculator assumes full power at Arecibo, which is currently operating at reduced power due to hurricane damage. For this list, some of the Arecibo values were provided by Patrick Taylor (private communications) and took into account reduced power.

Asteroid	Period	Amp	App	Last	R SNR
(363599) 2004 FG11 PHA BIN YORP	<4.	-	2	2014	**370 A** **30 G**
2016 JP PHA	-	-	-	-	**330 A** **175 G**
(194126) 2001 SG276	-	-	-	-	**36 G**
(242643) 2005 NZ6 PHA	-	-	-	-	**10 G**
(444193) 2005 SE71 PHA	-	-	-	-	**83 G**
(450648) 2006 UC63	-	-	-	-	10 G
2013 US3 PHA	-	-	-	-	**380 G**
2002 JR100	-	-	-	-	**30 G**
1999 FN19	3.5	0.1	1	1999	**160 A** **135 G**
(388945) 2008 TZ3 PHA NPAR?	44.2	0.56	2	2016	**8600 G**
(66391) 1999 KW4 PHA BIN	2.765	0.12	4	2016	**90 G**
(68347) 2001 KB67 PHA	-	-	-	-	**1100 G**
2014 WG365 PHA	-	-	-	-	**140 A** **29 G**
2015 DP155 PHA	-	-	-	-	**360 G**
(467309) 1996 AW1 PHA	-	-	-	-	**150 A** **57 G**
(469737) 2005 NW44	-	-	-	-	**30 G**
(441987) 2010 NY65 PHA	4.973	0.24	2	2017	**804 G**

Table I. Summary of radar-optical opportunities in 2018 April-June. Data from the asteroid lightcurve database (Warner *et al.,* 2009; *Icarus* **202**, 134-146). If no period is given, 4 hours was assumed to calculate the radar SNR. The asteroids are in ascending order of date of brightest.

The estimate in Table I is based on using the Arecibo (A) or Goldstone (G) radar. The estimate uses the current MPCORB absolute magnitude (*H*), a period of 4 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 Goldstone radar SNR > 10. This would produce a very marginal signal, not enough for imaging, but might allow improving orbital parameters.

(363599) 2004 FG11 (Apr, *H* = 21.0, PHA BIN YORP)

Taylor et al. (2012) used radar to determine that this is a binary system. The two bodies are somewhat similar in size (~150 meters) and separated by 200-300 meters. With an orbital period of about 20 hours, the system may be fully-synchronous, i.e., the rotation period of each body is the same as the orbital period. However, there was also evidence that the "primary" had an independent rotation period of less than 4 hours. Extremely good data (0.01-0.02 mag precision and equally-good linkages) will be needed to help determine the nature of the system.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/05	15 02.3	+12 54	0.11	1.09	17.9	33.2	143	37	-0.79	+56
04/06	15 11.0	+15 46	0.10	1.08	17.7	36.1	141	48	-0.71	+56
04/07	15 22.4	+19 23	0.09	1.07	17.5	39.9	137	57	-0.62	+55
04/08	15 38.0	+24 01	0.08	1.05	17.3	45.2	132	67	-0.53	+52
04/09	16 00.3	+29 58	0.07	1.04	17.2	52.4	125	75	-0.43	+49
04/10	16 34.3	+37 26	0.06	1.03	17.1	62.1	115	80	-0.34	+43
04/11	17 28.8	+45 53	0.05	1.01	17.2	74.8	102	82	-0.25	+33

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

The estimated diameter of 2016 JP is about 170 meters, just above the "limit" to expect super-fast rotation (*P* < 2 h). Use as short of exposures as possible for the initial observations to get an idea of the period and then adjust exposures as needed to improve SNR.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/22	23 13.1	+85 32	0.03	1.00	17.5	103.5	75	72	+0.40	+23
04/23	14 53.6	+81 07	0.03	1.00	17.1	91.7	86	73	+0.51	+35
04/24	14 15.2	+71 21	0.04	1.01	17.0	81.9	96	69	+0.63	+44
04/25	14 04.6	+63 26	0.04	1.02	17.0	74.1	104	64	+0.73	+52
04/26	13 59.7	+57 08	0.05	1.02	17.1	67.9	110	59	+0.82	+58
04/27	13 56.9	+52 08	0.05	1.03	17.2	63.2	114	54	+0.90	+62
04/28	13 55.1	+48 07	0.06	1.04	17.3	59.4	118	51	+0.95	+66
04/29	13 53.9	+44 50	0.07	1.04	17.4	56.4	120	50	+0.99	+68
04/30	13 52.9	+42 07	0.07	1.05	17.6	53.9	123	53	-1.00	+70
05/01	13 52.2	+39 50	0.08	1.05	17.7	51.9	125	57	-0.99	+72

(194126) 2001 SG276 (Apr-Jun, *H* = 17.7)

This planned Goldstone target has a diameter of about 860 meters. There is no period reported in the asteroid lightcurve database (LCDB; Warner et al., 2009).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	15 53.2	+35 45	0.24	1.14	16.7	49.7	120	54	-1.00	+51
04/11	15 38.4	+27 43	0.16	1.12	15.7	43.1	130	96	-0.25	+53
04/21	14 58.0	+04 54	0.10	1.10	13.9	20.9	157	123	+0.29	+53
05/01	13 20.7	-42 32	0.09	1.08	13.9	29.0	148	39	-0.99	+20
05/11	10 37.6	-65 11	0.14	1.08	15.7	57.9	115	108	-0.23	-6
05/21	08 43.0	-67 51	0.21	1.08	16.8	66.4	102	85	+0.37	-15
05/31	07 50.8	-67 43	0.28	1.08	17.5	68.1	97	89	-0.98	-20
06/10	07 25.7	-67 47	0.35	1.10	18.0	67.4	94	93	-0.19	-22
06/20	07 12.5	-68 26	0.41	1.11	18.3	65.6	93	88	+0.45	-23
06/30	07 04.4	-69 43	0.46	1.14	18.5	63.2	93	90	-0.97	-24

(242643) 2005 NZ6 (Apr-May, *H* = 17.4, PHA)

Coming in at almost a full kilometer, this is one of the larger NEAs in this list. The rotation period, almost certainly > 2 h, is unknown. Of course, there are a few exceptions to the rule in the LCDB, so be prepared for almost any possibility.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	20 00.4	-17 05	0.12	1.01	15.8	82.0	91	143	+0.19	-23
04/22	19 00.0	-20 43	0.12	1.05	15.2	66.1	108	174	+0.40	-11
04/24	17 57.8	-22 58	0.13	1.08	14.9	50.4	124	131	+0.63	+1
04/26	17 01.9	-23 39	0.14	1.11	14.8	36.6	139	91	+0.82	+11
04/28	16 16.6	-23 18	0.16	1.15	14.8	25.2	151	54	+0.95	+19
04/30	15 41.7	-22 27	0.18	1.18	14.9	16.3	161	21	-1.00	+26
05/02	15 15.2	-21 28	0.20	1.21	15.0	9.4	169	15	-0.96	+30
05/04	14 55.0	-20 31	0.23	1.24	15.1	4.5	175	42	-0.85	+34
05/06	14 39.3	-19 40	0.26	1.27	15.3	3.4	176	69	-0.69	+36
05/08	14 27.0	-18 56	0.29	1.30	15.8	6.0	172	96	-0.51	+38

(444193) 2005 SE71 (Apr-Jun, *H* = 18.2, PHA)

The rotation period for this 700-meter NEA is unknown. Mid-April favors northern observers and then southern observers get their chance once the asteroid's sky motion slows down a bit.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	20 01.1	+60 44	0.21	0.97	18.0	91.6	76	98	-1.00	+16
04/11	18 43.5	+61 44	0.14	1.00	16.9	85.3	87	84	-0.25	+25
04/21	15 46.1	+51 39	0.08	1.04	15.0	63.8	112	100	+0.29	+49
05/01	12 54.2	-02 08	0.07	1.07	13.7	25.5	153	38	-0.99	+61
05/11	11 48.5	-31 32	0.13	1.10	15.6	42.5	133	143	-0.23	+29
05/21	11 26.8	-40 28	0.20	1.13	16.9	50.0	121	66	+0.37	+20
05/31	11 23.0	-44 29	0.28	1.16	17.7	52.8	114	79	-0.98	+16
06/10	11 28.5	-46 56	0.36	1.19	18.3	53.9	109	129	-0.19	+14
06/20	11 40.2	-48 47	0.44	1.21	18.8	54.2	105	55	+0.45	+12
06/30	11 56.5	-50 23	0.51	1.23	19.2	54.1	102	92	-0.97	+12

(450648) 2006 UC63 (Apr-May, *H* = 19.7)

This is the only object in the list that was *not* listed on the radar web pages. The size is about 340 meters; the period is unknown.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/15	10 54.9	-54 39	0.10	1.07	16.8	50.1	125	121	-0.01	+4
04/18	11 34.3	-49 53	0.09	1.07	16.4	43.6	133	121	+0.05	+11
04/21	12 12.3	-43 09	0.09	1.07	16.0	35.5	142	102	+0.29	+19
04/24	12 46.8	-34 36	0.08	1.08	15.7	26.1	152	70	+0.63	+28
04/27	13 16.7	-24 53	0.08	1.09	15.3	16.6	162	34	+0.90	+38
04/30	13 41.8	-15 06	0.09	1.09	15.2	10.3	169	14	-1.00	+46
05/03	14 02.5	-06 12	0.09	1.10	15.4	11.9	167	46	-0.91	+53
05/06	14 19.6	+01 16	0.10	1.11	15.9	17.5	161	80	-0.69	+57
05/09	14 33.6	+07 14	0.11	1.11	16.3	23.0	155	114	-0.41	+59
05/12	14 45.2	+11 53	0.13	1.12	16.7	27.4	149	145	-0.15	+59

2013 US3 (Apr-May, *H* = 21.0, PHA)

Unfortunately, this 180 meter NEA is brightest when also closest in the sky to a nearly full moon. However, it should be bright enough to get good SNRs. Closest approach in on April 29 at about 0.025 AU, or about 10 lunar distances.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	11 42.5	+75 28	0.05	1.01	17.6	86.1	91	73	+0.19	+41
04/23	11 49.3	+65 02	0.04	1.01	16.8	79.1	99	57	+0.51	+51
04/26	11 53.8	+47 47	0.03	1.02	15.9	66.9	112	40	+0.82	+67
04/29	11 57.4	+21 37	0.03	1.02	15.1	49.6	129	37	+0.99	+77
05/02	12 00.5	-06 27	0.03	1.03	14.9	37.9	141	62	-0.96	+54
05/05	12 03.5	-26 24	0.04	1.04	15.5	38.0	141	90	-0.78	+35
05/08	12 06.5	-38 25	0.05	1.04	16.1	41.4	137	112	-0.51	+24
05/11	12 09.8	-45 46	0.06	1.05	16.7	44.3	133	128	-0.23	+17
05/14	12 13.5	-50 30	0.07	1.06	17.2	46.2	131	131	-0.03	+12
05/17	12 17.6	-53 43	0.08	1.07	17.6	47.4	129	116	+0.03	+9

1999 FN19 (May, *H* = 22.5)

This very small asteroid, only 90 meters, has a surprisingly long period of about 3.5 hours (Pravec et al., 1999). However, the LCDB gives U = 1, meaning the period is "probably wrong," so make no assumptions. Keep in mind that the very large phase angles may lead to extreme shadowing effects that can produce unexpected lightcurve shapes.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/01	09 13.8	+48 53	0.04	1.01	18.6	92.3	86	102	-0.99	+43
05/04	09 16.2	+62 23	0.03	1.00	18.4	98.4	80	126	-0.85	+40
05/07	09 27.6	+81 06	0.03	1.00	18.4	103.7	75	117	-0.60	+33
05/10	21 02.4	+76 59	0.03	1.00	18.5	105.3	73	88	-0.32	+20
05/13	21 09.6	+57 20	0.03	1.00	18.6	102.5	76	73	-0.08	+6
05/16	21 11.6	+42 49	0.03	1.01	18.7	97.5	81	88	+0.01	-4
05/19	21 12.6	+32 49	0.04	1.01	18.9	92.3	85	119	+0.17	-11
05/22	21 13.2	+25 52	0.05	1.01	19.1	87.3	90	139	+0.49	-15
05/25	21 13.6	+20 51	0.06	1.02	19.2	82.6	94	125	+0.79	-19
05/28	21 13.8	+17 05	0.07	1.02	19.4	78.3	98	95	+0.97	-21

(388945) 2008 TZ3 (Apr-May, *H* = 22.5)

Warner (2016) reported a period of about 44 h with the possibility of tumbling for this 250-meter NEA. With a long period not far from being commensurate with an Earth day, a campaign of observers at different longitudes has the best chance of success.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	13 58.7	+14 48	0.11	1.10	16.8	23.8	154	119	+0.19	+70
04/23	13 58.7	+13 30	0.09	1.09	16.4	23.8	154	80	+0.51	+69
04/26	13 58.7	+11 25	0.07	1.07	16.0	23.4	155	41	+0.82	+68
04/29	13 59.0	+08 01	0.06	1.06	15.4	21.9	157	14	+0.99	+65
05/02	13 59.7	+01 56	0.04	1.05	14.6	18.5	161	38	-0.96	+60
05/05	14 01.3	-10 33	0.03	1.04	13.5	12.1	168	69	-0.78	+49
05/08	14 06.7	-40 48	0.02	1.03	12.9	25.8	154	92	-0.51	+20
05/11	21 59.7	-87 38	0.02	1.02	14.3	71.6	107	82	-0.23	-29
05/14	01 45.3	-60 02	0.03	1.01	16.2	97.3	81	68	-0.03	-56
05/17	01 50.5	-47 58	0.04	1.00	17.5	106.6	71	80	+0.03	-66

(66391) 1999 KW4 (May-Jun, *H* = 16.5, PHA BINARY)

Based on radar observations, Benner et al. (2001) discovered the binary nature of this asteroid. Pravec et al. (2006), using data from 2001, found that the primary rotation period is 2.765 h and the orbital period is 17.45 h. The mutual eclipse events ranged from 0.09-0.12 mag in depth. In June, the phase angle bisector longitude and latitude, i.e., "viewing aspect," will be similar to those during the 2001 observations, meaning that it should be possible to detect the satellite as attenuations (mutual events) in the lightcurve.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/01	23 17.5	-27 53	0.30	0.91	17.3	99.1	64	108	-0.99	-69
05/06	23 03.3	-26 27	0.25	0.95	16.8	95.6	70	47	-0.69	-66
05/11	22 43.9	-23 57	0.20	0.98	16.2	91.3	77	23	-0.23	-61
05/16	22 14.3	-19 26	0.15	1.01	15.4	84.9	86	93	+0.01	-53
05/21	21 22.5	-10 12	0.11	1.04	14.3	74.2	100	173	+0.37	-38
05/26	19 44.5	+08 56	0.08	1.05	13.2	56.8	119	94	+0.87	-8
05/31	17 20.0	+29 57	0.09	1.07	13.2	49.4	127	50	-0.98	+32
06/05	15 28.0	+36 39	0.12	1.08	14.2	56.4	118	103	-0.67	+56
06/10	14 28.8	+37 02	0.17	1.08	15.1	62.5	109	136	-0.19	+67
06/15	13 57.3	+36 15	0.22	1.08	15.8	66.5	102	91	+0.02	+73

(68347) 2001 KB67 (Jun, *H* = 19.8, PHA)

There is no period in the LCDB for this 330-meter NEA. Closest approach is on May 29 at about 0.024 AU.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/29	22 34.4	+28 12	0.02	1.01	15.4	101.1	78	105	+1.00	-26
05/31	20 02.6	+35 24	0.03	1.02	14.7	74.5	104	65	-0.98	+2
06/02	18 25.0	+33 32	0.04	1.03	14.9	59.3	119	56	-0.89	+20
06/04	17 35.0	+30 33	0.05	1.05	15.4	51.9	126	69	-0.75	+29
06/06	17 07.2	+28 11	0.07	1.06	15.8	48.1	129	89	-0.58	+34
06/08	16 50.0	+26 25	0.08	1.07	16.2	46.1	131	110	-0.38	+37
06/10	16 38.4	+25 03	0.09	1.08	16.6	44.9	131	129	-0.19	+39
06/12	16 30.2	+23 56	0.11	1.09	16.9	44.2	131	140	-0.05	+41

2014 WG365 (May-Jun, *H* = 20.0, PHA)

Plans are for both Arecibo and Goldstone to observe the 310-meter asteroid. The rotation period is not known, but it should be greater than 2 hours.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/25	22 09.0	+21 08	0.07	1.01	17.6	94.0	82	137	+0.79	-28
05/26	22 05.6	+14 58	0.07	1.01	17.4	90.5	86	128	+0.87	-32
05/27	22 02.0	+08 05	0.06	1.02	17.1	86.5	90	116	+0.93	-36
05/28	21 58.3	+00 37	0.06	1.02	16.9	82.1	94	102	+0.97	-40
05/29	21 54.4	-07 15	0.06	1.02	16.7	77.5	99	87	+1.00	-44
05/30	21 50.3	-15 14	0.06	1.03	16.5	72.9	104	72	-1.00	-46
05/31	21 45.9	-23 02	0.06	1.03	16.5	68.6	108	57	-0.98	-48
06/01	21 41.2	-30 23	0.06	1.04	16.4	64.7	112	44	-0.95	-48
06/02	21 36.2	-37 05	0.07	1.04	16.5	61.4	115	33	-0.89	-48
06/03	21 30.8	-43 04	0.07	1.05	16.5	58.6	118	29	-0.83	-47

2015 DP155 (Jun, *H* = 21.6, PHA)

Little seems to be known about 2015 DP155: there's no reported period or IR-determined diameter listed in the LCDB. The assumed size is about 140 meters. This makes it a good candidate for having a period of less than 2 hours so, at the start, plan on short exposures to avoid *rotational smearing* (see Pravec et al., 2000; *Icarus* **147**, 477-486).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/01	15 49.4	+53 00	0.03	1.02	16.9	73.7	104	82	-0.95	+48
06/04	16 39.8	+47 27	0.03	1.02	16.4	68.2	110	87	-0.75	+42
06/07	17 32.1	+38 01	0.03	1.03	15.8	59.9	119	93	-0.48	+31
06/10	18 21.0	+24 15	0.02	1.03	15.3	49.1	130	108	-0.19	+17
06/13	19 02.8	+08 11	0.02	1.03	15.1	38.7	140	136	-0.01	+1
06/16	19 36.3	-06 27	0.03	1.04	15.1	32.6	147	166	+0.07	-13
06/19	20 02.5	-17 39	0.03	1.04	15.4	30.8	148	140	+0.34	-23
06/22	20 22.6	-25 35	0.04	1.05	15.8	31.0	148	103	+0.67	-30
06/25	20 37.9	-31 08	0.04	1.05	16.2	31.5	147	68	+0.91	-35
06/28	20 49.5	-35 06	0.05	1.06	16.5	31.7	147	36	+1.00	-38

(467309) 1996 AW1 (May-Jun, *H* = 20.0, PHA BINARY)

Pravec and Hahn (1997), using observations from 1994, found this to be a binary system with a primary period of 2.519 h and orbital period of 22.33 h. The estimated effective diameter ratio of the satellite to primary was Ds/Dp = 0.49 ± 0.02. In 2018, the phase angle bisector longitude will be about 140° greater than in 1994. This should produce different lightcurve shapes and so help model the system. This could be important because Warner (2016) reported finding a third period of 4.508 h. Assuming it was not an artifact of period analysis, this could indicate a third body in the system. With luck, radar observations will find the true nature of the system.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/25	17 07.3	-03 54	0.25	1.25	18.4	18.2	157	66	+0.79	+21
05/28	17 05.5	-02 30	0.22	1.22	18.1	18.2	158	31	+0.97	+22
05/31	17 02.9	-00 50	0.20	1.20	17.8	18.9	158	21	-0.98	+24
06/03	16 59.4	+01 14	0.17	1.17	17.5	20.4	156	52	-0.83	+25
06/06	16 54.6	+03 51	0.15	1.15	17.2	23.2	154	86	-0.58	+28
06/09	16 47.7	+07 21	0.12	1.12	16.9	27.4	149	123	-0.28	+31
06/12	16 37.6	+12 15	0.10	1.10	16.6	33.7	143	150	-0.05	+35
06/15	16 21.3	+19 36	0.08	1.07	16.3	43.2	134	127	+0.02	+42
06/18	15 51.3	+31 11	0.06	1.05	16.1	58.0	119	83	+0.24	+51
06/21	14 41.6	+48 43	0.05	1.02	16.3	81.5	96	55	+0.56	+60

(469737) 2005 NW44 (Jun, *H* = 18.3)

There is no information in the LCDB on this NEA with an estimated diameter of 250 meters. The size will likely mean that the period greater than 2 hours.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/15	17 14.5	+71 50	0.06	1.01	17.4	92.0	85	86	+0.02	+33
06/16	16 39.0	+65 24	0.05	1.02	17.2	86.3	91	87	+0.07	+38
06/17	16 17.6	+58 34	0.06	1.02	17.0	80.6	96	85	+0.15	+43
06/18	16 03.6	+51 45	0.06	1.03	16.8	75.2	102	80	+0.24	+47
06/19	15 53.8	+45 11	0.06	1.03	16.8	70.3	107	73	+0.34	+50
06/20	15 46.6	+39 03	0.06	1.04	16.7	66.0	111	64	+0.45	+52
06/21	15 41.1	+33 27	0.06	1.04	16.7	62.3	115	55	+0.56	+53
06/22	15 36.8	+28 25	0.07	1.05	16.8	59.2	118	45	+0.67	+54
06/23	15 33.4	+23 55	0.07	1.05	16.8	56.6	120	38	+0.76	+53
06/24	15 30.6	+19 56	0.08	1.06	16.9	54.6	122	32	+0.84	+53

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

Warner (2016; 2017) found an average period of about 4.975 h for this 150-meter NEA. Closest approach is on June 24 at only 0.019 AU, or about 7-8 lunar distances.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/25	13 05.8	+66 24	0.02	1.01	16.8	105.2	74	86	+0.91	+51
06/26	15 10.6	+55 05	0.02	1.02	16.3	86.7	92	75	+0.95	+52
06/27	15 58.8	+44 12	0.03	1.02	16.3	73.6	105	67	+0.99	+49
06/28	16 22.1	+36 14	0.03	1.03	16.4	64.7	114	63	+1.00	+45
06/29	16 35.6	+30 34	0.04	1.04	16.6	58.6	120	63	-0.99	+41
06/30	16 44.4	+26 25	0.04	1.04	16.8	54.2	124	66	-0.97	+38
07/01	16 50.6	+23 18	0.05	1.05	17.1	51.1	127	71	-0.93	+36
07/02	16 55.2	+20 53	0.06	1.05	17.3	48.7	129	78	-0.88	+34
07/03	16 58.8	+18 57	0.07	1.06	17.5	46.9	130	86	-0.81	+33
07/04	17 01.6	+17 22	0.07	1.07	17.7	45.4	132	95	-0.72	+32

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.

Number	Name	EP	Page
59	Elpis	71	181
126	Velleda	56	166
184	Dejopeja	87	197
295	Theresia	71	181
300	Geraldina	52	162
300	Geraldina	89	199
435	Ella	87	197
451	Patientia	80	190
597	Bandusia	89	199
763	Cupido	1	111
763	Cupido	2	112
775	Lumiere	52	162
868	Lova	89	199
882	Swetlana	2	112
904	Rockefellia	89	199
917	Lyka	7	117
920	Rogeria	2	112
958	Asplinda	37	147
964	Subamara	89	199
965	Angelica	89	199
1034	Mozartia	7	117
1065	Amundsenia	25	135
1105	Fragaria	89	199
1118	Hanskya	7	117
1134	Kepler	24	134
1167	Dubiago	7	117
1173	Anchises	14	124
1181	Lilith	89	199
1182	Ilona	2	112
1197	Rhodesia	89	199
1218	Aster	12	122
1255	Schilowa	89	199
1283	Komsomolia	2	112
1405	Sibelius	25	135
1426	Riviera	52	162
1439	Vogtia	37	147
1499	Pori	77	187
1529	Oterma	37	147
1590	Tsiolkovskaja	52	162
1599	Giomus	22	132
1637	Swings	5	115
1639	Bower	2	112
1664	Felix	77	187
1677	Tycho Brahe	77	187
1741	Giclas	52	162
1864	Daedalus	28	138
1883	Rimito	89	199
1888	Zu Chong-Zhi	22	132
1953	Rupertwildt	74	184
2052	Tamriko	9	119
2144	Marietta	52	162
2241	Alcathous	14	124
2353	Alva	93	203
2440	Educatio	93	203
2483	Guinevere	37	147
2578	Saint-Exupery	61	171
2633	Bishop	93	203
2733	Hamia	12	122
2759	Idomeneus	14	124
2847	Parvati	7	117
2881	Meiden	7	117
2893	Peiroos	14	124
2951	Perepadin	77	187
2998	Berendeya	80	190
3107	Weaver	7	117
3122	Florence	10	120
3122	Florence	64	174
3176	Paolicchi	7	117
3200	Phaethon	21	131
3262	Miune	7	117
3561	Devine	37	147
3694	Sharon	37	147
3737	Beckman	77	187
3809	Amici	80	190
3849	Incidentia	25	135
4039	Souseki	25	135

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The deadline for the next issue (45-3) is April 15, 2018. The deadline for issue 45-4 is July 15, 2018.