THE MINOR PLANET BULLETIN

BULLETIN OF THE MINOR PLANETS SECTION OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

VOLUME 46, NUMBER 2, A.D. 2019 APRIL-JUNE

PHOTOMETRY OF SELECTED ASTEROIDS ON THE OMT-800 TELESCOPE

Volodymyr Troianskyi
Institute Astronomical Observatory, Faculty of Physics
Adam Mickiewicz University in Poznan POLAND
voltro@amu.edu.pl
and
Astronomical Observatory of Odessa
I.I. Mechnikov National University UKRAINE
v.troianskyi@onu.edu.ua

Volodymyr Kashuba
Astronomical Observatory of Odessa
I.I. Mechnikov National University UKRAINE

Yu. Krugly
Institute of Astronomy
V.N.Karazin Kharkiv National University UKRAINE

(Received: 2018 Dec 11)

From 2016 to 2017, images of minor planets were collected to investigate their rotational lightcurve periods. Those minor planets were 3361 Orpheus, 3749 Balam, (66391) 1999 KW4, (153415) 2001 QP153, (357027) 1999 YR14, (496018) 2008 NU, and 2014 YC15.

We used an FLI 9000 camera on a 0.8-m OMT-800 telescope (Troianskyi *et al.*, 2014; MPC code 583) operating at *f*/2.67 to collect images on the nights of 2016 June 7–9, September 1-3, 5-8, 11, and of 2017 July 30-31, August 1-2, 19-21, 24-27, 29-30, September 18-20, 22, and October 17-18. The targeted minor planets were 3361 Orpheus, 3749 Balam, (66391) 1999 KW4, (153415) 2001 QP153, (357027) 1999 YR14, (496018) 2008 NU, and 2014 YC15. The images were processed using standard techniques with *MaxIm DL* and then measured and lightcurves generated with *MPO Canopus*.

Table I gives the observing circumstances and analysis results. For asteroid (153415) 2001 QP153, ours appears to be the first period found.

3361 Orpheus is an Apollo (NEO) asteroid and potentially hazardous asteroid (PHA) that was discovered on 1982 April 24 by Carlos Torres at Cerro El Roble Astronomical Station. Our period of 3.51 ± 0.03 h is in close agreement with the Skiff (2013) period of 3.532 ± 0.001 h.

3749 Balam was discovered on 1982 January 24 by American astronomer Edward Bowell at Lowell's Anderson Mesa Station near Flagstaff, Arizona. The S-type asteroid is a member of the Flora family (main-belt). Our period of 2.8033 ± 0.0008 h is in close agreement with the Marchis et al. (2008) period of 2.80483 ± 0.00002 h.

(66391) 1999 KW4. Classified as a potentially hazardous asteroid (PHA) of the Aten group, 1999 KW4 was discovered on 1999 May 20 by Lincoln Near-Earth Asteroid Research (LINEAR) at the Lincoln Laboratory's Experimental Test Site in Socorro, New Mexico. Our period of 2.776 ± 0.001 h is in close agreement with the Pravec et al. (2006) period of 2.7650 ± 0.002 h.

(153415) 2001 QP153. This Aten-type NEA was discovered on 2001 August 20 by LINEAR at Socorro. There were no previous entries in the LCDB (Warner et al., 2009) for (153415) 2001 QP153. We found period of 4.452 ± 0.005 h.

(357024) 1999 YR14. This asteroid was discovered by LONEOS at Anderson Mesa on 1999 December 31. It is an Apollo-type potentially hazardous asteroid (PHA). Our period of 4.2454 ± 0.0002 h is statistically the same as the period of 4.2477 ± 0.0005 h found by Warner (2017).

(496018) 2008 NU is an Amor (NEO) asteroid that was discovered 2008 July 1 by CSS at Catalina. The period of 4.7344 ± 0.0005 h we found disagrees with the period of 6.47 ± 0.01 h found by Warner (2018).

2014 YC15. This is classified as an Amor (NEO). Our period of 5.7635 ± 0.0001 h is statistically the same as that found by Pravec (2017): 5.7639 ± 0.0003 h.

The results will be used for numerical simulation of the motion of asteroids and asteroid systems (Troianskyi and Bazyey, 2018), taking into account non-gravitational perturbations.

References

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

Number	Name	yyyy mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	U	Exp
3361	Orpheus	2017 10/17-10/18	93	10.5	30	-3	3.51	0.03	0.17	0.05	2	90
3749	Balam	2017 09/18-09/22	252	3.6,3.9	356	7	2.8033	0.0008	0.10	0.02	3	90
66391	1999 KW4	2016 06/07-06/09	383	72.1,73.5	276	47	2.776	0.001	0.24	0.03	2	30
153415	2001 QP153	2017 08/26-08/29	204	84.3,81.3	319	56	4.452	0.005	0.27	0.05	2	120
357024	1999 YR14	2016 09/01-09/11	1010	60.1,85.6	24	-12	4.2445	0.0002	1.37	0.05	3	60
496018	2008 NU	2017 07/30-08/21	344	12.3,20.8	315	13	4.7344	0.0005	0.18	0.03	2	120
	2014 YC15	2017 08/24-09/30	258	18.1,31.7	0	12	5.7635	0.0001	1.02	0.02	3	90

Table I. 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). The U rating is our estimate and not necessarily the one assigned in the asteroid lightcurve database (Warner *et al.*, 2009). Exp is average exposure, seconds.

Marchis, F., Pollock, J., Pravec, P., Baek, M., Greene, J., Hutton, L., Descamps, P., Reichart, D.E., Ivarsen, K.M., Crain, J.A., Nysewander, M.C., Lacluyze, A.P., Haislip, J.B., Harvey, J.S. (2008). "(3749) Balam." *Central Bureau Electronic Telegrams* **1297**, #1.

Pravec, P., Scheirich, P., Kusnirák, P., Sarounová, L., Mottola, S., Hahn, G., Brown, P., Esquerdo, G., Kaiser, N., Krzeminski, Z., and 47 coauthors (2006). "Photometric survey of binary near-Earth asteroids." *Icarus* **181**, 63-93.

Pravec, P., Wolf, M., Sarounova, L. (2017). *http://www.asu.cas.cz/~ppravec/neo.htm*

Skiff, B.A. (2013). Posting on CALL web site. *http://www.minorplanet.info/call.html*

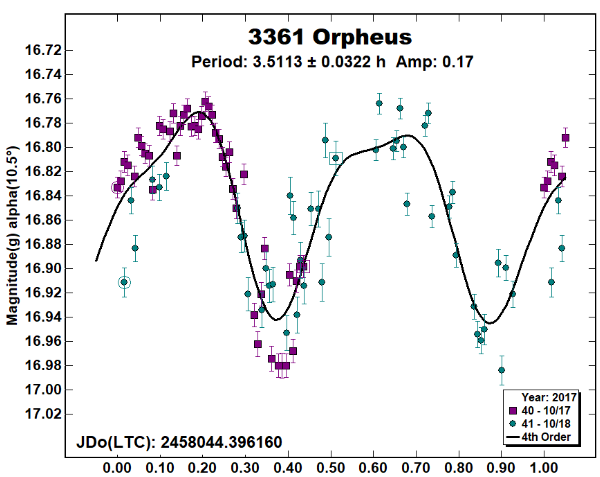
Troianskyi, V.V., Bazyey, A.A., Kashuba, V.I., Zhukov, V.V., Korzhavin, S.A. (2014). "Method for Calculating Orbits of Near-Earth Asteroids Observed with Telescope OMT-800." *Odessa Astronomical Publications* **27**, 154-155.

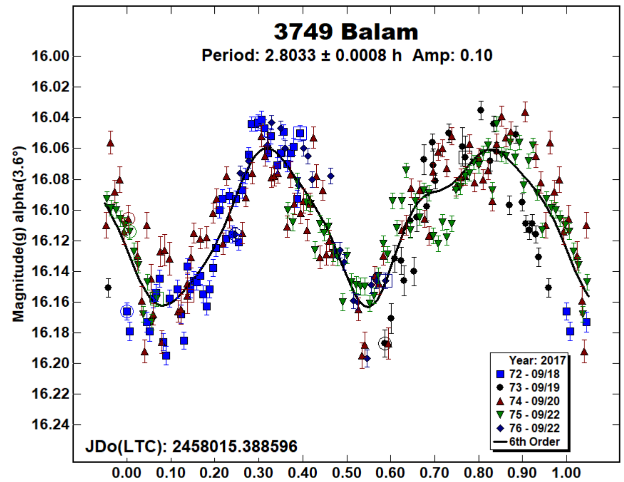
Troianskyi, V.V., Bazyey, O.A. (2018). "Numerical simulation of asteroid system dynamics." *Contrib. Astron. Obs. Skalnate Pleso* **48**, 356-380.

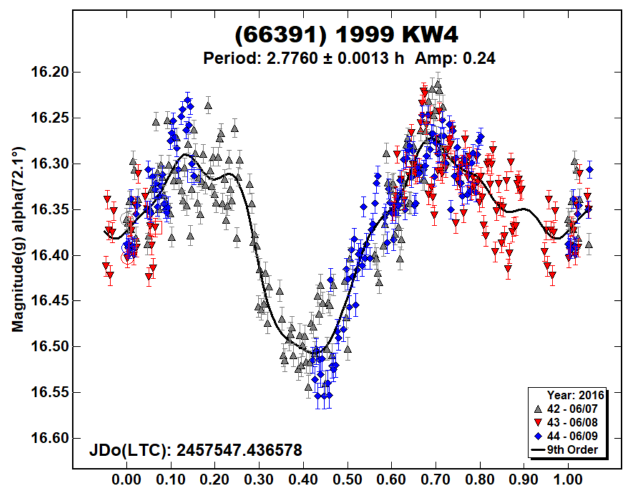
Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

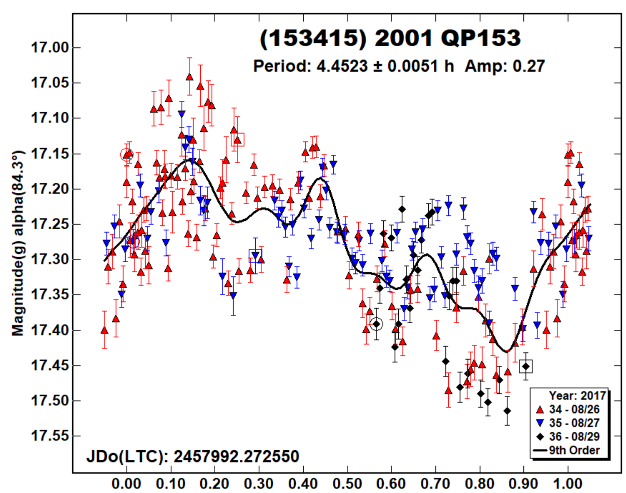
Warner, B.D. (2017). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 July-September." *Minor Planet Bull.* **44**, 22-36.

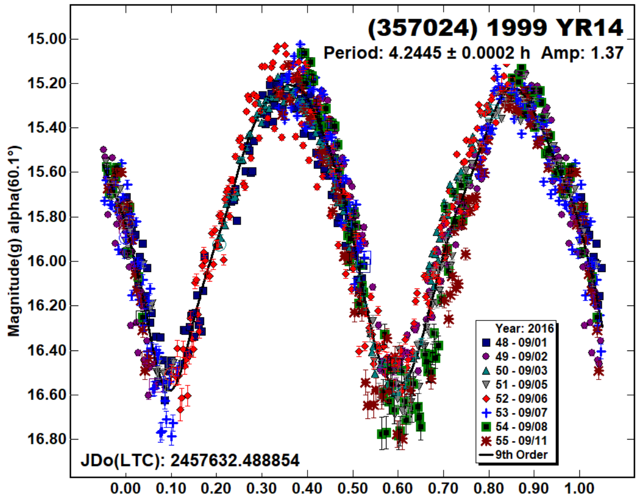
Warner, B.D. (2018). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2017 July through October." *Minor Planet Bull.* **45**, 19-34.

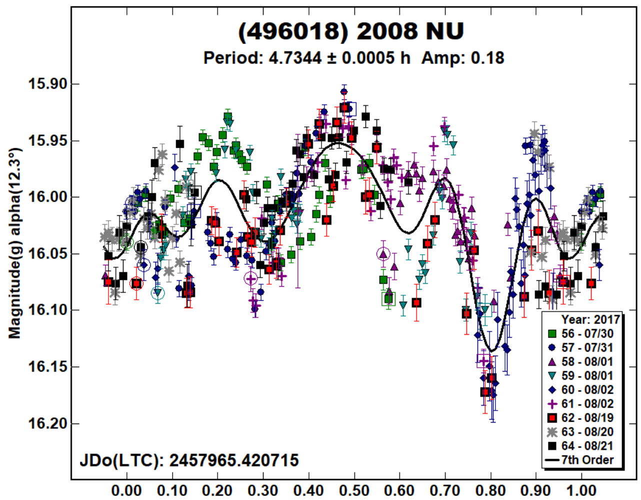


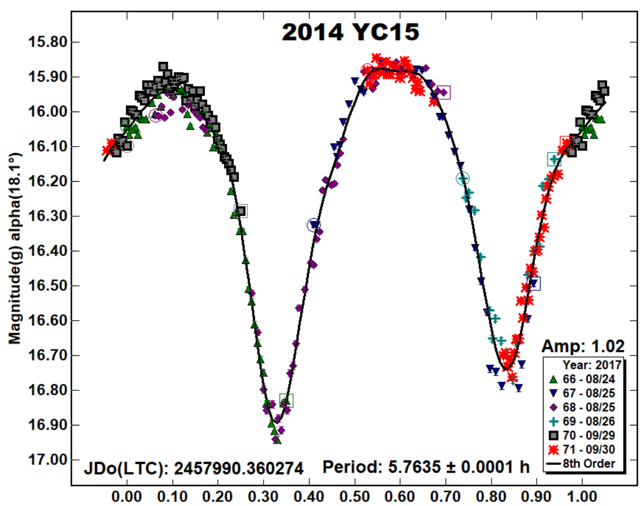












LIGHTCURVES AND ROTATIONAL PERIODS OF FIVE MAIN-BELT ASTEROIDS

Naomi Baxter, Austin Vent, Kent Montgomery, Cheri Davis, Sarah Cantu, Vanessa Lyons
Texas A&M University–Commerce
P.O. Box 3011
Commerce, TX 75429-3011 USA
Kent.Montgomery@tamuc.edu

(Received: 2018 Oct 31)

Lightcurves measurements are reported for five asteroids: 727 Nipponia, 857 Glasenappia, 1551 Argelander, 1676 Kariba, and 2556 Louise. Respectively their rotational periods are found to be 5.070 ± 0.001 h, 8.188 ± 0.006 h, 2.314 ± 0.012 h, 3.168 ± 0.002 h, 3.809 ± 0.001 h.

The purpose of this research was to determine the rotational periods of five main-belt asteroids: 727 Nipponia, 857 Glasenappia, 1551 Argelander, 1676 Kariba, and 2556 Louise. Photometric data taken over several nights were used to create lightcurves which were then analyzed to determine the rotational period and inverted to predict a shape. The asteroids were chosen because of their opposition date, declination, and apparent magnitude. Asteroids with negative declinations were selected for the southern hemisphere telescope, and the asteroids with positive declination were chosen for the northern hemisphere telescopes. For optimum signal-to-noise, asteroids with a magnitude of 16 and brighter were selected. To maximize the number of images per night, the asteroids were all observed within a week of their opposition date.

The following discovery and orbital information were taken from the JPL Small Bodies Node (JPL, 2018). 727 Nipponia was discovered by A. Massinger at Heidelberg in 1912. It has an orbital eccentricity of 0.105 and a semi-major axis of 2.566 AU. 857 Glasenappia was discovered by S. Belyavskij at Simeis in 1916. It has an orbital eccentricity of 0.088 and a semi-major axis of 2.190 AU. 1551 Argelander was discovered by Y. Vaisala at Turku in 1938. It has an orbital eccentricity of 0.066 and a semi-major axis of 2.394 AU. 1676 Kariba was discovered by C. Jackson in Johannesberg in 1939. It has an orbital eccentricity of 0.186 and a semi-major axis of 2.235 AU. 2556 Louise was discovered by N.G. Thomas at Flagstaff in 1981. It has an orbital eccentricity of 0.037 and a semi-major axis of 2.163 AU.

Three separate telescopes were used in this study. Two are part of the Southeastern Association of Research and Astronomy (SARA) Consortium. The telescope at SARA North is 0.9-m with an Apogee CCD camera and is located in Arizona at the Kitt Peak National Observatory (KPNO). SARA South is a 0.6-m telescope with an FLI CCD camera; it's located at the Cerro Tololo Inter-American Observatory (CTIO) in la Serena, Chile. The third telescope, a Meade 0.41-m LX200 Schmidt-Cassegrain with an SBIG CCD camera, was used at the Texas A&M University-Commerce Observatory in Commerce, Texas.

The images were reduced with flat, dark, and bias calibration images that were taken each night. The flat field images were taken against the twilight sky. The darks were exposed for the same duration as the respective light images, three minutes for all three telescopes. The SARA-North telescope used an IR-Blocking filter. At SARA-South, a Luminance-5 filter was used. The Texas

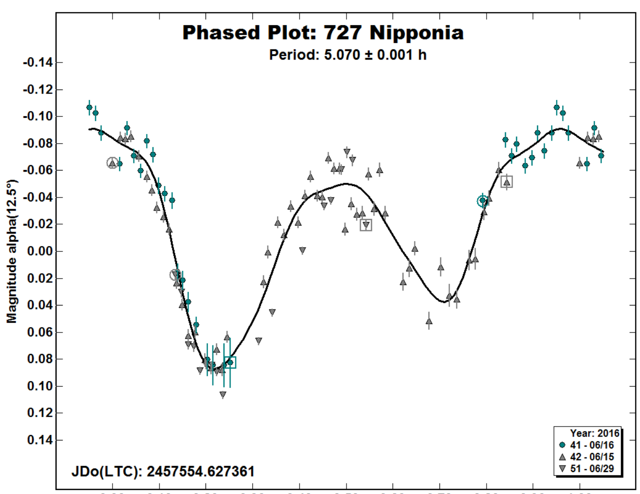
A&M University-Commerce telescope used an IR-Cutoff filter. All three transmit visible light but block the infrared.

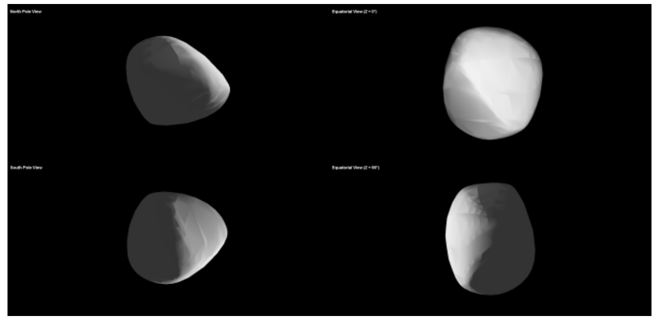
The program *MaximDL* was used to reduce and align the images. Afterward, the program *MPO Canopus* v10.2.1.0 (Warner, 2011) was used to perform differential photometry on the reduced data. For each data set, five stars were used as comparison light sources to the asteroid. Aperture photometry was used to determine the brightness of these comparison stars and the asteroid. The average difference in magnitude between the comparison stars and the asteroid was found for each image. This difference was then plotted versus time to create a lightcurve. A Fourier transform was then applied to the lightcurve to determine the rotational period and associated error.

In order to produce the asteroid models, the processed *MPO Canopus* files were exported to *MPO LCInvert* (Warner, 2011), which uses code based on Kaasalainen et al. (2001a; 2001b). Using this program, a rotational period with the lowest chi-squared value was found, indicating best fit. For all five asteroids, the resulting sidereal rotational periods were within ± 0.01 h of the synodic lightcurve periods, which gives credence to the accuracy of the 3D models. In addition, the model lightcurves very closely match the actual lightcurves. However, because the solar phase angle variation is limited, the actual shapes may vary from the ones found in this study.

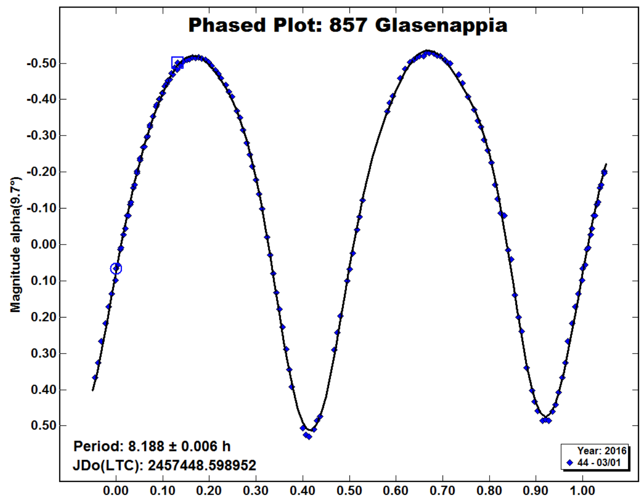
In the shape models below, the left-hand images are from above the north and south poles of the asteroid. The right-hand images are in the asteroid's equatorial plane at 0° and 90° Z-axis rotation.

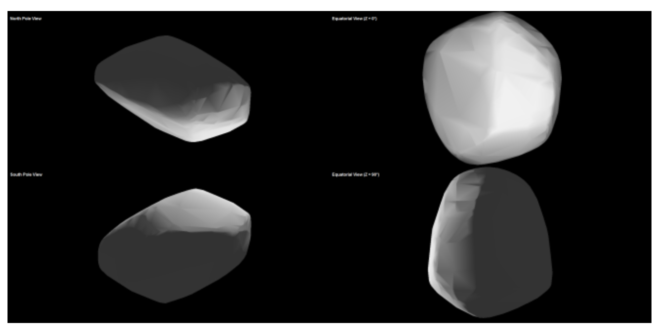
727 Nipponia. This asteroid was imaged 57 times on 2016 June 14, 30 times on June 15, and 23 times on June 29. All three nights used the A&M Commerce telescope. Analysis of the data gave a rotational period of 5.070 ± 0.001 h and amplitude of 0.22 mag. This period agrees with the period of 5.07 ± 0.01 h found by Kim et al. (2014) but it disagrees with the period of 4.6 ± 0.1 h found by Florczak et al. (1997).



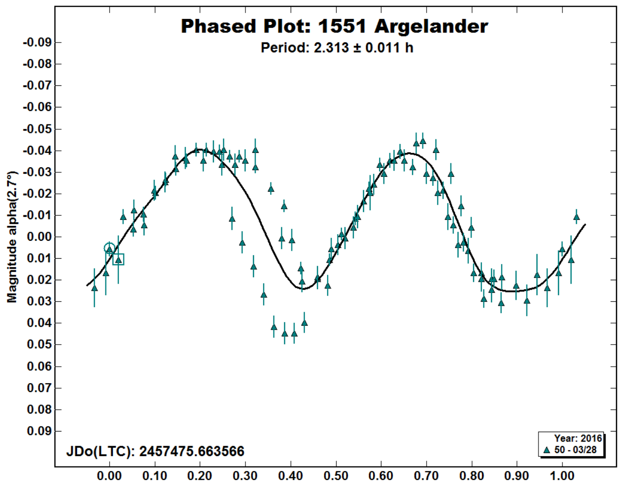


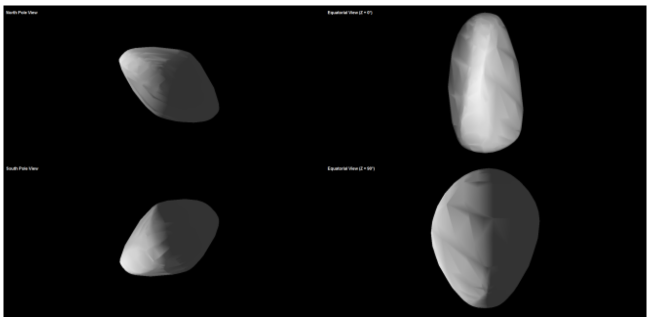
857 Glasenappia was imaged 172 times on 2016 March 1 with the SARA-North telescope. Analysis of the data found a synodic rotational period of 8.188 ± 0.006 h and amplitude of 1.00 mag. Even though only one night of observations was obtained, the lightcurve shows a clear period. A previous study (Lagerkvist et al., 1998) found a nearly identical rotational period of 8.23 h with no error listed.



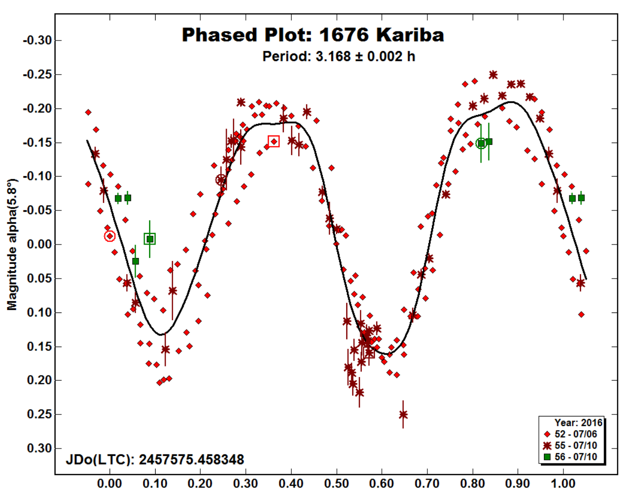


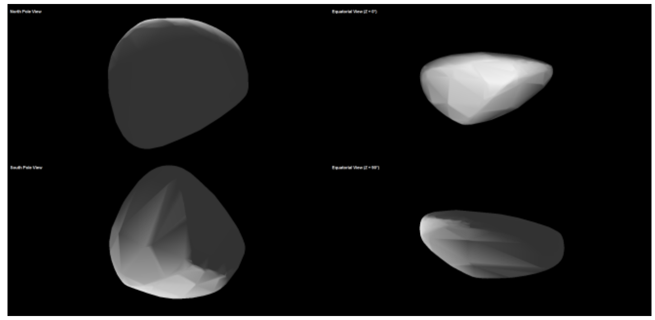
1551 Argelander. A total of 124 images were taken on 2016 March 28 using the SARA North telescope. The resulting data led to a rotational period of 2.213 ± 0.011 h and amplitude of 0.08 mag. Even though observed on only one night, the lightcurve showed more than two full rotations. Our result does not agree with Waszczak et al. (2015), who found a period of 4.0614 ± 0.0023 h. The difference is likely due to their sparse data set.



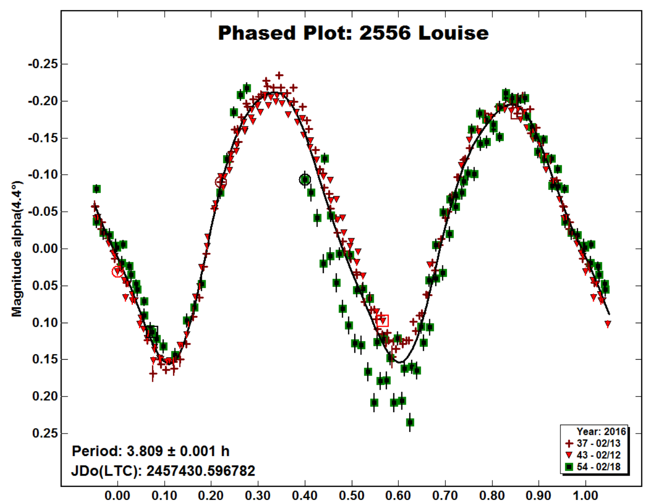


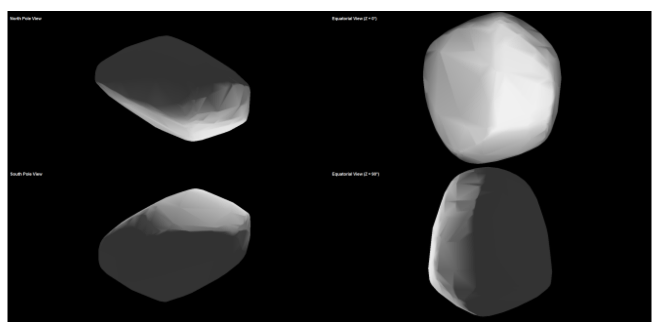
1676 Kariba. This asteroid was imaged 190 times on 2016 July 6 and 109 times on July 10. Both nights used the SARA South telescope. The resulting lightcurve produced a rotational period of 3.168 ± 0.002 h and amplitude of 0.45 mag. A previous study (Higgins and Warner, 2009) found a similar period of 3.1673 ± 0.0003 h.





2556 Louise. Louise was imaged 172 times on 2016 February 12, 183 times on February 13, and 121 times on February 18. All three nights used the SARA-North telescope. Analysis of the data found a rotational period of 3.809 ± 0.001 h and amplitude of 0.46 mag. Two previous studies found similar rotational periods. Alkema (2013) reported results of 3.809 ± 0.001 h and amplitude of 0.36 mag. Klinglesmith et al. (2016) found a period of 3.808 ± 0.002 h and amplitude of 0.35 mag.





Number	Name	2016/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
727	Nipponia	06/14-06/29	11.9,15.9	240	17	5.070	0.001	0.22	0.03	EUN
857	Glasenappia	03/01-03/01	9.6	143	6	8.188	0.006	1.00	0.01	FLOR
1551	Argelander	03/28-03/28	2.6	185	5	2.213	0.011	0.08	0.02	MB-I
1676	Kariba	07/06-07/10	5.9,7.3	281	-7	3.168	0.002	0.45	0.05	FLOR
2556	Louise	02/12-02/18	3.6,7.2	137	1	3.809	0.001	0.46	0.05	FLOR

Table I. Observing circumstances. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). Grp is the family or group (Warner et al., 2009). EUN: Eunomia; FLOR: Flora; MB-I: Inner Main-belt.

Acknowledgements

This work was done as a part of the REU program in Physics and Astronomy at Texas A&M University-Commerce funded by National Science Foundation grant PHY- 1359409.

References

Alkema, M.S. (2013). "Asteroid Lightcurve Analysis at Elephant Head Observatory: 2012 November - 2013 April." *Minor Planet Bull*. **40**, 133-137.

Florczak, M., Dotto, E., Barucci, M.A., Birlan, M., Erikson, A., Fulchignoni, M., Nathues, A., Perret, L., Thebault, P. (1997). "Rotational properties of main belt asteroids: photoelectric and CCD observations of 15 objects." *Planet. Space Sci.*. **45**, 1423-1435.

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

Higgins, D., Warner, B.D. (2009). "Lightcurve Analysis at Hunters Hill Observatory and Collaborating Stations - Autumn 2009." *Minor Planet Bull.* **36**, 159-160.

JPL (2018). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Kaasalainen, M., Torppa, J. (2001a). "Optimization Methods for Asteriod Lightcurve Inversion. I. Shape Determination." *Icarus* **153**, 24-36.

Kaasalainen, M., Torppa, J., Muinonen, K. (2001b). "Optimization Methods for Asteriod Lightcurve Inversion. II. The Complete Inverse Problem." *Icarus* **153**, 37-51.

Klinglesmith III, D.A., Hendrickx, S., Madden, K., Montgomery, S. (2016). "Asteroid Lightcurves from Estcorn Observatory." *Minor Planet Bull*. **43**, 234-239.

Lagerkvist, C.I., Belskaya, I., Erikson, A., Schevchenko, V., Mottola, S., Chiorny, V., Magnusson, P., Nathues, A., Piironen, J. (1998). "Physical studies of asteroids. XXXIII. The spin rate of M-type asteroids." *Astron. Astrophys. Suppl.* **131**, 55-62.

Kim, M.-J., Choi, Y.-J., Moon, H.-K., Byun, Y.-I., Brosch, N., Kaplan, M., Kaynar, S., Uysal, O., Guzel, E., Behrend, R., Yoon, J.-N., Mottola, S., Hellmich, S., Hinse, T.C., Eker, Z., Park, J.-H. (2014). "Rotational Properties of the Maria Asteroid Family." *Astron. J.* **147**, A56.

Warner, B.D. (2011). *MPO Canopus* software V10.2.1.0. Bdw Publishing. *http://bdwpublishing.com/*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

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.

CCD PHOTOMETRY OF SIX RAPIDLY ROTATING ASTEROIDS

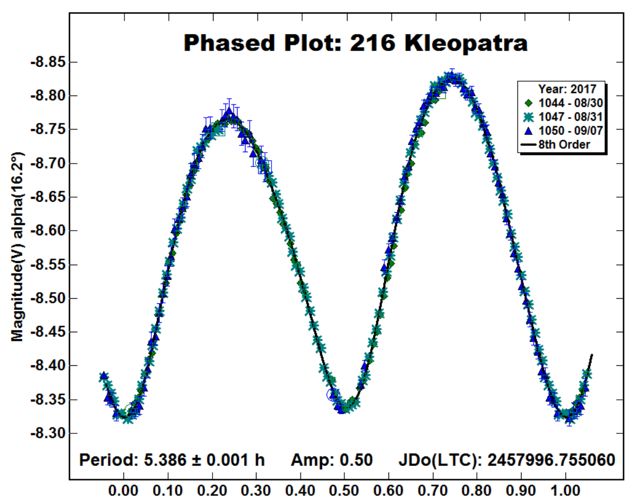
Kevin B. Alton
70 Summit Ave, Cedar Knolls, NJ 07927
kbalton@optonline.net

(Received: 2018 Nov 12)

Fourier analysis of ccd-based photometric data has led to the determination of synodic periods for the asteroids 216 Kleopatra (5.386 h), 218 Bianca (6.339 h), 276 Adelheid (6.320 h), 694 Ekard (5.922 h), 1224 Fantasia (4.995 h), and 1627 Ivar (4.796 h)

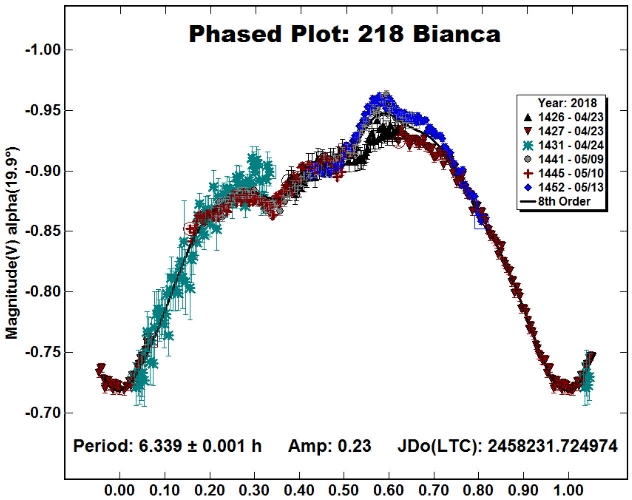
Photometric data from six rapidly rotating minor planets collected at UnderOak Observatory (UO: Cedar Knolls, NJ) and Desert Bloom Observatory (DBO: Benson, AZ) in 2017 and 2018 are reported herein. CCD image acquisition, calibration, registration and data reduction at both sites has been described elsewhere (Novak and Alton 2018; Alton 2018). In all cases, photometric data were subjected to Fourier period analysis (FALC; Harris *et al.* 1989) in order to produce a best fit folded lightcurve.

216 Kleopatra, a main belt M-type asteroid was first discovered in 1880 by J. Palisa. Due to its "dogbone" shape (217 km x 94 km x 71 km) (Ostro *et al*., 2000) it can produce large lightcurve (LC) amplitudes. A total of 275 values (V-passband; 75 s) were acquired between Aug 30 2017 and Sep 7 2017 at DBO; the best fit lightcurve corresponded to a synodic period of 5.386 ± 0.001 h. This rotational period is consistent with literature values most recently reported by Alton, 2009; Kaasalainen and Viikinkoski, 2012, and Shevchenko *et al*., 2014, Novak and Alton, 2018 along with other unpublished lightcurve data referenced at the JPL Solar System Dynamics website (http://ssd.jpl.nasa.gov/sbdb.cgi). During this apparition the minimum to maximum peak amplitude was mid-range (A=0.50) compared to those previously observed (0.12 – 1.22) for this system.

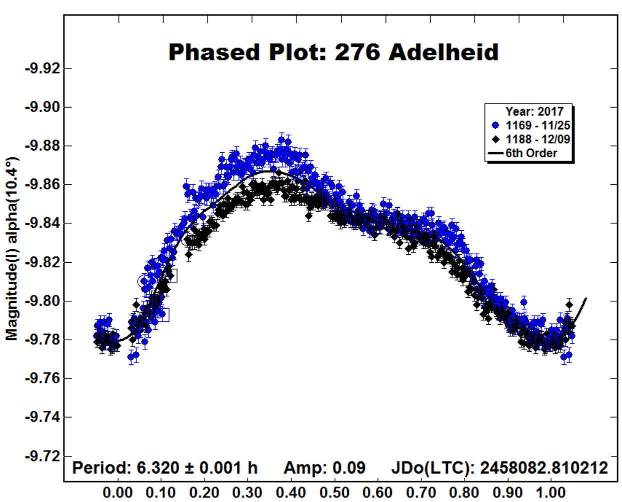


218 Bianca is a moderately sized (~60 km) main belt S-type asteroid discovered in 1880 by J. Palisa. The first lightcurve was published by Carlsson and Lagerkvist (1981) in which they proposed a period of 6.432 ± 0.144 h. Harris and Young (1989) and multiple other investigators since then (Kryszczyńska *et al*., 1996; Fauerbach and Bennett, 2005; Shevchenko *et al*., 2016) reported more accurate periods which are closely corroborated by

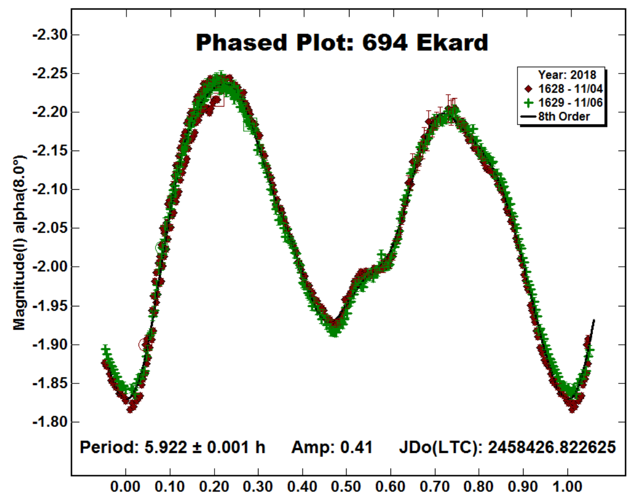
the period determined from the study reported herein. A physical model for 218 Bianca was derived by the lightcurve inversion method revealing its asymmetric shape (Ďurech *et al.*, 2007). A total of 603 values (clear; 75 s) were acquired between Apr 23 2018 and May 13 2018 at UO. The best fit lightcurve corresponded to a synodic period of 6.339 ± 0.001 h. The minimum to maximum peak amplitude (A=0.23) was near the maximum range (0.05 – 0.27) previously observed for this system.



276 Adelheid is an intermediate size (~122 km) main belt X-type asteroid discovered in 1888 by J. Palisa. The first published rotational period assessment by Dotto *et al.*, 1992 produced a value (6.328 ± 0.005 h) which is remarkably consistent with values reported by multiple investigators since then (Piironen *et al.*, 1994; Di Martino *et al.*, 1995; Pray, 2005; Sada, 2006). Physical models for 276 Adelheid were proposed by the lightcurve inversion method revealing its angular shape (Marciniak *et al.*, 2007; Ďurech *et al.*, 2011). During the 2017 apparition, the minimum to maximum peak amplitude (A=0.09) was near the minimum range of values (0.07 – 0.17) previously reported for this system. A total of 679 values (I_c; 75 sec) were acquired at DBO between Nov 25 2017 and Dec 9 2017. The best fit lightcurve corresponded to a synodic period of 6.320±0.001 h, a value consistent with published findings.



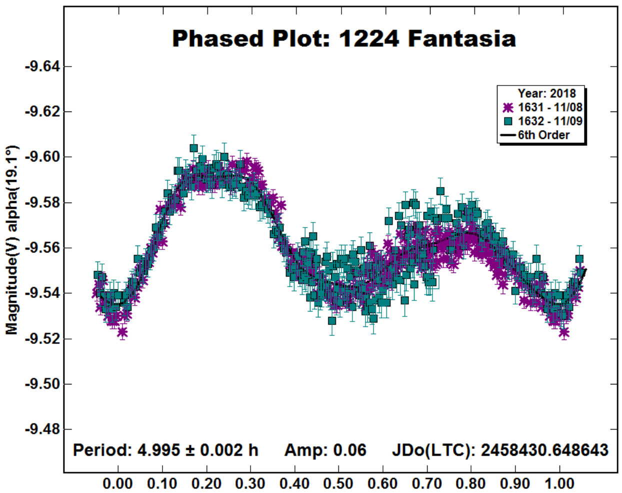
694 Ekard, a CP-type main belt asteroid (d=90.8 km), was discovered in 1909 by the American astronomer J. H. Metcalf. The first published rotational period assessment by Ziegler, 1984 produced a value (5.925 h) which has remained consistent with results reported by multiple investigators since then (Zeigler and Florence, 1985; Hainaut-Rouelle *et al.*, 1995; Chiorny *et al.*, 2007). A physical model for 694 Ekard was initially proposed by De Angelis, 1995 but then further refined using the lightcurve inversion method (Torppa *et al.*, 2003). A total of 626 values (I_c; 75 s) were acquired at DBO between Nov 4 2018 and Nov 6 2018. The best fit lightcurve corresponded to a synodic rotational period of (5.922±0.001 h), a value consistent with published findings. The minimum to maximum peak amplitude (A=0.41) during the 2018 apparition, was closer to the maximum range of values (0.2 – 0.5) previously reported for this system.



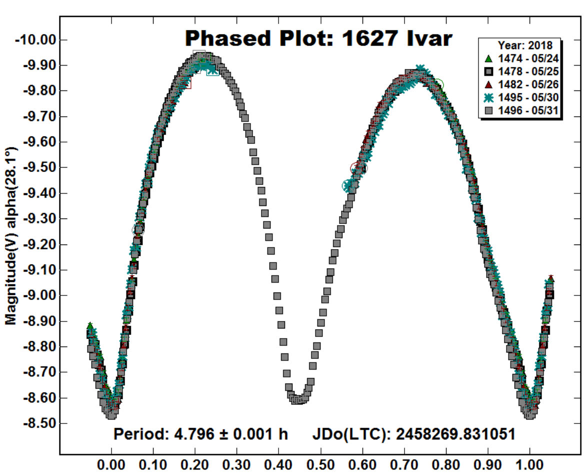
1224 Fantasia, a small (13.8 km) but rather bright (p_V=0.264) S-type main belt asteroid, was co-discovered in 1927 by S. Belyavskij, S. and N. Ivanov. The first published lightcurve (Barucci *et al.*, 1984) was highly variable and did not produce a reliable value for the rotational period. Other than lightcurve and period data posted at the Observatoire de Genevè (http://obswww.unige.ch/~behrend/page3cou.html#001224) no other data on this system have been published in the literature. A total of 570 values (clear; 75 s) were acquired at DBO between Nov 8 2018 and Nov 9 2018. The best fit lightcurve corresponded to a synodic rotational period of (4.995±0.002 h), a value consistent with findings from the Observatoire de Genevè. During this apparition, the lightcurve peak amplitude (A=0.06) was less than the minimum range of previously observed values (0.09 – 0.47).

Number	Name	mm/dd/yy	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
216	Kleopatra	08/30/17-09/07/17	275	16.2, 18.3	303	16	5.386	0.001	0.50	0.02	MB-O
218	Bianca	04/23/18-05/13/18	603	19.9, 23.4	168	3	6.339	0.001	0.23	0.02	EUN
276	Adelheid	11/25/17-12/09/17	679	10.4, 14.2	34	-5	6.320	0.001	0.09	0.02	MB-O
694	Ekard	11/04/18-11/06/18	626	8.0, 8.8	31	6	5.922	0.001	0.41	0.02	MB-M
1224	Fantasia	11/08/18-11/09/18	570	19.1, 19.5	19	9	4.995	0.002	0.06	0.02	FLOR
1627	Ivar	05/24/18-05/31/18	733	28.1, 33.0	227	19	4.796	0.001	1.34	0.02	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).



1627 Ivar (1929 SH) is an S-type near-Earth asteroid (d=9.12 km) discovered in 1929 by E. Hertzsprung. The first published rotational period assessment by Harris and Young, 1985 produced a value (4.8 h) which is consistent with results produced by multiple investigators since then. This includes investigations by Chernova et al., 1995; Kiss *et al*., 1999; Skiff *et al*., 2012; and Warner, 2014; 2015. A "somewhat banana-shaped" physical model for 1627 Ivar was proposed by Kaasalainen *et al*., 2004 and then later refined using radar and lightcurve shape modeling (Crowell *et al*., 2017). A total of 733 values (clear; 75 s) were acquired at DBO between May 24 2018 and May 31 2018. The best fit lightcurve corresponded to a synodic rotational period of (4.796±0.001 h), a value consistent with other published findings. The minimum to maximum peak amplitude (A=1.34) during the 2018 apparition, was closer to the maximum range of values (0.25 – 1.4) previously reported for this system.



Acknowledgements

Many thanks to the staff who support the SAO/NASA Astrophysics Data System, the JPL Small-Body Database Browser, and the asteroid lightcurve database (LCDB; Warner *et al.*, 2009), all of which were essential to locating relevant data and literature references.

References

Alton, K.B. (2009). "CCD lightcurve analysis of 216 Kleopatra." *Minor Planet Bulletin* **36**, 69.

Alton, K.B. (2018). "Multicolor Light Curves and Period Analysis of IL Cnc." *Information Bulletin on Variable Stars* **63**, 1.

Barucci, M.A., Di Martino, M. (1984). "Rotational rates of very small asteroids: 123 Brunhild, 376 Geometria, 437 Rhodia and 1224 Fantasia." *Astron. Astrophys. Suppl. Ser.* **57**, 103-106.

Carlsson, M., Lagerkvist, C.-I. (1981). "Physical studies of asteroids. I: Photoelectric observations of the asteroids 38, 218, 268, 344, 485, 683, and 792." *Astron. Astrophy. Suppl. Ser.* **44**, 15-22.

Chernova, G.P., Kiselev, N.N., Krugly, Y.N., Lupishko, D.F., Shevchenko, V.G., Velichko, F.P. (1995). "Photometry of Amor asteroids 1036 Ganymede and 1627 Ivar." *Astron. J.* **110**, 1875-1878

Chiorny, V.G., Shevchenko, V.G., Krugly, Y.N., Velichko, F.P., Gaftonyuk, N.M. (2007). "Photometry of asteroids: Lightcurves of 24 asteroids obtained in 1993-2005." *Planet. Space Sci.* **55**, 986-997.

Crowell, J.L., Howell, E.S., Magri, C., Nolan, M.C., Fernández, Y.R., Richardson, J.E., Warner, B.D., Marshall, S.E., Springmann, A.,Vervack, R.J. Jr. (2017). "Radar and lightcurve shape model of near-Earth asteroid (1627) Ivar." *Icarus*, **291**, 254-267.

De Angelis, G. (1995). "Asteroid spin, pole and shape determinations." *Planet. Space Sci.* **43**, 649-682.

Di Martino, M., Dotto, E., Celino, A., Barucci, M.A., Fulchignoni, M. (1995). "Intermediate size asteroids: Photoelectric photometry of 8 objects." *Astron. Astrophy. Suppl. Ser.* **112**, 1-7.

Dotto. E. Rotundi, A., de Sanctis, M.C. (1992). "Rotational properties of small asteroids; 1992 observational results." *Observations and Physical Properties of Small Solar System Bodies, Proceedings of the Liege International Astrophysical Colloquium 30, June 24-26, 1992, Institut d'Astrophysique, Liege.* Edited by A. Brahic, J.-C. Gerard, and J. Surdej. Liege: Universite de Liege, Institut d'Astrophysique, 211.

Ďurech, J., Kaaslainen, M., Marciniak, W.H., and 29 other colleagues (2007). "Physical models of ten asteroids from observers' collaboration network." *Astron. Astrophy.* **465**, 331-337.

Ďurech, J., Kaaslainen, M., Herald, D., Dunham, D., Timerson, B., Hanuš, J., Frappa, E., Talbot, J., Hayamizu, T., Warner, B.D., Pilcher, F., Galád, A. (2011). "Combining asteroid models derived by lightcurve inversion with asteroidal occultation silhouettes." *Icarus* **214**, 652-670.

Fauerbach, M., Bennett, T. (2005). "Photometric lightcurve observations of 125 Liberatrix, 218 Bianca, 423 Diotime, 702 Alauda, 1963 Bezovec, and (5849) 1990 HF1." *Minor Planet Bulletin* **32**, 80-81.

Hainaut-Rouelle, M.-C., Hainaut, O.R., Detal, A. (1995). "Lightcurves of selected minor planets." *Astron. Astrophy. Suppl. Ser.* **112**, 125-142.

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

Harris, A.W., Young, J.W. (1985). "Photometric results for Earth approaching asteroids." *Bull. Amer. Astron. Soc.* **17**, 726.

Harris, A.W., Young, J.W. (1989). "Asteroid lightcurve observations from 1979-1981." *Icarus* **81**, 314-364.

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

Kaasalainen, M., Pravec, P., Krugly, Y.N. and 19 other colleagues (2004). "Photometry and models of eight near-Earth asteroids." *Icarus*, **167**, 178-196.

Kaasalainen, M., Viikinkoski, M. (2012). "Shape reconstruction of irregular bodies with multiple complementary data sources." *Astron. Astrophys*. **543**, A97.

Kiss, L.L., Szabó, Gy., Sárneczky, K. (1999). "CCD photometry and new models of 5 minor planets." *Astron. Astrophy. Suppl. Ser.* **140**, 21-28.

Kryszczyńska, A., Colas, F., Bertheir, J., Michałowski, T. (1996). "CCD Photometry of Seven Asteroids: New Spin Axis and Shape Determinations." *Icarus* **124**, 134-140.

Marciniak, A., Michałowski, T., Kaasalainen, M., Ďurech, J., Polińska, M., Kwiatkowski, T., Kryszczyńska, A., Hirsch, R., Kamiński, K., Fagas, M., Colas, F., Fauvaud, S., Santacana, G., Behrend, R., Roy, R. (2007). "Photometry and models of selected main belt asteroids IV. 184 Dejopeja, 276 Adelheid, 556 Phyllis." *Astron. Astrophy.* **473**, 633-639.

Novak, R., Alton, K.B. (2018). "Lightcurve Analysis of 216 Kleopatra." *Minor Planet Bulletin*, **45**, 243.

Ostro, S.J., Scott, R., Hudson, Nolan, M.C., Margot, J.-L., Scheeres, D.J., Campbell, D.B., Magri, C., Giorgini, J.D., Yeomans, D.K. (2000). "Radar observations of asteroid 216 Kleopatra." *Science* **288,** 836-839.

Piironen, J., Bowell, E., Erikson, A., Magnusson, P. (1994). "Photometry of eleven asteroids at small phase angles." *Astron. Astrophy.Suppl. Ser.* **106**, 587-595.

Pray, D.P. (2005). "Lightcurve analysis of Asteroids 276, 539, 1014, 1067, 3693 and 4774." *Minor Planet Bulletin* **32**, 8-9.

Sada, P.V. (2006). CCD photometry of asteroids 276 Adelheid, 1490 Limpopo, and 2221 Chilton from the Universidad de Monterrey Observatory." *Minor Planet Bulletin* **33**, 78-79.

Shevchenko, V.G., Velichko, F.P., Checha, V.A., Krugly, Y.N. (2014). "Photometric study of selected asteroids." *Minor Planet Bulletin* **41**, 195-198.

Shevchenko, V.G, Belskaya, I.N., Muinonen, K., Penttilä, A., Krugly, Y.N., Velichko, F.P., Chiorny, V.G., Slyusarev, I.G., Gaftonyuk, N.M., Tereschenko, I.A., (2016). "Asteroid observations at low phase angles. IV. Average parameters for the new H, G_1, G_2 magnitude system.*" Planet. Space Sci.* **123**, 101-106.

Skiff, B.A., Bowell, E., Koehn, B.W., Sanborn, J.J., McLelland, K.P., Warner, B.D. (2012). "Lowell Observatory near-Earth asteroid photometric survey (NEAPS) – 2008 May through 2008 December." *Minor Planet Bulletin* **39**, 111-130.

Torppa, J., Kaasalainen, M., Michałowski, T., Kwiatkowski, T., Kryszczyńska, A., Denchev, P., Kowalski, R. (2003). "Shapes and rotational properties of thirty asteroids from photometric data." *Icarus* **164**, 346-383.

Warner, B.D. (2014). "Near-Earth asteroid lightcurve analysis at CS3-Palmer Divide Station: 2013 June-September." *Minor Planet Bulletin* **41**, 41-47.

Warner, B.D. (2015). "Near-Earth asteroid lightcurve analysis at CS3-Palmer Divide Station: 2015 January-March." *Minor Planet Bulletin* **42**, 172-183.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

Zeigler, K.W. (1984). "Photoelectric photometry of asteroid 694 Ekard." *Minor Planet Bulletin* **11**, 21-22.

Zeigler, K.W., Florence, W.B. (1985). "Photoelectric photometry of asteroids 9 Metis, 18 Melpomene, 60 Echo, 116 Sirona, 230 Athamantis, 694 Ekard, and 1984 KD." *Icarus* **62**, 512-517.

PATTERN OF MINOR PLANET NUMBERS VERSUS CUMULATIVE NUMBER OBSERVED

Andrew Salthouse
560 Heritage Road, Millington NJ 07946 USA
asalthouse@hotmail.com

(Received: 2018 Aug 31)

The author finds that as the cumulative number of minor planets that are visually observed increases, several effects are noticed. The author examines the pattern of assigned minor planet numbers observed versus the total number of distinct objects seen.

The author visually observed about 2900 minor planets over a period of several decades (Salthouse, 2019). As the number of distinct objects seen continued to increase, certain patterns emerged. One of these was the manner in which the distribution of minor planet numbers related to the total number observed.

In the following discussion let *N* be the total number of distinct objects observed. Let *Q* be the number of minor planets observed whose assigned minor planet number *n* is less than or equal to *N*. Also let *R* be the number of minor planets observed whose assigned minor planet number *n* is greater than *N* (including those without assigned numbers). Then $Q + R = N$. Thus, the number of objects with $n \leq N$ *not* seen must equal *R*. We wish to analyze the behavior of *Q* and *R* and their relation to *N*.

The author tracked the ratio of *Q* to *N* over a wide range of *N* and observed that it approached an asymptote around 79% as *N* increased, until about *N* = 1800 in the autumn of 2007. Figure 1 shows how the ratio *Q/N* approached the asymptote as more and more observations were collected. The data have been binned into 18 sets of 100 each.

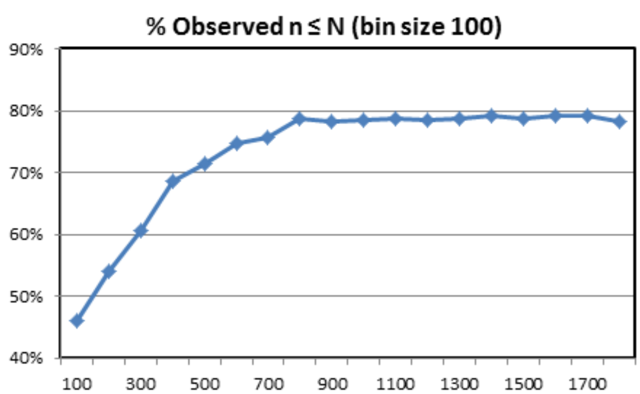


Figure 1. The ratio of Q/N up to N = 1800, in increments of 100 each.

In the late summer of 2007, the author acquired a new telescope with better limiting magnitude. He added an additional 1100 distinct new objects over the next eleven years, bringing total *N* up to 2900. He observed that the ratio *Q/N* declined during this time, and appeared to approach a new asymptote closer to 72%. Figure 2 shows how the ratio *Q/N* changed during the last 1100 new additions. The data have been binned into 29 sets of 100 each.

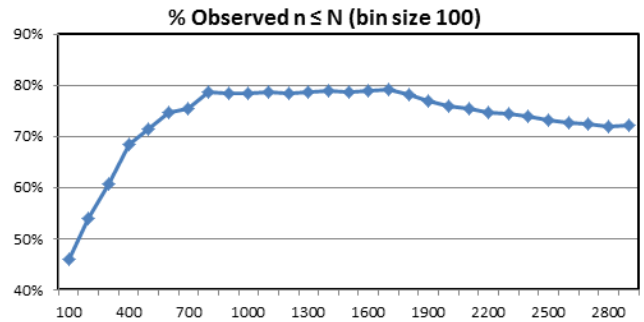


Figure 2. The ratio of Q/N up to N = 2900, in increments of 100 each. Note the change in pattern after the author acquired a new telescope around N = 1800.

This leads to two hypotheses.

- As an observer with a given aperture observes an ever larger set of distinct objects, the ratio of *Q/N* will approach an asymptote (as would *R/N*).
- This asymptote will be smaller for larger apertures.

If the first hypothesis is roughly correct, then the second makes intuitive sense. At larger apertures, there is a much larger set of available targets with higher assigned numbers, whereas at smaller apertures the set of available targets is much smaller, generally limited to lower numbered objects.

The author would be very interested to learn whether other visual observers with large data sets have noted a similar pattern, and he encourages them to share their findings. Potentially we could learn how the asymptotic ratio of *Q/N* depends on aperture, or on limiting magnitude.

If an asymptote exists for each given telescope, the implications are intriguing. Among other things, it implies some sort of large-scale distribution of minor planet magnitudes relative to their assigned numbers.

No equipment other than telescope and eyeball were employed in collecting this data (no CCD or photo technology). Using such technologies would likely produce very different results.

The author is unaware of prior published research on this topic. A search of the last twenty years of *Minor Planet Bulletin* issues did not reveal any articles of a similar nature.

Acknowledgements

The author thanks Mr. Brian Warner for providing the Minor Planet Observer suite of products and services (Warner, 2019), without which this work would have been impossible. He also thanks Ms. Mary Ellen Salthouse for the gift of a 45-cm reflector in the summer of 2007.

References

Salthouse, A. (2019). "Visual Observation of Minor Planets." *Minor Planet Bulletin* **46**, 5-7.

Warner (2019). Minor Planet Info website. *http://www.MinorPlanet.info*

LIGHTCURVE ANALYSIS OF ASTEROIDS FROM BMO AND DRO IN 2016. II.

Julian Oey
Blue Mountains Observatory (MPC Q68)
94 Rawson Pde. Leura, NSW, AUSTRALIA
and
Perth Observatory
Perth, WA AUSTRALIA
julianoey1@optusnet.com.au

Roger Groom
Darling Range Observatory
Perth, West Australia

(Received: 2018 Nov 21 Revised: 2019 Feb 27)

Photometric observations of selected asteroids were done from Blue Mountains Observatory (BMO), Perth Observatory (PO), and Darling Range Observatory (DRO) in 2016. The observations were made during a favorable apparition for each asteroid. Most of these objects were selected from a list of targets that matches the criteria for binary asteroids.

CCD photometric observations were made in 2016 from Blue Mountains Observatory (BMO) and remotely at Perth Observatory (PO) by Oey. The observations from Darling Range Observatory (DRO) were made by Groom. Table I describes the equipment that was used. Further information of the instruments used at BMO can be found at its website (BMO, 2016).

Obs	Scope	Ap (m)	*f*	Camera	Pixel	Bin	Scale
DRO	D12	0.30	7.4	ST-8XME	9.0	1x1	0.84
BMO	B14	0.35	6.0	ST-8XME	9.0	1x1	0.88
BMO	B24	0.61	6.8	U42	13.5	1x1	0.70
BMO	B14E	0.35	11.0	U6	24.0	1X1	1.28
PO	P14	0.35	6.1	ST-10XME	7.4	1X1	0.66

Table I. Equipment specifications. The Scope column gives the code used in Table II. Pixels sizes are in microns. Scale is arcsec/pixel. BMO = Blue Mountains Observatory. DRO = Darling Range Observatory. PO = Perth Observatory.

Images taken with telescopes B14 and D12 were unfiltered with exposures of 300 s to maximize SNR but at the same time provide enough data points for the more common rotational periods of main-belt asteroids. Images taken with B24, B14E, and P14 were unfiltered with exposures ranging from 120 to 180 s.

The raw data from BMO (B14), and DRO were reduced with a library of flats, darks, and bias frames using *CCDSoft V5*. The raw images from BMO (B24 and B14E) and Perth Observatory were processed using *Maxim DL V6*.

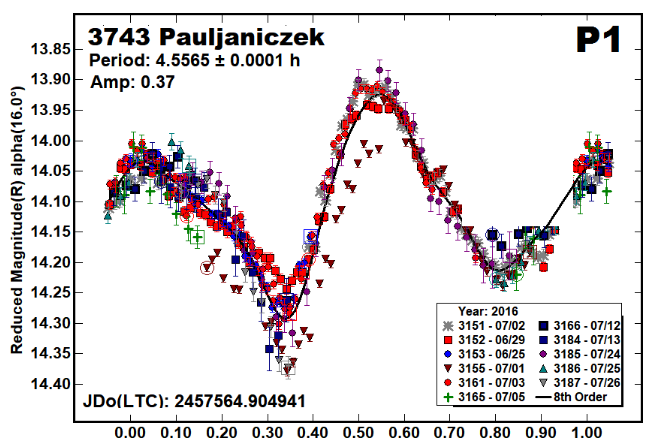
All data measurement and reduction were done using *MPO Canopus* V10. The period analysis used the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* or APASS (Henden *et al.*, 2009) catalogs. When insufficient catalog stars were found, MPOSC3 catalog stars were used. The comparison stars used Cousins R magnitudes that were converted from 2MASS J-K values (Warner, 2007). This resulted in an internal consistency of < 0.05 mag. Due to interstellar reddening, the MPOSC3 has significant systematic errors and so some zero-point adjustments were required.

Most of the targets in this paper were observed to support the Photometric Survey of Asynchronous Binary Asteroids (PSABA; Pravec, 2016). Unless stated otherwise, the description, processes, and rationale for observing each object was described in Oey et al. (2015). Table II shows the absolute magnitude (*H*), the asteroid family, and the instruments used for each asteroid.

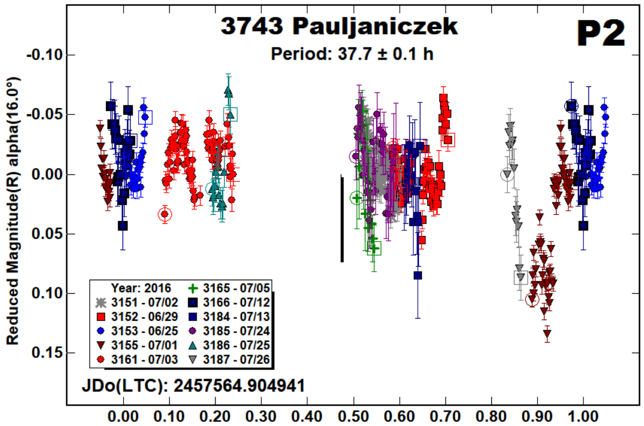
Number	H	Group	Comment
3743	13.7	FLOR	B24, D12
4689	13.2	FLOR	B14, B24
5940	11.9	MB-O	B14, D12, B24
6097	13.3	FLOR	B14, B24, PO14
6488	12.8	MB-I	B24
8078	14.2	MB-I	B24
9583	14.6	PHO	B14
10301	14.5	FLOR	B24
11873	13.7	FLOR	B24, B14
12867	13.7	FLOR	B14, B24
15202	14.2	MB-I	B14
17325	14.9	FLOR	B24, B14
18851	14.3	MB-I	B14, D12
19711	13.7	PHO	B14, B24, D12
36524	14.7	MB-I	B24, D12
37586	13.5	PHO	B14, B24, D12
44142	15.5	MB-I	B24, B14
57292	13.8	MB-O	B14, D12
65433	15.5	MC	B14, B24, P14
93259	15.8	MB-I	B24
94346	14.2	PHO	B14, B14E, D12, P1B24
181081	15.4	MB-O	B24
327649	17.8	FLOR	B24

Table II. The *H* values are from the MPC. The orbital groups are from the LCDB (Warner et al., 2009). MB-I/O: Main-belt Inner/Outer, FLOR: Flora, MC: = Mars-crossing, PHO: Phocaea

3743 Pauljaniczek was observed as part of the PSABA project. The nightly zero point was adjusted so that each session could be matched to the internal accuracy of the APASS catalogue (0.01-0.02 mag).

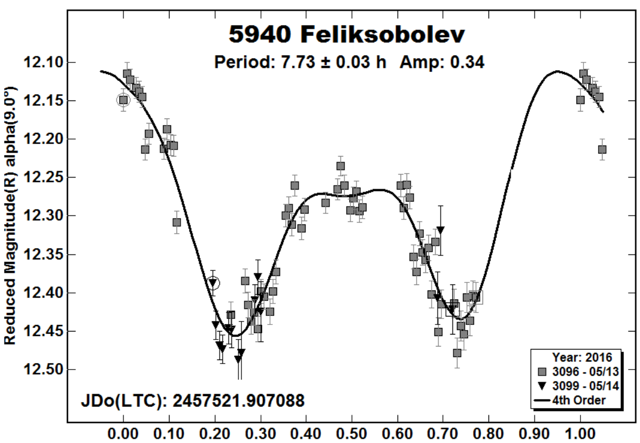


A total of 390 data points were used. "P1" shows the lightcurve with a single period. The attenuations are similar to those caused by a satellite. The dual-period search method in *MPO Canopus* was used to detect a secondary period ("P2") by subtracting the primary period from the data before doing the period search.

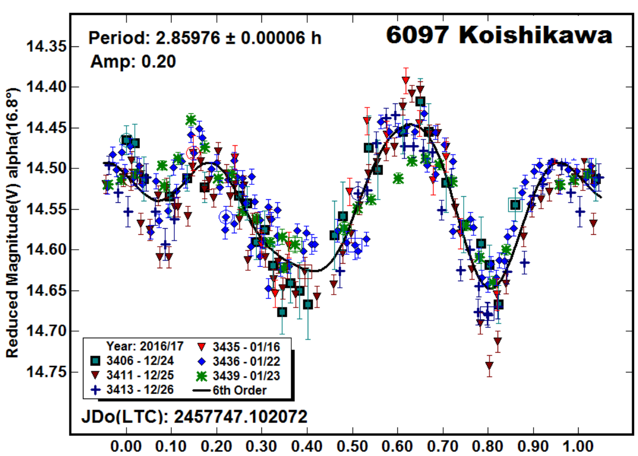


The assumed event was captured twice at phase 0.90 in “P2”. The first event on July 1 is deeper than the one on July 26, making it more reliable. No other events were captured to confirm that it was binary.

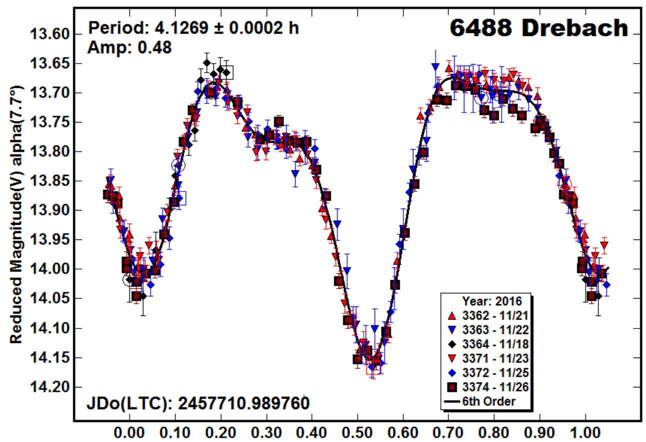
5940 Feliksobolev was previously studied by Warner (2011), who obtained a period of 7.62 h. That is slightly faster than the current study. The lightcurve does not cover the whole period even though data were obtained over two consecutive nights.



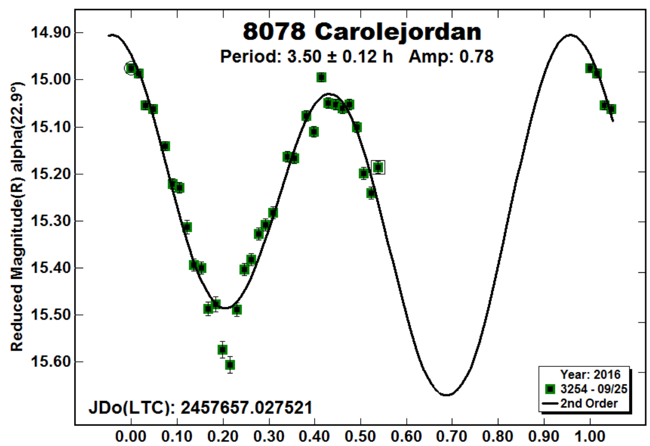
(6097) Koishikawa was selected as a “prime suspect” for beomg a binary asteroid after being previously observed in 2010 (Pravec, 2016). The new result is consistent with Pravec’s 2.85979 h.



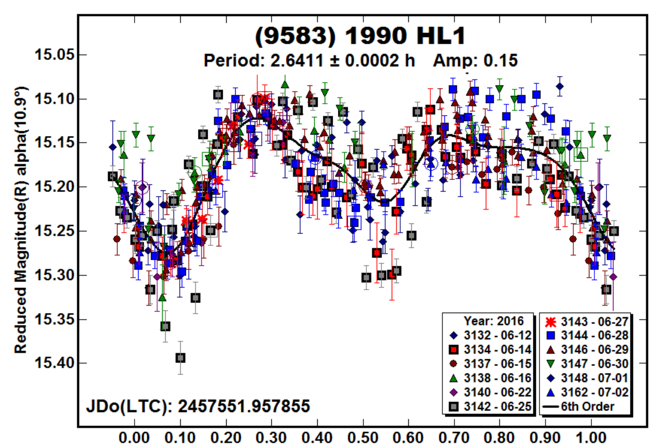
6488 Drebach was observed as part of the PSABA project.



(8078) Carolejordan was a target of opportunity that was in the same field as (2100) Ra-Shalom. The rotation period had not been determined before. Due to the incomplete lightcurve, and despite the large amplitude of 0.78 mag, the period of 3.5 h should be used only as a guide.

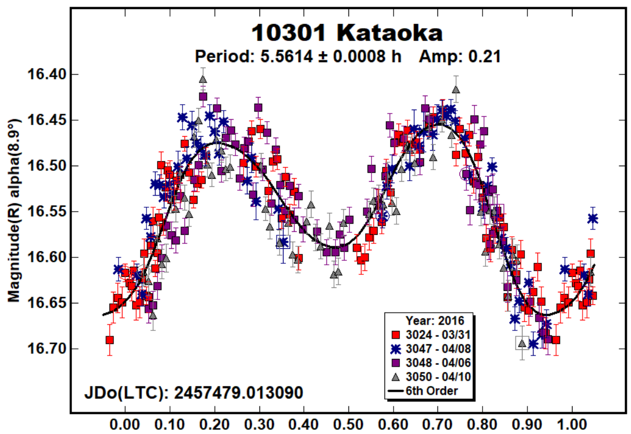


(9583) 1990 HL1 was selected from the PSABA target list since there had been no reported studies form the past. The observations were made as the asteroid was receding, so the data could not be refined further.

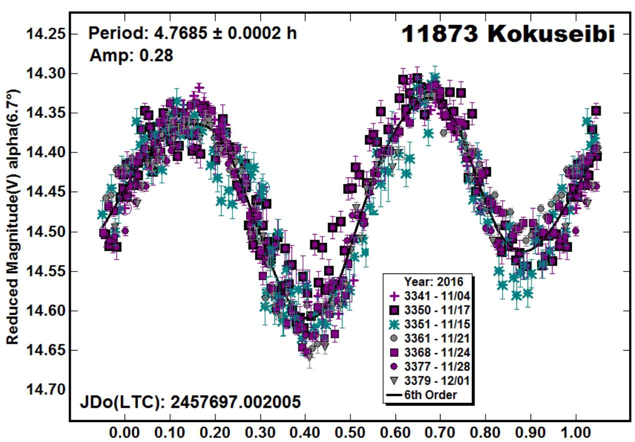


There was an attenuation detected on June 25. Despite the relatively long observing sessions on June 29 and July 3, no additional attenuations were detected, making this asteroid a "prime suspect" that should be observed at a future apparition.

10301 Kataoka had no previously reported period. A member of the Flora family in the inner main-belt, it was part of the PSABA target list. No deviations were seen. However, being a binary cannot be excluded since the viewing geometry may not have allowed seeing mutual events.

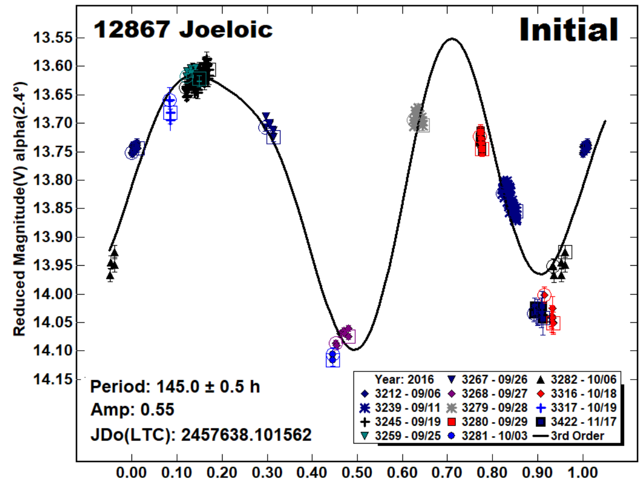


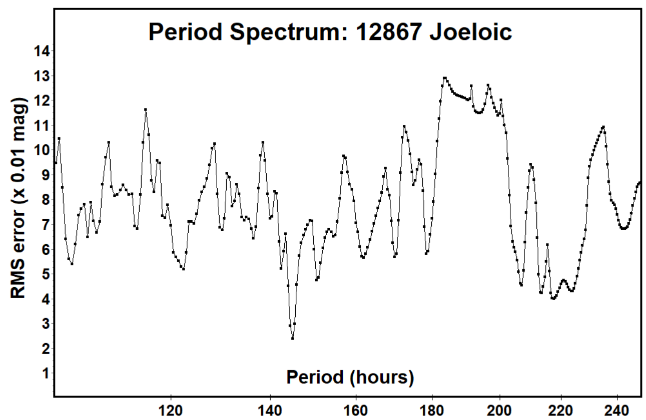
11873 Kokuseibi was selected from PSABA targets. It is an inner main-belt asteroid belonging to the Flora family. Prior to this campaign, no rotation periods had been published. The recent observations showed no significant deviations of the lightcurve.

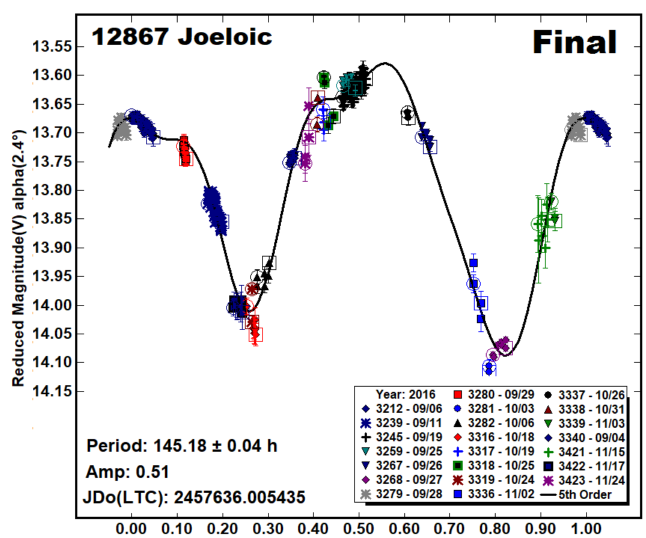


12867 Joeloic, an inner main-belt asteroid of the Flora family, was another PSABA target. Its lightcurve period was not immediately apparent. An initial group of sessions showed either a very gradual brightening or dimming of about 0.05 mag over the 5 to 8 hours for each session. The next group, which was added to make a total of 13 sessions, had starting and ending points along with sparse points obtained during each session of 5-8 hours. The slopes in the group were checked against the lightcurve ("Initial") to make sure they all matched. No adjustments were made to the zero points for the period search, which found a period of 145 h.

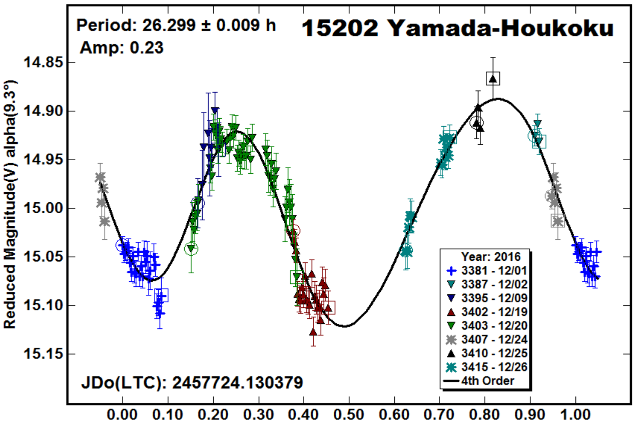
Additional sessions containing only a few data points each were included. The original period of about 145 h remained. Nightly zero points were adjusted to arbitrarily match the model lightcurve. Adjustments ranged from 0.1-0.5 mag; this is far beyond the accuracy of the catalogue stars used to obtain the final lightcurve ("Final"). The reason for the unusually large magnitude adjustments was likely due to non-photometric conditions.



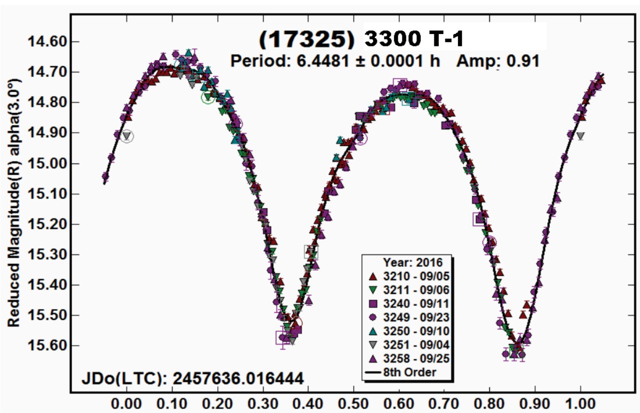




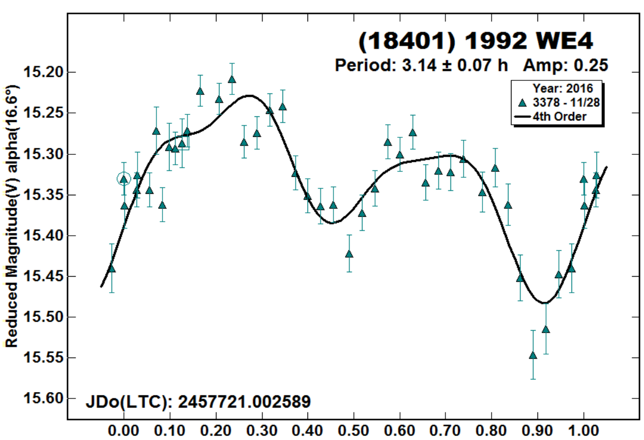
15202 Yamada-Houkoku was a PSABA target selected after the asteroid has passed opposition. Unfortunately, when a low amplitude target has a moderate to long rotation period, observations should start prior to opposition. This maximizes the length of each lightcurve segment, which can eventually allow an accurate determination of the rotation period. The period of 26.299 h was one of serval possible solutions. Follow-up observations at future apparitions, especially if starting well before opposition, are encouraged.



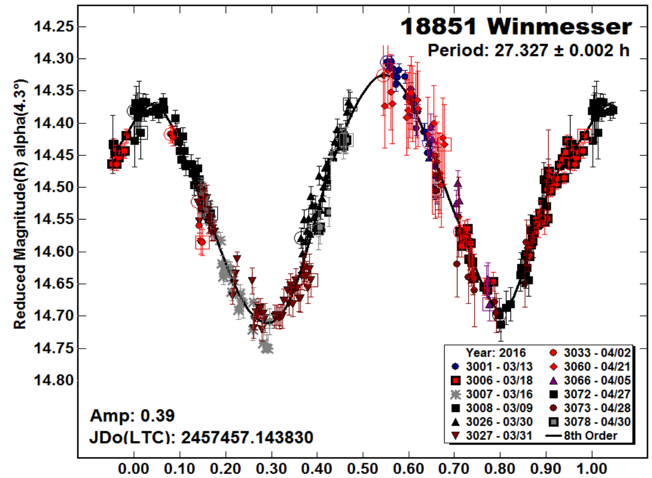
(17325) 3300 T-1 was a PSABA target. It is another Flora family member in the inner main-belt. Despite less than double coverage of the lightcurve between rotation phase 0.9 to 1.0, the large 0.91 mag amplitude indicated that the period was secure (Harris et al., 2014).



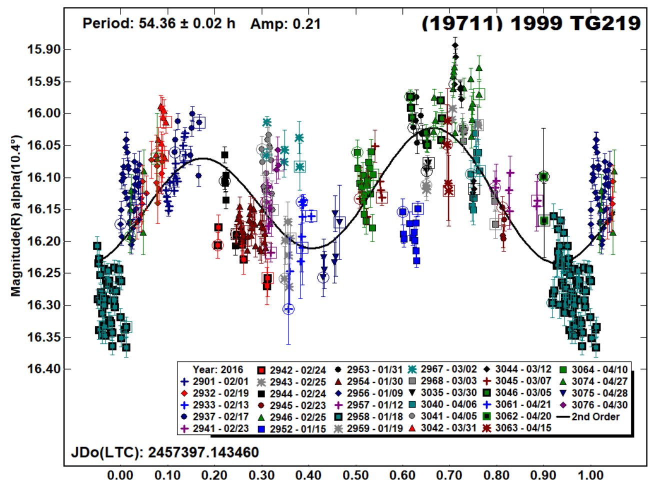
(18401) 1992 WE4. No previous period results were found. This was a target of opportunity within the same field as 3352 McAuliffe. Only a single night of data was obtained. The period reported here is not secure but can be used as a guide in the future.



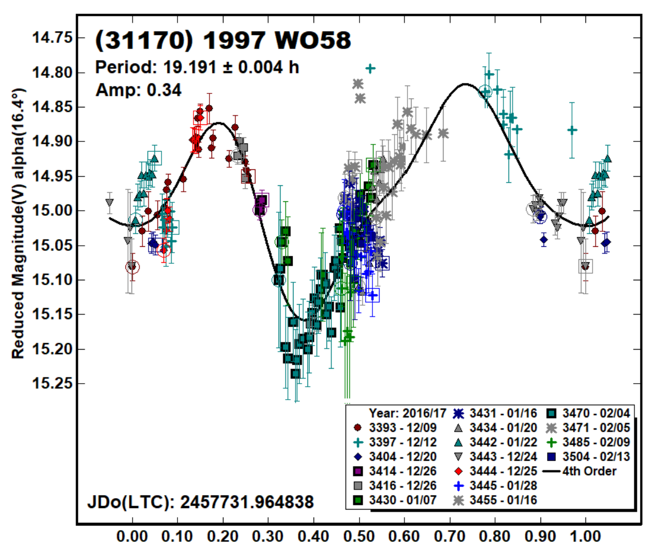
18851 Winmesser is an inner main-belt asteroid; the rotation period had not been determined before. The lightcurve was plotted with zero-point adjustments to the data from April 21, 27, 28, and 30. These allowed matching them to the data from the March observations. A better fit was found using $G = 0$ instead of the default $G = 0.15$ (Peter Kusnirak, private communication).



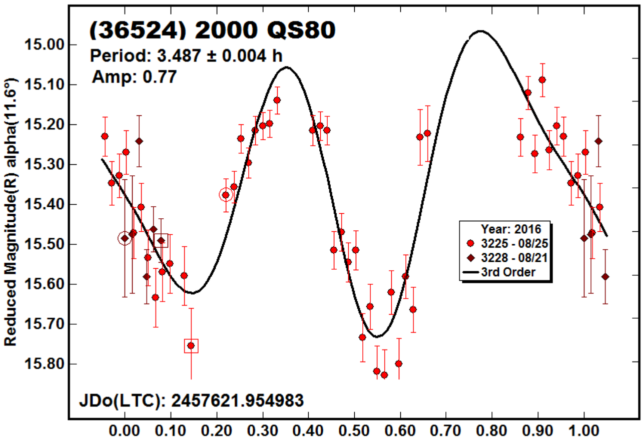
(19711) 1999 TG219 was observed for three months. Finding a period was difficult since the asteroid appeared to be a slow rotator. The changing shape and lack of repeating sections in the lightcurve indicated that the asteroid might be tumbling (Pravec et al., 2005).



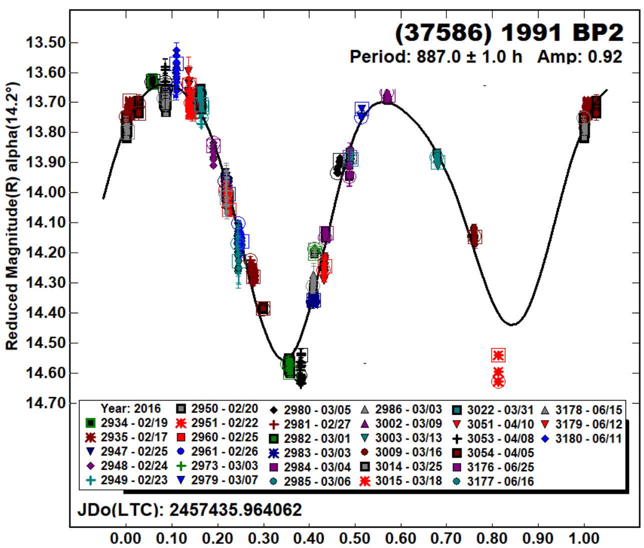
(31170) 1997 WO58 was a PSABA target. All sessions were reduced as described previously, except for 2016 Dec 9 and 2017 Jan 20. The zero points for those sessions were shifted by 0.5 mag.



(36524) 2000 QS80 was a target of opportunity in the same field as 5481 Kiuchi. No previous periods were found. Despite the short run on Aug 21 and single coverage of the lightcurve on Aug 25, the 3.487 h period is reliable due to the large amplitude.



(37586) 1991 BP2 was a target selected for PSABA. This extremely slow rotating asteroid was followed in a four-month campaign that covered just more than three rotations. There was a slight deviation from the lightcurve that indicated tumbling, which is typical of long period asteroids (Pravec et al., 2005).

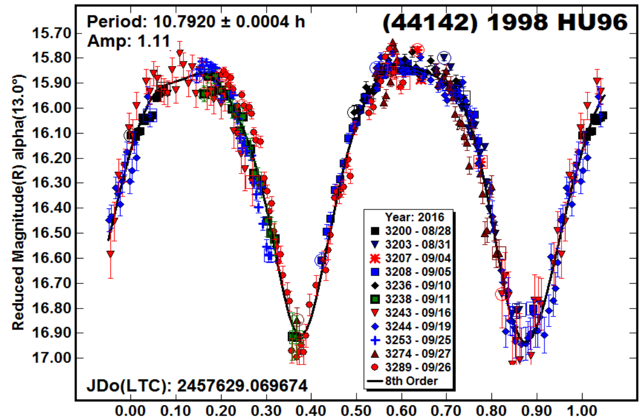


(44142) 1998 HU96 was a PSABA target. There were no previous lightcurve studies found. The bimodal lightcurve with its large amplitude of 1.11 mag indicates a very elongated object. Assuming an equatorial view of the asteroid, the ratio (*a*/*b*) of the two longer axes of a triaxial ellipsoid is given by

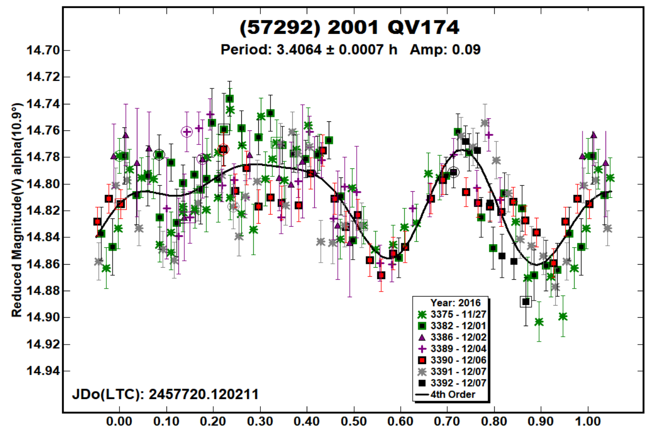
$$a/b = 10^{(\mathrm{Amplitude} * 0.4)} = 2.78:1$$

The axis of rotation (*c*) is fixed at $c = 1.0$.

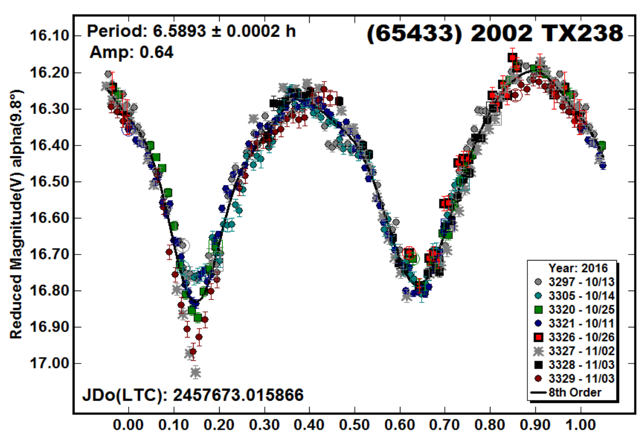
This target was started post-opposition and receded rapidly, preventing a proper analysis for binary signature. In any event, such elongated objects being binary are quite rare.



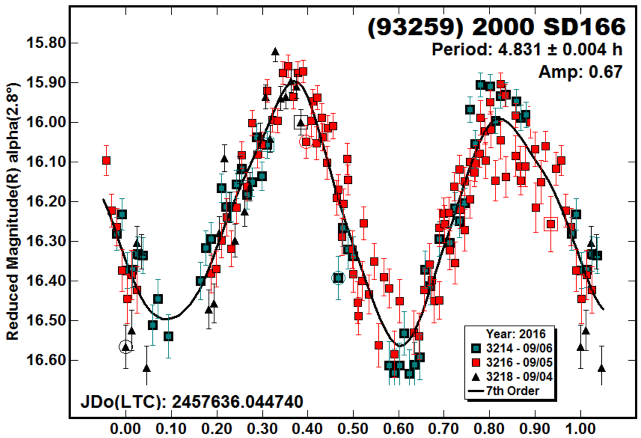
(57292) 2001 QV174 was a PSABA target. A collaborative effort between BMO and DRO was used to find a solution for this difficult low-amplitude target. At a small phase angle of 11°, a small amplitude usually indicates a near spheroidal shape or a close to pole-on viewing aspect.



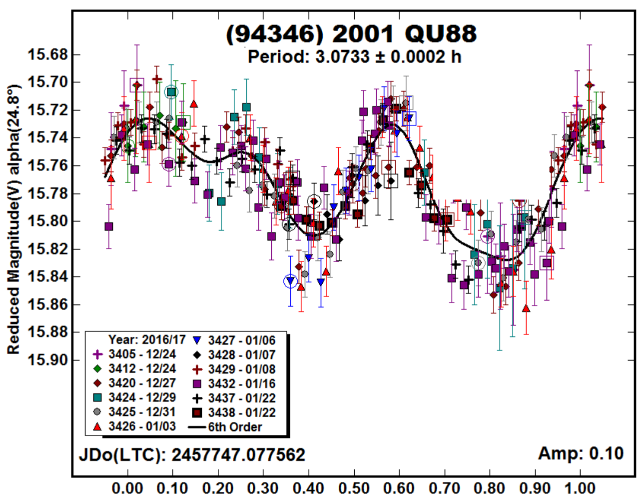
(65433) 2002 TX238 was selected and observed from the list of PSABA targets. The lightcurve is unique with no sign of the asteroid being binary. The deviation of increasing amplitude in the lightcurve at phase 0.15 was due to the well-known phase-amplitude relationship found by Zappala et al. (1990), which is where the amplitude increases with phase angle.



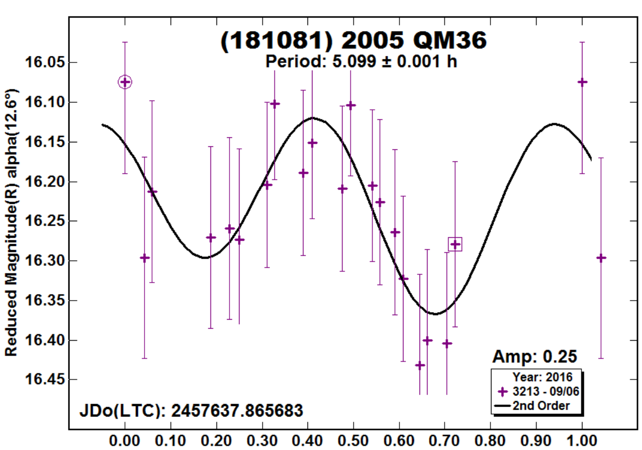
(93259) 2000 SD166. Waszczak et al. (2015) found a period of 4.820 h and amplitude of 0.63 mag. The latest period and amplitude are consistent with those earlier results. This asteroid, along with (181081) 2005 QM36 and (327649) 2006 QT26, were targets of opportunity in the same field as the PSABA target (17325) 1978 QW1. Only 2000 SD166 had a period reported before this work.



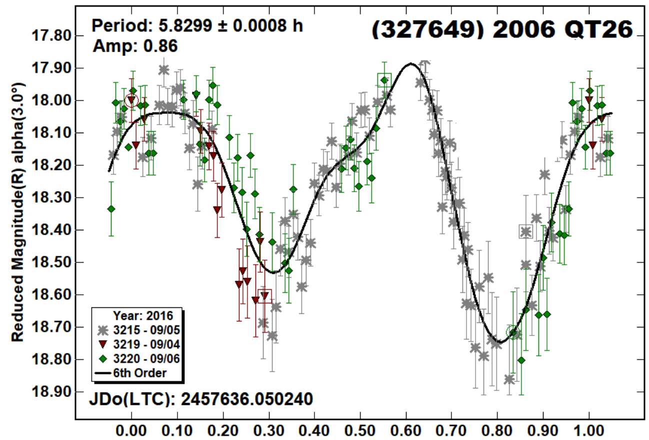
(94346) 2001 QU88 was a PSABA target. Despite the large scatter, a unique period was found. There was nothing seen that could suggest that the asteroid is binary.



(181081) 2005 QM36. The data are from a single night under poor observing conditions. The period given here should be used only as a guide for future observations.



(327649) 2006 QT26. As mentioned previously, this was a target of opportunity in the same field as a PSABA target.



Acknowledgements

The purchase of an Apogee U42 camera was made possible by a 2015 Shoemaker NEO Grant. I would like to recognise and appreciate the work of Petr Pravec and Peter Kusnirak for maintaining the Photometric Survey of Asynchronous Binary Asteroid program that allows the collaborative effort between professional and amateurs. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

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/*)

References

BMO (2016). Blue Mountains Observatory Website. *bluemountainsobservatory.com.au/asteroid/observatory.html*

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

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Number	Name	2016(7) mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3743	Pauljaniczek	06/25-07/26	390	12.5,25.1	260	5	4.5565	0.0001	0.37	0.02
5940	Feliksobolev	05/13-05/14	75	9.0,9.3	208	-1	7.73	0.03	0.34	0.02
6097	Koishikawa	12/24-01/23	253	16.8,4.8	125	-8	2.85976	0.00006	0.20	0.02
6488	Drebach	11/18-11/28	227	6.9,9.3	50	-11	4.1269	0.0002	0.48	0.02
8078	Carolejordan	09/25	33	22.9	325	2	3.5	0.1	0.78	0.02
9583	1990 HL1	06/12-07/03	391	10.9,21.2	256	15	2.6410	0.0002	0.15	0.02
10301	Kataoka	03/31-04/10	270	8.9,3.6	205	3	5.5614	0.0008	0.21	0.02
11873	Kokuseibi	11/04-12/01	520	6.7,16.2	44	-9	4.7685	0.0002	0.28	0.02
12867	Joeloic	09/06-11/24	290	2.4,0,29.7	355	-3	813	3.5	0.71	0.05
15202	Yamada-Houkoku	12/01-12/26	164	9.4,17.4	68	-13	26.299	0.009	0.23	0.05
17325	3300 T-1	09/04-09/25	342	3.0,15.2	340	1	6.4481	0.0001	0.91	0.01
18401	1992 WE4	11/28	40	16.6	38	-9	3.14	0.07	0.25	0.03
18851	Winmesser	03/09-04/30	308	6.0,3.7,22.5	180	-5	27.327	0.002	0.39	0.03
19711	1999 TG219	01/09-04/21	383	16.9,10.4,32.5	145	-15	54.36	0.02	0.21	0.05
31170	1997 WO58	16/12/09-17/02/13	222	16.4,29.6	85	-25	19.191	0.004	0.34	0.02
36524	2000 QS80	08/21-08/25	47	9.8,11.6	309	-2	3.487	0.004	0.77	0.02
37586	1991 BP2	02/19-06/25	936	14.5,30.6	175	-20	887	1	0.92	0.3
44142	1998 HU96	08/28-09/26	359	13.0,25.9	323	3	10.7920	0.0004	1.11	0.02
57292	2001 QV174	11/27-12/07	193	10.9	69	-16	3.4064	0.0007	0.09	0.03
65433	2002 TX238	10/13-11/03	427	10.4,9.7,15.2	24	-10	6.5893	0.0002	0.64	0.02
93259	2000 SD166	09/04-09/06	173	1.8,2.8	339	1	4.831	0.004	0.67	0.03
94346	2001 QU88	16/12/24-17/01/22	304	24.8,17.1	130	-15	3.0733	0.0002	0.10	0.03
181081	2005 QM36	09/06	20	12.6	319	4	5.10	0.01	0.25	0.05
327649	2006 QT26	09/04-09/06	149	2.4,3.6	339	1	5.8299	0.0008	0.86	0.03

Table III. Observing circumstances and results. [P]Period of primary in a (suspected) binary system. Pts is the number of data points. The phase angle is given for the first and last date. If there are three values, the middle value is for the minimum during the range. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

Oey J., Williams H., Groom R., Pray D., Benishek V. (2015). "Lightcurve analysis of binary and potential binary asteroids in 2015". *Minor Planet Bull.* **43,** 200-204.

Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G., Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galád, A., Brown, P., Degraff, D.R., Lambert, J. V., Cooney, W.R., Foglia, S. (2005). "Tumbling asteroids." *Icarus* **173**, 108-131.

Pravec, P. (2016). "Photometric Survey of Asynchronous Binary Asteroids." *http://www.asu.cas.cz/~asteroid/binastphotsurvey.htm*

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

Warner, B.D. (2011). "Upon further review: VI. An examination of previous lightcurve analysis from the Palmer Divide Observatory." *Minor Planet Bull*. **38**, 96-101.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2019 Jan. *http://www.minorplanet.info/lightcurvedatabase.html*

Waszczak, A., Chang, C., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y., Ip, W., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid lightcurves from the Palomar Transient Factory survey: Rotation periods and phase functions from sparse photometry." *Astron. J.* **150**, A75

Zappala, V., Cellino, A., Barucci, A.M., Fulchignoni, M., Lupishko, D.F. (1990). "An analysis of the amplitude-phase relationship among asteroids". *Astron. Astrophys.* **231**, 548-560.

ROTATIONAL PERIOD OF 3677 MAGNUSSON

Angelo Tomassini, Maurizio Scardella, Francesco Franceschini
Fernando Pierri
Associazione Tuscolana di Astronomia (D06)
F. Fuligni Observatory
Via Lazio, 14 - località Pratoni del Vivaro – 00040
Rocca di Papa (RM) – ITALY
nikkor5@gmail.com

(Received: 2018 Dec 10)

The inner main-belt asteroid (3677) Magnusson has been observed over several nights in the late 2018 summer in order to determine its synodic rotation period and amplitude. Lightcurve analysis shows a synodic period P = 7.90 ± 0.01 h with an amplitude A = 0.89 mag.

The main-belt asteroid 3677 Magnusson has been selected from the listing of "Lightcurve Photometry Opportunities" July-September (Warner, 2018). This asteroid, belonging to the Flora family, has been discovered by Edward Bowell in 1984 and is named in honor of Per Magnusson, a planetary astronomer at Uppsala Observatory. All the observations were carried out from F. Fuligni Observatory, using a 0.35-m f/10 Advanced Coma Free telescope and SBIG ST8-XE CCD camera with Bessel R filter and from Franceschini's equipment using a 9.25" f/6.3 reflector telescope equipped with Atik 314L- CCD camera with Astrodon R filter. All images were calibrated with dark frames. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2012).

The derived synodic period was P = 7.90 ± 0.01 h (Fig.1) with an amplitude of A = 0.89 mag.

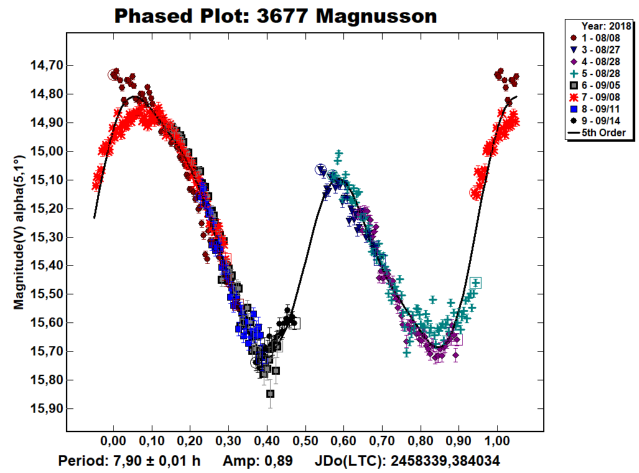


Figure 1.The lightcurve of (3677) Magnusson with a period of 7.90 ± 0.01 h and an amplitude of 0.89 mag.

References

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

Warner, B.D. (2012). MPO Software, Canopus version 10.4.1.9. Bdw Publishing, *http://minorplanetobserver.com/*

Warner, B.D. (2018). "Lightcurve Photometry Opportunities 2018 July-September." *MPB* 45-3.

Number	Name	20xx/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
3677	Magnusson	18/08/08-18/09/14	455	5.3,20.3	319	6	7.90	0.01	0.89	0.10

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

LIGHTCURVE ANALYSIS OF MINOR PLANETS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2018 JANUARY–MARCH

Richard Ditteon
Rose-Hulman Institute of Technology
5500 Wabash Ave., Terre Haute, IN 47803, USA
ditteon@rose-hulman.edu

(Received: 2019 Dec 12)

Beginning 16 January 2018 and continuing through 17 March 2018 a total of seventeen minor planets were target for observation from the Oakley Southern Sky Observatory. Images were taken of 936 Kunigunde, 1281 Jeanne, 1644 Rafita, 1905 Ambartsumian, 2079 Jacchia, 2279 Barto, 2396 Kochi, 2463 Sterpin, 2677 Joan, 2764 Moeller, 3470 Yaronika, 3706 Sinnott, 4181 Kivi, 4628 Laplace, 5079 Brubeck, 7186 Tomioka, and (29934) 1999 JL46.

The Oakley Southern Sky Observatory has a 0.5-m, f/6.7 Planewave telescope with an STX-16803 camera. For this observing campaign the camera was binned 3x3 resulting in a plate scale of 1.63 arcseconds per pixel. A luminance filter was used to take the images.

The observing campaign was carried out in three phases. From 16 January to 21 January images were taken of 2396 Kochi, 2764 Moeller, 3470 Yaronika, 3706 Sinnott, 4628 Laplace, and (29934) 1999 JL46. From 9 March to 17 March the targeted minor planets were: 1905 Ambartsumian, 2279 Barto, 4181 Kivi, 5079 Brubeck, and 7186 Tomioka. Finally, between 18 March and 28 March the targets were 936 Kunigunde, 1291 Jeanne, 1644 Rafita, 2079 Jacchia, 2463 Sterpin, and 2677 Joan. These targets were chosen because they either had a poorly determined period or no period as listed by Warner et al. (2009).

Standard image processing with bias, dark and dome flat images was done using *MaxImDL*. Photometric measurements of the minor planets were done with *Canopus*.

Table I lists the targets, range of dates, phase angle, phase angle bisector longitude and latitude as well as the period if one was determined. I was unable to determine periods for 1644 Rafita, 1905 Ambartsumian, 2396 Kochi, 4181 Kivi, 5079 Brubeck, and 7186 Tomioka because my data were just too noisy.

936 Kunigunde. The period reported here of 8.82 ± 0.02 h is just within experimental uncertainty of the period found by Angeli, et al. (2001) of 8.80 h (no period uncertainty given).

1281 Jeanne. Behrend (2002) found a period of 15.18 ± 0.06 h which is just within the uncertainty range of this reported period of 15.3 ± 0.1 h.

2463 Sterpin. Bembrick and Allen (2006) report a period of 13.44 ± 0.03 h for 2463 Sterpin which agrees with the result reported here of 13.43 ± 0.01 h.

2677 Joan. The period of 16.98 ± 0.02 h found here agrees with the result of Waszczak *et al*. (2015) of a period of 16.97 ± 0.01 h.

2764 Moeller. Waszczak *et al*. (2015) report a period of 5.954 ± 0.002 h for this minor planet which agrees with the newly found result of 5.94 ± 0.03 h.

3706 Sinnott. Waszczak *et al*. (2015) report a period of 4.0379 ± 0.0005 h for 3706 Sinnott which agrees with the period derived from these observation having a value of 4.04 ± 0.01 h.

4628 Laplace. Angeli, *et al.* (1996) found a period of 9.011 ± 0.005 h while Behrend (2004) found a period of 11.105 ± 0.003 h. I tried to fit my data to 11.105 hours, but got a significantly better fit with for a period of 9.00 ± 0.01 h.

References

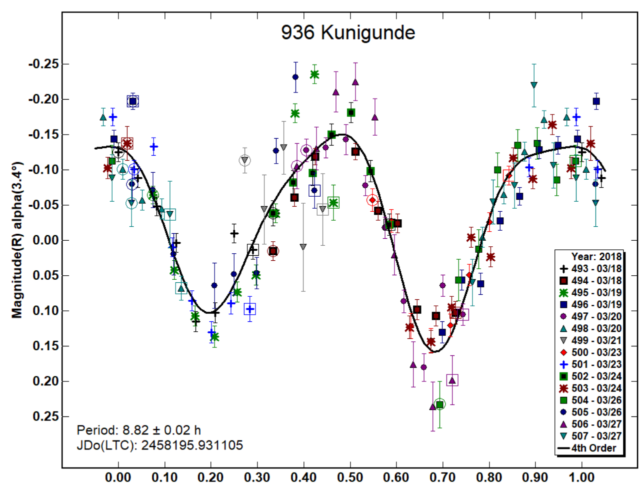
Angeli, C.A., Guimaraes, T.A., Lazzaro, D., Duffard, R., Fernandez, S., Florczak, M., Mothe-Diniz, T., Carvano, J.M., and Betzler, A.S. (2001). "Rotation Periods for Small Main-Belt Asteroids from CCD Photometry." *Astron. J.* **121**, 2245-2252.

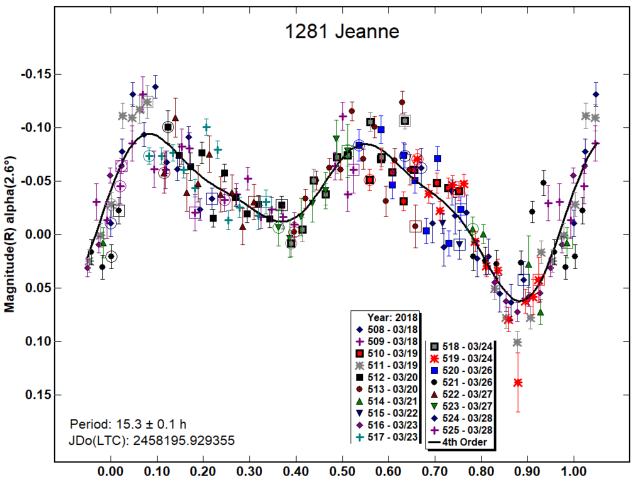
Behrend, R. (2002, 2004). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html*

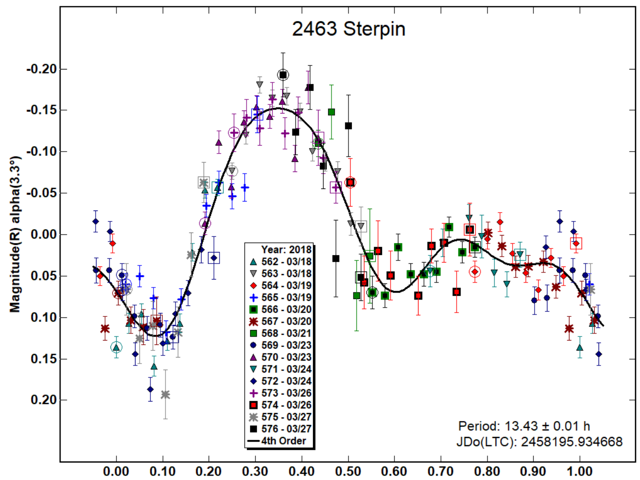
Bembrick, C., Allen, B. (2006). "Rotation Periods for 1427 Ruvuma and 2463 Sterpin." *Minor Planet Bulletin* **33**, 10-11.

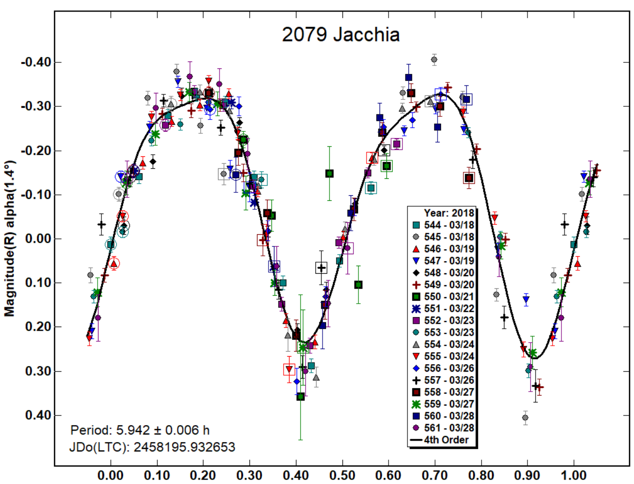
Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2017 Jan. *http://www.minorplanet.info/lightcurvedatabase.html*

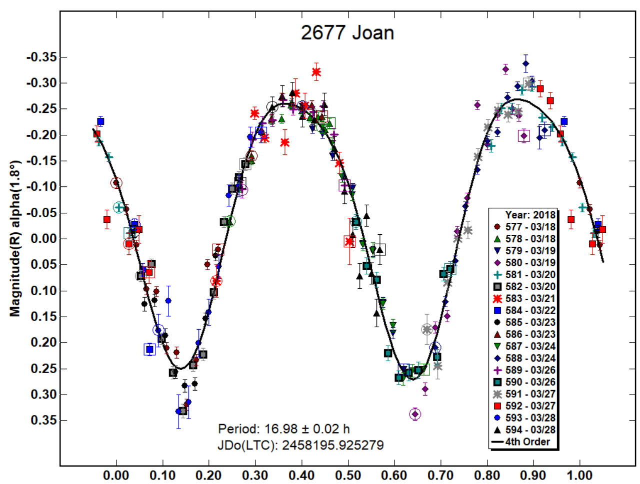
Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry."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

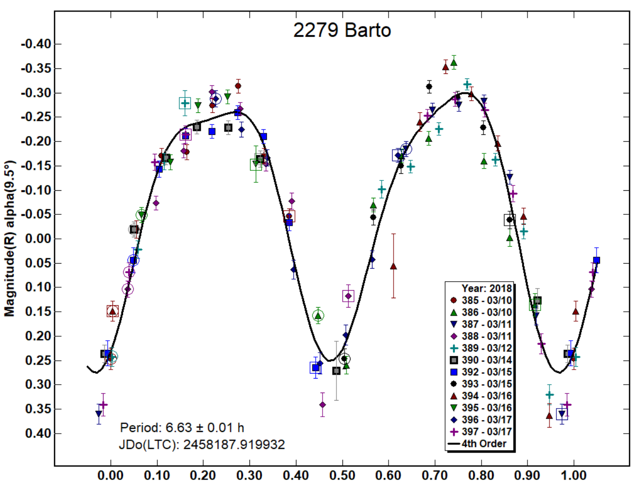


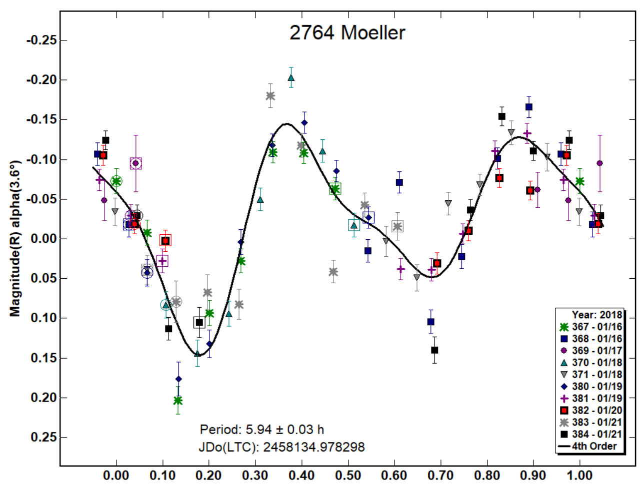

1281 Jeanne
Magnitude(R) alpha(2.6°)
Period: 15.3 ± 0.1 h
JDo(LTC): 2458195.929355
Year: 2018
508 - 03/18
509 - 03/18
510 - 03/19
511 - 03/19
512 - 03/20
513 - 03/20
514 - 03/21
515 - 03/22
516 - 03/23
517 - 03/23
518 - 03/24
519 - 03/24
520 - 03/26
521 - 03/26
522 - 03/27
523 - 03/27
524 - 03/28
525 - 03/28
4th Order

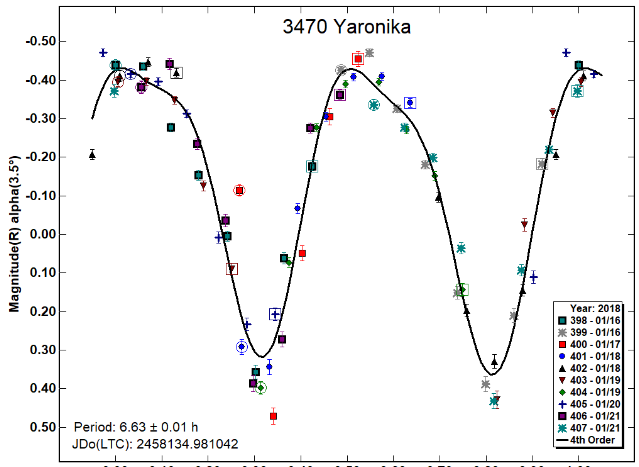

2463 Sterpin
Magnitude(R) alpha(3.3°)
Year: 2018
562 - 03/18
563 - 03/18
564 - 03/19
565 - 03/19
566 - 03/20
567 - 03/20
568 - 03/21
569 - 03/23
570 - 03/23
571 - 03/24
572 - 03/24
573 - 03/26
574 - 03/26
575 - 03/27
576 - 03/27
4th Order
Period: 13.43 ± 0.01 h
JDo(LTC): 2458195.934668

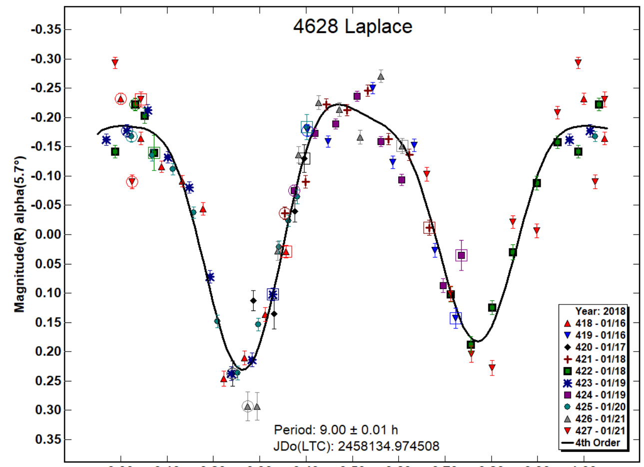

2079 Jacchia
Magnitude(R) alpha(1.4°)
Year: 2018
544 - 03/18
545 - 03/18
546 - 03/19
547 - 03/19
548 - 03/20
549 - 03/20
550 - 03/21
551 - 03/22
552 - 03/23
553 - 03/23
554 - 03/24
555 - 03/24
556 - 03/26
557 - 03/26
558 - 03/27
559 - 03/27
560 - 03/28
561 - 03/28
4th Order
Period: 5.942 ± 0.006 h
JDo(LTC): 2458195.932653

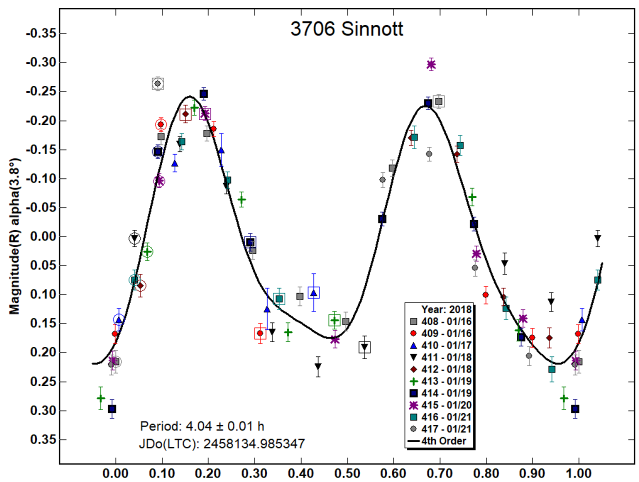

2677 Joan
Magnitude(R) alpha(1.8°)
Year: 2018
577 - 03/18
578 - 03/18
579 - 03/19
580 - 03/19
581 - 03/20
582 - 03/20
583 - 03/21
584 - 03/22
585 - 03/23
586 - 03/23
587 - 03/24
588 - 03/24
589 - 03/26
590 - 03/26
591 - 03/27
592 - 03/27
593 - 03/28
594 - 03/28
4th Order
Period: 16.98 ± 0.02 h
JDo(LTC): 2458195.925279

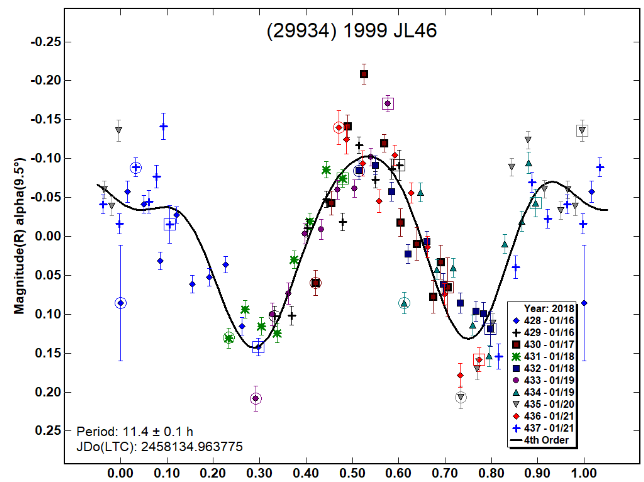

2279 Barto
Magnitude(R) alpha(9.5°)
Year: 2018
385 - 03/10
386 - 03/10
387 - 03/11
388 - 03/11
389 - 03/12
390 - 03/14
392 - 03/15
393 - 03/15
394 - 03/16
395 - 03/16
396 - 03/17
397 - 03/17
4th Order
Period: 6.63 ± 0.01 h
JDo(LTC): 2458187.919932


2764 Moeller
Magnitude(R) alpha(3.6°)
Year: 2018
367 - 01/16
368 - 01/16
369 - 01/17
370 - 01/18
371 - 01/18
380 - 01/19
381 - 01/19
382 - 01/20
383 - 01/21
384 - 01/21
4th Order
Period: 5.94 ± 0.03 h
JDo(LTC): 2458134.978298









Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
936	Kunigunde	3/18 - 3/28	128	3.2, 6.3	167	3	8.82	0.02	0.3	0.1
1281	Jeanne	3/18 - 3/28	172	2.6, 2.4, 4.4	179	-5	15.3	0.1	0.15	0.05
1644	Rafita	3/18 - 3/28	253	7.6, 4.9	189	-9			0.2	0.1
1905	Ambartsumian	3/10 - 3/17	124	3.7, 7.5	163	-2			0.5	0.1
2079	Jacchia	3/18 - 3/28	175	1.1, 6.0	175	-1	5.942	0.006	0.55	0.05
2279	Barto	3/10 - 3/17	98	9.2, 12.8	154	1	6.63	0.01	0.65	0.05
2396	Kochi	1/16 - 1/21	80	6.1, 4.5	123	-9			0.20	0.05
2463	Sterpin	3/18 - 3/28	131	3.0, 7.6	171	-2	13.43	0.01	0.25	0.05
2677	Joan	3/18 - 3/28	189	1.9, 1.3, 3.1	180	-3	16.98	0.02	0.50	0.05
2764	Moeller	1/16 - 1/21	96	3.9, 1.1	122	-1	5.94	0.03	0.24	0.04
3470	Yaronika	1/16 - 1/21	76	3.7, 1.9	121	-3	6.63	0.01	0.8	0.1
3706	Sinnott	1/16 - 1/21	70	4.1, 1.2	122	-1	4.04	0.01	0.44	0.06
4181	Kivi	3/10 - 3/17	84	10.9, 14.0	149	1			0.10	0.05
4628	Laplace	1/16 - 1/21	86	5.9, 4.4	125	-7	9.00	0.01	0.40	0.06
5079	Brubeck	3/9 - 3/17	220	12.0, 9.8	183	-15			0.10	0.05
7186	Tomioka	3/9 - 3/17	190	8.4, 7.4, 7.5	175	-12			0.10	0.05
29934	1999 JL46	1/16 - 1/21	97	9.6, 7.9	127	-11	11.4	0.1	0.2	0.1

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.

NEW LIGHTCURVES OF 153 HILDA, 293 BRASILIA, AND 318 MAGDALENA

Frederick Pilcher
Organ Mesa Observatory (G50)
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA
fpilcher35@gmail.com

(Received: 2018 Dec 15)

Synodic rotation periods and amplitudes are found for 153 Hilda: 5.9585 ± 0.0001 h, 0.22 ± 0.01 mag; 293 Brasilia: 8.173 ± 0.001 h, 0.17 ± 0.01 mag; and 318 Magdalena: 42.65 ± 0.01 h, 0.08 ± 0.01 mag.

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 sec, unguided, with a clear filter. Photometric measurement and lightcurve construction was 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 min.

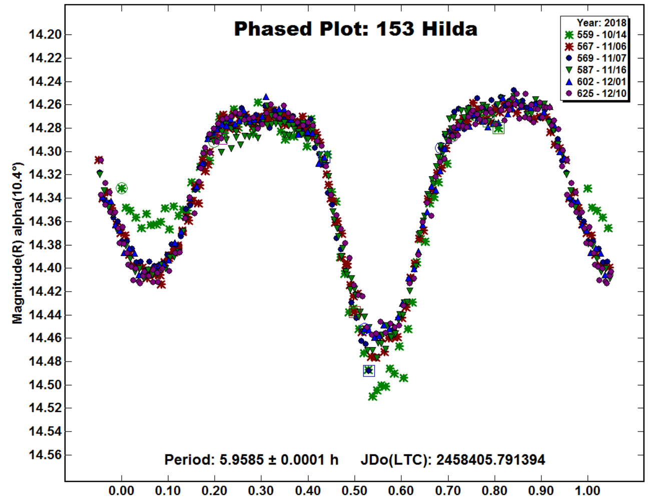
153 Hilda. The asteroid lightcurve data base (Warner et al., 2009) includes several period determinations near 5.957 h with amplitudes that vary with the phase angle bisector longitude (L_{PAB}). They are listed below in sequence of increasing L_{PAB}.

Author	Obs Date yyyy mm/dd	L_{PAB}	Amp
Warner and Stephens 2018	2017 09/10	29	0.11
Shevchenko et al. 2009	2002 11/21	65	0.20
Shevchenko et al. 2009	2005 05/22	148	0.20
Shevchenko et al. 2009	2006 04/16	195	0.07
Shevchenko et al. 2009	1992 07/29	323	0.05
Warner et al. 2017	2016 07/16	336	0.04

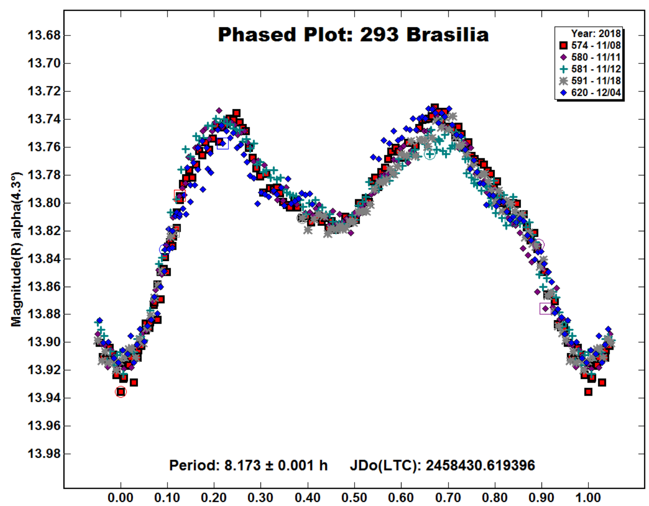
Table I. Listing of previous results giving the authors, approximate mid-date of observations, the PAB longitude, and lightcurve amplitude.

Two other published rotation periods are 8.11 h (Zappala et al., 1989) and 5.11 h (Lagerkvist et al. 1995). New observations on six nights from 2018 Oct. 14 through Dec. 10 provide a good fit to an unsymmetrical bimodal lightcurve with period 5.9585 ± 0.0001 h and amplitude 0.22 ± 0.01 mag at phase angle bisector longitude 70 deg. The period is consistent with many other period determinations and the amplitude is the largest yet observed.

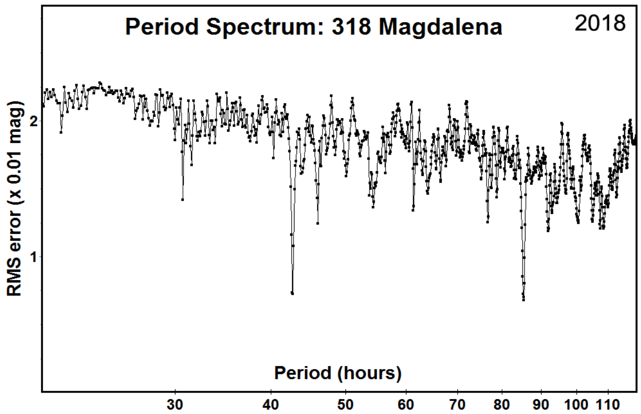
The amplitude-aspect relationship is an approximate method used for several decades to find the location of the rotational pole. It presumes that the amplitude is proportional to the sine of the angle between the line of sight and the rotational pole. From the table above, the pole is probably near celestial longitude 330 deg, latitude ± 15 deg. The current observations were likely near the asteroid equator and the phase angle bisector moved primarily in latitude through the interval of observation. This means that the synodic period of 5.9585 h established in this study is close to the sidereal period; this is information that is useful for future lightcurve inversion modeling.

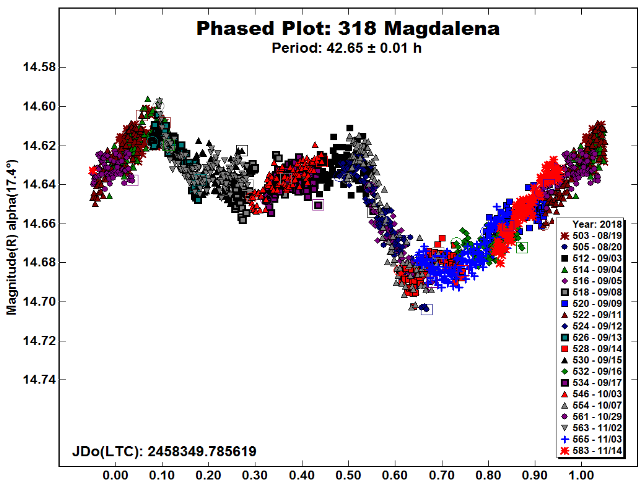


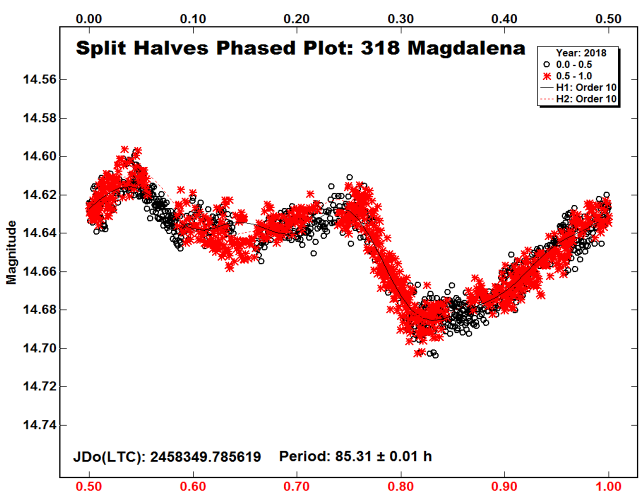
293 Brasilia. Previously published period determinations are 6.518 h (Behrend, 2005) and parallel studies near the year 2006 opposition: 8.173 h (Oey, 2006) and 8.17 h (Stephens, 2006). New observations on five nights from 2018 Nov. 8 through Dec. 4 provide a good fit to an unsymmetrical bimodal lightcurve with period 8.173 ± 0.001 h, amplitude 0.17 ± 0.01 mag. This is in good agreement with the periods found by Oey and by Stephens.



318 Magdalena. In the asteroid lightcurve data base (LCDB; Warner et al., 2009, updated 2018 November), 318 Magdalena is the lowest numbered asteroid whose rotation period reliability is listed as less than 3–. Previously published period determinations are 59.5 h (Behrend, 2004), and 42.49 h (Pilcher and Martinez, 2015) with a slightly asymmetric bimodal lightcurve that looks convincing. New observations on 20 nights provide a good fit to a highly asymmetric bimodal lightcurve with period 42.65 ± 0.01 h, amplitude 0.08 ± 0.01 mag. The observations include about 95% of the double period 85.31 h. A split-halves plot of the double period shows close agreement between the two halves of the double period. This is additional evidence that favors the 42.65-hour period over the double period. A period spectrum between 20 hours and 120 hours is also provided, for which the only deep minima are at 42.65 and 85.31 h, respectively. The 2015 and 2018 lightcurves have very different shapes, indicating that their viewing aspects were at very different asteroidcentric latitudes. The synodic period determinations for these years are compatible.







After 318 Magdalena there are 13 other asteroids numbered 500 and below whose rotation periods are listed in Warner et al. (2009) with reliability 2+ or less, i.e., not fully reliable. These are numbers 357, 384, 395, 421, 426, 445, 449, 455, 464, 470, 488, 491, 494. For most of these objects, the period is poorly established because it is very long, the amplitude is small, or both. It will require much persistence and telescope time to acquire sufficient data to obtain a secure period for each of them. Current rotation statistics are skewed away from long periods and low amplitudes due to difficulty of observation. Obtaining unbiased statistics requires that the difficult objects be solved.

References

Behrend, R. (2004, 2005, 2010). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*.

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

Lagerkvist, C.-I., Di Martino, M., Blanco, C., Dahlgren, M., Erikson, A., Lahulla, J.F., Lazzarin, M., Lumme, K., Pohjolainen, S., Riccioli, D. (1995). "Physical studies of asteroids XXX: The asteroid 153 Hilda." *Earth, Moon, and Planets* **71**, 189-194.

Oey, J. (2006). "Lightcurve analysis of 10 asteroids from Leura Observatory." *Minor Planet Bull.* **33**, 96-99.

Pilcher, F., Martinez, L. (2015). "Rotation Period Determinations for 318 Magdalena and 335 Roberta." *Minor Planet Bull.* **42**, 239.

Shevchenko, V.C., Tungalag, N., Chiorny, V.C., Gaftonyuk, N.M., Krugly, Yu.N., Harris, A.W., Young, J.W. (2009). "CCD-photometry and pole coordinates for eight asteroids." *Plan. Space Sci.* **57**, 1514-1520.

Stephens, R.D. (2006). "Asteroid lightcurve photometry from Santana and GMARS observatories – winter and spring 2006." *Minor Planet Bull.* **33**, 100-101.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 Nov. *http:/www.minorplanet.info/lightcurvedatabase.html.*

Warner, B.D., Stephens, R.D., Coley, D.R. (2017). "Lightcurve analysis of Hilda asteroids at the Center for Solar System Studies: 2016 June-September." *Minor Planet Bull.* **44**, 36-41.

Warner, B.D., Stephens, R.D. (2018). "Lightcurve analysis of Hilda asteroids at the Center for Solar System Studies: 2017 July through September." *Minor Planet Bull* .**45**, 35-39.

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 Function from Sparse Photometry." *Astron. J.* **150**, A75.

Zappala, V., Di Martino, M., Cellino, A., Farinello, P., De Sanctis, C. (1989). "Rotational properties of outer belt asteroids." *Icarus* **82**, 354-368.

Number	Name	yyyy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E
153	Hilda	10/14-12/10	2076	10.4,0.8,2.3	70	-3	5.9585	0.0001	0.22	0.01
293	Brasilia	11/08-12/04	1933	4.2,0.9,6.9	55	-2	8.173	0.001	0.17	0.01
318	Magdalena	08/19-11/14	5174	17.4,4.8,9.4	70	-9	42.65	0.01	0.08	0.01

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

LIGHTCURVES OF ELEVEN MAIN-BELT MINOR PLANETS

Tom Polakis
Command Module Observatory
121 W. Alameda Dr.
Tempe, AZ 85282 USA
tpolakis@cox.net

Brian Skiff
Lowell Observatory
Flagstaff, AZ USA

(Received: 2019 Jan 10 Revised: 2019 Feb 27)

Synodic rotation periods were determined for eleven main-belt asteroids: 527 Euryanthe, 42.986 ± 0.021 h; 1302 Werra, 14.013 ± 0.012 h; 1385 Gelria, 2.3118 ± 0.0007 h; 1475 Yalta, 70.77 ± 0.05 h; 1707 Chantal, 79.74 ± 0.04 h; 1839 Ragazza, 210.9 ± 0.4 h; 2056 Nancy, 1343 ± 5 h; 2487 Juhani, 344.6 ± 0.5 h; 3165 Mikawa, 5.086 ± 0.004 h; 4078 Polakis, 4.8274 ± 0.0001 h; and 6582 Flagsymphony, 113.3 ± 0.2 h. All the data have been submitted to the ALCDEF database.

CCD photometric observations of eleven main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe. One of these asteroids was also observed at the Lowell Observatory Anderson Mesa Station (MPC 688) outside Flagstaff. 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. Images taken at 688 employed the 0.7-m *f*/8 telescope, which has a CCD camera system designed and built in the Lowell instrument shop (Buie, 2010). The image scale was 0.91 arcsec/pixel with 2x2 binning. Exposure time was 5 minutes through a Cousins R filter. Table I shows the observing circumstances and results. All of the images for these eleven asteroids were obtained between 2018 October and December.

The V02 images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel. Image calibration and alignment was performed using MaxIm DL software. The 688 data made use of 20 full-frame biases and 15 or more twilight flats taken each night under an automated exposure routine with the telescope aimed at the 'Chromey spot' (Chromey et al., 1996), tracked at the sidereal rate but dithered 30" between frames. The thinned, back-illuminated e2v CCD was kept at roughly –110° C using a Cryotiger chiller and so had negligible dark current.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2017). The 45'x30' field of the CCD at V02 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.

Since the sensitivity of the KAF-6303 chip peaks in the red, the Clear-filtered images were reduced to Sloan r' to minimize error with respect to a color term. Comp star magnitudes were derived from a combination of CMC15 (Muiñoz et al. 2014), APASS DR9 (Munari et al. 2015), and GAIA2 G (Sloan r´ = G 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 for the V02 data. The apertures used on the 0.7-m data varied depending on seeing, but were typically 13 or 15 pixels (12 or 14 arcsec) diameter. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, we 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). Phased lightcurves show the maximum at phase zero. Magnitudes in these plots are apparent, and scaled by *MPO Canopus* to the first night.

Asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude greater than 14.5 and quality of results, U, less than 2+. In this set of observations, seven of the 11 asteroids had no previous period analysis.

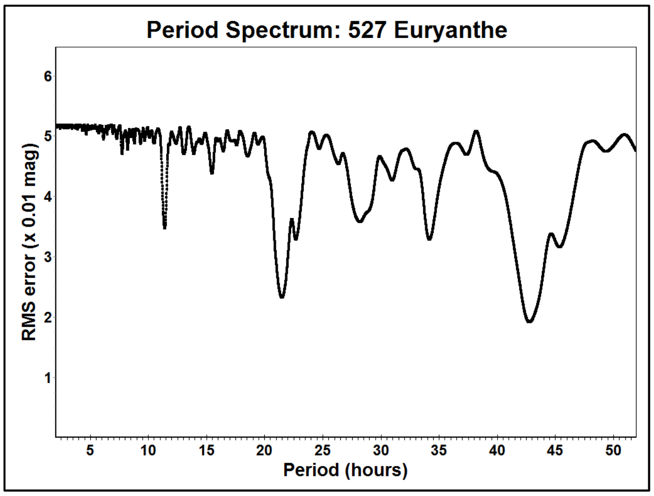
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
527	Euryanthe	10/11-12/02	838	14.5,5.5,10.1	49	-12	42.986	0.021	0.15	0.02	MB-O
1302	Werra	11/06-11/11	622	1.8,3.8	40	-3	14.013	0.012	0.09	0.02	THM
1385	Gelria	11/09-11/11	207	4.3,4.5	45	-9	2.3118	0.0007	0.20	0.02	MB-O
1475	Yalta	11/12-11/26	564	4.3,2.6,5.9	55	-4	70.77	0.05	0.59	0.05	MB-I
1707	Chantal	11/03-11/19	1102	12.8,21.0	24	3	79.74	0.04	0.85	0.06	MB-I
1839	Ragazza	11/12-11/26	873	2.1,0.3,5.2	53	1	210.9	0.4	0.99	0.08	MB-M
2056	Nancy	10/19-12/16	1117	5.8,28.2	21	1	1343.	5.	0.68	0.03	MB-I
2487	Juhani	10/10-11/07	830	5.2,19.7	13	10	344.6	0.5	1.03	0.07	MB-I
3165	Mikawa	11/27-11/29	306	2.1,3.0	62	-2	5.086	0.004	0.27	0.05	FLOR
4078	Polakis	11/04-11/13	143	5.7,3.1	54	-7	4.8274	0.0001	0.40	0.01	EOS
6582	Flagsymphony	10/10-11/05	1222	5.7,0.1,9.5	26	0	113.3	0.2	0.28	0.03	MB-M

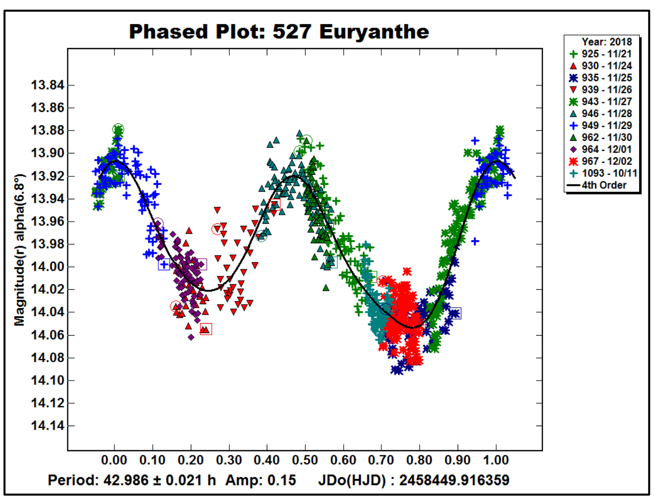
Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum or maximum, which is then the second of three values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All the new data for these eleven asteroids may be found in the ALCDEF database.

527 Euryanthe was discovered by Max Wolf at Heidelberg in 1904. The only rotation period in the LCDB is that of Brinsfield (2010), who obtained a period of 26.06 ± 0.01 h.

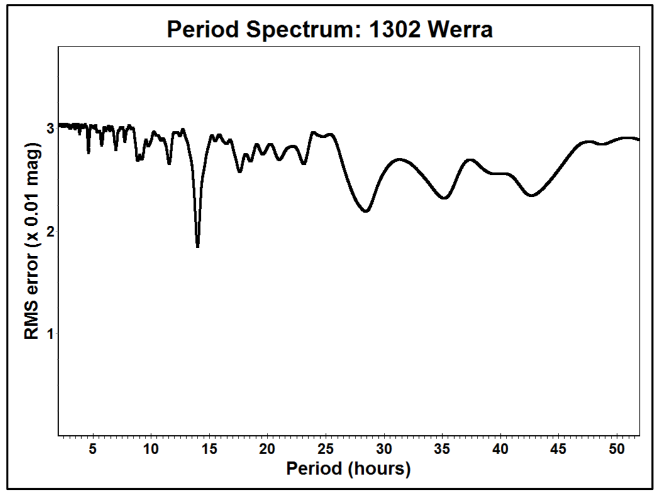
During the ten nights of observation at V02, 726 images were obtained. An additional 112 data points acquired at Organ Mesa Observatory (G50) were provided by Frederick Pilcher (private communications). The period solution yielded a result of 42.986 ± 0.021 h, which disagrees with Brinsfield's result. Note that the power spectrum shows aliases, which was expected due to the long interval between Pilcher's October 11 and later observations. The amplitude is 0.15 ± 0.02 mag, and the RMS scatter on the fit shown in the phased plot is 0.019 mag.

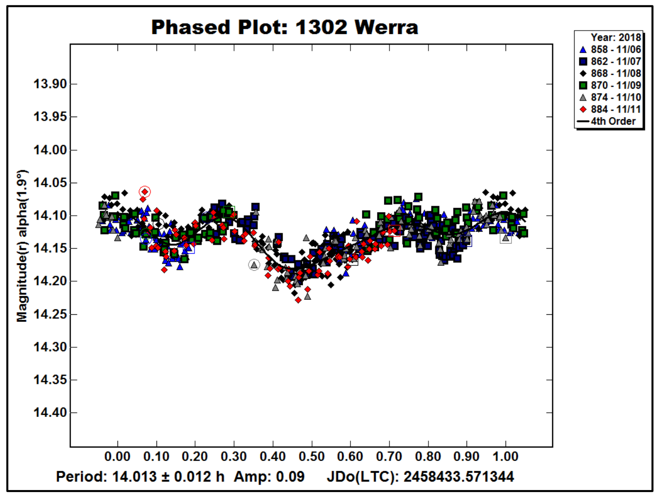




1302 Werra. This Themis-family asteroid was discovered at Heidelberg in 1924 by Karl Reinmuth. No period solutions appear in the LCDB.

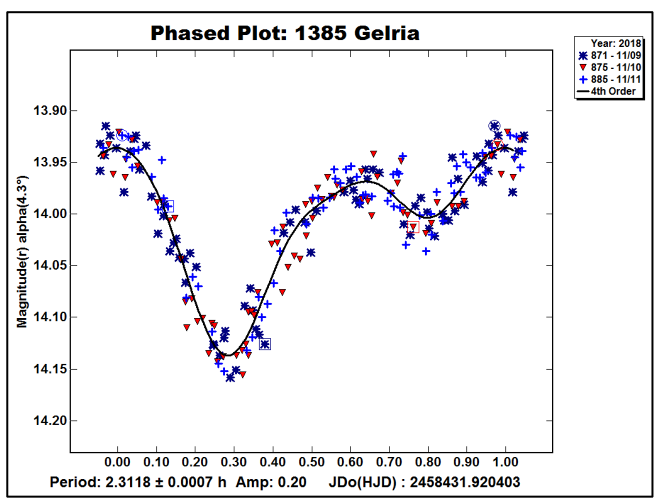
A total of 622 images were gathered during six observing nights. Obtaining a period solution was complicated by the low amplitude of the lightcurve. A 4th-order fit produced 14.013 ± 0.012 h. The amplitude is 0.09 ± 0.02 mag. The RMS scatter on the fit is 0.019 mag.





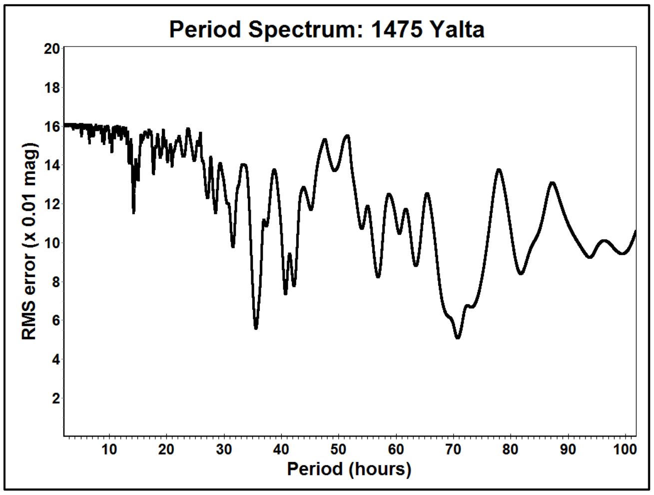
1385 Gelria. was discovered at Johannesburg in 1936 by Hendrik Van Gent. The LCDB shows no published rotation periods for this asteroid.

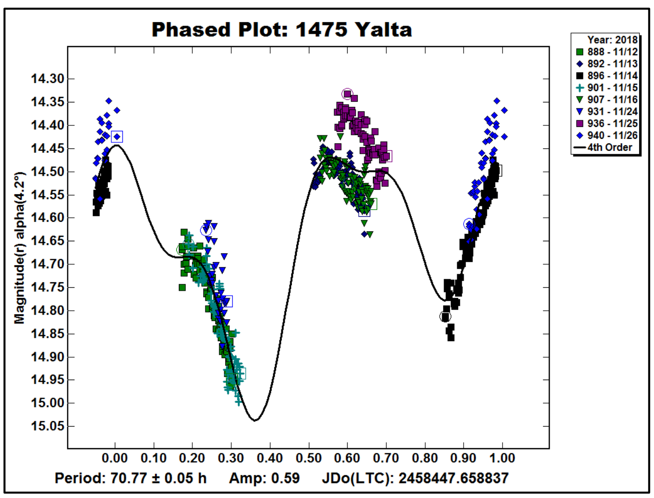
Only three nights and 207 images were sufficient to determine a rotation period of 2.3118 ± 0.0007 h. The full amplitude is 0.20 ± 0.02 mag, and the RMS scatter of the fit is 0.019 mag.



1475 Yalta. Pelageya Shajn discovered this inner-belt asteroid in 1935 at Simeis. The LCDB again shows no period solutions.

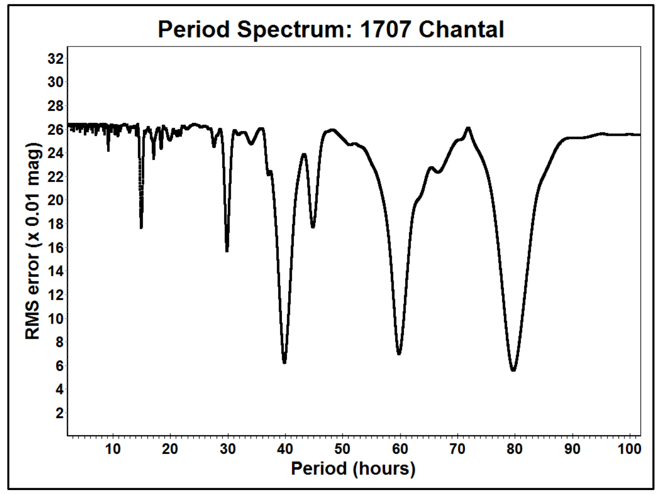
A total of 564 images were gathered during eight nights. It became apparent during the run that the asteroid's long period is nearly commensurate with three earth days. While the lightcurve is incomplete, the period spectrum shown below indicates a solution of 70.77 ± 0.05 h. The misalignment of data points is evidence of tumbling. The lightcurve has an amplitude of 0.59 ± 0.05 mag, and an RMS error on the fit of 0.051 mag. Note that, in the case of tumbling asteroids, the computed RMS error is conservative, since the Fourier curve cannot fit misaligned data.

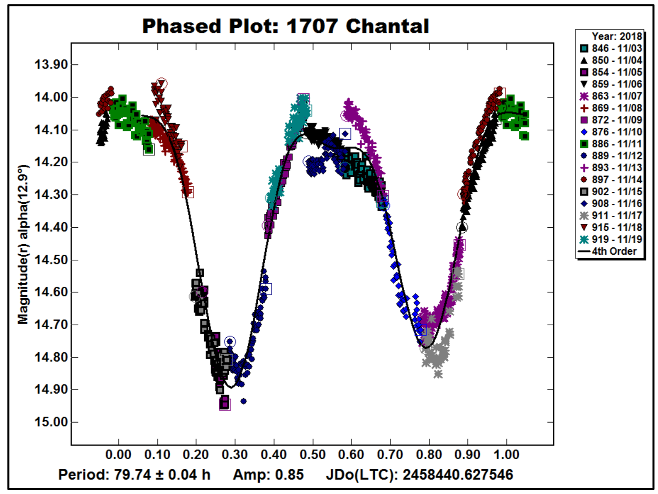




1707 Chantal. This minor planet was discovered at Uccle by Eugène Delporte in 1932. Lagerkvist (1978) published a period of >10 h.

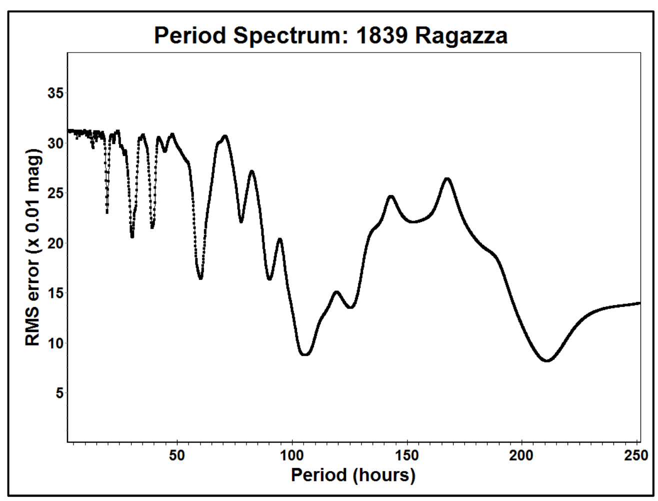
The lightcurve for this asteroid remained challenging even after acquiring 1102 images in 17 nights. While the period spectrum shows two nearly equal minima, the mono-modal solution of shorter period is prohibited for such a large amplitude. The rotational period of 79.74 ± 0.04 h appears secure, but the misalignment of points in the lightcurve suggests tumbling motion. The RMS scatter on the fit is 0.055 mag. The amplitude is 0.85 ± 0.06 mag.

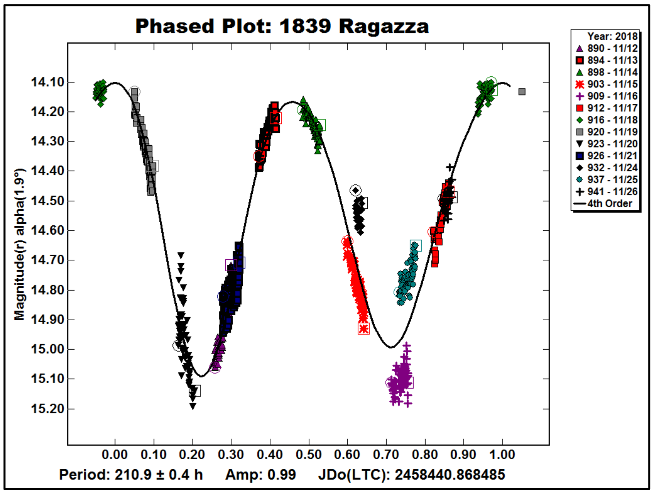




1839 Ragazza. In 1971, Paul Wild discovered this asteroid at Zimmerwald. No period solutions for it appear in the LCDB.

As was the case with 1707 Chantal, tumbling behavior made for a difficult lightcurve, in which points do not overlay well on the Fourier fit. A rotation period of 210.9 ± 0.4 h was computed, using the bi-modal solution from the period spectrum. The amplitude of the lightcurve is 0.99 ± 0.08 mag, and the RMS error on the fit is 0.082 mag.



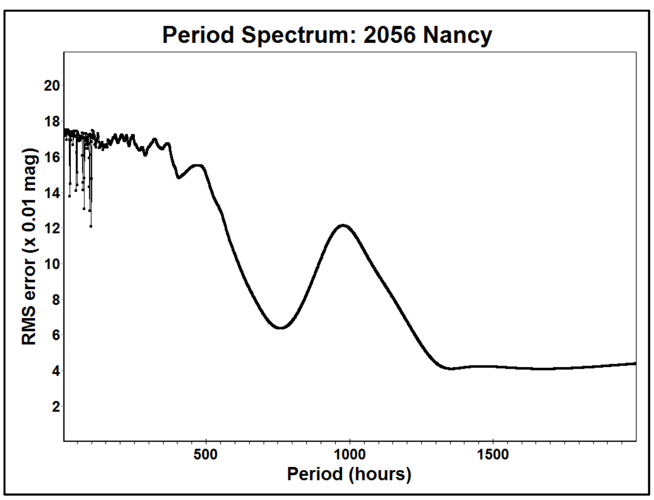


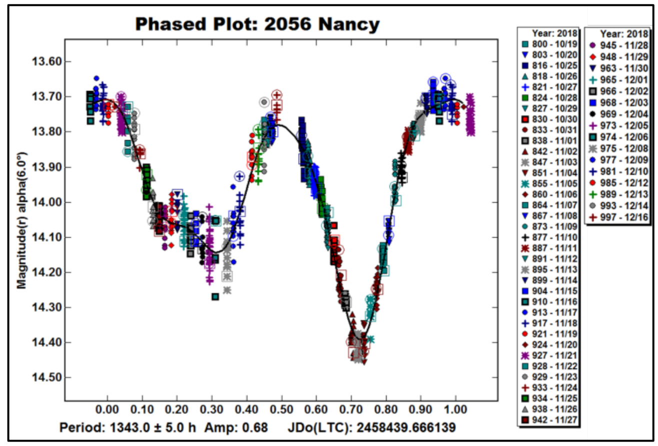
<u>2056 Nancy</u> was discovered by Joseph Helffrich at Heidelberg in 1909. It is named after Nancy Lou Zissell Marsden, wife of former Minor Planet Center Director Brian Marsden. The LCDB lists one period solution of >15 h at the CALL site.

The first week of observations revealed an extremely slow decline in brightness, suggesting that this asteroid would have a long period.

The minor planet was followed for nearly two months, during which time it completed just over one rotation. Fifty two of the 58 nights were clear enough to acquire 1117 useable images to construct a lightcurve. During this interval, the nominal magnitude of the asteroid faded by 1.5 magnitudes, so the H-G correction in *MPO Canopus* proved useful.

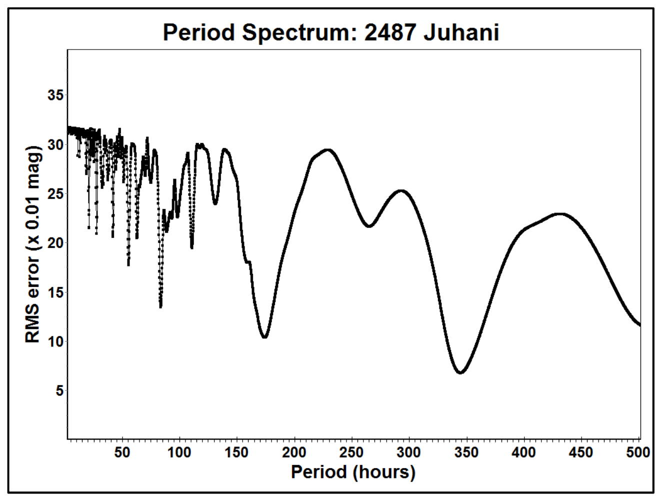
A 5th-order fit produced a synodic period of 1343 ± 5 h, making it the third longest reliable period in the LCDB. The lightcurve has an amplitude of 0.68 ± 0.03 mag, and an RMS error of 0.033 mag.

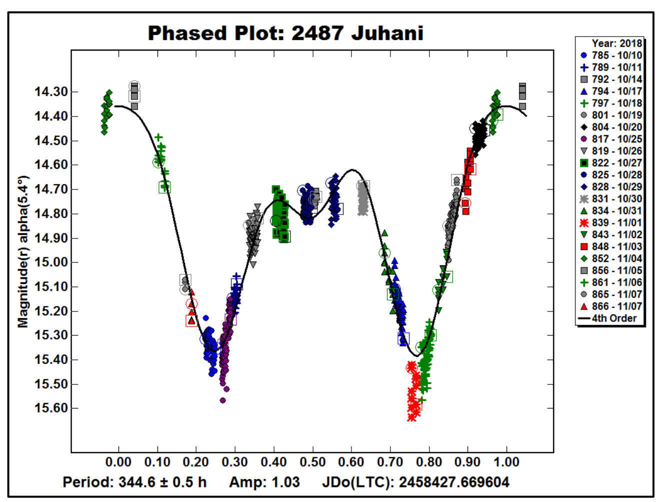




<u>2487 Juhani</u>. This inner-belt asteroid was discovered at Turku in 1940 by Heikki Alikoski. The LCDB contains no period solutions for it.

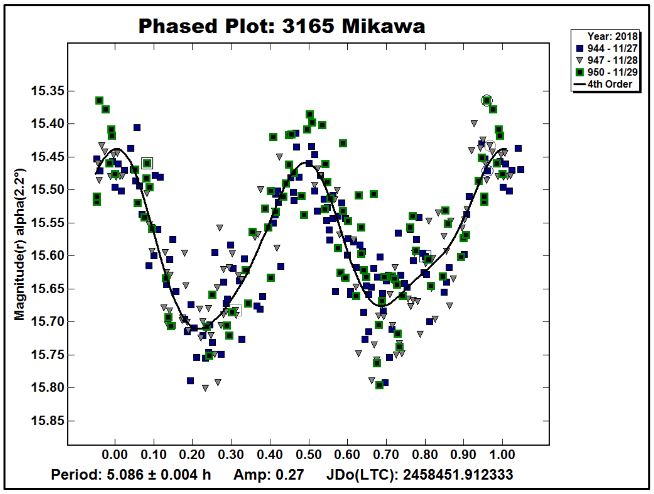
During 21 nights in 2018 October and November, 830 data points were obtained. A synodic period of 344.6 ± 0.5 h was determined, again using the bi-modal curve fit. RMS scatter on the fit is 0.068 mag. The amplitude of the lightcurve is 1.03 ± 0.07 mag.





3165 Mikawa, a Flora-family asteroid, was discovered in 1984 by Kenzō Suzuki and Takeshi Urata at the JCPM Oi Station. Periods in the LCDB include those by Ellsworth (2002), who shows 5.02 ± 0.02 h and Hawkins (2008), who computed 5.100 ± 0.001 h.

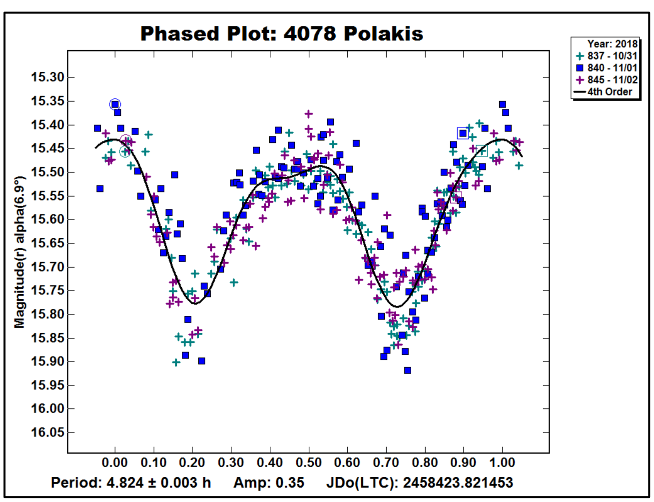
A three-night run was sufficient to construct a lightcurve using 306 images. A rotation period of 5.086 ± 0.004 h was computed. The lightcurve's amplitude is 0.27 ± 0.05 mag, and the RMS error of the curve fit is 0.052 mag. This scatter is rather high relative to the amplitude due to the asteroid being near the faint limit for the telescope and site.



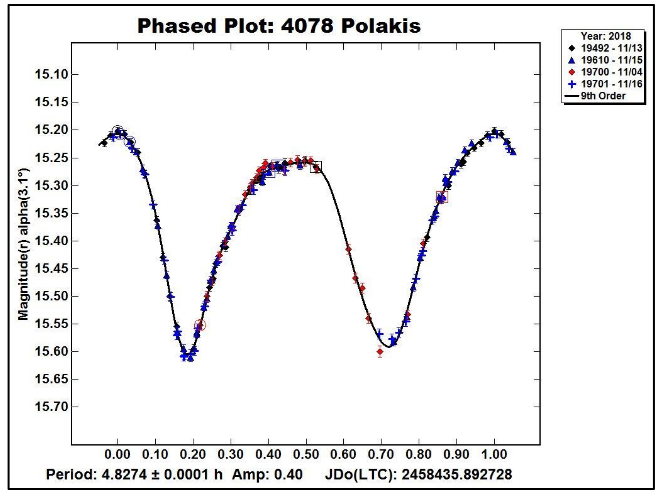
4078 Polakis was discovered in 1983 by Brian Skiff at Lowell Observatory. Two period solutions were found in the LCDB. Torno (2008) obtained a period of 4.831 ± 0.003 h, while Behrend (2016) shows 4.87 ± 0.01 h.

Images were taken at both V02 and 688, and results from the two observatories are compared.

During three nights at V02, 354 images were taken, resulting in a synodic period of 4.824 ± 0.003 h, in line with previous determinations. The amplitude of the lightcurve is 0.35 ± 0.06 mag, and the RMS error of the fit is 0.058 mag.

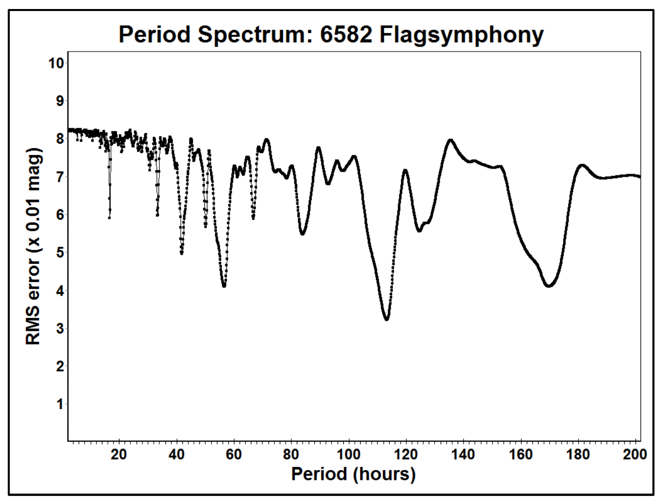


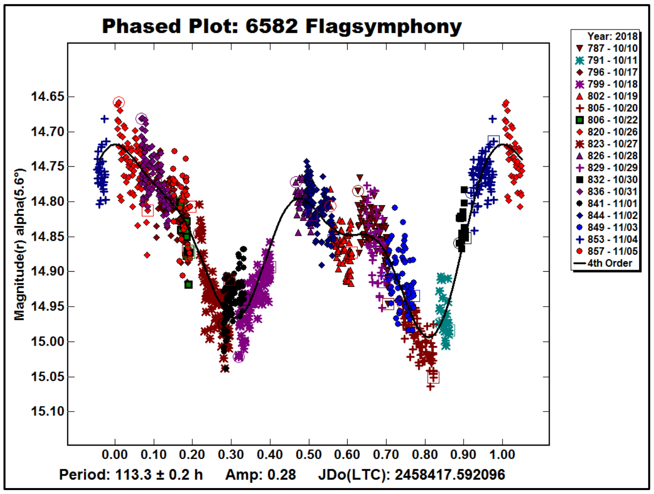
In four nights at 688, 143 data points were acquired. A rotational period of 4.8274 ± 0.0001 h was determined. The lightcurve has an amplitude of 0.40 ± 0.01 mag, and the RMS scatter of the fit is 0.007 mag.



6582 Flagsymphony. This minor planet was discovered in 1981 by Edward Bowell at Lowell Observatory. No period solutions were found in the LCDB. The eccentric orbit brought the asteroid to nearly 1.0 a.u. during this apparition; it will be situated at twice that distance and 2.6 magnitudes fainter during the 2020 opposition.

Over the course of 18 nights of observation, 1222 data points were gathered, resulting in a period of 113.3 ± 0.2 h. The amplitude of the fit is 0.28 ± 0.03 mag, and the RMS scatter of the curve fit is 0.032 mag.





Acknowledgments

The authors would like to express their gratitude to Brian Warner for support of his *MPO Canopus* software package.

References

Behrend, R. (2016). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Brinsfield, J. (2010). “Asteroid Lightcurve Analysis at Via Capote Observatory: 4th Quarter 2009.” *Minor Planet Bull*., **37**, 50.

Buie, M.W. (2010). “Converting from Classical to Robotic Astronomy: The Lowell Observatory 0.8-m Telescope.” *Adv. in Astron*. *https://www.hindawi.com/journals/aa/2010/130172*

Chromey, F.R., Hasselbacher, D.A. (1996). “The Flat Sky: Calibration and Background Uniformity in Wide Field Astronomical Images.” *PASP* **108**, 944-949.

Ellsworth, N., Hughes, S., Ditteon, R. (2002). “Photometry of Asteroid 2962 Otto and 3165 Mikawa.” *Minor Planet Bull*., **29**, 68.

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

Hawkins, S., Ditteon, R. (2008). “Asteroid Lightcurve Analysis at the Oakley Observatory - May 2007.” *Minor Planet Bull*., **35**, 1.

Lagerkvist, C. (1978). ‘Photographic photometry of 110 main-belt asteroids.” *Astron. Astrophys. Suppl. Ser*., **31**, 361.

Muiñoz, J.L., Evans, D.W. (2014). “The CMC15, the last issue of the series Carlsberg Meridian Catalogue, La Palma.” *Astron. Nach*. **335**, 367.

Munari, U., Henden, A., Frigo, A., Zwitter, T., Bienayme, O., Bland-Hawthorn, J., Boeche, C., Freeman, K.C., Gibson, B.K., Gilmore, G., Grebel, E.K., Helmi, A., Kordopatis, G., Levina, S.E., and 13 coauthors. (2015). “APASS Landolt-Sloan BVgri photometry of RAVE stars. I. Data, effective temperatures, and reddenings.” *Astron. J*., **148**, 81.

Torno, S., Oliver, R., Ditteon, R. (2008). “Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory - October 2007.” *Minor Planet Bull*., **35**, 2.

VizieR (2017). *http://vizier.u-strasbg.fr/viz-bin/VizieR*

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146. Updated 2016 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2011). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

Warner. B.D. (2017). *MPO Canopus* software. *http://bdwpublishing.com*

ROTATIONAL PERIOD DETERMINATION FOR ASTEROIDS 755 QUINTILLA, 1830 POGSON, 5076 LEBEDEV-KUMACH, AND (29153) 1988 SY2

Michael Fauerbach
Florida Gulf Coast University
10501 FGCU Blvd.
Ft. Myers, FL33965-6565
mfauerba@fgcu.edu

Matthew Fauerbach
United States Military Academy
606 Thayer Road
West Point, NY 10996

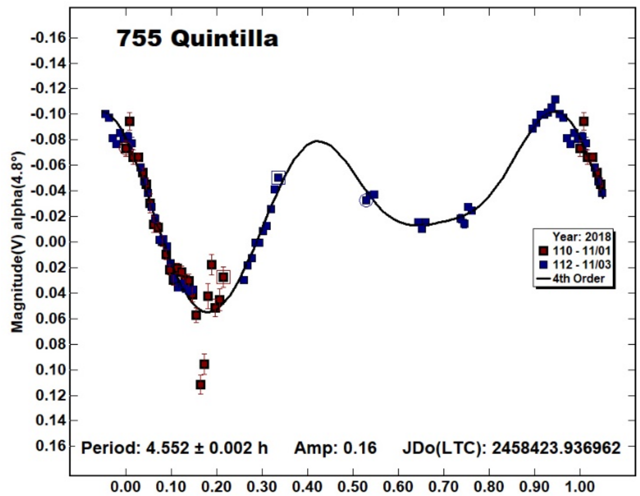
(Received: 2018 Dec 30)

Photometric observations of four main-belt asteroids were obtained on the nights of 2018 November 1 and 3 using the SARA-North telescope at Kitt Peak National Observatory. We derived the following rotational periods: 755 Quintilla 4.552 ± 0.002 h; 1830 Pogson 2.570 ± 0.001 h; 5076 Lebedev-Kulmach 3.215 ± 0.003 h; and (29153) 1988 SY2 3.492 ± 0.002 h.

We report on the results of photometric observations obtained with the Southeastern Association for Research in Astronomy (SARA) consortium 0.9-m telescope at Kitt Peak National Observatory. The telescope is coupled with an ARC CCD. The data were calibrated using *MaximDL* and photometric analysis was performed using *MPO Canopus* (Warner, 2017). A total of seven nights over a two-week period were allocated to us. Unfortunately, all but the last two fell victim to poor weather conditions. Therefore, the original list of target asteroids had to be scuttled and we refocused on asteroids with shorter periods. Two of the target asteroids, 5076 Lebedev-Kulmach and (29153) 1988 SY2, were chosen from the asteroid lightcurve database (LCDB; Warner et al., 2009) because they had a high uncertainty in their rotational periods associated with previous observations. The other two targets, 755 Quintilla and 1830 Pogson, were chosen from the Shape Modelling Target list published in the *Minor Planet Bulletin* (Warner et al., 2018).

755 Quintilla was selected from the Shape Modelling Target list published by Warner et al. (2018). There are four previously published rotational periods for 755 Quintilla. Two are from April 2004 (Behrend, 2004; Buchheim, 2005), one is from 2005 (Behrend, 2005), and one is from 2006 (Masiero, 2009).

We derived a rotational period of 4.552 ± 0.002 h and amplitude of 0.16 mag, which is in agreement with all four previous measurements. We will submit our data to the Database of Asteroid Models from Inversion Techniques (DAMIT; Durech et al., 2010) web site and hopefully contribute to a viable shape model of 755 Quintilla.



1830 Pogson. This asteroid was selected from the Shape Modelling Target list published by Warner et al. (2018). It is a member of the Flora family and a known asynchronous binary asteroid (Higgins, 2007). What makes 1830 Pogson an even more interesting target is that it is a candidate for a tertiary system (Pravec et al., 2012). The established period of the primary is 2.5699 ± 0.0001 h, and the binary component has an orbital period of 24.24580 ± 0.00006 h (Pravec et al., 2012).

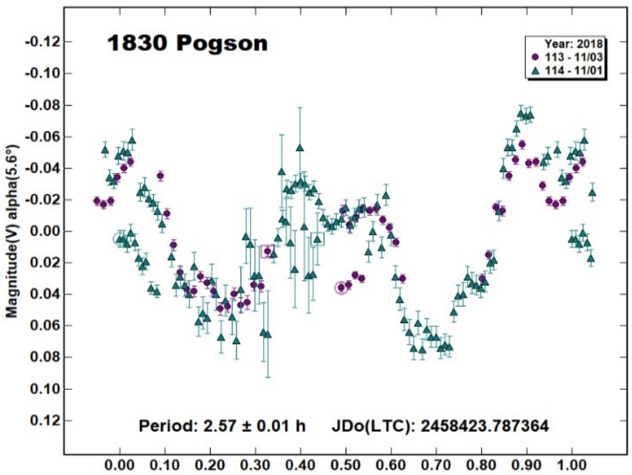
We observed 1830 Pogson for approximately 4 h and 5.5 h on 2018 Nov 1 and 3, respectively, thereby covering well more than a whole rotational period of the primary during each night. When plotting our data against the established period for the primary of ~2.57 h, one can clearly see that the data taken on the same night do not overlap, indicating an additional rotational component. We attempted to resolve the two rotational components using the double period search function in *MPO Canopus*.

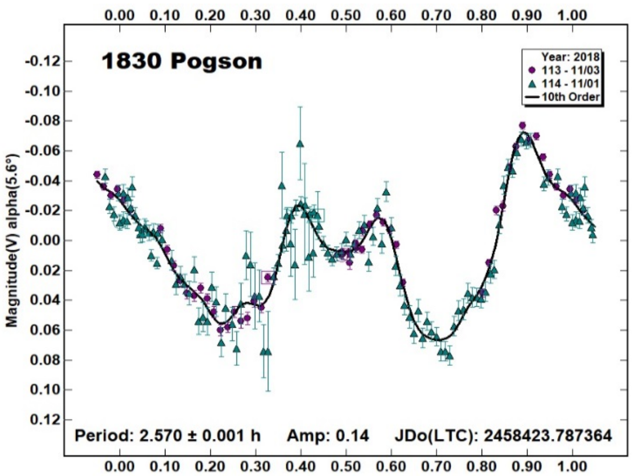
Unfortunately, our attempt was not successful, either due to user error or to the fact that the primary and tertiary periods are very close to each other. However, we were able to use the suggested period of the tertiary of 3.2626 ± 0.0004 h (Pravec et al., 2012) and subtracted it from the original dataset. The result is shown below and shows a much smoother curve with a period of 2.570 ± 0.001 h and an amplitude of 0.14 mag. This gives further evidence for the presence of the tertiary component as suggested by Pravec et al. (2012).

We will submit our data to the Database of Asteroid Models from Inversion Techniques (DAMIT) (Durech et al., 2010) web site and hopefully contribute to a viable shape model of 1830 Pogson.

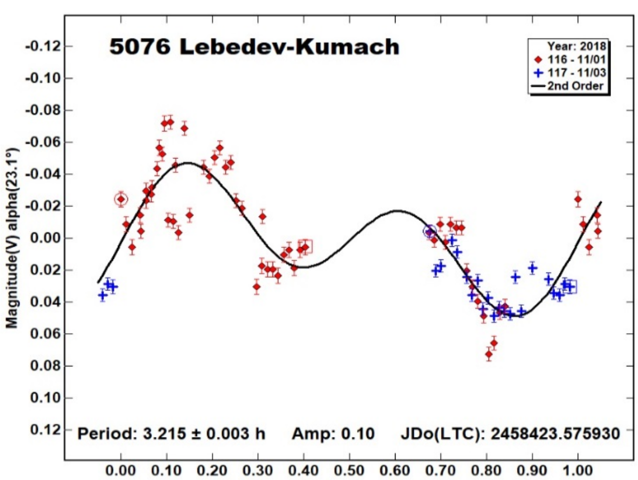
Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
755	Quintilla	11/01-11/03	76	4.8,4.3	54	-3	4.552	0.002	0.16	0.02	MB-O
1830	Pogson	11/01-11/03	161	6.6,5.6	48	-5	2.570	0.001	0.14	0.01	FLOR
5076	Lebedev-Kulmach	11/01-11/03	76	23.1,23.7	1	-1	3.215	0.003	0.10	0.02	MB-I
29153	1988 SY2	11/01-11/03	107	15.2,16.0	17	-9	3.492	0.002	0.38	0.02	MB-M

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).

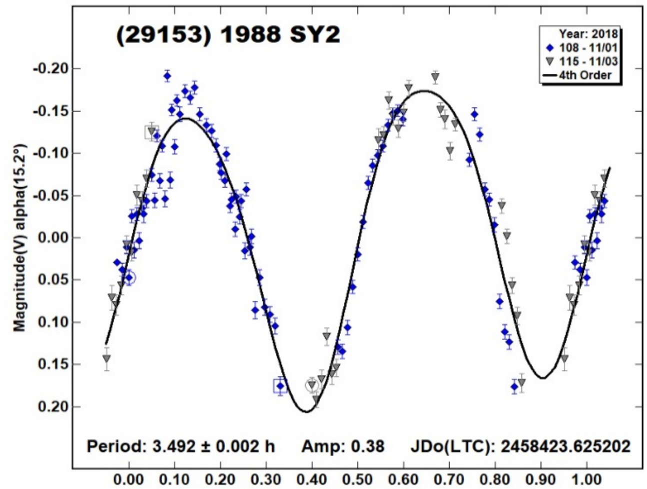




5076 Lebedev-Kumach. Only one prior measurement of the rotational period exists. Warner (2004) reported a period of 3.2190 ± 0.0005 h. We obtained a rotational period of 3.215 ± 0.003 h and amplitude of 0.10 mag, which is in good agreement with the previous measurement.



(29153) 1988 SY2. We observed (29153) 1988 SY2 on two nights and derived a rotational period of 3.492 ± 0.002 h with an amplitude of 0.38 mag. The only previously reported rotational period is by Waszczak et al. (2015) based on a fit to sparse data. They reported a period of 3.493 ± 0.0057 h with an amplitude of 0.36 mag. Their result is in good agreement with ours.



References

Behrend, R. (2004, 2005). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Buchheim, R.K., Pray, D. (2005). "Lightcurve of 755 Quintilla." *Minor Planet Bull.* **32**, 1.

Durech, J., Sidorin, V., Kaasalainen, M. (2010). "DAMIT: a database of asteroid models." *Astronomy and Astrophysics* **513**, A46. *http://astro.troja.mff.cuni.cz/projects/asteroids3D*

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

Higgins, D., Pravec, P., Kusnirak, P., Oey, J., Pray, D. (2007). "(1830) Pogson." *CBET* **957**, #1

Masiero, J., Jedicke, R., Ďurech, J., Gwyn, S., Denneau, L., Larsen, J. (2009). "The Thousand Asteroid Light Curve Survey." *Icarus* **204**, 145-171.

Pravec, P. Scheirich, P., Vokrouhlicky, D., Harris, A.W., Kusnirak, P., Hornoch, K., Pray, D.P., Higgins, D., Galad, A., Vilagi, J., and 32 coauthors. (2012). "Binary asteroid population. 2. Anisotropic distribution of orbit poles of small, inner main-belt binaries." *Icarus* **218**, 125-143.

Warner, B.D. (2004). "Lightcurve analysis for numbered asteroids 1351, 1589, 2778, 5076, 5892, and 6386." *Minor Planet Bull.* **31**, 36-39.

Warner, B.D. (2017). *MPO Canopus* V10.7.10.0. *http://www.bdwpublishing.com*

Warner, B.D., Harris, A.W., Ďurech, J., Benner, L.A.M. (2018). "Lightcurve Photometry Opportunities: 2018 October–December." *Minor Planet Bull.* **45**, 404–408.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., and 8 coauthors. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry," *Astron. J.* **150**, A75, 35 pp.

A NEW LIGHTCURVE AND SPIN-SHAPE MODEL FOR 46 HESTIA

Lorenzo Franco
Balzaretto Observatory (A81)
Rome, ITALY
lor_franco@libero.it

Frederick Pilcher
4438 Organ Mesa Loop
Organ Mesa Observatory (G50)
Las Cruces, NM 88011 USA

(Received: 2019 Jan 4)

At its opposition in late 2018, minor planet 46 Hestia has a synodic rotation period of 21.039 ± 0.001 h and amplitude 0.11 ± 0.01 mag. A lightcurve inversion model based on four dense data sets in the years 1978-2018 plus sparse observations provides a sidereal period of 21.04010 ± 0.000035 h with two mirrored pole solutions at longitude 291 deg, latitude +13 deg; or longitude 110 deg, latitude 7 deg; all ± 5 degrees, respectively. A shape model is also provided.

Minor planet 46 Hestia has a semi-major axis of 2.5252 AU and revolution period of 4.013 years. Each sequence of three oppositions repeats after four years under early identical circumstances with only a very slow westward circulation. Three previously published dense lightcurves all state rotation periods within 0.005 h of 21.040 h and amplitudes near 0.11 mag, as does the current study. All four studies are shown in the table I with the respective year and month of mid date of observing campaign and longitude of phase angle bisector (LPAB).

Author	Mid date	LPAB
Scaltriti et al. (1981)	1978-11-14	58
Pilcher (2012)	2012-03-06	154
Pilcher (2017)	2017-05-23	235
This study	2018-10-14	34

Table I. Observational circumstances for 46 Hestia over four apparitions

A new photometric data set was obtained with 12 sessions 2018 Sept. 9 – Nov. 18 by second author Pilcher at Organ Mesa Observatory with a 0.35-m f/10 Meade LX200 GPS Schmidt-Cassegrain (SCT) telescope and SBIG STL-1001E CCD, unguided with an R filter. These data provide a good fit to a lightcurve phased to period of 21.039 ± 0.001 h, and amplitude of 0.11 ± 0.01 mag.

Lightcurve inversion was performed using MPO LCInvert v.11.7.5.1 (BDW Publishing, 2016). For inversion process we have also used sparse data from (689) USNO Flagstaff station in addition to the dense data. Figures 2 and 3 show respectively PAB longitude/latitude distribution for dense / sparse data and the

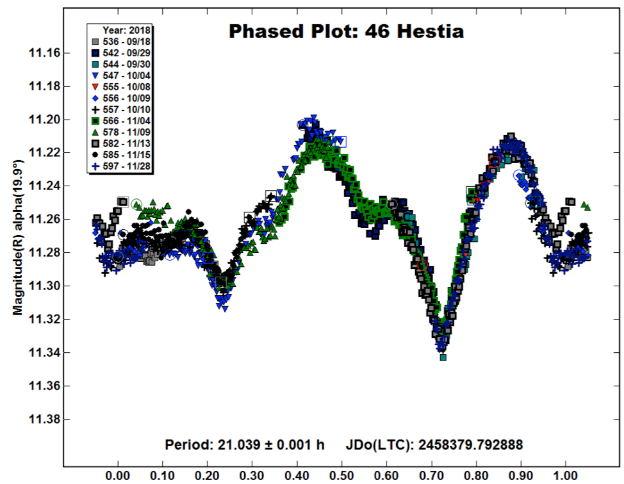


Fig. 1: The lightcurve acquired at the 2018 apparition.

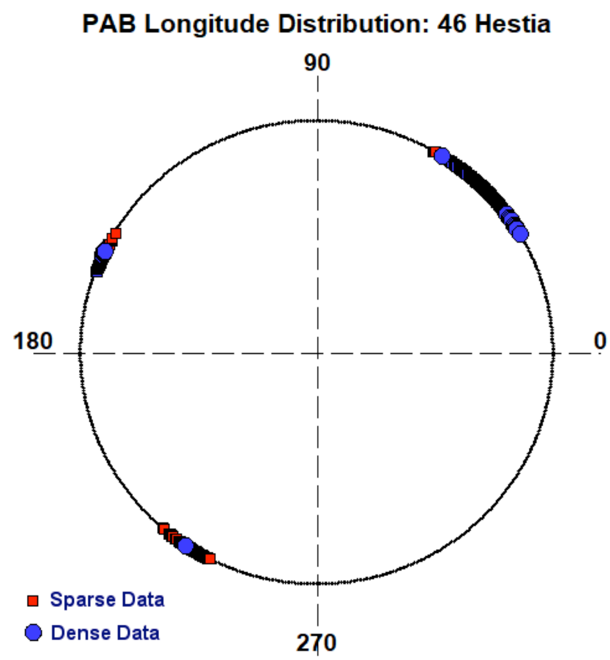


Fig. 2: PAB longitude distribution of the data used for the lightcurve inversion model.

sparse photometric data distribution with the corresponding phase curve.

The photometric data of the 1978 apparition were no longer available and therefore were reconstructed by the digitization of the published lightcurve.

The sidereal period search was started around the average of the synodic periods found in the previous studies. We found two sidereal periods with a lower chi square value near 21.040 and

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
46	Hestia	09/09-11/18	3950	19.8,4.2,15.6	33.6	-1.5	21.039	0.001	0.11	0.01

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first date, minimum value reached, 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).

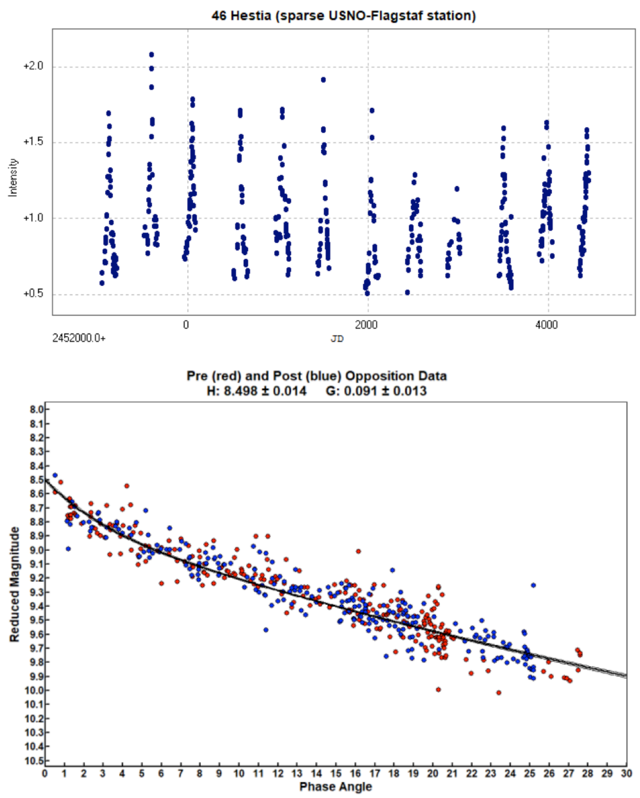


Fig. 3: Sparse photometric data point distribution from USNO Flagstaff station with the phase curve (reduced magnitudes vs phase angle).

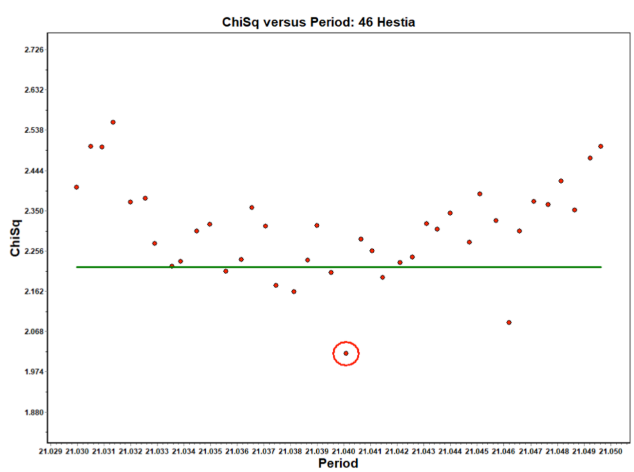


Fig. 4: The period search for 46 Hestia shows two lower chi square values. For the inversion process the one with the lowest chi square value was used.

21.046 hours (Figure 4). The second of which leads to solutions with a higher chi square values, so the first period was used for the subsequent steps.

The pole search was started using the "medium" option with the previously found sidereal period set to "float". The "dark facet" weighting factor was set to 0.8 and the number of iterations was set to 50. From this step we found two rough mirrored lower chi square solutions (Figure 5) separated by 180° in longitude at (300°, 15°) and (120°, 15°). The subsequent "fine" search, centered on these rough positions, allowed us to refine the position of the pole (Figure 6). The analysis shows two clustered solutions

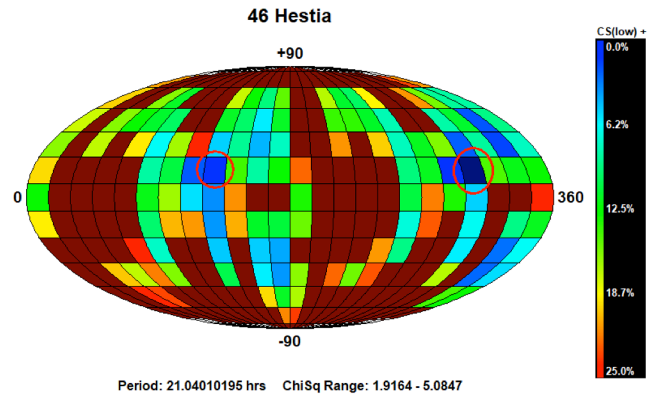


Fig. 5: Pole search distribution. The dark blue indicates the better solutions, while maroon the worst ones.

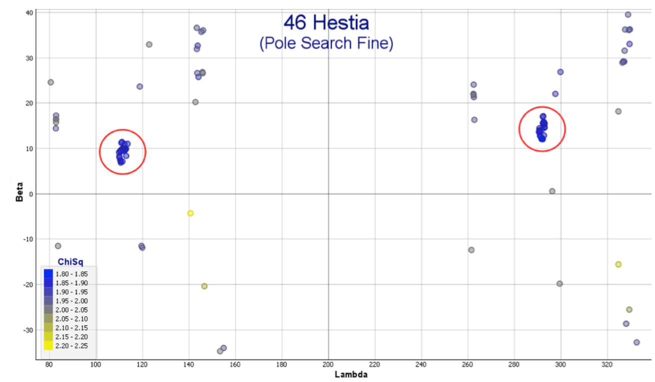


Fig. 6: The "fine" pole search shows two clustered solutions centered at the ecliptic longitude/latitude (292°, 14°) and (112°, 9°) with chi square values below 5% than the others.

within 5 degrees in longitude-latitude pairs with chi square values below 5% than the other solutions. The two best solutions (lowest chi square values) are reported in Table III. The sidereal period has been obtained averaging the two solutions found in the pole search process. Typical errors in the pole solution are ± 5 degrees and the uncertainty in sidereal period has been evaluated as a rotational error of 10° over the total time span of the dense data set. Figure 7 shows the shape model (first solution) while Figure 8 shows the fit between the model (black line) and observed lightcurves (red points).

λ °	β °	Sidereal Period (hours)	RMS
291	13	21.040101 ± 0.000035	0.0137
110	7		0.0138

Table III. The two spin axis solutions for 46 Hestia. The sidereal period was the average of the two solutions found in the pole search process.

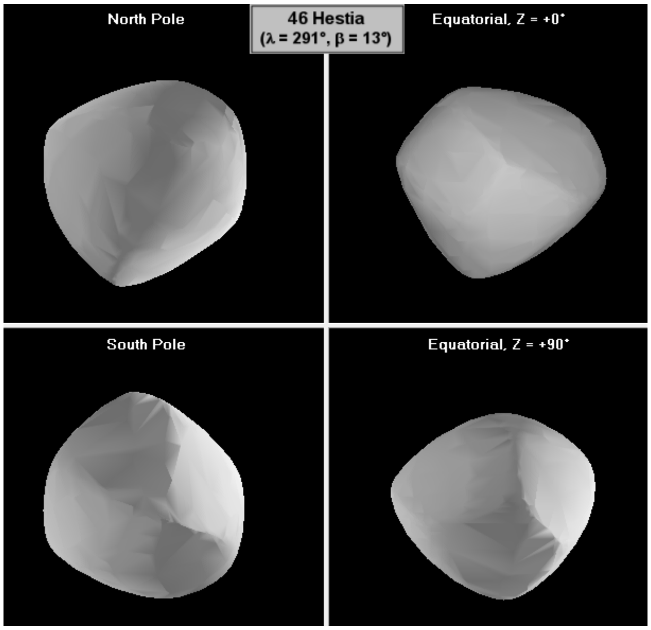


Fig. 7: The shape model for 46 Hestia (λ = 291°, β = 13°).

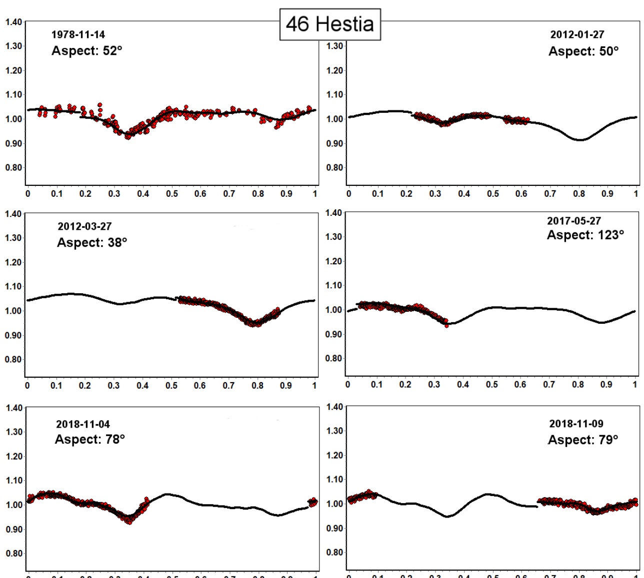


Fig. 8: Model fit (black line) versus observed lightcurves (red points) for (λ = 291°, β = 13°) solution.

References

BDW Publishing (2016). *http://www.minorplanetobserver.com/MPOSoftware/MPOLCInvert.htm*

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

Pilcher, F. (2012). "Rotation period determinations for 46 Hestia, 223 Rosa, 225 Henrietta, 266 Aline, 750 Oskar, and 765 Mattiaca." *Minor Planet Bull.* **39**, 171-173.

Pilcher, F. (2017). "Rotation period determinations for 46 Hestia, 118 Peitho, 333 Badenia, 356 Liguria, and 431 Nephele." *Minor Planet Bull.* **44**, 294-297.

Scaltriti, F., Zappala, V., Harris, A. W. (1981). "Photoelectric lightcurves and rotation periods of the asteroids 46 Hestia and 115 Thyra." *Icarus* **46**, 275-280.

LIGHTCURVE FOR 3951 ZICHICHI

Richard H. Downey
Physics Department, United States Naval Academy
572C Holloway Rd, Stop 9C, Annapolis, MD 21402 USA
downey@usna.edu

Jeffrey A. Larsen
Physics Department, United States Naval Academy
larsen@usna.edu

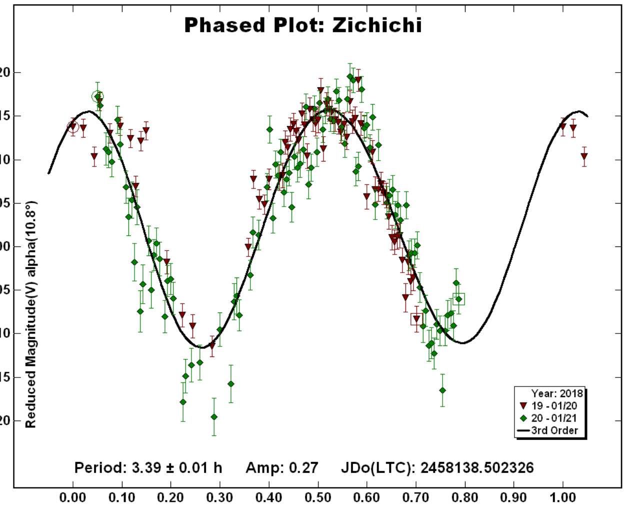
(Received: 2019 Jan 4)

Photometric observations of 3951 Zichichi were made in order to acquire a lightcurve for shape/spin axis modeling. The synodic rotation period is 3.39 ± 0.01 h and the amplitude is 0.27 mag. Results are consistent with previously reported values.

Photometric observations of 3951 Zichichi were made in order to acquire a lightcurve for shape/spin axis modeling as suggested in Warner et al. (2018). Observations were made in January 2018 using the United States Naval Academy (USNA) PlaneWave CDK20 telescope, SBIG STXL-11002 CCD, and Schott OG-515 blue-blocking filter. Lightcurve analysis was done at USNA using *MPO Canopus* (BDW Publishing, 2016). Each image was calibrated with dark and flat frames and converted to V magnitudes using solar-colored field stars from the MPOSC3 catalog distributed with *MPO Canopus*. The observing circumstances and results are in Table I. The lightcurve period and amplitude are consistent with previous reports in the asteroid lightcurve database (LCDB; Warner et al., 2009) including a recent report using observations taken around the same time as these (Franco et al., 2018).

Acknowledgements

Partial funding was provided by the USNA Kinnear Fellowship.



References

Franco, L., Marchini, A., Baj, G., Scarfi, G., Casalnuovo, G.B., Luna, V., Bachini, M., Maestripieri, M., Bacci, R., Galli, G. (2018). "Lightcurves for 1318 Nerina, 1342 Brabantia, 1981 Midas, and 3951 Zichichi." *Minor Planet Bull.* **45**, 273-275.

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 Jun. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Harris, A.W., Ďurech, J., Benner, L.A.M. (2018). "Lightcurve Photometry Opportunities: 2018 January-March." *Minor Planet Bull.* **45**, 103-108.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3951	Zichichi	01/20-01/21	174	10.3-10.8	259.9	259.7	3.39	0.01	0.27	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 approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 SEPTEMBER-DECEMBER

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Robert D. Stephens
Center for Solar System Studies / MoreData!
Rancho Cucamonga, CA 91730

(Received: 2019 Jan 13)

Lightcurves for 32 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2018 September-December were analyzed for rotation period and signs of satellites or tumbling.

CCD photometric observations of 32 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2018 September-December. 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 five is most 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.

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.

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 taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs.

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 between the two catalogs and 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). The same algorithm is used in an iterative fashion if it appears there is more than one period. This works well for binary asteroids but not for tumbling asteroids.

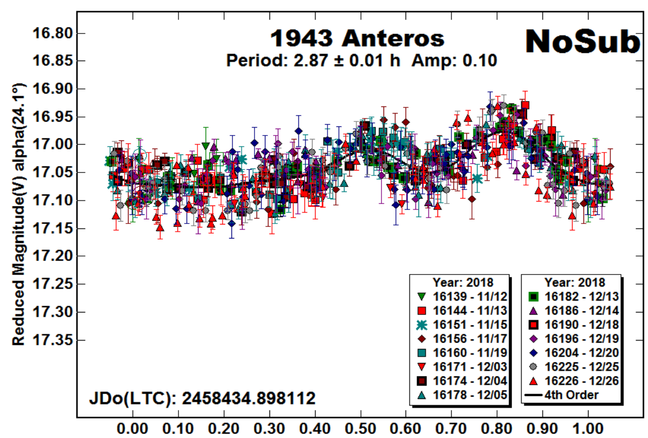
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distances by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances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

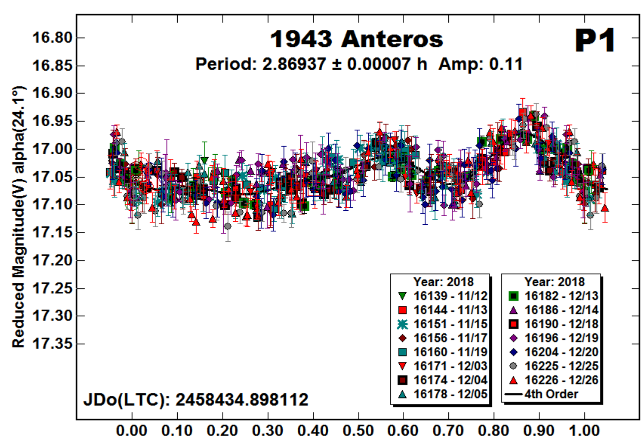
If the plot includes an amplitude, e.g., "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

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 bibcode, is also available for download. Readers are strongly encouraged, when possible, to cross-check with the original references listed in the LCDB.

<u>1943 Anteros</u>. This is a known binary (Warner et al., 2017). At the time of the 2016 observations, the orbital period was set at 23.548 h along with a primary rotation period of 2.869323 h. The CS3 observations in 2018 were used to confirm, if possible, the original results.

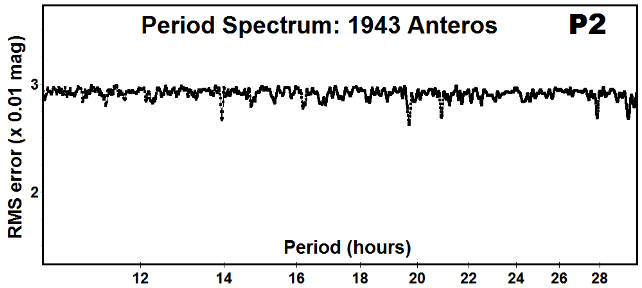
The "NoSub" plot shows the complete data set phased to the approximate rotation period for the primary. Overall, there are no *dramatic* signs of a binary, only subtle attentions that are almost hidden in the noise.

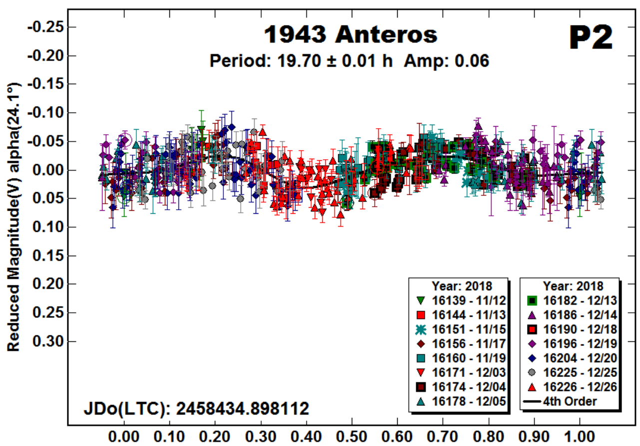




The "P1" plots shows the primary lightcurve after doing a dual-period search in *MPO Canopus*. There was a noticeable improvement.

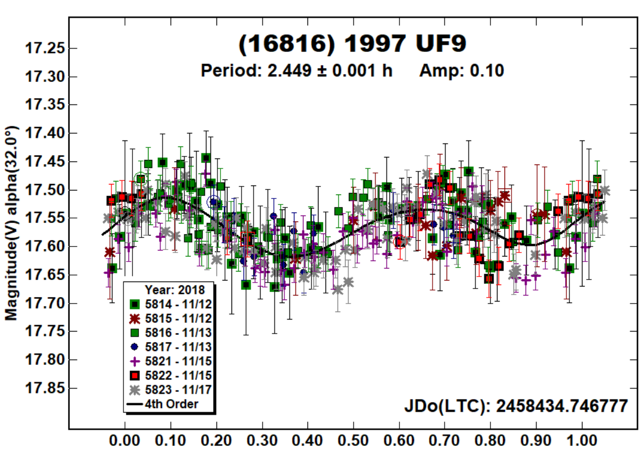
The search for P2 found no mutual occultation/eclipse events, the usually conclusive evidence for a satellite. The search did find a bimodal lightcurve with a period of 19.70 h, or a 6:5 ratio with the longer orbital period. Attempts to force the 2018 data to the 2016 results were fruitless as were attempts to force the 2016 data to the 2018 result.



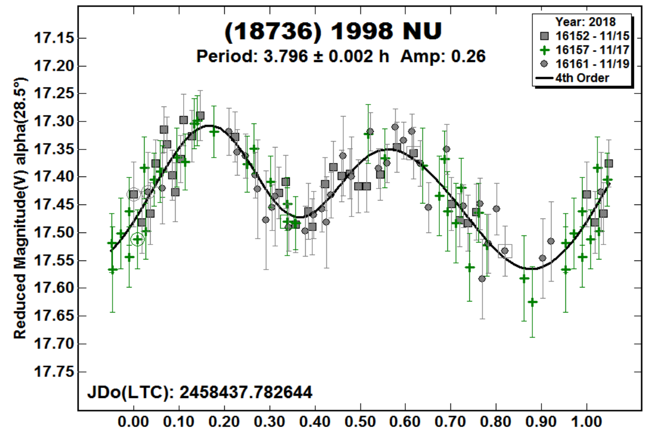


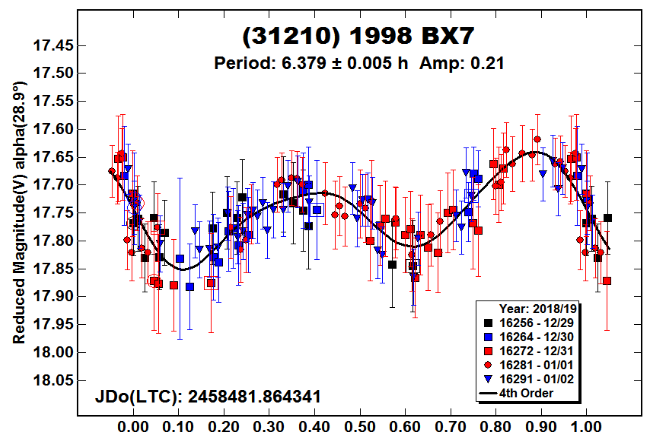
It's worth noting that the 2016 observations included data from observers at well-separated longitudes; the 2018 data were from CS3 alone. The period from 2016 is very nearly commensurate with an Earth day. In such cases, data from multiple longitudes is often required to reach the proper final conclusion.

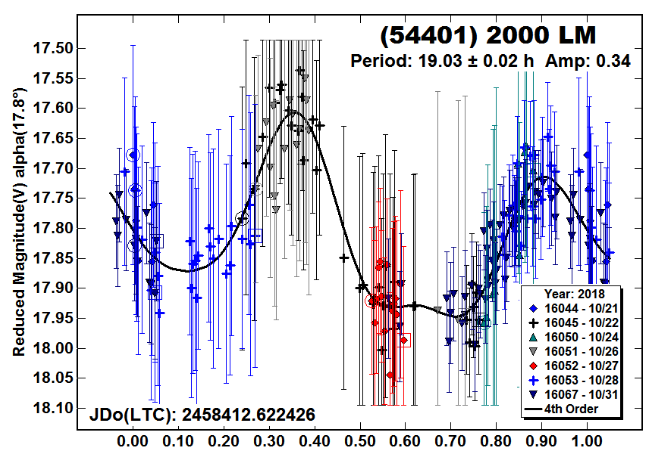
(16816) 1997 UF9. Erasmus et al. (2017) used a sparse data set from the Korea Microlensing Telescope Net (KMTNet; Kim et al., 2016) to find a period of 2.4 h. The result from the denser CS3 data set refines that result. The large noise in comparison to the amplitude makes the solution almost, but not quite, secure. The asymmetry of the lightcurve precludes a monomodal solution that would require an extraordinarily short period. The period spectrum showed the double period to be considerably weaker.



(18736) 1998 NU, (31210) 1998 BX7, (54401) 2000 LM. There were no rotational periods in the LCDB for these three NEAs. The solutions for 1998 NU and 1998 BX7 are considered secure. The one for 2000 LM is a best guess based on a noisy data set.

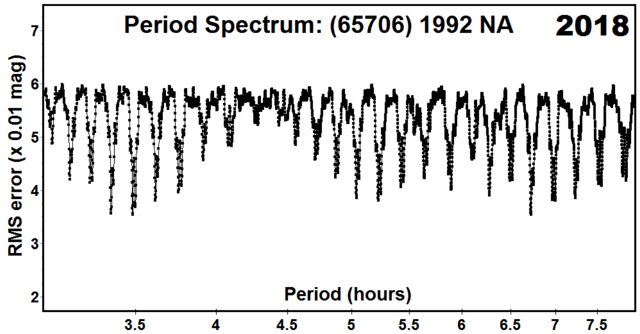




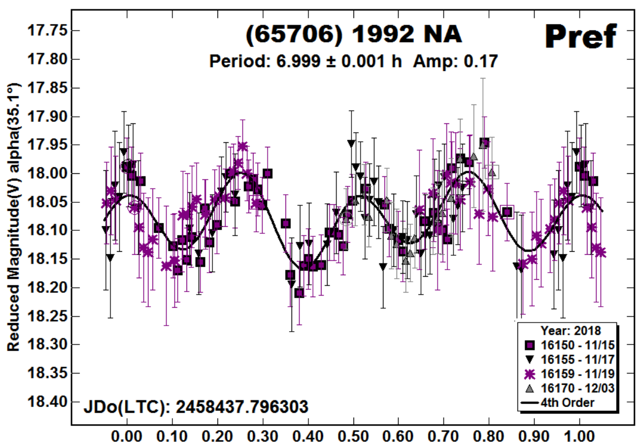


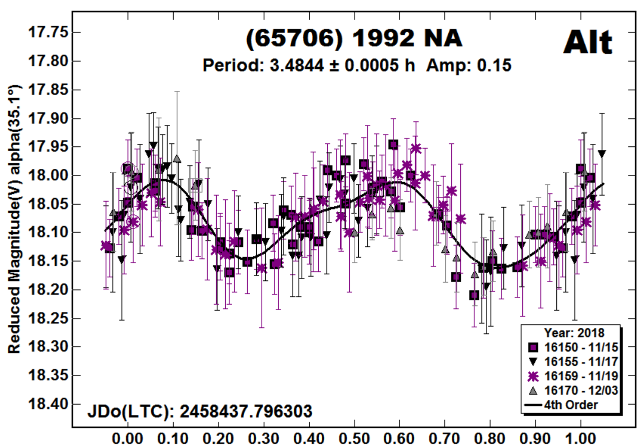
(65706) 1992 NA. Wisniewski and Harris (1994) found a period of 6.992 h with a complex trimodal lightcurve using data from three nights in 1992 Sept. They also noted "If this object had been observed on 25 September only, we would have interpreted its lightcurve as regular two maxima two minima with a period of rotation of 3.5 h." The period spectrum from 2018 shows the 3.5 and 7.0 h periods are equally possible.

Our lightcurve had an amplitude of only 0.15 mag compared to 1992 lightcurve amplitude of 0.37 mag. Harris et al. (2014) showed that a bimodal lightcurve cannot be assumed at low amplitudes at low phase angles. The 1992 and 2018 observations were at high to large phase angles, which further complicates analysis.

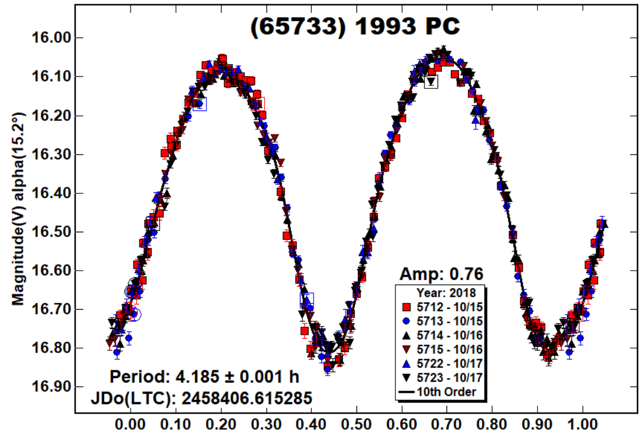


We used a split-halves plot (Harris et al., 2014) to check on the symmetry of the two halves of the lightcurve at 6.999 h. There appears to be just enough asymmetry to favor the longer period.

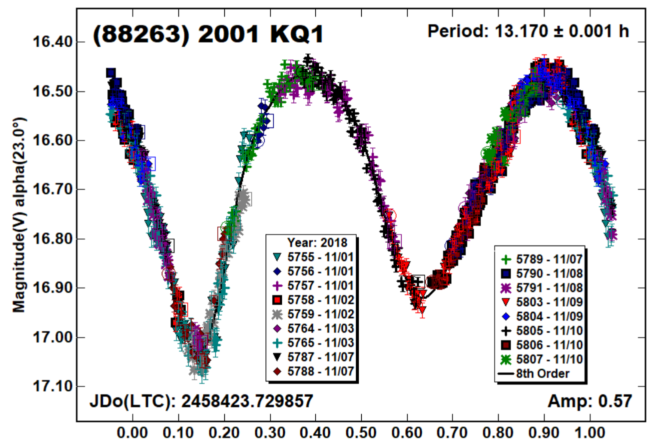




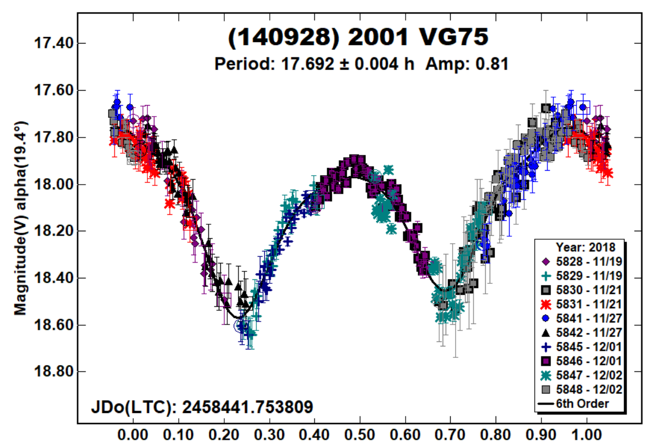
(65733) 1993 PC. Previous work by Warner (2014) found a period of 4.184 h using the second half of a data set from 2013 October. The lightcurve amplitude in 2013 showed a strong dependency on phase angle, increasing from 0.73 to 0.97 mag as the phase angle went from 12.2 to 34.5 deg. The 2018 observations were at 15.2 deg. We did not follow the asteroid long enough to see if the lightcurve behavior showed a similar dependency on phase angle.

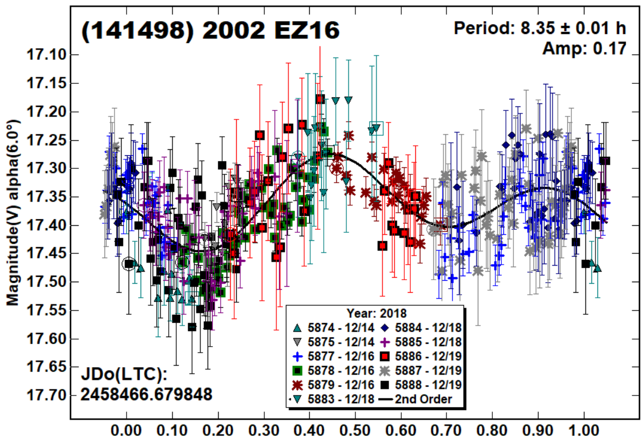


(88263) 2001 KQ1. Previous works include Warner (2016; 13.16 h) and Linder (2017; 13.163 h), which are in close agreement with our result of 13.170 h.

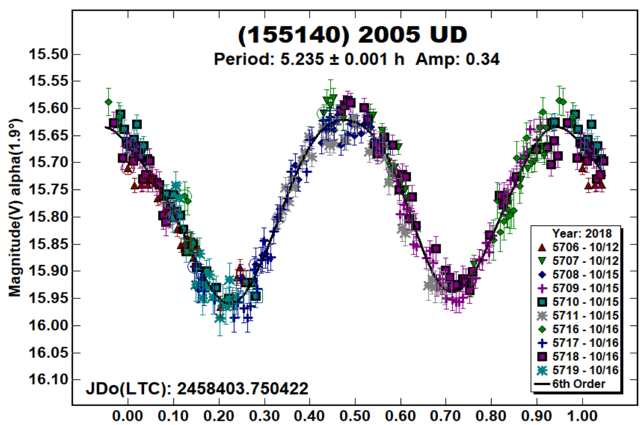


(140928) 2001 VG75, (141498) 2002 EZ16. There were no previous rotation periods given in the LCDB. The solution for 2001 VG75 is considered secure. Due to the noise rivaling the amplitude, the solution for 2002 EZ16 is "probably correct" but not secure.

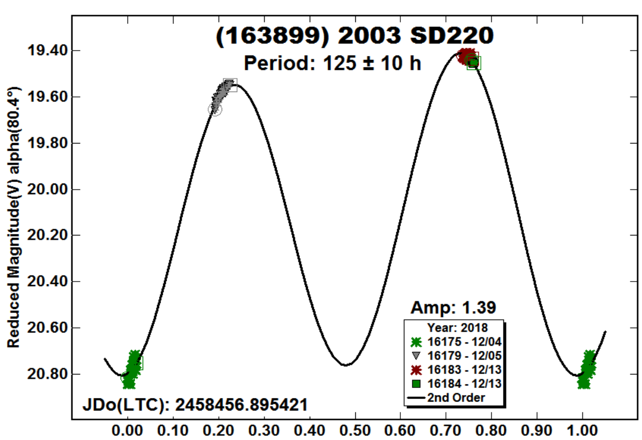




[(155140) 2005 UD]{.underline}. Kinoshita et al. (2007) reported a period of 5.2310 h using data from 2005. The lightcurve amplitude was 0.44 mag at phase angle 37°. Our 2018 observations were made at 20° and nearly the same phase angle bisector longitude and latitude and so the lower amplitude at the lower phase angle is expected (Zappala et al., 1990).

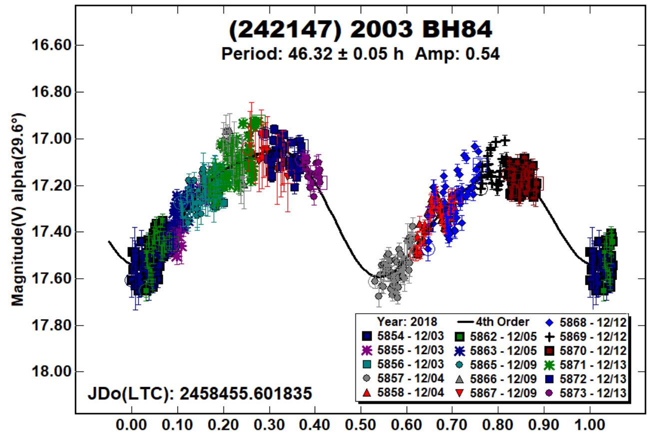


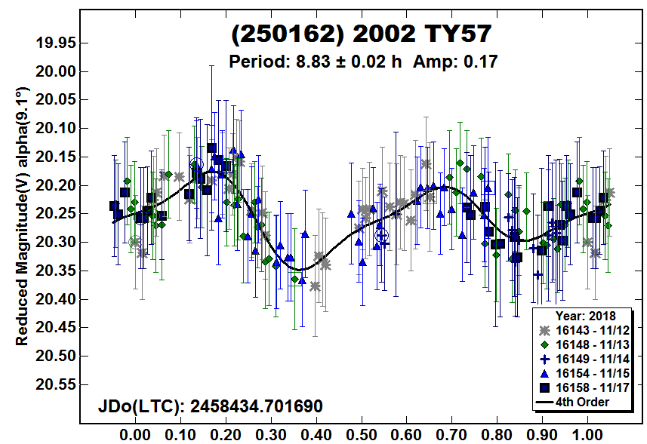
(163899) 2003 SD220. Aznar et al. (2018) found a period of 173 h for this NEA. Warner (2016) found a period of 285 h based on a data set with observations on almost every night over a 22-day span. While there were signs of tumbling, the solution was considered very strong since the lightcurve was well covered.

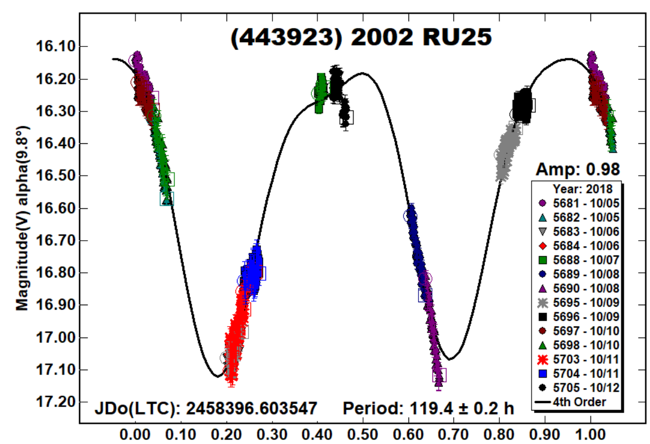


We were not able to get a similar data set in 2018, so comparisons to the earlier results are suspect. This is shown by the fact that our data best fit a large amplitude bimodal lightcurve with a period less than half the previous result.

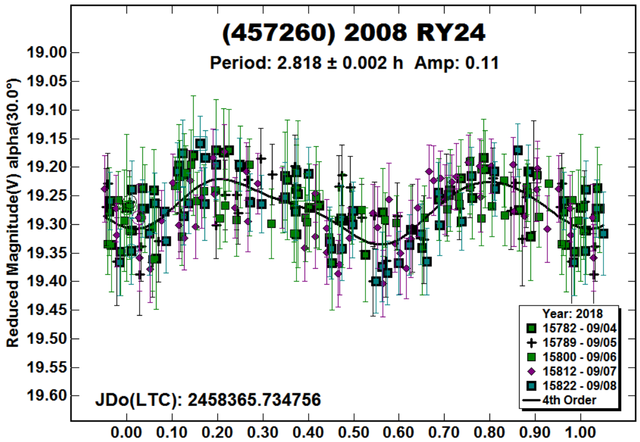
(242147) 2003 BH84, (250162) 2002 TY57, (443923) 2002 RU25. The LCDB had no previous rotation periods listed for these three NEAs. The amplitude for 2003 BH84 nearly assures a bimodal solution (Harris et al., 2014). Tumbling cannot be ruled out for 2002 RU25.



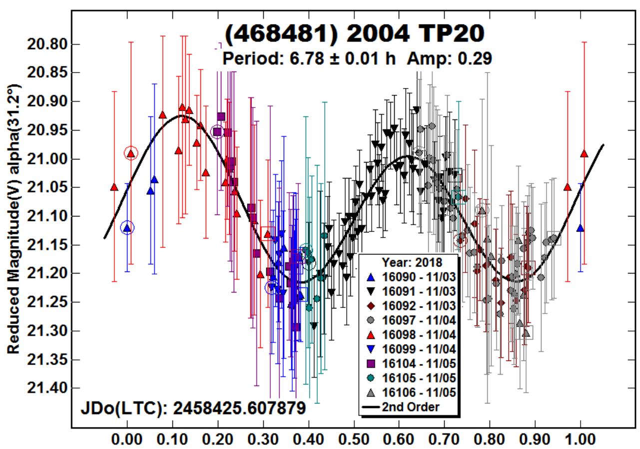


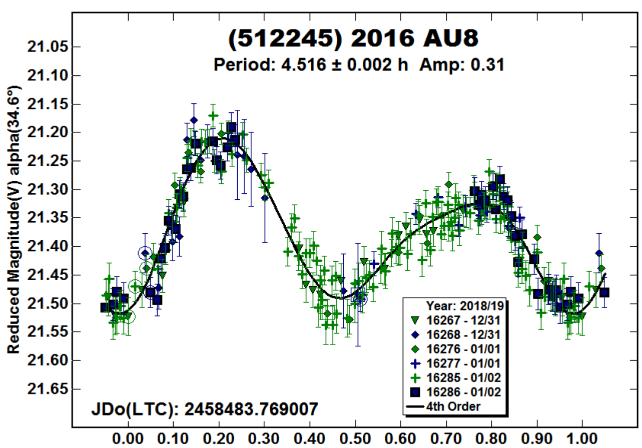


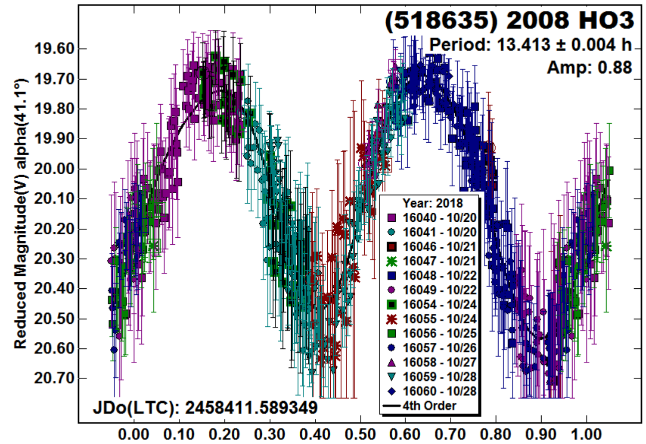
(457260) 2008 RY24. Pravec et al. (2018web) observed this NEA in 2018 November and found a secure period of 2.5308 h. Warner (2019) first reported a period of 8.19 h using data from 2018 Sept. The Pravec et al. posting prompted another look at our September data. After minor adjustments to nightly zero points, we found a solution close to, but not the same as, Pravec et al. Our shorter data set had a large amount of noise, which probably contributed to the difference in periods. The asteroid was out of reach by the time we learned of the other result and so we could not try again to confirm or improve our period.



(468481) 2004 TP20, (512245) 2016 AU8, (518635) 2008 HO3. This trio of NEAs had no previously reported rotational periods in the LCDB. Of the three, the solution for 2004 TP20 is considered the least secure because of the level of noise in the data.



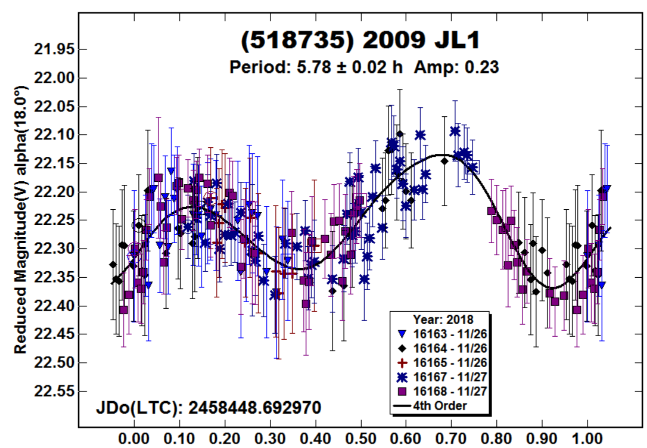


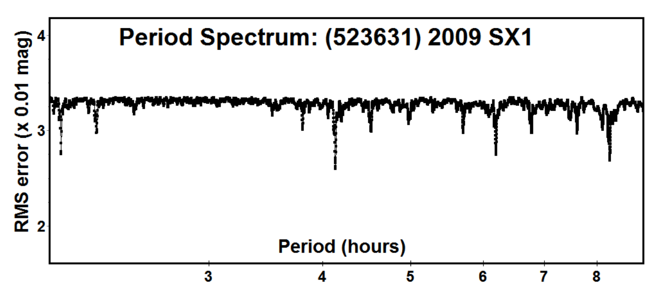


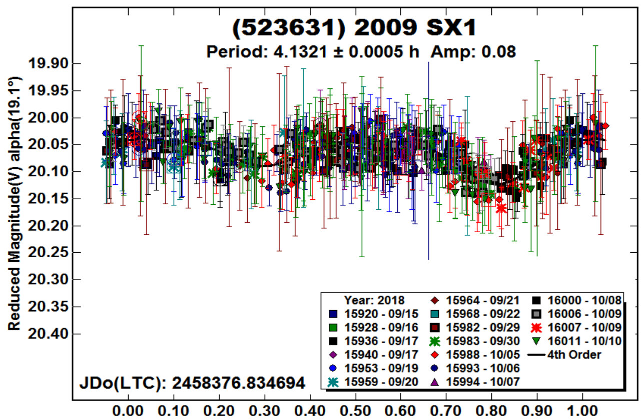
(518735) 2009 JL1, (523631) 2009 SX1, (523815) 2009 HW44. All three of these NEAs were first-time entries into the LCDB.

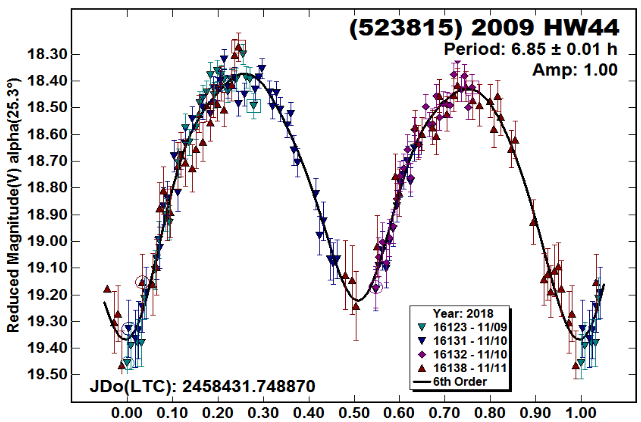
Since we try to stretch the limits of our observations and analysis, our data often have a large amount of noise and large error bars for each data point. Even so, if the lightcurve amplitude is large enough, we can find a period that is good enough for statistical studies. Such was the case for all three asteroids but not to the same degree.

The larger amplitude for 2009 JL1 makes our period of 5.78 h reasonably secure, i.e., higher quality data would unlikely change the solution by more than a few 0.01 h. The period spectrum for 2009 SX1 shows a number of possibilities. The low amplitude allows for solutions ranging from monomodal to trimodal and higher. We adopted the bimodal solution at 4.1321 h. For 2009 HW44, the large amplitude and good data leave no doubts.

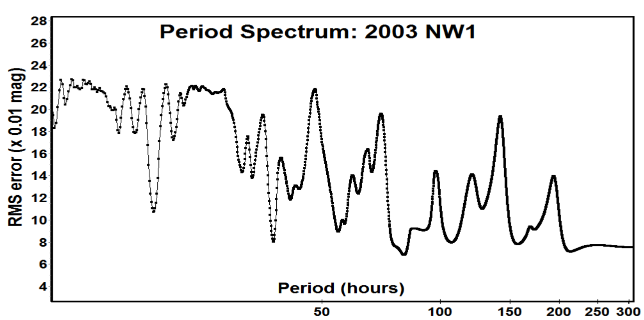


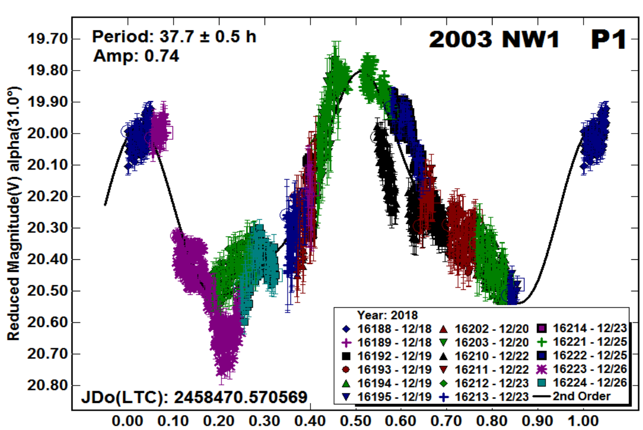


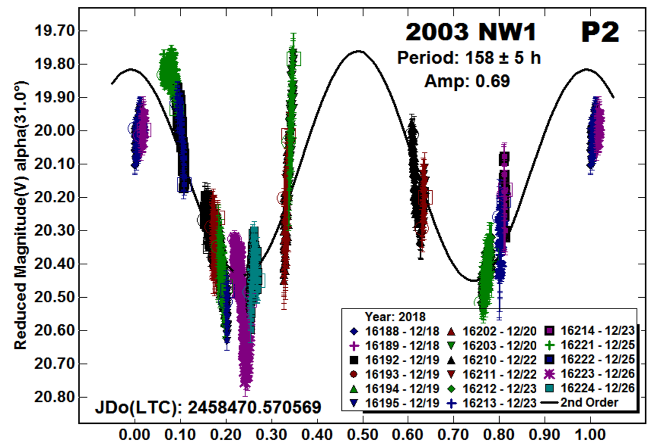




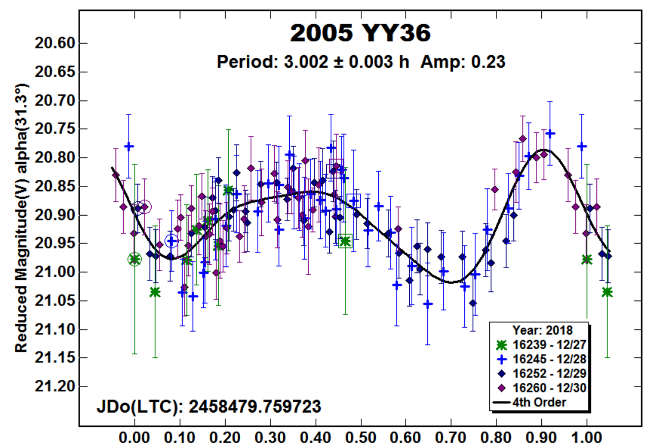
2003 NW1. There were no rotational period entries in the LCDB. It was hard to fit the data to any single period. Even the shorter period exceeds what's required for an asteroid to dampen from tumbling to single axis rotation (Pravec et al., 2014; 2005) so it's very likely the object is tumbling and the two periods are the best fits *MPO Canopus* could find.

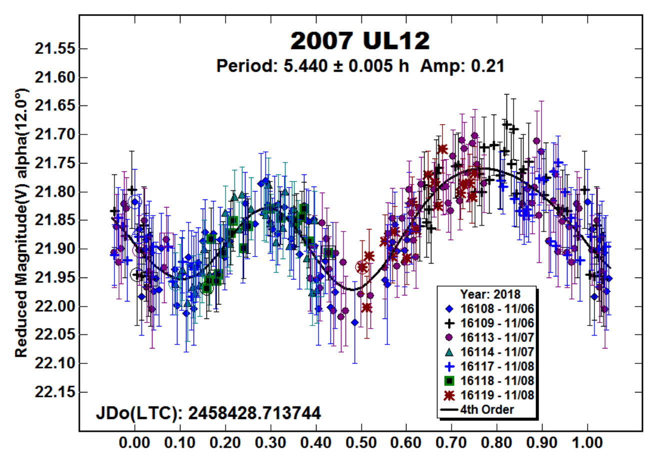




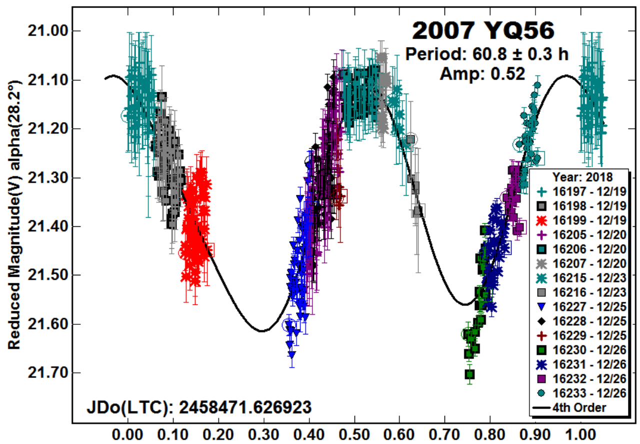


2005 YY36, 2007 UL12. This is another pair of NEAs that didn't have rotation periods in the LCDB Both solutions are considered secure.



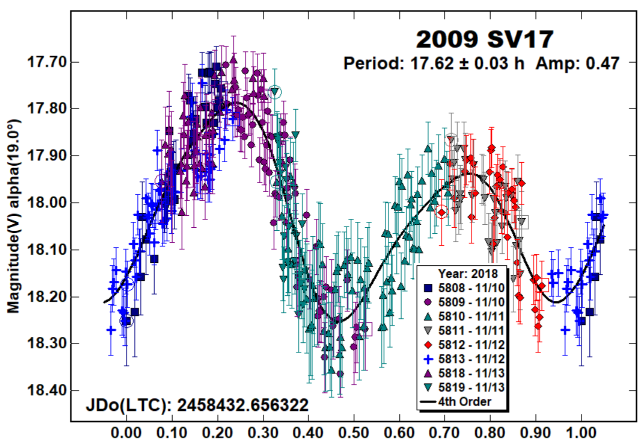


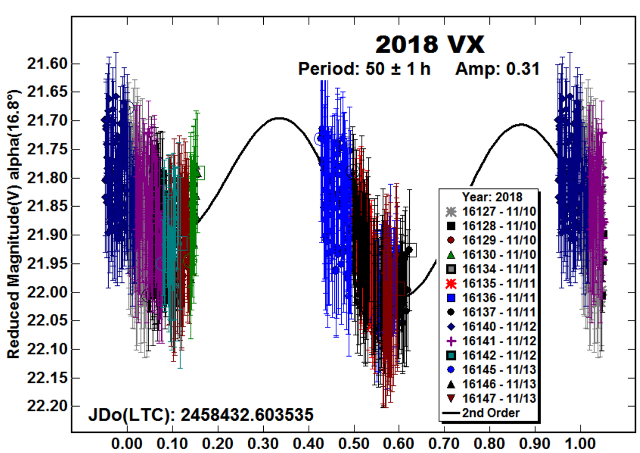
2007 YQ56. Given the estimated diameter of only 310 meters and the very long period, it would be no surprise to see signs of non-principal axis rotation (NPAR; Pravec et al., 2014; 2005). One indication is that the slope of the data on a given night is different from the slope of the model curve. Another is data obtained on different rotations cannot be reconciled to one another and/or the Fourier curve. There are marginal signs of these in the lightcurve plot. It would take a much more extensive data set using multiple observers at well-separated longitudes to find a fully convincing result.

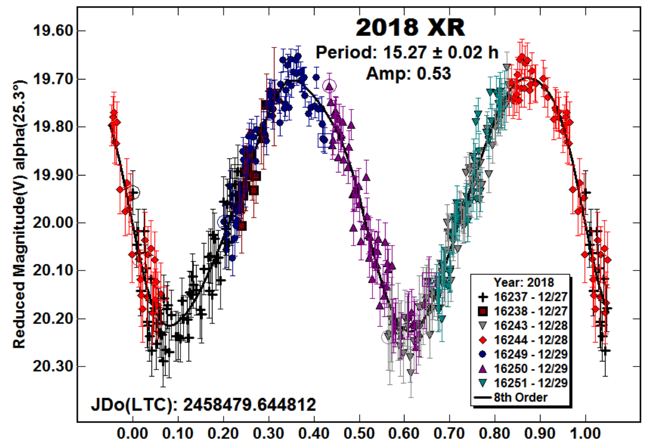


2009 SV17, 2018 VX, 2018 XR. None in this set of NEAs had a rotation period listed in the LCDB. The solutions for 2009 SV17 and 2018 XR are considered secure.

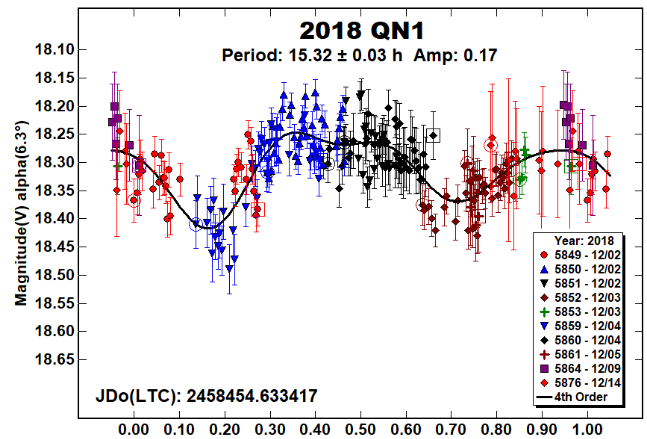
While the lightcurve is not filled in for 2018 VX, there seems little doubt that a period of 50 h is very close to the actual period. The slopes of the sessions match the lightcurve and the shape of the model lightcurve is reasonable for a bimodal lightcurve, which is nearly assured because of the apparent amplitude and relatively low phase angle (Harris et al., 2014).



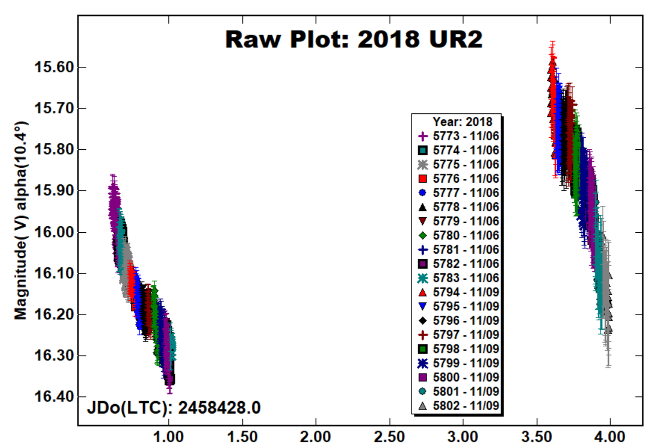


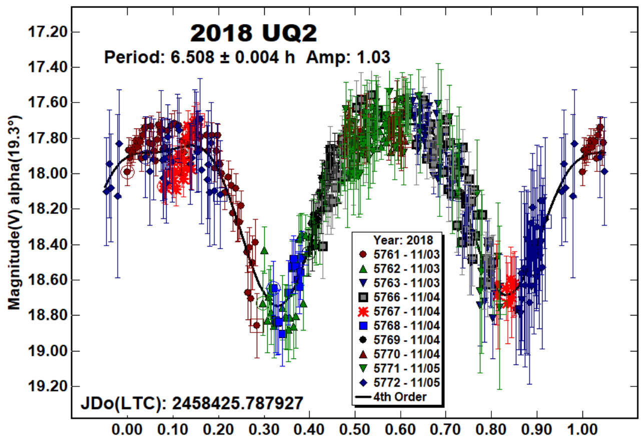


2018 QN1, 2018 UR2, 2018 UQ2. The period spectrum did not show any convincing solutions for 2018 QN1. The data were fit to the best result that gave a bimodal lightcurve, which is a plausible assumption because its asymmetry.



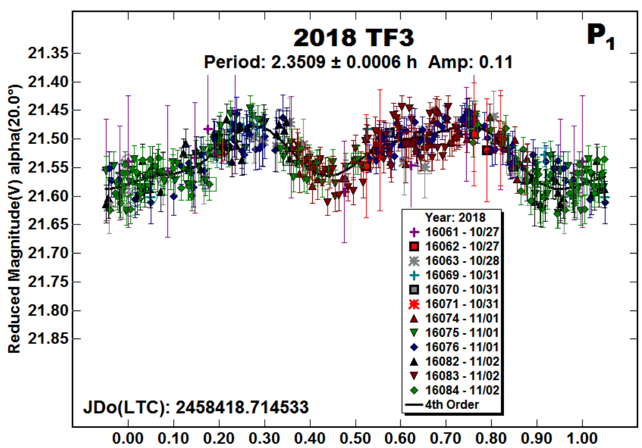
No period could be found for 2018 UR2, though it's a reasonable estimate that the period is on the order of 48 hours based on the amplitude rise of the data on each night and the assumption that the amplitude is not significantly larger than seen.

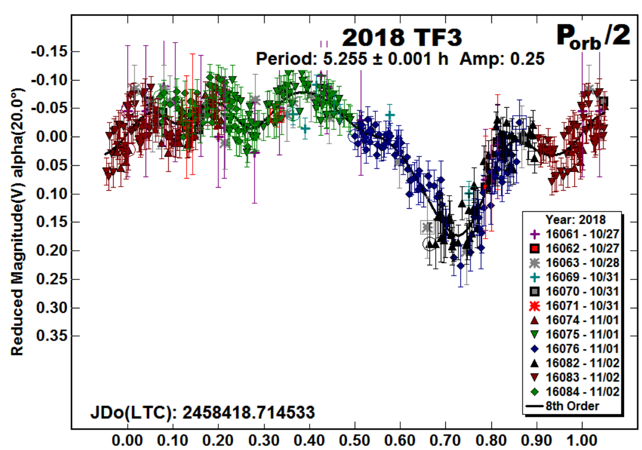




Given the amplitude and despite the somewhat noisy data, the result is considered secure, although the accuracy and precision could be improved with future observations.

2018 TF3. This is a known binary, Pravec et al. (2018a) having made that discovery from data obtained in 2018 September-October. They found a primary period of 2.3498 h and an orbital period for the asynchronous satellite of 10.511 h. The mutual eclipse/occultation events were used to find a ratio of 0.23 for the secondary-to-primary effective diameters.





The CS3 observations were made at the end of 2018 October. While we found a primary period of 2.3509 h, in close agreement with the Pravec et al. (2018a) result, our data set was too limited to find a reliable solution for the satellite's orbital period. In order to get a lightcurve where the Fourier curve and lightcurve matched one another, we forced a P2 solution around the half-period found by Pravec et al. The doubled result gives 10.51 h, which is essentially the same as Pravec et al. However, the lightcurve shape is not what was expected, having a much larger amplitude in the "main event." Without the Pravec et al. results, ours would not be a conclusive case for a binary asteroid.

Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database Warner et al., 2009) and ALCDEF database (*alcdef.org*) are supported by NASA grant 80NSSC18K0851.

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/*).

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research.

References

References from web sites should be considered transitory, unless from an agency with a long lifetime expectancy. Sites run by private individuals, even if on an institutional web site, do not necessarily fall into this category.

Aznar Macias, A., Predatu, M., Vaduvescu, O., Oey, J. (2018). "EURONEAR - First Light Curves and Physical Properties of Near Earth Asteroids." arXiv:1801.09420. *Romanian J. Phys*. **62**, 904.

Erasmus, N., Mommert, M., Trilling, D.E., Sickafoose, A.A., van Gend, C., Hora, J.L. (2017). "Characterization of Near-Earth Asteroids Using KMTNET-SAAO." *Astron. J.* **154**, A162.

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

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Kim, S.-L., Lee, C.-U., Park, B.-G., Kim, D.-J., Cha, S-M., Lee, Y., Han, C., Chun, M.Y., Yuk, I. (2016). "KMTNET: A Network of 1.6 m Wide-Field Optical Telescopes Installed at Three Southern Observatories." J. Korean Ast. Soc. **49**, 37-44.

Kinoshita, D., Ohtsuka, K., Sekiguchi, T., Watanabe, J., Ito, T., Arakida, H., Kasuga, T., Miyasaka, S., Makamura, R., Lin, H.-C. (2007). "Surface heterogeneity of 2005 UD from photometric observations." *Astron. Astrophys*. **466**, 1153-1158.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1943	Anteros	11/12-12/26	466	24.2,4.3,9.6	84	-3	2.86937	0.00005	0.11	0.01
16816	1997 UF9	11/12-11/17	295	32.0,32.7	78	23	2.449	0.001	0.1	0.02
18736	1998 NU	11/15-11/17	101	28.5,28.2	93	3	3.796	0.002	0.26	0.02
31210	1998 BX7	12/31-01/02	132	27.8,26.6	134	-6	6.379	0.005	0.21	0.02
54401	2000 LM	10/21-10/31	188	17.7,13.5	35	16	19.03	0.03	0.34	0.04
65706	1992 NA	11/15-12/03	149	35.2,22.9	92	16	[A]6.999	0.001	0.17	0.02
65706							3.4844	0.0005	0.15	0.02
65733	1993 PC	10/15-10/17	410	15.2,15.6	26	10	4.185	0.001	0.76	0.01
88263	2001 KQ1	11/01-11/10	821	23.0,16.1	62	1	13.170	0.001	0.57	0.02
140928	2001 VG75	11/19-12/02	399	19.4,11.5	75	-3	17.692	0.004	0.81	0.03
141498	2002 EZ16	12/14-12/19	364	5.8,4.8,6.2	85	-3	8.35	0.01	0.17	0.05
155140	2005 UD	10/12-10/16	300	1.8,6.5	18	0	5.235	0.001	0.34	0.02
163899	2003 SD220	12/04-12/13	106	80.8,91.1	107	34	125	10	1.39	0.1
242147	2003 BH84	12/03-12/13	586	29.4,19.5	79	23	46.32	0.05	0.54	0.05
250162	2002 TY57	11/12-11/19	147	9.1,10.3	50	-8	8.83	0.02	0.17	0.03
443923	2002 RU25	10/05-10/12	718	9.9,17.4	6	8	119.4	0.2	1.00	0.05
457260	2008 RY24	09/04-09/05	223	30.0,29.9	10	8	2.818	0.002	0.11	0.03
468481	2004 TP20	11/03-11/05	180	31.6,36.8	20	-6	6.78	0.01	0.29	0.03
512245	2016 AU8	12/31-01/02	224	34.7,31.1	118	13	4.516	0.002	0.31	0.02
518635	2008 HO3	10/20-10/28	639	41.0,34.5	49	3	13.413	0.004	0.88	0.06
518735	2009 JL1	11/26-11/27	186	17.8,15.2	72	-5	5.78	0.02	0.23	0.03
523631	2009 SX1	09/15-10/10	445	19.1,4.3,22.4	53	10	4.1321	0.0005	0.08	0.01
523815	2009 HW44	11/09-11/11	165	25.4,26.1	24	-2	6.85	0.01	1.00	0.05
	2003 NW1	12/18-12/26	1660	30.4,21.2	74	-1	37.7	0.5	0.74	0.1
	2005 YY36	12/28-12/30	128	31.2,31.0	120	-2	3.002	0.003	0.23	0.02
	2007 UL12	11/06-11/08	270	12.0,14.2	45	-8	5.440	0.005	0.21	0.03
	2007 YQ56	12/19-12/26	516	28.0,13.8	92	12	60.8	0.3	0.52	0.05
	2009 SV17	11/10-11/13	372	19.1,19.4	58	11	17.62	0.03	0.47	0.05
	2018 VX	11/10-11/13	906	16.8,17.9	38	1	50	1	0.31	0.04
	2018 XR	12/27-12/29	380	25.4,27.9	103	20	15.27	0.02	0.53	0.03
	2018 QN1	12/02-12/14	227	6.3,10.3	75	5	15.32	0.03	0.17	0.05
	2018 UR2	11/06-11/09	1006	11.6,28.8	45	12	>50		>0.7	
	2018 UQ2	11/03-11/05	480	19.3,16.5	52	-3	6.508	0.004	1.03	0.05
	2018 TF3	10/27-11/02	389	20.1,35.9	39	-15	2.3509	0.0006	0.11	0.01

Table II. Observing circumstances. [A] indicates an ambiguous solution: the first line gives the preferred result. The phase angle (α) is given at the start and end of each date range. If there are three values, the middle one is the minimum phase angle reached during the period. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude.

Linder, T.R., Puckett, A., Holmes, R., Nowinski, M., Hardersen, P., Haislip, J., Reichart, D. (2017). "Near Earth Asteroid Rotational Analysis by Astronomical Research Institute: 2015 November thru 2016 August." *Minor Planet Bull*. **44**, 95-98.

Munos, J.L. (2017) Carlsberg Meridian Catalog web site. *http://svo2.cab.inta-csic.es/vocats/cmc15/*

Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G., Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galád, A., Brown, P., Degraff, D.R., Lambert, J. V., Cooney, W.R., Foglia, S. (2005). "Tumbling asteroids." *Icarus* **173**, 108-131.

Pravec, P., Scheirich, P., Durech, J., Pollock, J., Kusnirak, P., Hornoch, K., Galad, A., Vokrouhlicky, D., Harris, A.W., Jehin, E., Manfroid, J., Opitom, C., Gillon, M., Colas, F., Oey, J., Vrastil, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Pravec, P., Kusnirak, P., Hornoch, K., Kucakova, H., Fatka, P. (2018a). *CBET* **4567**.

Pravec, P., Wolf, M., Sarounova, L. (2018web). *http://www.asu.cas.cz/~ppravec/neo.htm*

Rubincam, D.P. (2000). "Relative Spin-up and Spin-down of Small Asteroids." *Icarus* **148**, 2-11.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 April. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2014). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2013 September-December." *Minor Planet Bull*. **41**, 113-124.

Warner, B.D. (2016). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 October-December." *Minor Planet Bull*. **43**, 143-154.

Warner, B.D., Benishek, V., Harris, A.W. (2017). "1943 Anteros: A Possible Near-Earth Binary Asteroid." *Minor Planet Bull*. **44**, 186-188.

Warner, B.D., Stephens, R.D. (2019). "Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2018 July-September." *Minor Planet Bull*. **46**, 27-40.

Wisniewski, W.Z., Harris, A.W. (1994). "The complex lightcurve of 1992 NA." *Planet. Space Sci.* **42**, 337-339.

Zappala, V., Cellini, A., Barucci, A.M., Fulchignoni, M., Lupishko, D.E. (1990). "An analysis of the amplitude-phase relationship among asteroids." *Astron. Astrophys*. **231**, 548-560.

ANOTHER TRIO OF POSSIBLE VERY WIDE BINARY ASTEROIDS

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Robert D. Stephens
Center for Solar System Studies / MoreData!
Rancho Cucamonga, CA 91730

(Received: 2019 Jan 13)

Lightcurve analysis of the near-Earth asteroids (442742) 2012 WP3, (523604) 2004 QB17, and 2018 RL indicate that they are potential members of a relatively rare class of "very wide binary asteroids." These objects feature a primary rotational period of tens to hundreds of hours and a secondary rotational period less than 24 hours, usually less than 10 hours. These three bring to 30 the number of suspected members of the class.

CCD photometric observations of near-Earth asteroids at the Center for Solar System Studies (CS3) in 2018 October-November found three that may fit into a class of rare objects called "very wide binary asteroid." In brief, these are objects where the primary has been spun down by YORP (Rubincam, 2000) to a very long period while the orbit of a smaller satellite has expanded to a point just short of the satellite being able to break free. Depending on the mass ratio between the secondary and primary, the system can collapse or the satellite eventually break away. The latter may result in an "asteroid pair" (Vokrouhlicky and Nesvory, 2008). In either case, the satellite period is not tidally-locked to its orbital period and so the system is "fully asynchronous." Additional details on the formation and evolution of this class can be found in Warner (2016c and references therein).

Table I gives the equipment used for the most recent observations. All observations were unfiltered and guided at sidereal rate. The exposure time was varied to reach maximum SNR while minimizing trailing of the asteroid.

Asteroid	Telescope(s)	Camera(s)
(442742) 2012 WP3	0.30-m SCT 0.35-m SCT	SBIG STL-1001E FLI ML-1001E
(523604) 2004 QB17	0.50-m R-C	FLI PL-1001E
2018 RL	0.35-m SCT	FLI ML-1001E

Table I. List of telescopes and CCD cameras used for each 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 taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs. Period analysis was also done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989). The dual-period feature of the software was used to find the periods of the primary and secondary.

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 $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. Unless otherwise stated, the magnitudes were normalized to the phase angle in parentheses using $G = 0.15$. 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 bibcode, is also available for download. Readers are strongly encouraged, when possible, to cross-check with the original references listed in the LCDB.

Observing and Analysis Methodology

In recent years, the work at CS3 has concentrated on near-Earth asteroids under a grant from NASA. The three objects here were observed as part of that program. The usual method is to choose an NEA that is within reach of our equipment (V < 19.2) and follow it for as many nights as needed to find a period, if possible. In some cases, the data for a single night show only a slow increase or decrease in brightness. On rarer cases, there is a moderate to strong indication of a short period being superimposed on the down or upward trend.

After each night, the data are plotted with the raw reduced magnitudes (see above) to check if the lightcurve eventually shows some sort of periodic shape. No changes are made to nightly zero points since that may mask the true trend in the data. When sufficient data are obtained (a minimum/maximum pair seems to be defined), a low-order Fourier solution is attempted with the period search range based on the assumption of a bimodal lightcurve and so the time from one extrema to the next is about one-quarter the rotational period.

The low-order Fourier model curve is subtracted from the data and a 2^{nd} or 4^{th} order period search is made within a range that seems appropriate based on the raw data from each night. As more data become available and they continue to indicate a viable long-period solution, the dual-period search is applied after each observing run to confirm that the short period also seems viable and is not just noise on which the Fourier analysis has falsely found a period.

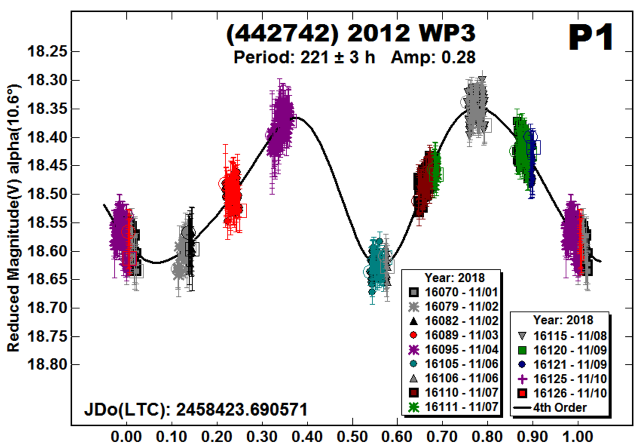
There are important considerations in this process. One is the possibility that the lightcurve is evolving with changing phase and phase angle bisector if the asteroid is followed for weeks or even months. This may affect the long period solution if the data are able to cover a second rotation at the presumed period. If they don't quite fit the model and previous data at the same rotation phase, the question becomes whether the discrepancy is because of an evolving lightcurve or because the asteroid is tumbling.

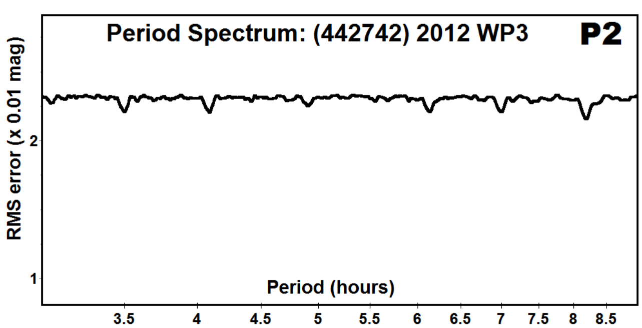
If the asteroid is tumbling, then the secondary period *might* be a low-amplitude component of a complex lightcurve. It will depend on the amplitude of the two lightcurves and the periods. A rule of thumb is that the rotation and "wobble" frequencies cannot be separated by more than a factor of about the inverse amplitude of variation (Alan Harris, private communications). For example, if the larger amplitude is 1 magnitude, the two periods must be of the same order. If the amplitude is 0.3 mag, then the two periods might be as much a factor of 3.3 different. Of all the candidates to-date (see Table II), two or three could be tumbling or a very wide binary.

This brings up the most important consideration: lack of definitive proof. When using lightcurve data alone, an asteroid is usually not considered to be binary unless mutual eclipse/occultation events are captured. These are seen as attentions in the primary lightcurve as the satellite passes in front of the primary (primary event) and behind the primary (secondary event). Because the orbital periods of very wide binaries are very long, the chances of capturing one event, let alone two or more for confirmation, are exceedingly small. For this reason, all candidates for the very wide binary group at this time are, at best, only *suspected* and not confirmed binaries.

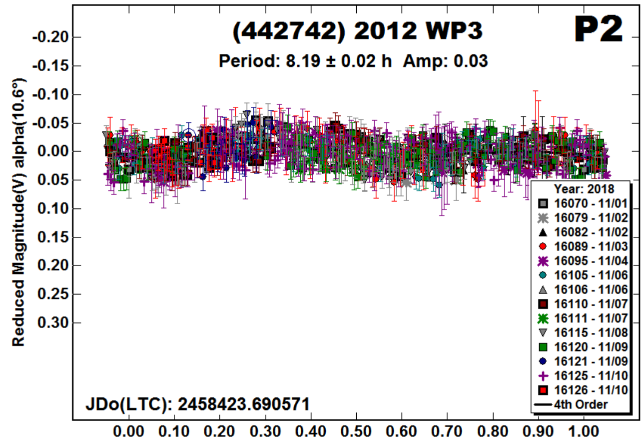
The Nominees Are...

(442742) 2012 WP3. The observations for 2012 WP3 were made on nine nights 2018 November. At that time, the LCDB did not have any rotational periods listed. After several nights, a long period component was seen and the dual-period analysis described above was implemented. The solution for the long period is mostly secure. One important feature that helps support this is that the slope of data for each night's run fits the slope of the Fourier curve. If this were not the case, then tumbling action might have been the better interpretation.

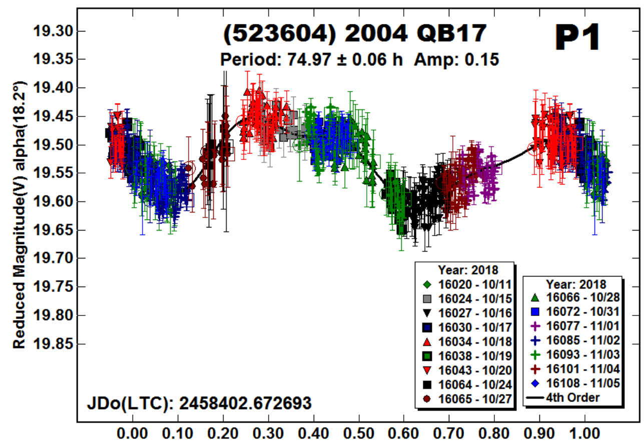


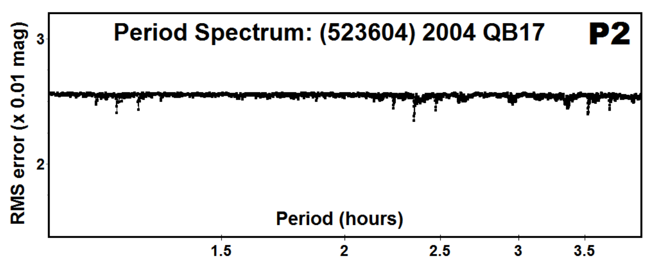


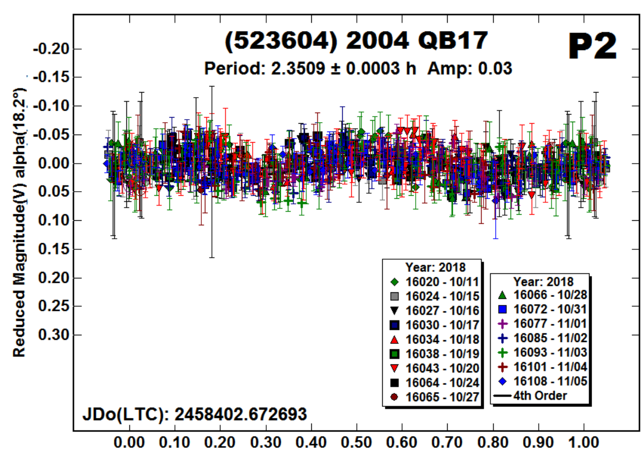
The period spectrum for a secondary period shows several weak possibilities. We adopted the one that gave a bimodal lightcurve, i.e., P = 8.19 h. Given that the noise in the data rivals the amplitude of the secondary lightcurve, 2012 WP3 is among the weaker candidates for belonging to the very wide binaries group.



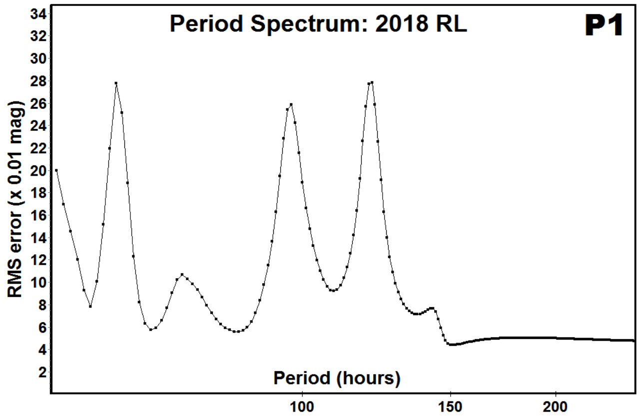
(523604) 2004 QB7. The secondary solution with a bimodal lightcurve is slightly better than for 2012 WP3, even though the noise again rivals the amplitude of the lightcurve and the overall data set was noisy because of interference from the moon.

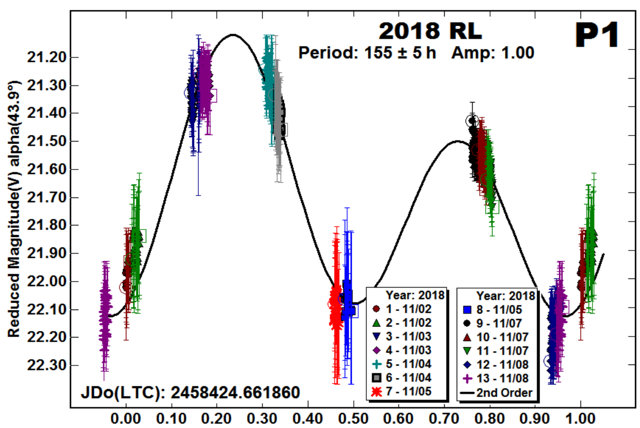


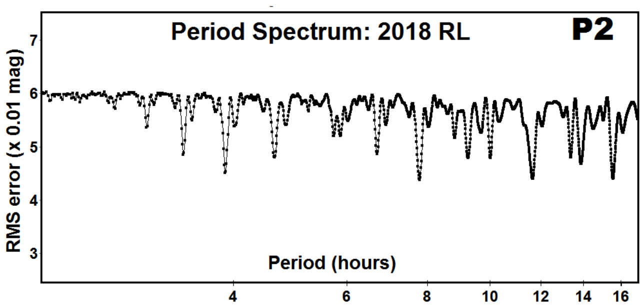


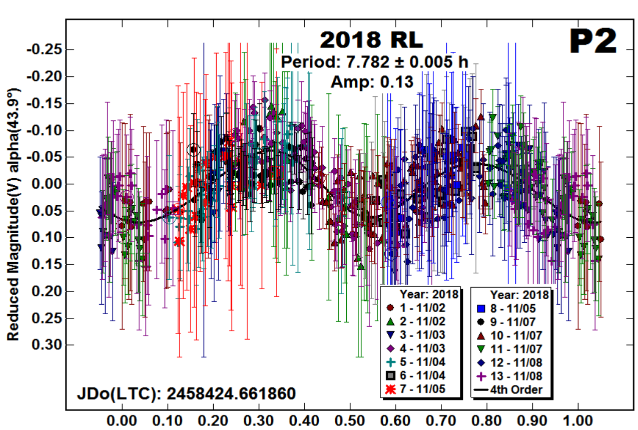


2018 RL. The presence of a long period component for 2018 RL was well-established but the period solution was not because of the large gaps in the lightcurve. Once a short period seem sufficiently defined, attention was turned to other targets because the data for 2018 RL were too noisy. After a point, additional data did not improve the solution and only added more noise.









Conclusions

Table II shows the current list of candidates for the very wide binary asteroid class. To be certain, not all have equal status. About a dozen are considered "convincing" that there are two periods and they are not the result of tumbling. Others, such as two of the three here, are "marginal," if that. The rest fall somewhere in-between.

Number	Name	F/G	P1	P2	Reference
1876	Napolitania	H	45	2.825	WBD 2016a
2759	Idomeneus	TJ	479	32.17	SRD 2018a
5626	1991 FE	NEA	134	2.735	WBD 2017c
6063	Jason[1]	NEA	682	48.6	WBD 2017d
8026	Johnmckay	H	355	14.93	WBD 2011
15778	1993 NH	MC	113	3.320	WBD 2015b
19204	Joshuatree	PHO	480	21.25	SRD 2016
23615	1996 FK12	H	367	3.646	BDW 2015d
24495	2001 AV1	MC	24	2.737	SRD 2017
52750	1998 KK17	NEA	26	3.131	WBD 2017a
67175	2000 BA19	H	275	2.716	WBD 2013
119744	2001 YN42	MBI	625	7.24	WBD 2014
139345	2001 KA67	NEA	44	6.011	SRD 2018b
190208	2006 AQ	NEA	182	2.621	WBD 2015c
215442	2002 MQ3	NEA	473	2.649	WBD 2016c
218144	2002 RL66	MC	587	2.49	WBD 2010
252793	2002 FW5	NEA	61	8.33	WBD 2017b
442742	2012 WP3	NEA	221	8.19	This work
463380	2013 BY45	NEA	428	15.63	WBD 2016b
464797	2004 FZ1	NEA	45	12.49	WBD 2017a
523604	2004 QB17	NEA	75	2.351	This work
	2009 EC	NEA	48	3.261	WBD 2016c
	2009 ES	NEA	28	2.988	WBD 2017a
	2013 US3	NEA	450	2.405	WBD 2018b
	2014 PL51	NEA	205	5.384	WBD 2015a
	2015 KN120[2]	NEA	46	9.107	WBD 2018a
	2016 BU13	NEA	39	2.450	WBD 2016c
	2016 EV27	NEA	61	18.0	WBD 2016b
	2018 RL	NEA	75	7.782	This work
	2018 KE3	NEA	47	4.168	WBD 2019

Table II. Current list of very wide binary candidates. [1]Radar could not confirm long period. [2]Might be tumbling instead binary. F/G is the family or orbital group using definitions from Warner et al., (2009): H, Hungaria; MC, Mars-crosser; MBI, inner main-belt; NEA, near-Earth asteroid, PHO, Phocaea; TJ, Jupiter Trojan. WBD: Warner (et al.); SRD: Stephens (et al.).

Properly working the very wide binaries requires either an extended campaign from one station or one involving several stations that are well-separated in longitude. In either case, careful night-to-night zero point calibrations are required. If the situation arises where the zero point adjustments become excessive, especially if they follow a trend up or down, the data should be examined anew after forcing the zero points back to 0.0 (or other fixed value) and seeing if a plot of the raw data starts to show something like a long period lightcurve.

Since the secondary periods are often less than 10 hours, it becomes important to get sufficiently dense data sets each observing run such that a single period could be found if forcing the zero points to get the data sets to match. This generally precludes working more than one target a night or getting only a few data points, even if at the start and end of the night. If nothing else, observers should be aware of the possibilities and, if a short

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
442742	2012 WP3	11/01-11/10	669	10.6,0.5	47	2	221	3	0.30	0.02	NEA
							8.19	0.01	0.03	0.01	NEA
523604	2004 QB17	10/11-11/05	675	18.2,17.2,19.2	35	13	74.97	0.06	0.15	0.02	NEA
							2.3509	0.0003	0.03	0.01	NEA
	2018 RL	11/02-11/08	552	43.8,38.2	19	14	155	5	1.00	0.10	NEA
							7.782	0.005	0.13	0.03	NEA

Table III. Observing circumstances. The first line for each asteroid gives the period of the primary; the second line gives the period of the presumed satellite. The phase angle (α) is given at the start and end of each date range. If there are three values, the middle one is the minimum phase angle reached during the period. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude (Harris et al., 1984). Grp is the family or group (Warner et al., 2009).

period is seen superimposed on a steady trend of data in a given night, they should consider altering their observing program to see what results might come of concentrating on the single asteroid.

Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database (Warner et al., 2009) and ALCDEF database (*alcdef.org*) are supported by NASA grant 80NSSC18K0851.

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research.

References

References from web sites should be considered transitory, unless from an agency with a long lifetime expectancy. Sites run by private individuals, even if on an institutional web site, do not necessarily fall into this category.

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Munos, J.L. (2017) Carlsberg Meridian Catalog web site. *http://svo2.cab.inta-csic.es/vocats/cmc15/*

Rubincam, D.P. (2000). "Relative Spin-up and Spin-down of Small Asteroids." *Icarus* **148**, 2-11.

Stephens, R.D., Warner, B.D. (2016). "19204 Joshuatree - Not so Fast." *Minor Planet Bull*. **43**, 220-222.

Stephens, R.D., Warner, B.D., Aznar Macias, A., Benishek, V. (2017). "(24495) 2001 AV1 - A Suspected Very Wide Binary." *Minor Planet Bull*. **44**, 319-320.

Stephens, R.D., Warner, B.D. (2018a). "Lightcurve Analysis of L5 Trojan Asteroids at the Center for Solar System Studies 2017 September to December." *Minor Planet Bull*. **45**, 124-128.

Stephens, R.D., Warner, B.D. (2018b). "(139345) 2001 KA67: A Potential NEA Very-wide Binary Asteroid." *Minor Planet Bull.* **45**, 360-362.

Vokrouhlicky, D., Nesvorny, D. (2008). "Pairs of Asteroids Probably of a Common Origin." *Astron. J.* **136**, 280-290.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 April. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Pravec, P., Kusnirak, P., Harris, A.W. (2010). "A Tale of Two Asteroids: (35055) 1984 RB and (218144) 2002 RL66." *Minor Planet Bull*. **37**, 109-111.

Warner, B.D. (2011). "A Quartet of Known and Suspected Hungaria Binary Asteroids." *Minor Planet Bull*. **38**, 33-36.

Warner, B.D. (2013). "Rounding Up the Unusual Suspects." *Minor Planet Bull*. **40**, 36-42.

Warner, B.D. (2014). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2013 September-December." *Minor Planet Bull*. **41**, 102-112.

Warner, B.D., Stephens, R.D., Harris, A.W. (2015a). "A Trio of Binary Asteroids." *Minor Planet Bull*. **42**, 31-34.

Warner, B.D. (2015b). "A Sextet of Main-belt Binary Asteroid Candidates." *Minor Planet Bull*. **42**, 60-66.

Warner, B.D. (2015c). "A Quartet of Near-Earth Asteroid Binary Candidates." *Minor Planet Bull*. **42**, 79-83.

Warner, B.D. (2015d). "Three Unusual Hungaria Asteroids." *Minor Planet Bull*. **42**, 183-186.

Warner, B.D. (2016a). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 June-September." *Minor Planet Bull*. **43**, 57-65.

Warner, B.D. (2016b). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 January-April." *Minor Planet Bull*. **43**, 240-250.

Warner, B.D. (2016c). "Three Additional Candidates for the Group of Very Wide Binaries." *Minor Planet Bull.* **43**, 306-309.

Warner, B.D. (2017a). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 July-September." *Minor Planet Bull*. **44**, 22-36.

Warner, B.D. (2017b). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 October-December." *Minor Planet Bull*. **44**, 98-107.

Warner, B.D. (2017c). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 December thru 2017 April." *Minor Planet Bull*. **44**, 223-237.

Warner, B.D., Aznar Macias, A., Benishek, V., Oey, J., Groom, R. (2017d). "Lightcurve Analysis of the Near-Earth Asteroid 6063 Jason." *Minor Planet Bull*. **44**, 325-326.

Warner, B.D. (2018a). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2017 July Through October." *Minor Planet Bull*. **45**, 19-34.

Warner, B.D. (2018b). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2018 April-June." *Minor Planet Bull*. **45**, 366-379.

Warner, B.D., Stephens, R.D. (2019). "Near-Earth Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2018 July-September." *Minor Planet Bull*. **46**, 27-40.

(12538) 1998 OH: A CONTINUING NON-RESOLUTION

Brian D. Warner
Center for Solar System Studies – Palmer Divide Station
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

(Received: 2019 Jan 13)

CCD photometric observations at the Center for Solar System Studies (CS3) were made of the near-Earth asteroid (12538) 1998 OH in 2018 November. The goal was to find a secure period and so resolve ambiguous solutions from previous years. Final analysis of the 2018 data found that it is anything but ordinary. One possibility is that it is a low-amplitude, fast-rotating tumbler. The other, more exotic, *possibility* is that it *may* be an asteroid pair in the making, i.e., the two fast-rotating components have not yet broken their mutual bond. Future observations may show that one of these, or yet another solution, correctly describes the asteroid.

The near-Earth asteroid (12538) 1998 OH has an estimated diameter of 2 km. It was observed by the author at two apparitions prior to 2018. The first was 2014 (Warner, 2015) where a period of 5.833 h was adopted but noting that the half-period of 2.914 h could not be formally excluded. The second time was in 2016 (2017) which also featured ambiguous periods but the two periods were 5.154 h or 5.191 h. The latter was based on reexamining the data from 2014. The 5.154 h period seemed very secure at that time. The shorter period from 2014 seemed even less likely.

Lozano et al. (2017) reported a period of 5.088 h; this was rated U = 2– in the asteroid lightcurve database (Warner et al., 2009), meaning the period was marginally useful for statistical studies. Vaduvescu et al. (2017) found a period of 2.582 h, which also seemed secure. Their publication came out after the one by Warner (2017). CCD photometric observations of 1998 OH were made at CS3 in 2018 November in hopes of finding a unique, secure period. The result was anything but that.

The observations on 2018 November 4-9 were made with a 0.35-m Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD camera. Those on November 10 and 11 were made with a 0.30-m SCT and Finger Lakes ML-1001E. Both cameras used the same CCD chip, KAF-1001E, and all exposures were 1x1 binning (1024x1024x9μ). This made the photometric characteristics nearly the same. The 240 s exposures were guided and unfiltered.

The science images were processed with master flat and dark frames. Photometry on the processed images was done using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for ensemble differential photometry. Catalog V magnitudes were taken from

Number	Name	20xx mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
12538	1998 OH	2018/10/22-10/25	176	5.1,3.8	33	6	2.4680	0.0005	0.11	0.01
							2.5262	0.0004	0.09	0.01
12538	1998 OH	2016/10/01-10/06	196	22.7,20.8	46	3	2.5780	0.0007	0.18	0.02
12538	1998 OH	2014/10/22-10/25	176	5.1,3.8	33	6	2.592	0.002	0.10	0.01

Table I. 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 first line gives the results for the primary in the binary system. For 2018, the second line gives the second period with both periods being those found by Pravec (see text).

the APASS catalog (Henden et al., 2009). The only zero point shift was 0.01 mag on November 10. Fourier period analysis was done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989). *MPO Canopus* is capable of an iterative, but not simultaneous, dual-period search. This would become important in the analysis.

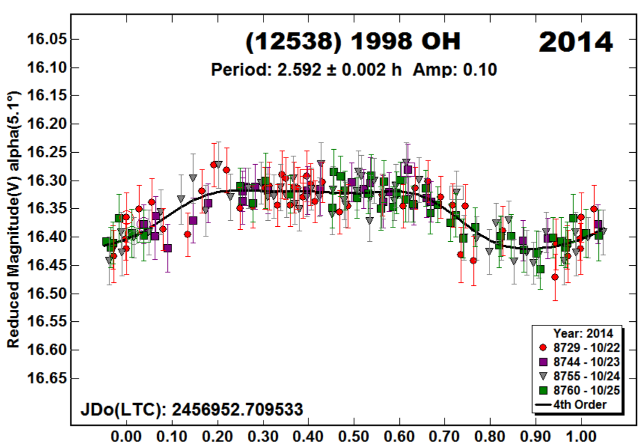
In the lightcurves below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid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

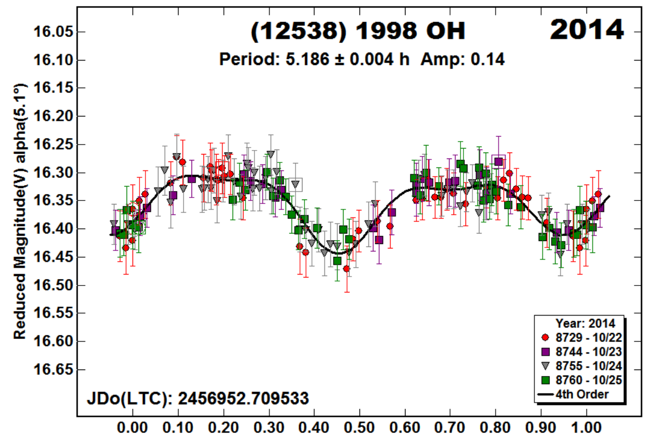
Back to the Past

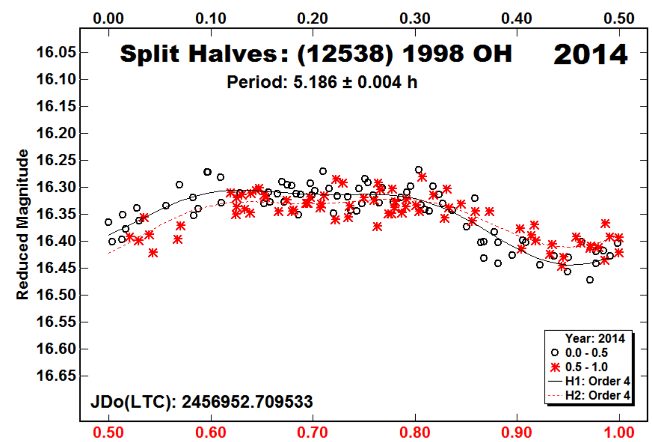
A quick review of the previous results by Warner (2015; 2017) provides some background for the 2018 results. The results presented here are based on new analysis of the original data and do not necessarily repeat what was previously reported.

2014 October. The period spectrum showed nearly equal solutions for two periods (and lesser quality ones at several other periods). The amplitude of the lightcurves was $A \leq 0.14$ mag. Harris et al. (2014) have shown that a bimodal solution cannot be assumed at low amplitudes and if the data are from low phase angles, as they were in 2014. Solutions that involved tri- and higher modal lightcurves were unconvincing and so either a monomodal or bimodal solution remained.

The monomodal lightcurve had an amplitude of 0.10 mag when fit to a period of 2.592 h. The bimodal lightcurve amplitude was 0.14 mag with a period of 5.186 h. A split-halves plot (see Harris et al., 2014) was used to see if the two halves of the bimodal solution were sufficiently different to adopt the longer period with confidence. They were not and so both solutions were possible.

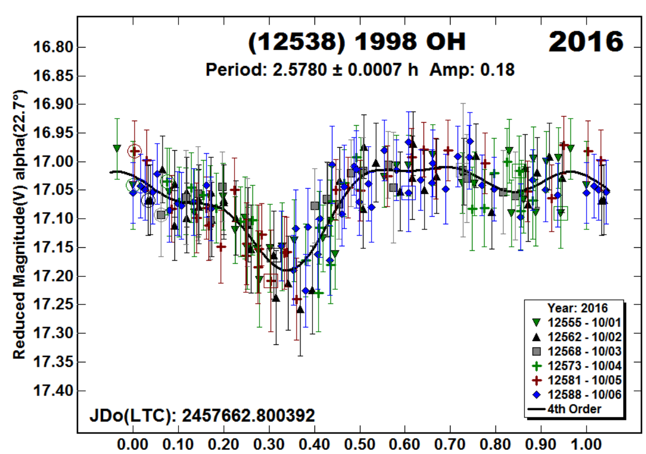


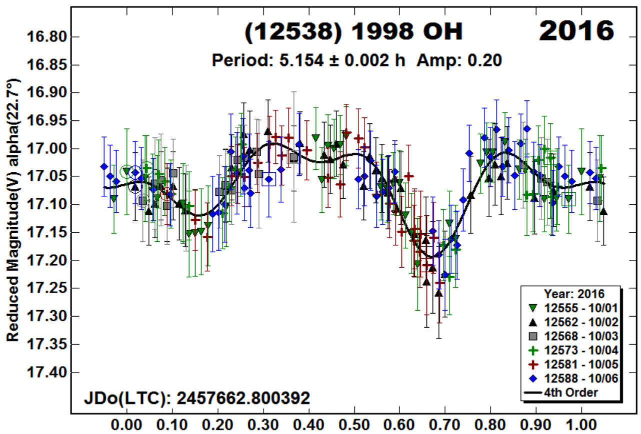


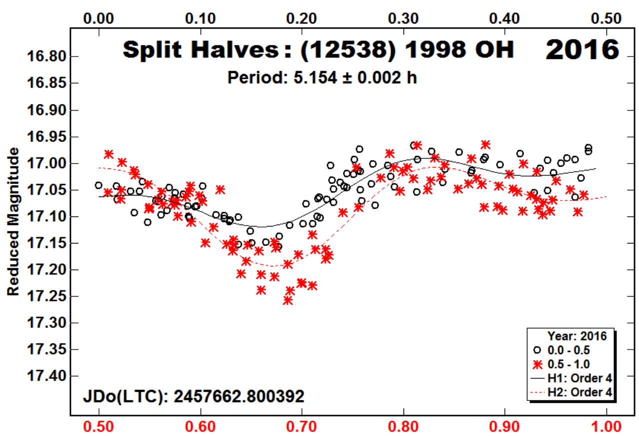


2016 October. The period spectrum allowed only one of two periods. The *P* = 2.5780 h result corresponded to a monomodal lightcurve, although it *might* be considered bimodal by assuming an usual shape for the asteroid. This didn't seem likely. The *P* = 5.154 h solution, which was slightly favored in the period spectrum, was a more convincing bimodal solution.

The split-halves plot for the longer period showed two, distinct parts and so the longer period was adopted. Attempts to fit the 2016 data, within 1-sigma, to either of the 2014 solutions proved fruitless.

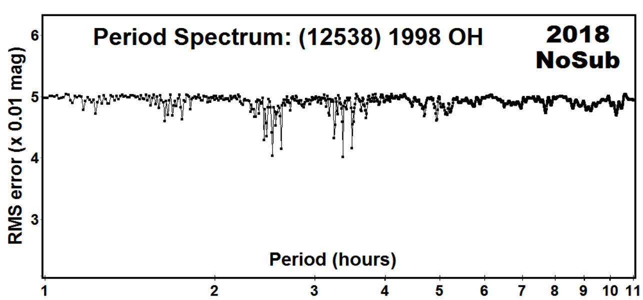


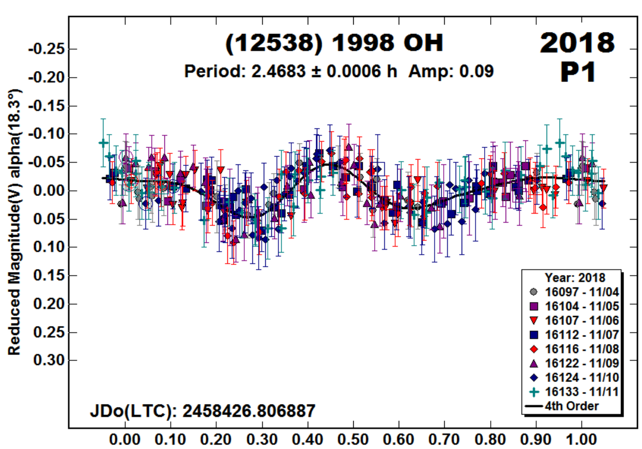


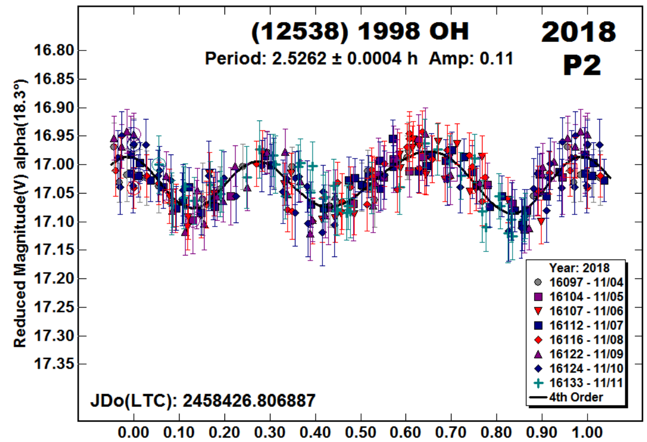


Back to the Future

Analysis of the 2018 data showed two possible solutions near the shorter periods previously reported, i.e., $P \sim 2.5$ h.







The dual-period search in *MPO Canopus* found two fast periods that were close to one another but not harmonically related, meaning that the two could not be represented by an integral ratio.

There are previous examples (see Harris et al., 2014) where the two periods of a tumbling asteroid produced a beat frequency. Fourier analysis that led to finding the beat frequency period produced an improbable, if not impossible, lightcurve shape. With this is mind, the CS3 data were sent to Petr Pravec (Astronomical Institute, Czech Republic) who has the necessary software to analyze tumbling asteroids properly.

The next part of this discussion quotes extensively from Pravec's findings (private communication). They are used with his permission and are enclosed in quotes. Comments or paraphrases are enclosed in square brackets if within a quote or in a standalone paragraph without quotes.

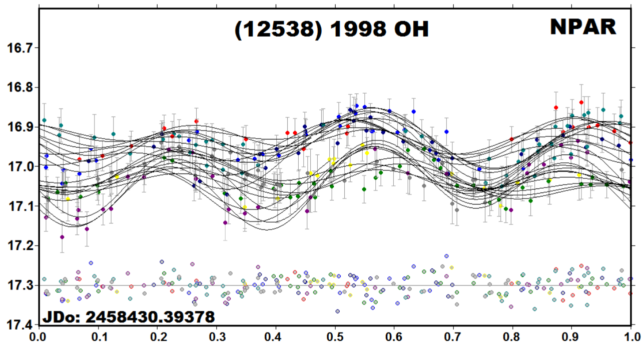
"We cannot resolve between [1998 OH] being a binary with two short rotational periods or a tumbler. Both models fit the data equally well (RMS residual 0.026-0.027 mag). If a binary, the lightcurve consists of two additive components with periods 2.4680 ± 0.0005 h and 2.5262 ± 0.0004 h."

[The CS3 dual-period lightcurves are shown above and have slightly different periods from those found by Pravec. His periods are adopted for this paper and appear in Table I.]

"We might be tempted to consider it unlikely that it could be a binary with both bodies rotating fast and showing similar amplitudes in the combined lightcurve. However, I note that we observed three near-equal mass ratio asteroid pairs (q = 0.6-0.8) with both the primary and secondary rotating fast (periods 2.7 to 4.7 h) and having amplitudes < 0.3 mag and sizes 1-2 km (see Section 6.1, paragraph 3 in our new paper "Asteroid pairs: a complex picture…" [(Pravec et al., 2019)]. "What if (12538) is a similar system, just with the components bound, not separated into an asteroid pair (yet)?"

"[If a tumbler], the NPA rotation frequencies are two of the following three: 1/2.4664 h, 1/2.5257 h, 1/105 h. Note that 1/2.4664 – 1/2.5257 = 1/105." Note that in a plot of a tumbling asteroid, there are no "simple" curves since the lightcurve is never the same over multiple rotations.

"[The asteroid] may be somewhat similar to 99942 Apophis (Pravec et al. 2014). It could be a SAM [Short Axis Mode] with I_2/I_3 close to 1, P_ψ = 105 h and $P\varphi$ = 2.4664 h. [However,] it would require physical modeling (probably using data from more than one viewing geometry) to confirm.



Conclusions

Without mutual occultation/eclipse events or other definitive observations such as a stellar occultation, the binary status of 1998 OH cannot be confirmed. With the data fitting two significantly different solutions, binary or tumbling, the ultimate resolution will have to wait on further observing campaigns that are planned to allow for either solution. For those looking ahead, Table II shows data for the next five apparitions.

Year	Opposition Date	Opposition V Mag	Brightest Date	Brightest V Mag	Dec
2019	None	-	May 23.3	15.2	+35
2020	None	-	Dec 27.5	16.4	-49
2021	Jan 02.1	16.4	Apr 17.7	16.3	-09
2022	None	-	Dec 31.9	17.4	+03
2023	Jul 31.0	18.1	Jan 02.1	17.4	-47

Table II. The opposition and brightest dates through 2023 are given for 1008 OH. Opposition is judged by the time the asteroid's RA is 180° from the Sun's. It is not unusual for an NEA to fail to meet this requirement in one or more years.

Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database (Warner et al., 2009) and ALCDEF database (*alcdef.org*) are supported by NASA grant 80NSSC18K0851. The author gratefully acknowledges a Shoemaker NEO Grant from the Planetary Society (2007) that was used to purchase some of the equipment used in the research at CS3.

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

References

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

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Lozano, J., Flores, A., Mas, V., Fornas, G., Rodrigo, O., Brines, P., Forna, A., Herrero, D., Carreno, A., Arce, E. (2017). "Seven Near-Earth Asteroids at Asteroids Observers (OBAS) - MPPD: 2016 June-November." *Minor Planet Bull*. **44**, 108-111.

Pravec, P., Scheirich, P., Durech, J., Pollock, J., Kusnirak, P., Hornoch, K., Galad, A., Vokrouhlicky, D., Harris, A.W., Jehin, E., Manfroid, J., Opitom, C., Gillon, M., Colas, F., Oey, J., Vrastil, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Pravec, P., Fatka, P., Vokrouhlicky, D., Scheirich, P., Durech, J., Scheeres, D.J., Kusnirak, P., Hornoch, K., Galad, A., Pray, D.P., Krugly, Yu.N., Burkhonov, O., and 36 coauthors (2019). "Asteroid pairs, a complex picture." *Icarus*, submitted.

Vaduvescu, O., Macias, A. Aznar, Tudor, V., Predatu, M., Galád, A., Gajdoš, Š., Világi, J., Stevance, H.F., Errmann, R., Unda-Sanzana, E., and 17 coauthors (2017). "The EURONEAR Lightcurve Survey of Near Earth Asteroids." *Earth, Moon, and Planets* **120**, 41-100.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 Nov. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2015). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 October-December." *Minor Planet Bull*. **42**, 115-127.

Warner, B.D. (2017). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 October-December." *Minor Planet Bull.* **44**, 98-107.

LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 SEPTEMBER-DECEMBER

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Robert D. Stephens
Center for Solar System Studies / MoreData!
Rancho Cucamonga, CA

(Received: 2019 Jan 13)

Lightcurves for four Hilda asteroids were obtained at the Center for Solar System Studies (CS3) from 2018 September-November: 3514 Hooke, 3557 Sokolsky, 4495 Dassanowksy, and 10331 Peterbluhm. 4495 Dassanowksy appears to be a binary asteroid with a primary period of either 2.6314 hr or 5.263 hr and an orbital period of 18.516 hr. The secondary-to-primary ratio of the effective diameters is 0.26 ± 0.02.

CCD photometric observations of four Hilda asteroids were made at the Center for Solar System Studies (CS3) from 2018 September-November. 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 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.

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.

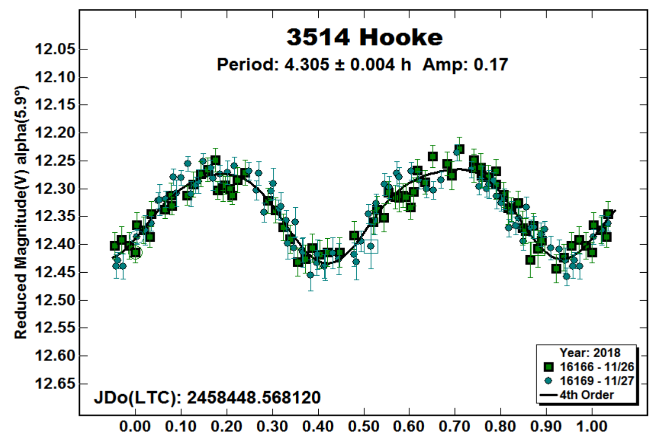
Table I lists the telescopes and CCD cameras that are combined to make observations. Up to nine telescopes can be used for the campaign, although five is most common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 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.

Photometric measurements were made using *MPO Canopus*. The Comp Star Selector (CSS) 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. Period analysis was done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989).

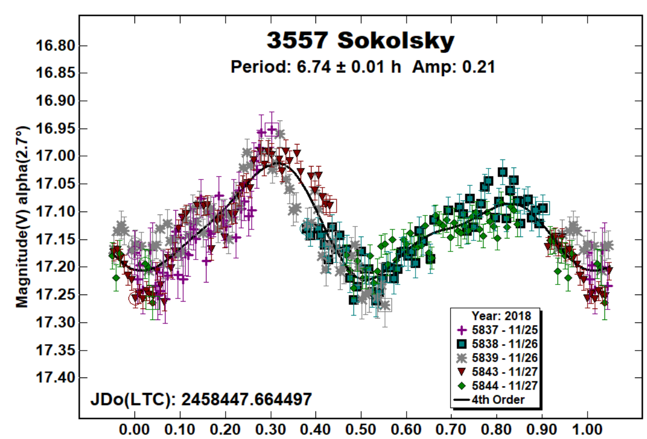
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle in parentheses using $G = 0.15$. 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*.

Only some of previous works may be referenced. 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. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

3514 Hooke. The estimated size of this Hilda is 34 km if assuming a visual albedo of 0.057 (Warner et al., 2009). Waszczak et al. (2015) found a rotation period of 4.307 hr and amplitude of 0.17 mag, which is in good agreement with our denser data set.



3557 Sokolsky. Dahlgren et al. (1998) reported a rotation period of 6.725 hr and amplitude of 0.19 mag. Analysis of our data obtained in 2018 November found similar results: 6.74 ± 0.01 hr and 0.21 ± 0.02 mag.



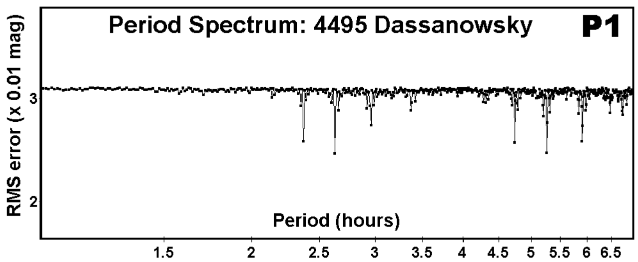
4495 Dassanowsky. The LCDB did not list any rotation periods for Dassanowsky. Mainzer et al. (2016) used data from the WISE mission to find $D = 24.43 \pm 0.26$ km and visual albedo $p_V = 0.082 \pm 0.014$ when using $H = 11.4$.

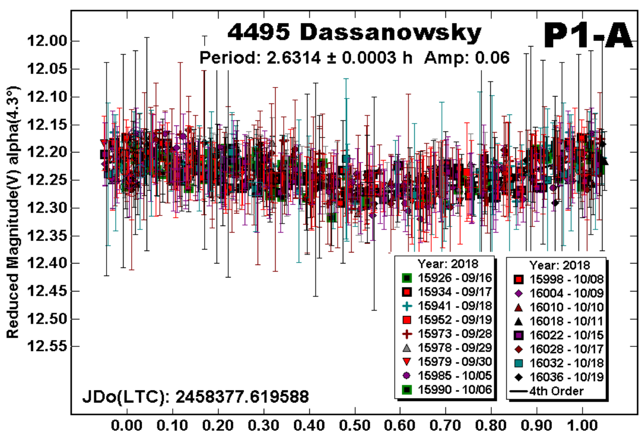
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3514	Hooke	11/26-11/27	151	6.0,6.3	46	2	4.305	0.004	0.17	0.02
3557	Sokolsky	11/25-11/27	280	2.8,3.2	54	-5	6.74	0.01	0.21	0.02
4495	Dassanowsky	09/16-10/19	548	4.3,5.9	326	3	2.6314	0.0003	0.06	0.01
							5.263	0.002	0.06	0.01
							18.516	0.003	0.13	0.01
10331	Peterbluhm	09/16-10/31	763	13.7,1.8	38	-5	379	5	1.1	0.1

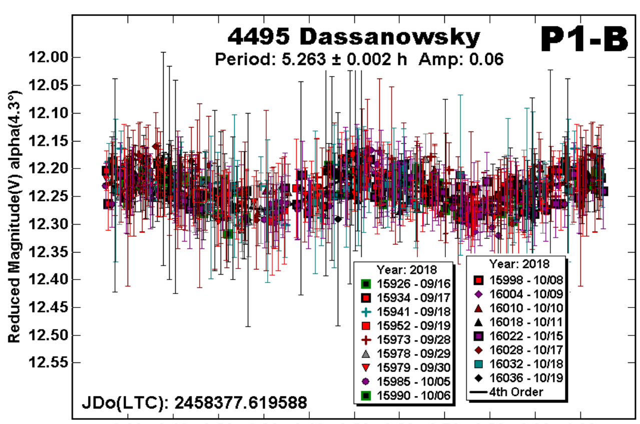
Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). For 4495 Dassanowsky, the first line gives the preferred rotation period for the primary of a binary system. The second line gives an alternate primary period. The third line is the orbital period of the presumed satellite.

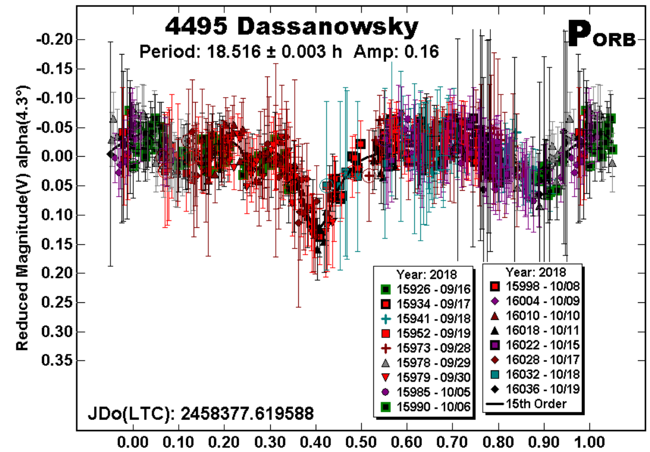
We observed the asteroid for more than a month, from 2018 Sep 16 through Oct 19. After the first few nights, the data showed attenuations that were consistent with the system being binary.

The amplitude of the purported primary lightcurve had a low amplitude of only 0.06 mag; this was nearly overshadowed by the large photometric error bars on some nights. The period spectrum shows two distinct possibilities, 2.63 hr (P1-A) or 5.26 hr (P1-B). Harris et al. (2014) have shown that either one could be right because of the low amplitude.









We used both solutions when looking for the lightcurve of the suspected satellite. The final plot (P_{ORB}) is based on using $P_1 = 2.6314 \pm 0.0003$ hr. Using $P_1 = 5.623 \pm 0.002$ hr produced an identical solution for the orbital period.

The depth of the mutual eclipses/occultations led to an estimate of the ratio of the secondary-to-primary effective diameters of 0.26 ± 0.02. This is a lower limit since the secondary (shallower) event was not total. The lightcurve outside the events showed an amplitude of about 0.07 mag. After accounting for dilution of the satellite's lightcurve by the primary, the satellite has an ellipsoidal a/b ratio of about 1.5:1.0

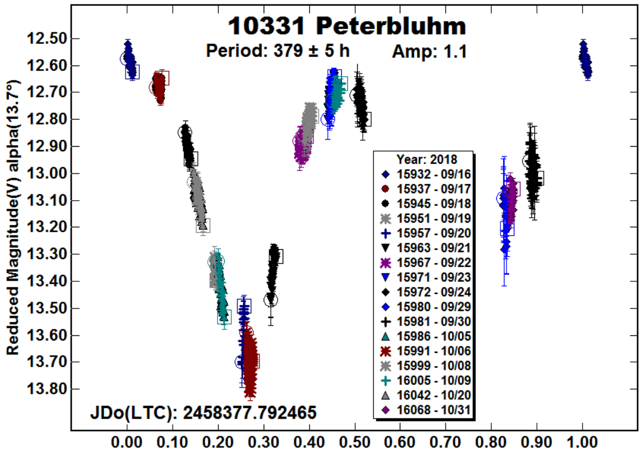
10331 Peterbluhm. After following this Hilda for almost six weeks, we still did not have enough data to produce a fully-covered lightcurve. Some sessions were after one rotation and so covered a part of the lightcurve more than once.

A solution based on a half-period (monomodal lightcurve) was used to find a likely solution. That period was doubled to give our final result of 379 ± 5 hr. This makes this the fourth longest period listed in the LCDB for a Hilda.

The combined diameter and period make this a good candidate for tumbling (Pravec et al., 2014; 2005). However, there were no obvious signs of tumbling seen in the data. One indicator would be sessions at the same point in the phased curve not fitting a relatively smooth model curve (one is significantly high or low). Another is when two sessions at the same point in the phased curve have opposing trends, i.e., one shows a steady rise over the run and the other shows a steady decline.

Mainzer et al. (2016) found $D = 19.57 \pm 0.40$ km and $p_V = 0.127 \pm 0.044$ when using $H = 11.4$. This is brighter than the average Hilda (0.057; Warner et al., 2009) but not unrealistic since WISE albedos for the Hilda population range from 0.012 to 0.371.

25



Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database Warner et al., 2009) and ALCDEF database (*alcdef.org*) are supported by NASA grant 80NSSC18K0851.

This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These allowed purchasing some of the telescopes and CCD cameras used in this research.

References

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

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Mainzer, A.K., Bauer, J.M., Cutri, R.M., Grav, T., Kramer, E.A., Masiero, J.R., Nugent, C.R., Sonnett, S.M., Stevenson, R.A., Wright, E.L. (2016). "NEOWISE Diameters and Albedos V1.0." NASA Planetary Data System.
EAR-A-COMPIL-5-NEOWISEDIAM-V1.0.

Munos, J.L. (2017) Carlsberg Meridian Catalog web site.
http://svo2.cab.inta-csic.es/vocats/cmc15/

Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G., Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galád, A., Brown, P., Degraff, D.R., Lambert, J. V., Cooney, W.R., Foglia, S. (2005). "Tumbling asteroids." *Icarus* **173**, 108-131.

Pravec, P., Scheirich, P., Durech, J., Pollock, J., Kusnirak, P., Hornoch, K., Galad, A., Vokrouhlicky, D., Harris, A.W., Jehin, E., Manfroid, J., Opitom, C., Gillon, M., Colas, F., Oey, J., Vrastil, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Rubincam, D.P. (2000). "Relative Spin-up and Spin-down of Small Asteroids." *Icarus* **148**, 2-11.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

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.

(20882) 2000 VH57: AN INNER MAIN-BELT BINARY ASTEROID

Brian D. Warner
Center for Solar System Studies–Palmer Divide Station
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Amadeo Aznar Macías
APT Observatory Group
EURONEAR
SPAIN

M. Serra-Ricart, J. Licandro
Instituto de Astrofísica de Canarias (IAC), C/ Vía Láctea s/n
Departamento de Astrofísica, Universidad de La Laguna
La Laguna, Tenerife
SPAIN

Petr Pravec
Academy of Sciences of the Czech Republic
Ondrejov, CZECH REPUBLIC

(Received: 2019 Jan 15)

CCD photometric observations of the inner main-belt asteroid (20882) 2000 VH57 were made from 2018 Sept. 15 through Oct. 20. Analysis of the data showed that the asteroid is binary with a primary rotational period of 2.5586 hr and a satellite orbital period of 32.81 hr. Mutual eclipse/occultation events indicate a lower limit on the secondary-to-primary mean diameter ratio (Ds/Dp) of 0.23. During the period of observations, the primary and secondary lightcurves evolved as the viewing aspect changed. In particular, the depth of the secondary event increased significantly towards the end of the observations.

The minor planet (20882) 2000 VH57 is a member of the inner main-belt with an estimated diameter of 3.9 km. The asteroid lightcurve database (LCDB; Warner et al., 2009) had no previous rotational period when observations were started in 2018 September.

OBS	Telescope	Camera
CS3-PDS	0.30-m *f*/9.6 SCT	SBIG STL-1001E
TAR1-TO	0.46 *f*/2.8 reflector	SBIG STL-1001E

Table I. List of equipment at the two locations.

Observations were made on 23 nights at CS3-PDS between 2018 Sept. 15 and Oct. 20. Exposures were 240 sec, guided, and unfiltered. Observations at Teide Observatory (TAR1-TO, Tenerife, Spain) were made on Oct. 10 and 12. Exposures were 80 sec without a filter.

All of the images were processed with master flat and dark frames prior to being measured with *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* was used to find near solar-color stars for ensemble differential photometry. The V magnitudes of the stars were taken from the APASS catalog (Henden *et al.*, 2009).

The initial observations from CS3-PDS on Sept 15, 16, and 18 showed attenuations that suggested that the asteroid was binary. By Oct 9, the presence of a satellite was virtually assured but the orbital period was inconclusive since it was greater than 24 hours. This made finding the correct solution from a single station very difficult. Additional observations made at Teide Observatory (TO) proved to be essential for finding the orbital period.

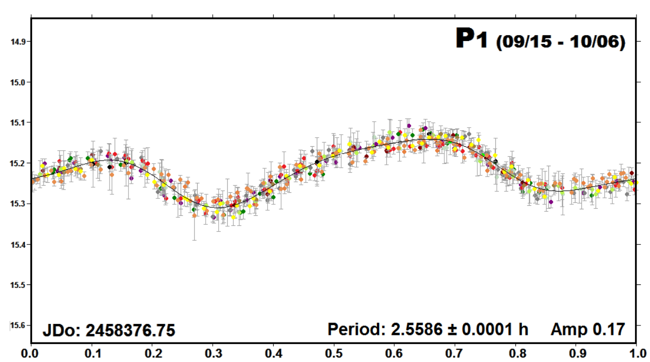
Lightcurve Evolution

Over the range of observations, the phase angle decreased from 19° to 2°, reaching a minimum of 0.5° on Oct. 17, a date for which there were no observations. As a result, the amplitude of the primary lightcurve, as expected (Zappala et al., 1990), became smaller. This complicated the lightcurve analysis somewhat but it was the secondary lightcurve that presented the greater challenge.

We analyzed the complete combined dataset of about 1500 observations and found that there were two significantly different solutions if the data set was split into two subsets, the first from Sept. 15 to Oct. 6 and the second from Oct. 8-20.

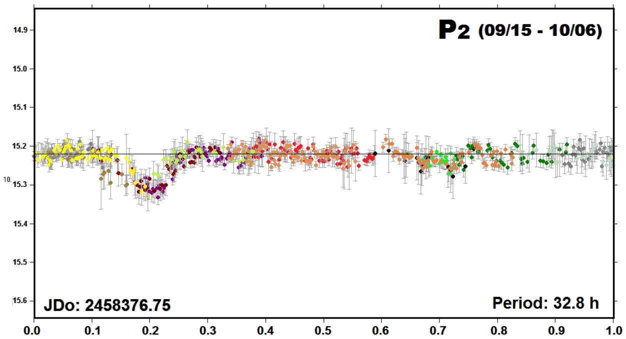
The lightcurves from each set are shown below. "P1" is the lightcurve for the primary while "P2" is the lightcurve showing the mutual events. The periods in the plots for the second set, Oct. 8-20, were forced to match those of the first set.

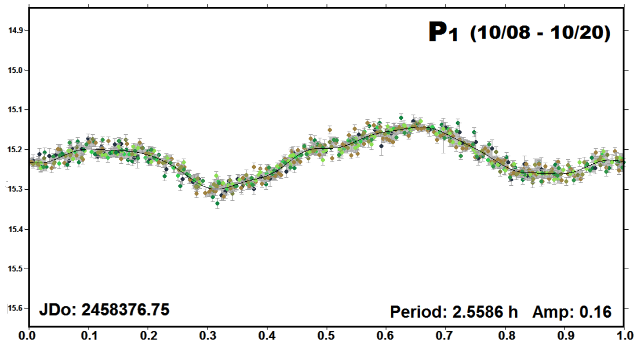
The mutual events evolved as the geometry between the Earth, the mutual orbit of the binary, and the Sun changed. This caused the secondary event, where the secondary is behind the primary, to deepen. Because of the evolving lightcurves, only a lower limit of *Ds/Dp* = 0.23 ± 0.02 could be given for the secondary-to-primary effective diameters since the data did not establish that the event had become total.

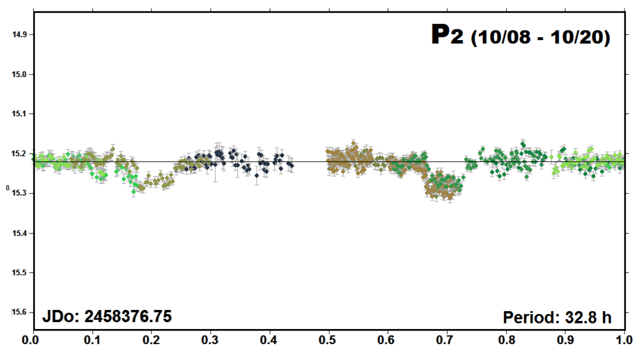


Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
20882	2000 VH7	09/15-10/20	1504	19.30.7,2.1	21	0	2.5586	0.0001	0.16	0.02
							32.81	0.02		

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the dates of first, lowest, and last observations at 0:00 UT. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). The first line gives the details for the primary body of the binary system. The second line gives the orbital period of the satellite.







Acknowledgements

Observations at CS3 and work on the asteroid lightcurve database (LCDB) and Asteroid Lightcurve Data Exchange Format (ALCDEF) database are supported by NASA grant 80NSSC18K0851. J. Licandro and M. Serra-Ricart acknowledge support from the AYA2015-67772-R (MINECO, Spain). This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund, and by data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*. The author gratefully acknowledges a Shoemaker NEO Grant from the Planetary Society (2007), which helped purchase some of the equipment used in this research.

References

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Zappala, V., Cellini, A., Barucci, A.M., Fulchignoni, M., Lupishko, D.E. (1990). "An analysis of the amplitude-phase relationship among asteroids." *Astron. Astrophys*. **231**, 548-560.

STAFF POSITION OPENING - ASSOCIATE PRODUCER, *MINOR PLANET BULLETIN*

The *Minor Planet Bulletin* announces the opening a new staff position of Associate Producer, with the probability of taking over the *MPB* Producer's position in about two years following a period of mentoring and collaboration. The responsibilities will be to assist the current Producer, Bob Werner, with the layout construction of each quarterly issue of the *Minor Planet Bulletin*, demonstrating proficiency for transitioning to the Producer position. For each *MPB* issue produced, the required tasks and capabilities to be demonstrated include:

- Reformatting approximately 30–40 manuscript documents from the editors.
- Responsive communication with the editorial and distribution staff.
- Able to commit to and adhere to deadlines throughout the calendar year.
- Corresponding with authors via email with article proofs.
- Handling formatting inquiries from new and seasoned authors who contribute manuscripts to the *MPB*.
- Laying out an issue's articles in a single master document, resulting in the ready-to-print and ready-to-release electronic version of each *MPB* issue.
- Constructing a full index of each annual volume.
- Maintaining a long-term electronic archive of all issues.

The skills required for the position of Associate Producer, *Minor Planet Bulletin* include:

- Proficiency with Microsoft Word 2013/2010, Portable Document Format (pdf) computer documents, and email. Production status is tracked using Excel.
- Knowledgeable expertise with asteroid astronomy sufficient for some error checking and recommending editorial corrections.
- Strong skills with written English.

The time commitment required varies from issue to issue, but typically occupies 25 or 30 hours each quarter. *The Minor Planet Bulletin* publishes four issues per year. All *MPB* staff positions, including this announced opening for Associate Producer, are volunteer positions without pay or other compensation. Materials and postage costs, as necessary, are reimbursed.

Persons wishing to be considered for the Associate Producer position should send a statement of interest, a statement on the level of available commitment, and a summary of qualifications to the Editor: rpb@mit.edu Review of applications will begin February 1, 2019. The position will remain open until filled.

LIGHTCURVE ANALYSIS OF ASTEROIDS OBSERVED BY KMTNET-SAAO

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave, Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Nicolas Erasmus
South African Astronomical Observatory (SAAO)
Cape Town, SOUTH AFRICA

(Received: 2019 Jan 14)

Observations from the South Africa node of the Korea Microlensing Telescope Network (KMTNe-SAAO) were analyzed using the open source Photometry Pipeline (PP). PP can identify serendipitously observed asteroids in the observation fields which led to the extraction of 53 asteroid lightcurves. Rotational periods for 49 of these targets could be determined and are presented here

The primary objective of the Korea Microlensing Telescope Network (KMTNet; Kim et al., 2016) is to search for extrasolar planets. The network, which consists of three 1.6-m telescopes located in South Africa, Korea, and Chile, was designed to provide continuous coverage of the galactic center looking for gravitational microlensing phenomenon.

The asteroid observations presented here were performed over three nights (2018 Jan 9-11) with the 1.6-m telescope in South Africa. The observed fields were originally intended for an unrelated study but due to the large 2x2 deg field of view, covered by four 9kx9k CCDs, untargeted asteroids were bound to appear in the images. For these observations 53 asteroids were identified in the observation fields.

This was done by using the Photometry Pipeline (PP; Mommert, 2017) which uses the IMCCE SkyBoT service (Berthier et al., 2006) to identify serendipitously observed asteroids. All observations were performed using the Rc filter with 120-second exposures taken at a 190-second cadence. Based on work by Pravec et al. (2000), the 120 sec exposures would allow finding periods for asteroids where P > 0.178 hr (~ 10.7 min).

The 53 asteroid lightcurves are presented here along with rotational periods for 49 of those targets. A similar analysis using PP on KMTNet-SAAO data (with the addition of V-R and V-I colors) for approximately 1000 objects were published by Erasmus et al. (2018).

Data Manipulation and Analysis

The photometry data extracted from the KMTNet-SAAO data were converted by Erasmus to ALCDEF-compatible files (*http://alcdef.org*). The format goes beyond simple JD/magnitude pairs to include metadata about the object, the system used to make observations, the filter used, etc. so that the end-user can use the data correctly to confirm results derived from the original dataset or independent analysis for other purposes.

The ALCDEF files were imported into *MPO Canopus*, which was used for period analysis and lightcurve generation. *MPO Canopus* incorporates the FALC Fourier analysis algorithm developed by Harris (Harris et al., 1989). The initial search used 4th order Fourier analysis in a range from 2 to 27 hours in steps of 0.01 hr. At first, the raw data were plotted in order to find any obvious outliers since the photometry pipeline did not automatically scrub the data. A quick review of the raw plots indicated if the initial search parameters needed to be revised.

In the Fourier analysis, the general principle is to find a minimum RMS fit of the model lightcurve versus the data. The algorithm can be tricked into finding a false RMS minimum by reducing the number of overlapping data points. This is called a *fit by exclusion*, which often leads to significant gaps in lightcurve coverage. When a solution was one of several of nearly equal RMS values, those periods (usually shorter) that did not produce gaps in coverage were generally favored.

In those cases where there were two solutions that could not be formally excluded, one producing a monomodal lightcurve and the other a bimodal, we labeled the bimodal lightcurve as the “Full” period solution and a monomodal lightcurve as the “Half” solution. This does not necessary indicate that the full period is the correct one and, in fact, neither might be correct if the amplitude was < 0.1 mag (Harris et al., 2014).

Table I gives the observing circumstances and results. The last two columns give the measured (bold text) or estimated diameter and visual albedo. The measured values were taken almost exclusively from WISE data (Mainzer et al., 2016). Assumed albedo values were taken from the LCDB (Warner et al., 2009). These were based on analysis of measured results for different taxonomic and family/orbital groups.

About the Lightcurve Plots and LCDB References

Only two objects had previous lightcurve entries in the asteroid lightcurve database (LCDB; Warner et al., 2009), which is available at *http://www.minorplanet.info/lightcurvedatabase.html*. Those previous results are referenced directly in the discussion for the asteroid in question.

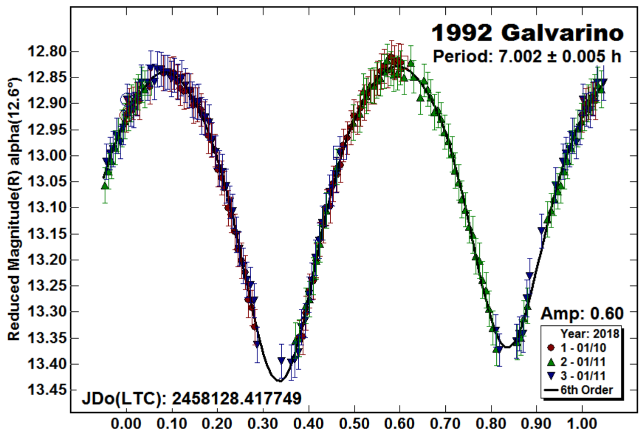
The LCDB page allows direct queries of the LCDB that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB tables, including the references with bibcode, is also available for download. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB for their work.

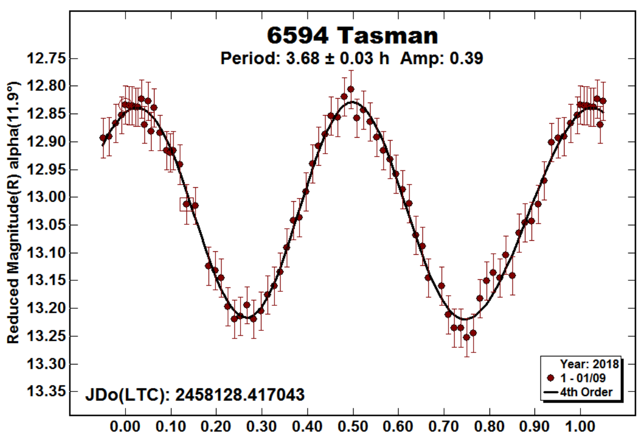
In the plots below, the “Reduced Magnitude” is Cousins R_c as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle in the parentheses 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*.

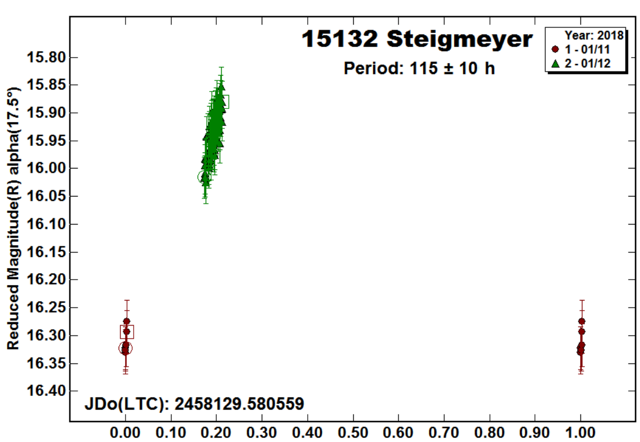
Many of the lightcurves are presented without comment. Where required, a discussion of the results is included.

1992 Galvarino, 6594 Tasman. Birlan et al. (1996) found a period of 7.004 hr for 1992 Galvarino. The period here is essentially identical. The LCDB had no lightcurve entries for 6594 Tasman.



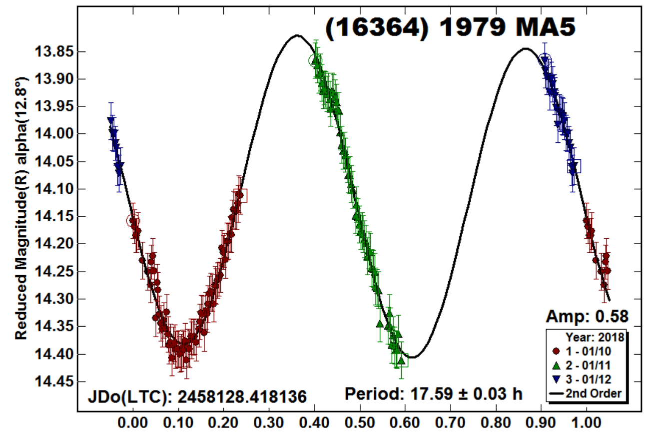


15132 Steigmeyer. There was only one night of extended observations. Based on the slope joining the two nights, the slope of the data on the extended night, and assuming the two sessions were each at an extrema, a period of about 115 hr is a plausible solution. If nothing else, this forewarns those making future observations that an extended campaign might be required.

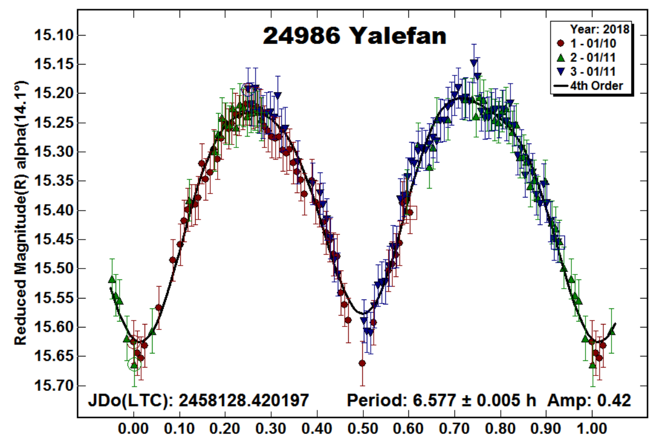


(16364) 1979 MA5. A half-period solution was used to help remove ambiguities for the full period. Given the 0.6 mag amplitude and low phase angle, a bimodal solution is all but guaranteed (Harris et al., 2014).

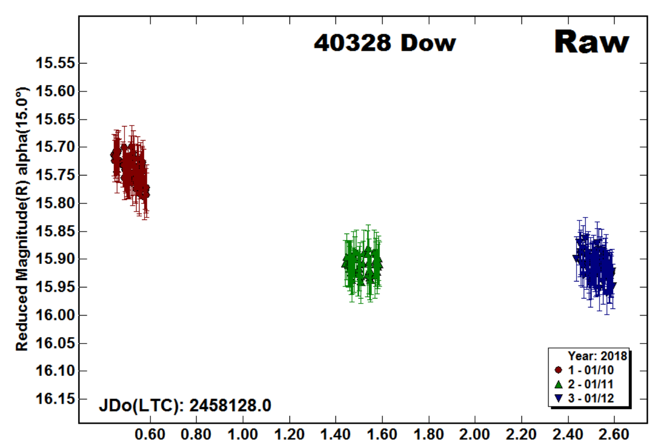
The three upcoming apparitions, 2019 April, 2020 July, and 2021October are V ≤ 18, or within reach of those with 0.5-m or larger telescopes.



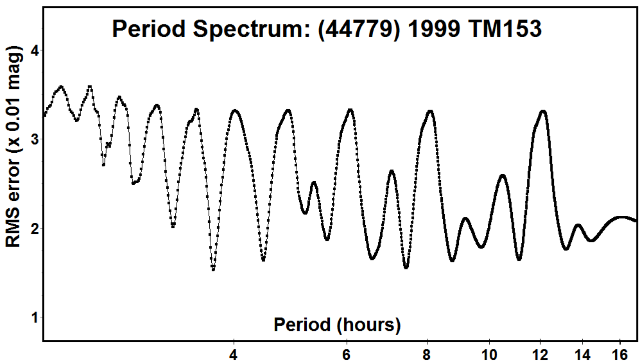
24986 Yalefan. There were no previously reported rotation periods in the LCDB. For backyard observers, the next good chance comes in 2023 September (V = 16.3).

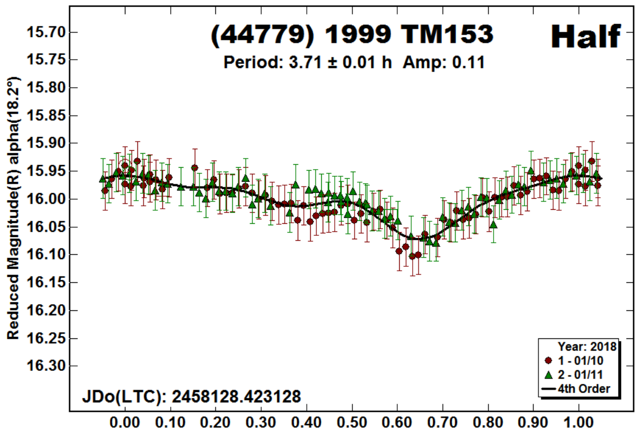


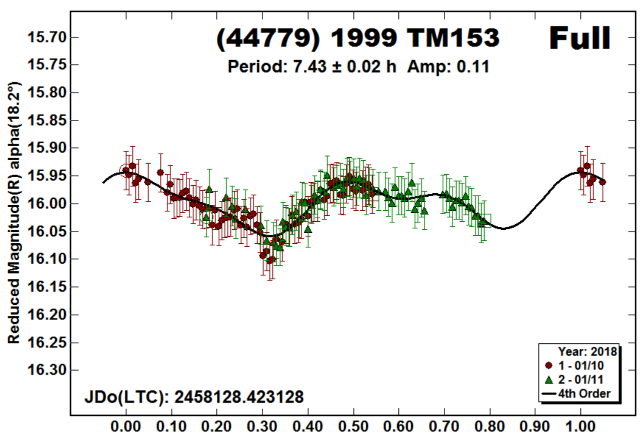
40328 Dow. No solution with a plausible fit of the Fourier curve could be found. The plot shows the raw data from three nights. The 2019 July apparition is at V = 16.8, making it a relatively easy target.



(44779) 1999 TM153. The period spectrum shows several possible solutions. Two solutions are given on the presumption of a monomodal or bimodal lightcurve. A higher-modal lightcurve (longer period) would have produced even larger gaps, almost assuring a *fit by exclusion*. In this case, we have adopted the longer ("full") period of 7.43 hr.



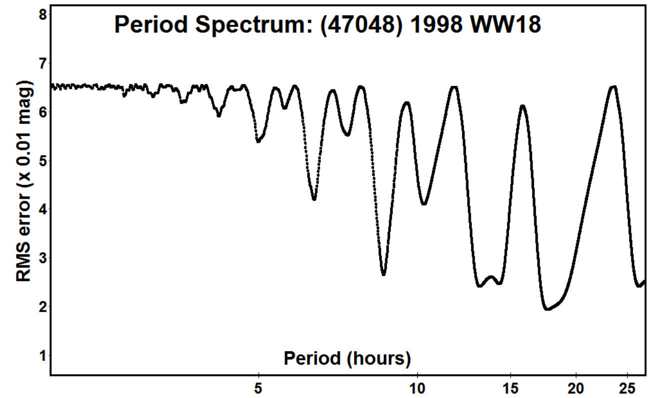


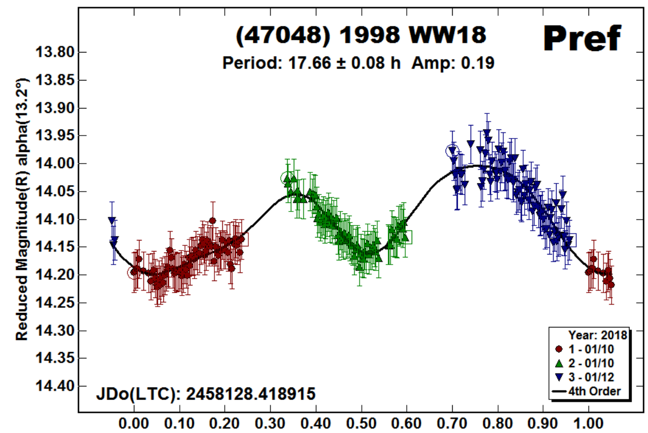


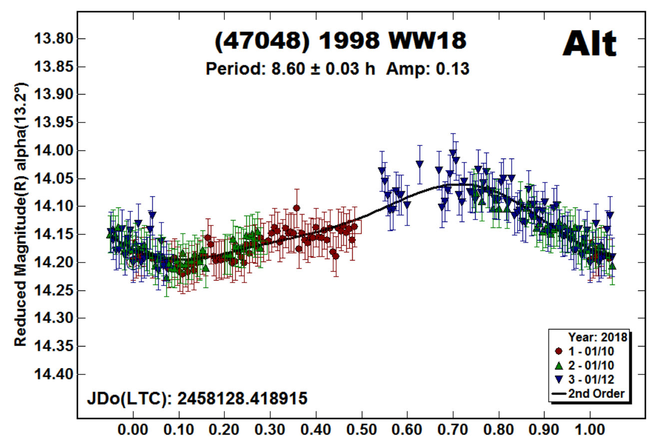
<u>(47048) 1998 WW18</u>. Using data from multiple sources, Durech et al. (2018) found a shape and spin axis model with a sidereal period of 12.82438 hr. The “Pref” and “Alt” lightcurves are based on no zero point adjustments to the original data.

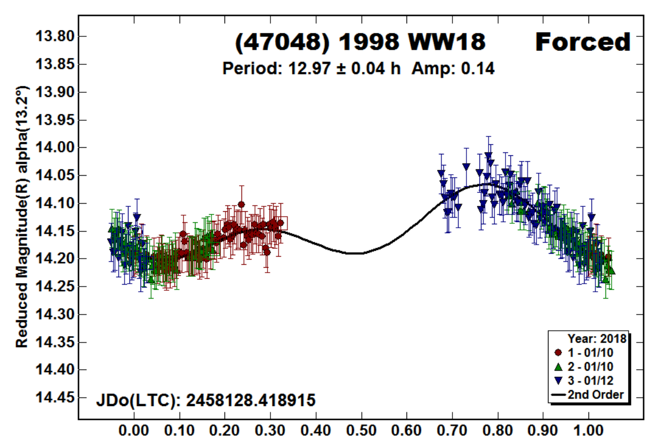
It was possible to get an approximate match to the Durech et al. period (“Forced”) but only with zero point adjustments of 0.05-0.07 mag. Almost all other lightcurves required no more than a 0.02 mag adjustment to fine-tune the result, making the 12-hour solution dubious when based on our data alone.

The apparitions in 2019 May and 2020 September are V = 17.2. Those will be good opportunities to find a better solution for the rotation period.

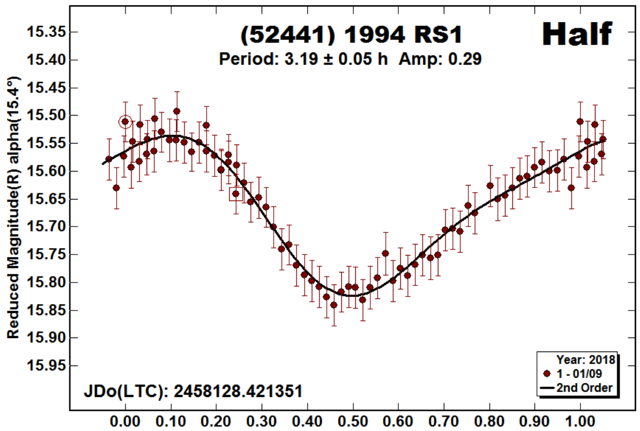


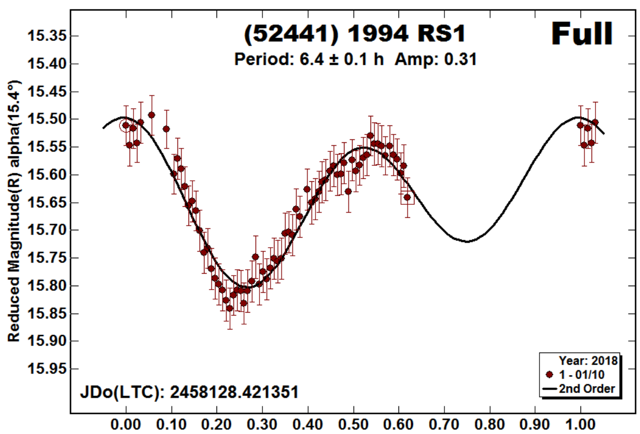




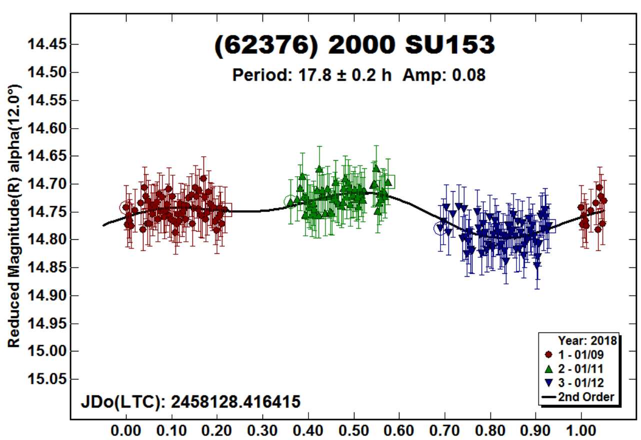


(52441) 1994 RS1. The period spectrum was very vague. Monomodal and bimodal solutions are given with the "full" period preferred because of the amplitude (Harris et al., 2014).



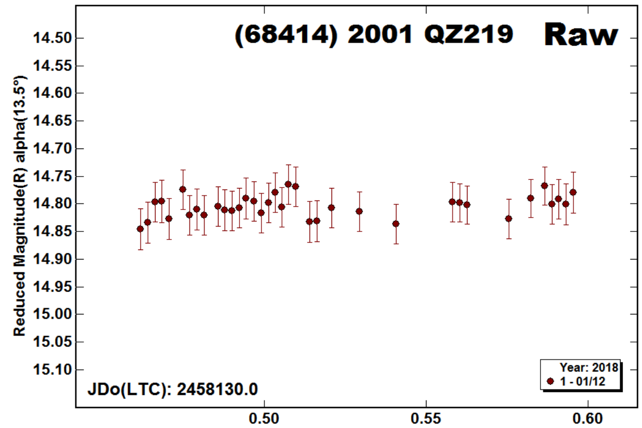


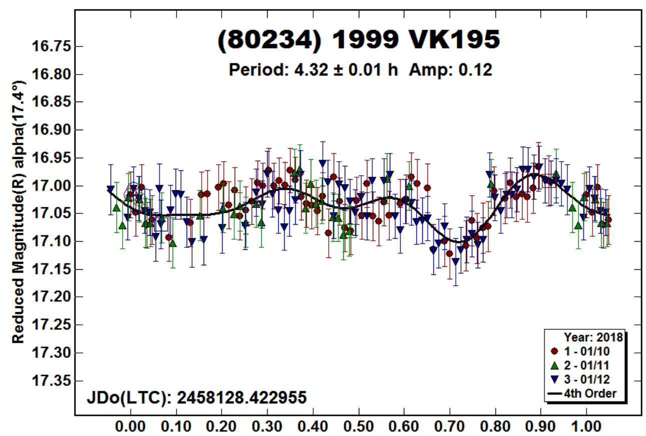
(62376) 2000 SU153. The period is a best guess and could easily be wrong. It is presented to indicate that data are available.



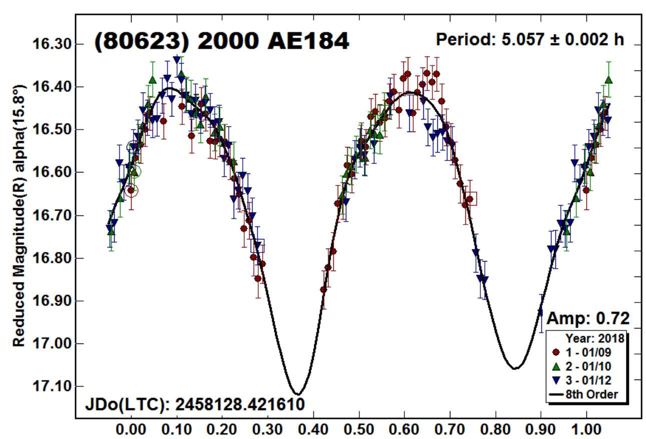
(68414) 2001 QA219, (80234) 1999 VK195. There were insufficient data for 2001 QA219 to show a definitive up or down trend let alone to find a period and so only the raw plot (mag vs. JD) is shown. It reaches V = 16.1 in 2019 August.

Despite the low amplitude, the solution for 1999 VK195 is considered nearly secure. Lightcurves using a half or double period, and others, were unrealistic and/or required excessive zero point adjustments.



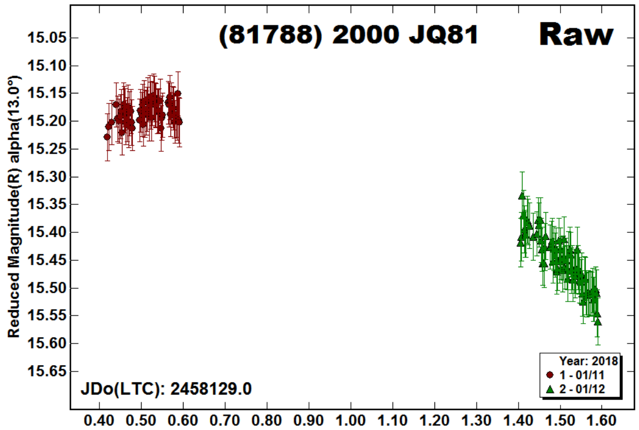


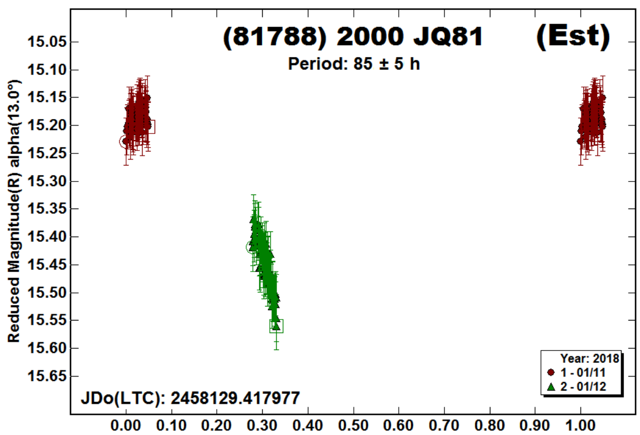
(80623) 2000 AE184. Neither the half- or full-period lightcurve was entirely covered by the data. The large amplitude at a relatively low phase angle assures a bimodal solution (Harris et al., 2014). The 2020 November apparition is V = 18.2 for those looking to get a complete lightcurve.



(81788) 2000 JQ81. Using the slope of the data between the two nights, the slope of the data on January 12, and assuming a symmetrical bimodal lightcurve that takes about 0.25 rotation phase to go from one extrema to the next, produces a solution of about 85 hr. This result should not be used for statistical rotation studies.

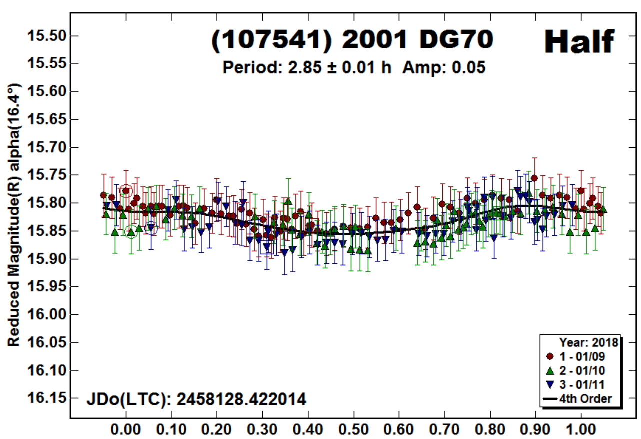
The 2019 June apparition is V = 18.3, followed by 2020 October (V = 18.8) and 2023 March (V = 18.5). It will likely take a coordinated observing campaign with observers who are well-separated in longitude to find the rotation period.

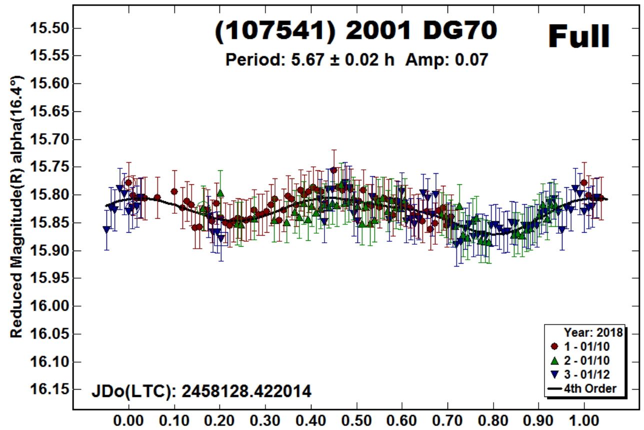




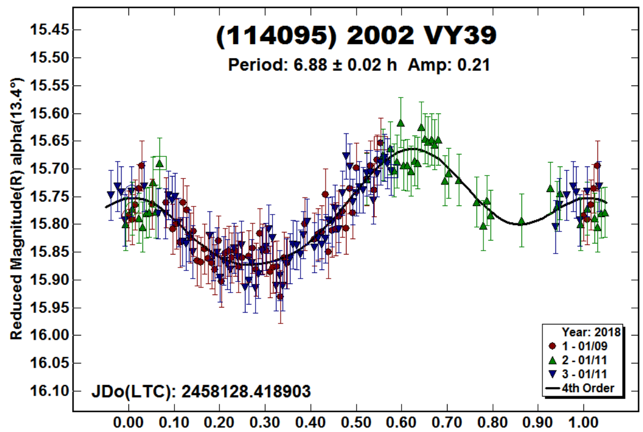
(107541) 2001 DG70. The low amplitude produced a highly-ambiguous solution set. We adopted periods that produce either a monomodal or bimodal lightcurve. By default, we adopted the "full" period of 5.67 hr for this work.

Until the apparition in 2031 March (V = 17.9), a 1-2 meter telescope will be required to get useful photometry.

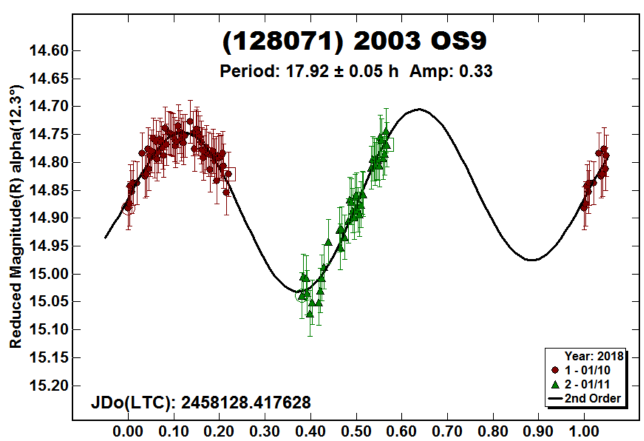




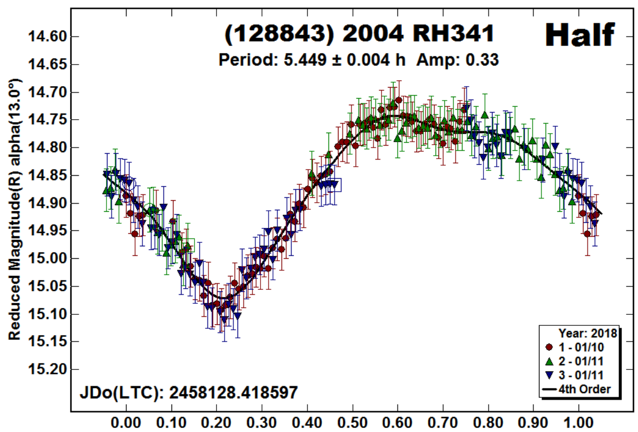
(114095) 2002 VY39. Despite the asymmetry of the lightcurve, this appeared to be the most likely solution. There are no apparitions V ≤ 18.8 through 2050.

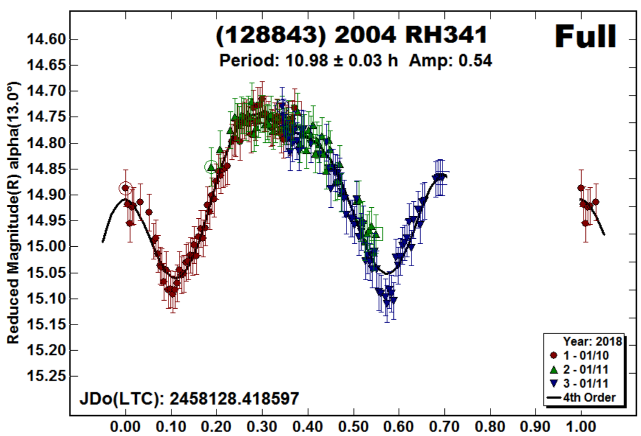


(128071) 2003 OS9. The amplitude almost assures a bimodal lightcurve (Harris et al., 2014). Based on this, the data fit well to a period of 17.92 hr using 2nd order analysis. Higher orders produced unrealistic model curves. Apparitions V < 19 and away from low galactic latitudes are rare; the next one is 2041.



(128843) 2004 RH341. The half-period lightcurve was used to find the preferred full period of 10.98 hr. The resulting Fourier curve had an excessively deep, artificial minimum between 0.7-1.0 rotation phase; this was removed for the final lightcurve plot.

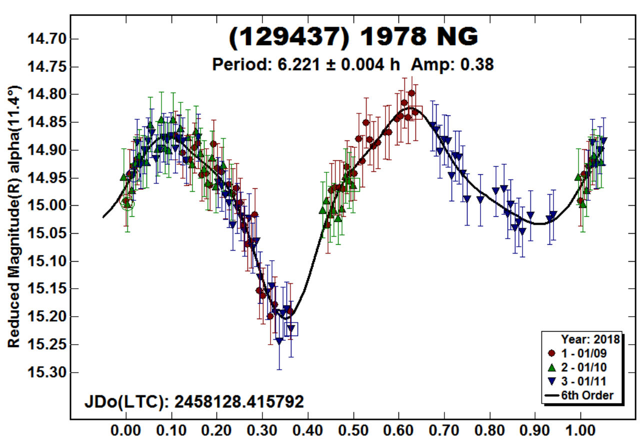


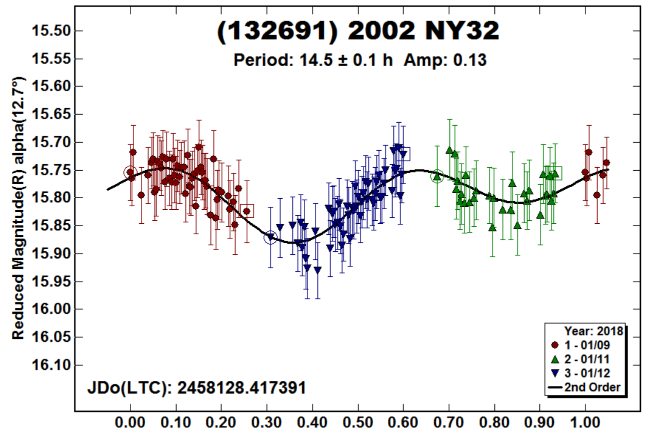


The asteroid will reach V = 18.7 in 2024 March, the next time it's one that is also not close to the galactic plane.

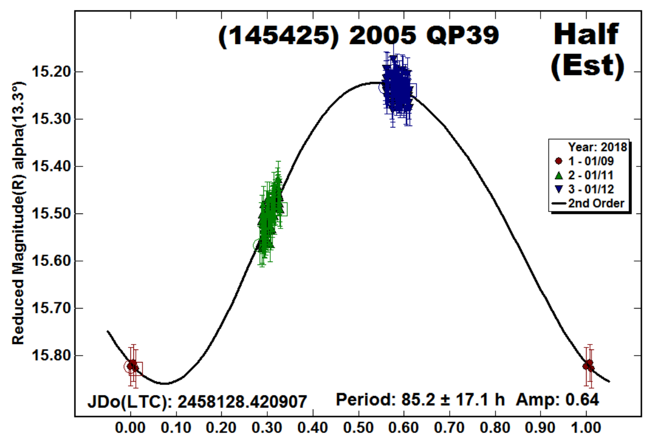
<u>(129437) 1978 NG, (132691) 2002 NY32</u>. The solution for 1978 NG is considered nearly secure, the main concern being the lack multiple coverage between 0.60 and 1.0 rotation phase.

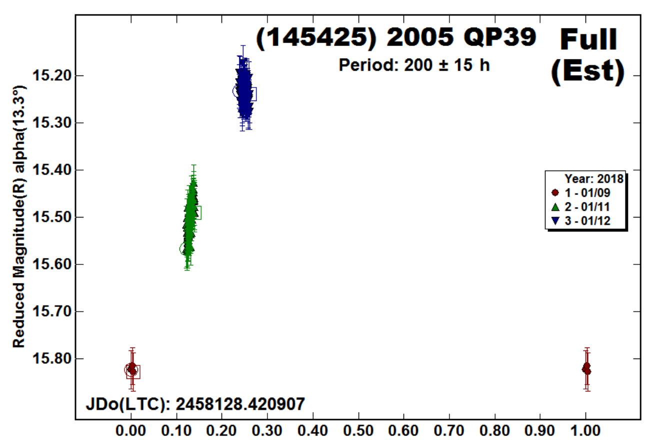
For 2002 NY32, a half-period solution near 7.25 hr was affected by what would be the asymmetry of the full-period lightcurve at 14.5 hr. The result is good enough for statistical studies but needs confirmation. For those with 1-2 meter telescopes, the next chance comes in 2020 October (V = 18.8)





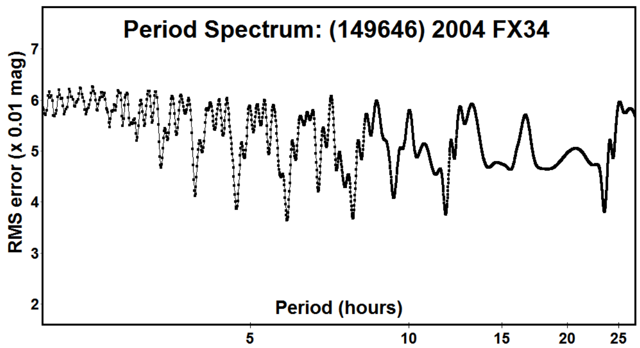
<u>(145425) 2005 QP39</u>. The full period is based on the assumption of a symmetrical bimodal lightcurve. Doubling the half-period gives a result that is within 1-sigma of the full period error. All apparitions through 2050 are V ≥ 19.0.

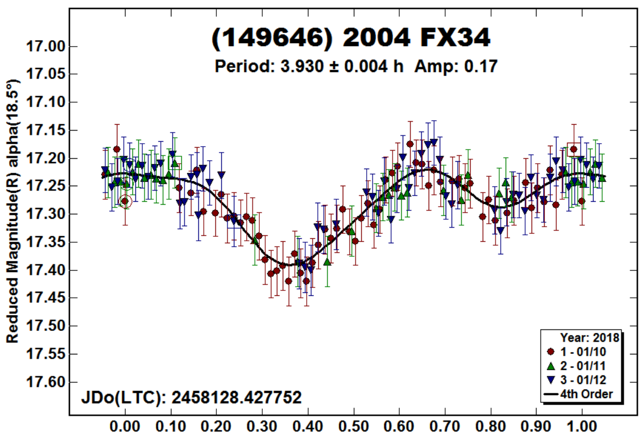




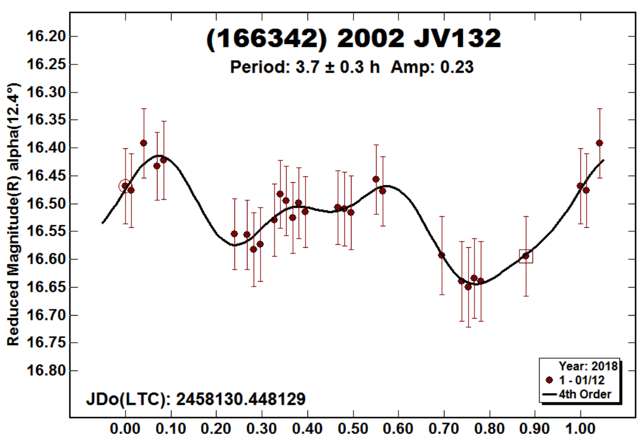
<u>(149646) 2004 FX34</u>. The period spectrum shows the "best" period as 5.9 hr. However, this gave an asymmetrical lightcurve with a large gap over about 0.2 rotation phase. This was taken to be a *fit by exclusion* and not the true period. Therefore, we adopted the next best, shorter period solution.

V = 18.9 is the brightest that 2005 OP39 will be through 2050; that is in 2020 November.



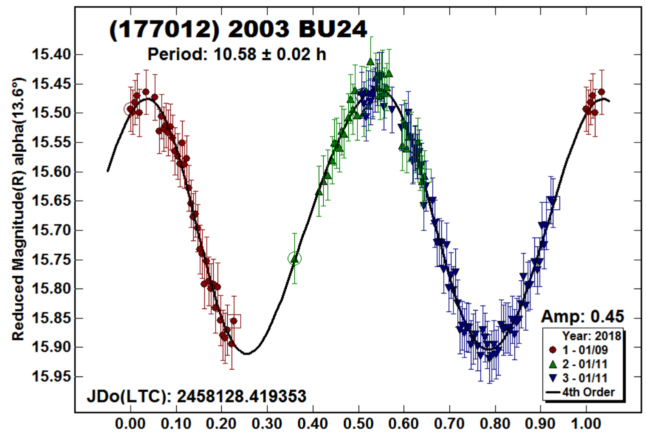


(166342) 2002 JV132, (177012) 2003 BU24. The period for 2002 JV132 is likely wrong. The lightcurve is included to show that data are available. The 2019 apparition is at V = 18.0 in June, but at galactic latitudes near 0° (almost directly in front of the galactic center.

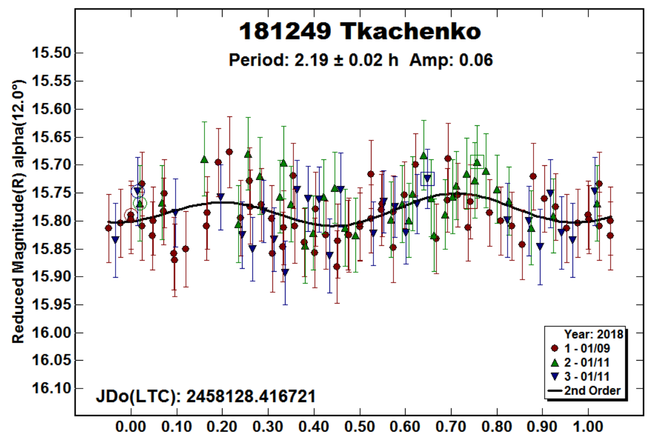


On the other hand, the solution of 10.58 hr for 2003 BU24 is very nearly secure, i.e., the period is almost certainly correct, but the shape of the lightcurve is not fully defined.

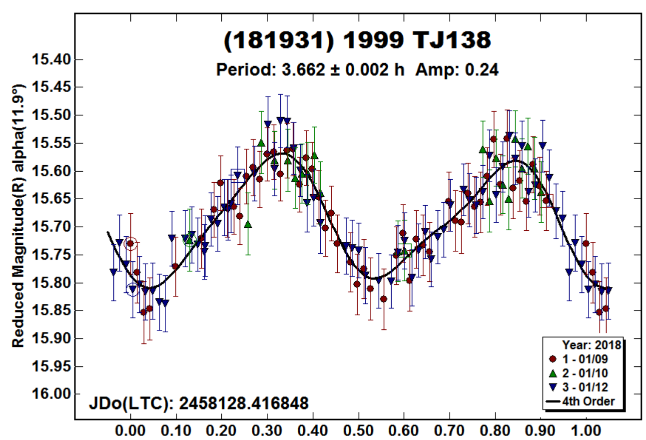
This asteroid barely reaches V = 19 through 2050. A 1-2 meter telescope will be needed to confirm these results.



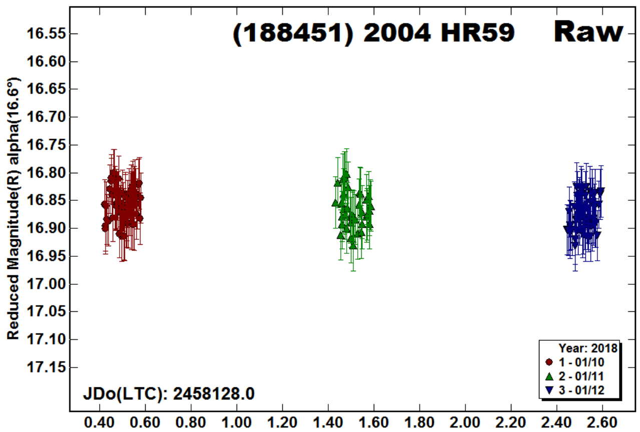
181249 Tkachenko. The lightcurve is presented to indicate that data were available and show their general quality. The period solution should not be used for statistical rotation period analysis. Large telescope owners (D > 1 m) might try to find a period in 2021 October when the asteroid reaches V = 19.3.



(181931) 1999 TJ138. The amplitude, which nearly assures a bimodal solution (Harris et al., 2014), helped remove several longer periods with accompanying higher-modal lightcurves



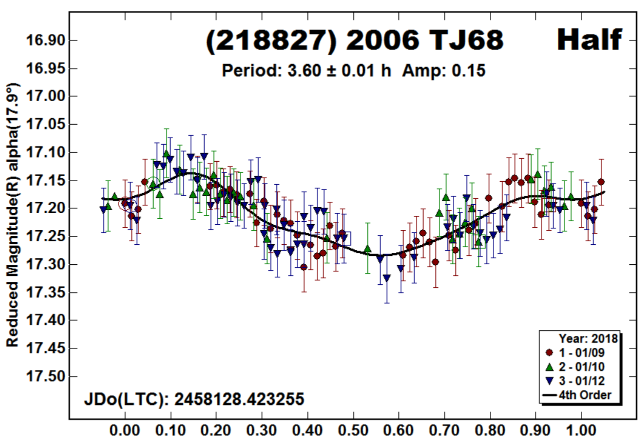
(188451) 2004 HR59. No solution could be found. The raw plot is used to show the quality and any trends in the data. All the brighter apparitions take place in the southern celestial hemisphere. The two closest ones with V ≤ 19.0 take place in 2022 April and 2026 June.

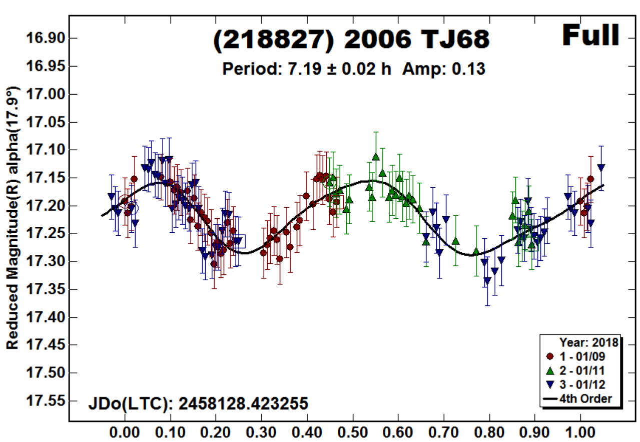


The 2019 apparition reaches brightest, V = 19.3, on Aug 3 .

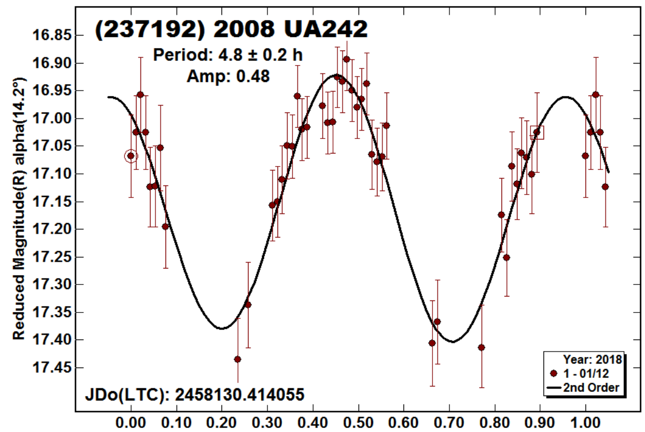
(218827) 2006 TJ68. Neither the half-period (monomodal) nor the full-period (bimodal) solution can be formally excluded; the preferred solution is the full-period of 7.19 hr.

It might be possible to resolve the ambiguity in 2020 November when 2006 TJ68 reaches V = 18.5.

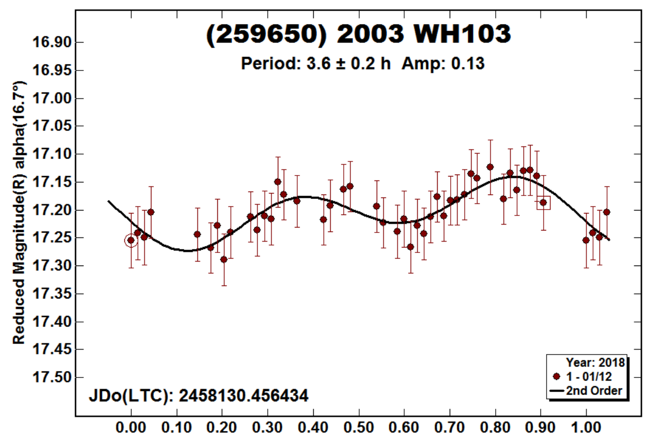




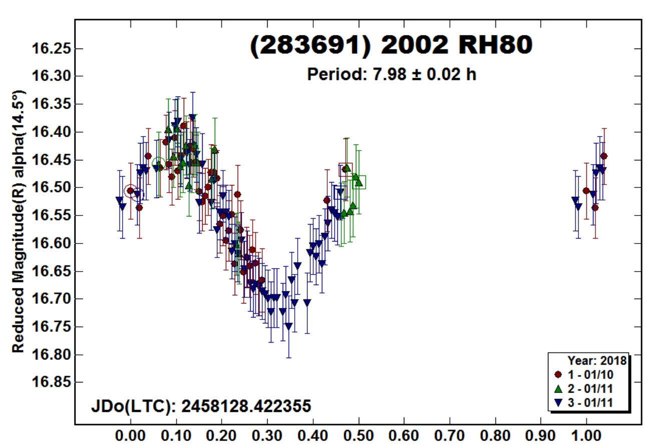
(237192) 2008 UA242. The raw and half-period plots support our adopted period of 4.8 hr with a bimodal lightcurve. However, this needs confirmation. Unfortunately, the next time 2008 UA242 is V ≤ 19.0 is 2037 November. Until then, it hovers near V = 20 at brightest during an apparition.



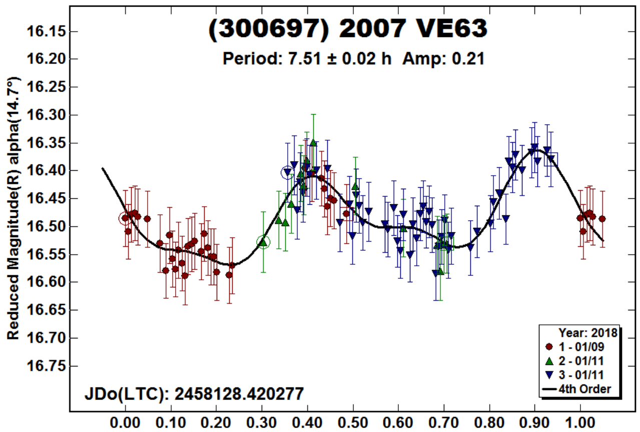
(259650) 2003 WH103. The period of 3.6 hr is a best fit of the data. The lightcurve amplitude is on the order of error bars and, with only one night of data, the solution should not be used for statistical studies. The next apparition that's not too close to the galactic plane and might be within reach of 0.5-1.0 meter telescopes is 2023 September at V = 18.5.

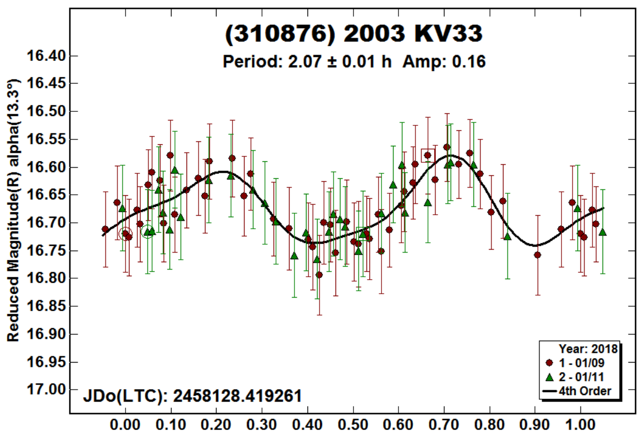


(283691) 2002 RH80. The period is almost exactly commensurate with an Earth-day. Other commensurate periods, e.g., 4, 6, 12 hr, were eliminated by using a half-period solution and considering that the amplitude approaching 0.30 mag made a bimodal lightcurve likely. The 2025 September apparition is the next one with reasonable chances of success with a 1-2 meter telescope (V = 19.4).

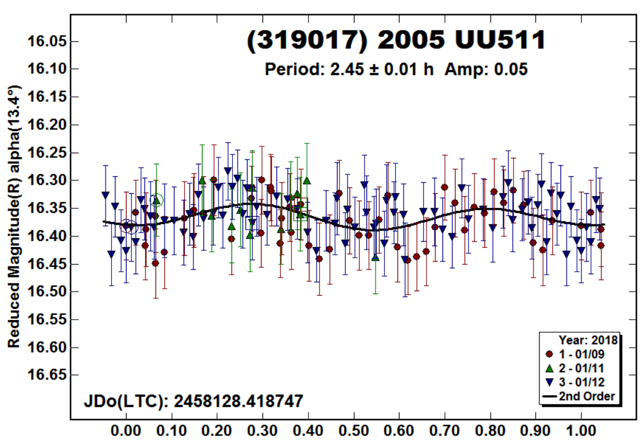


(300697) 2007 VE63, (310876) 2003 KV33. There were no rotational period entries in the LCDB for either asteroid. Of the two, the solution for 2003 KV is considered secure. The solution for 2007 VE63 needs confirmation. That will require a 1-2 meter telescope since the asteroid is V ≥ 19.4 through 2050.

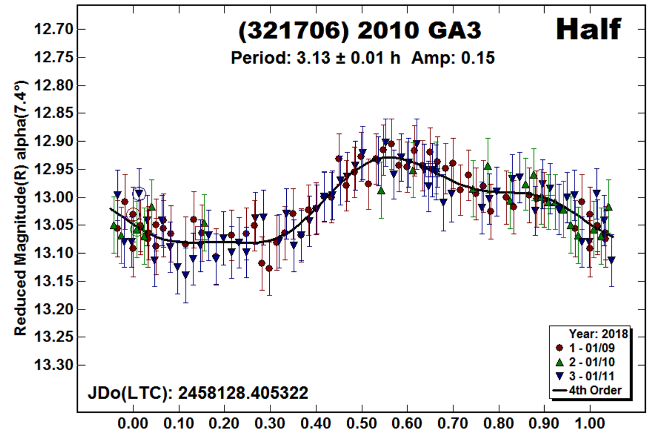


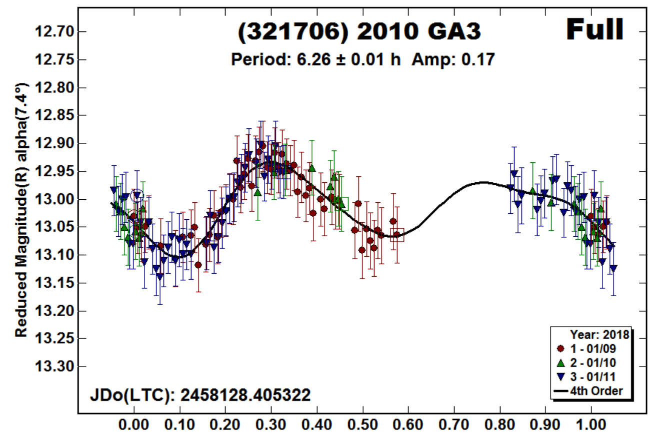


(319017) 2005 UU511. This is a weak solution that is very possibly wrong. The brightest 2005 UU511 gets through 2050 is V = 19.7. It and others V < 20 are in December at low galactic latitudes.



(321706) 2010 GA3. The significant gap in the full-period solution might be considered a *fit by exclusion*. However, the two halves of the bimodal lightcurve are different enough that the 6.26 hr period cannot be formally excluded.

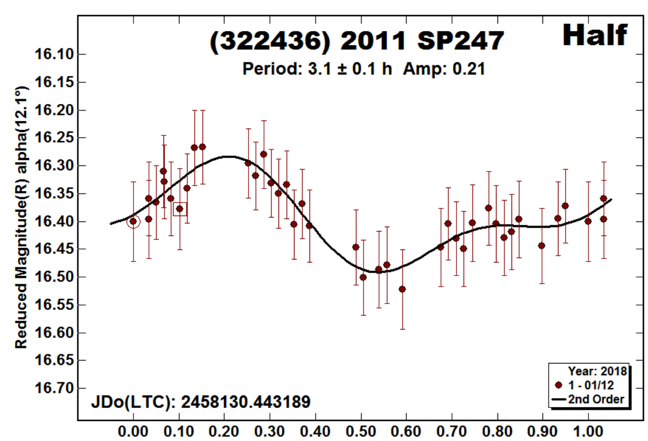


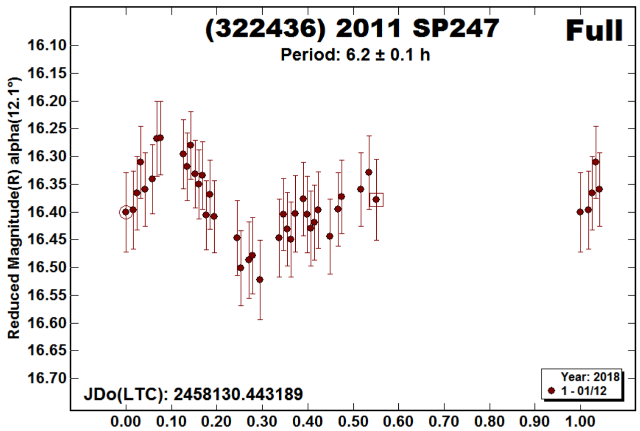


Looking ahead through 2050, the asteroid is between V = 19.4-19.9 at every apparition. The brightest one in the next ten years is 2023 August at V = 19.4.

(322436) 2011 SP247. The half-period solution supports the adopted period of 6.2 hr. Because of the low amplitude, neither solution can be formally excluded (Harris et al., 2014).

Starting with 2020 August 22.3, 2011 SP247 reaches V = 19.5 and every five years plus ~ 2.2 days after. In 2050, the date of brightest will have moved into September (4.3). The declination on the date of brightest is about –3° each time.

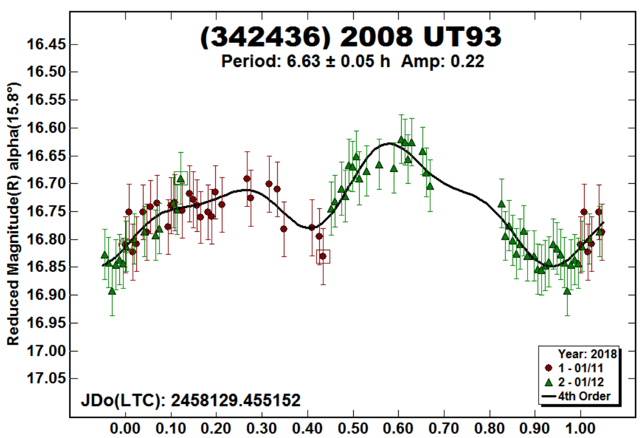


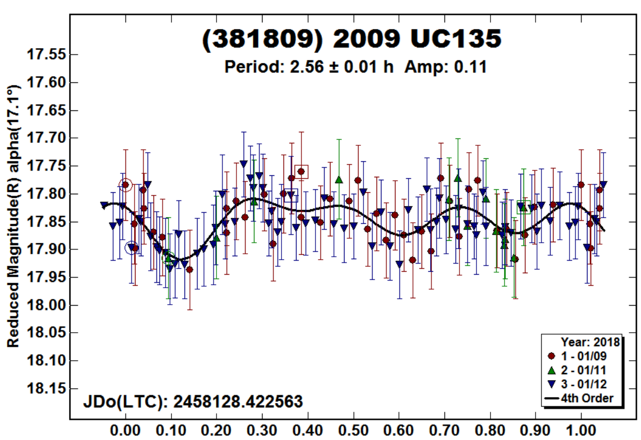


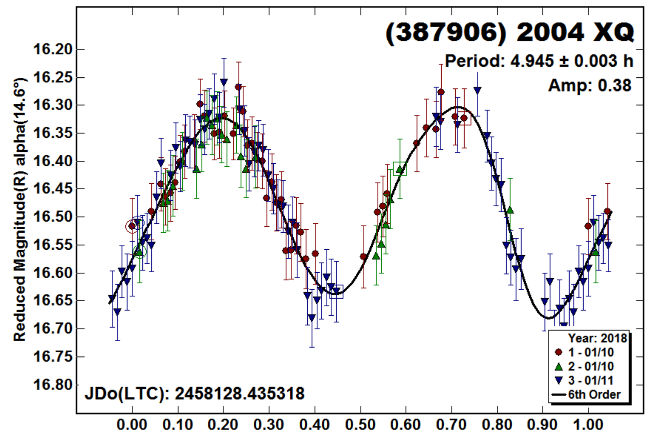
(342436) 2008 UT93, (381809) 2009 UC135, (387906) 2004 XQ. The period of 6.63 hr for 2008 UT93 represents the best fit among several possibilities. The asteroid will be V = 19.2 in 2022 January, the next "best" apparition.

Trimodal lightcurves are not uncommon at low amplitudes (Harris et al., 2014) and so, for 2009 UC135, the period is supported by the asymmetry of the lightcurve. A forced solution with a (nearly) bimodal solution was unsatisfactory. Finding the true period will be difficult since 2009 UC135 is rarely brighter than V = 20. The next opportunity is 2020 October at V = 19.7.

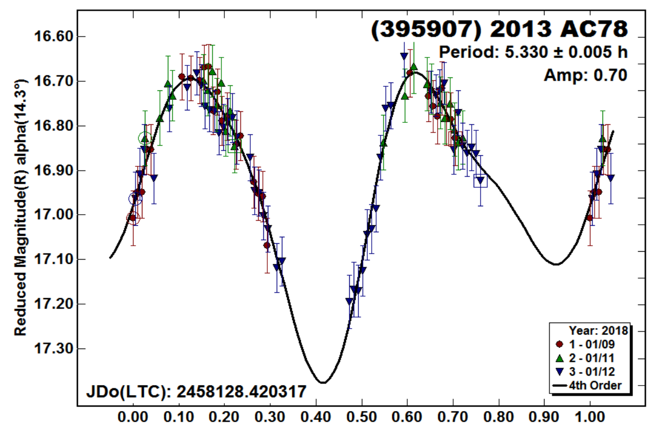
The solution for 2004 XQ is considered secure: there is complete coverage and the amplitude assures a bimodal lightcurve.



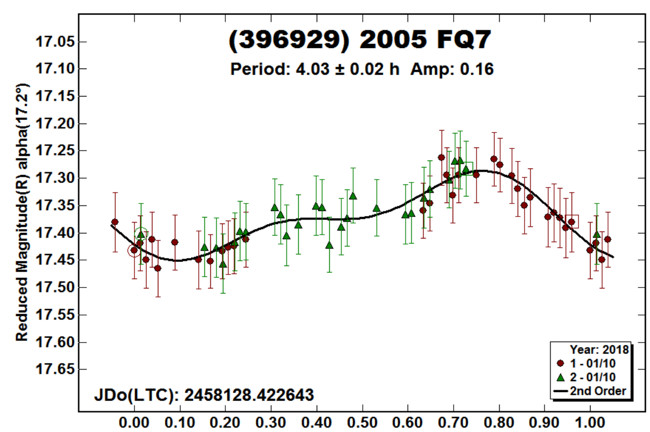




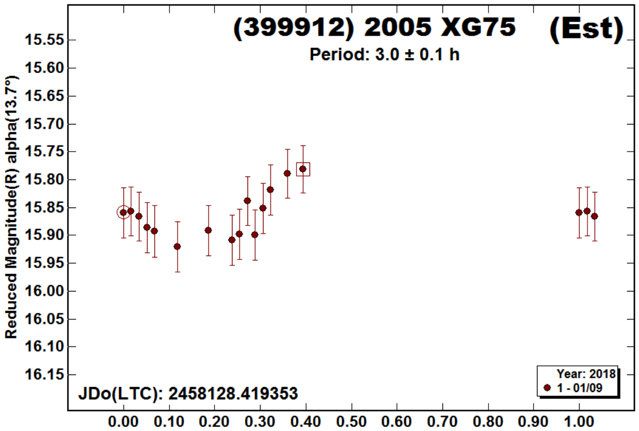
(395907) 2013 AC78. A period of 5.33 hr produced the most symmetrical lightcurve when assuming a total rise or fall from one extrema to the next of 0.25 rotation phase. The period represents 4.5 rotations per Earth day. Without a 2-m telescope, there probably won't be another lightcurve through at least 2050.



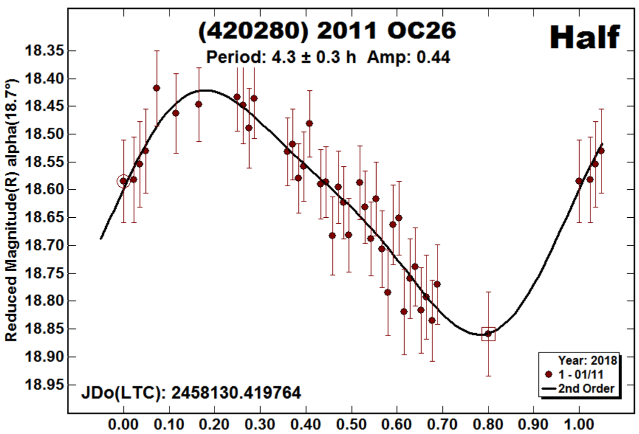
(396929) 2005 FQ7. The period spectrum showed numerous nearly-equal minimums. A bimodal lightcurve had too large of gaps to make it preferable to the monomodal lightcurve of 4.03 hr. It's not until 2027 March that 2005 FQ7 reaches V = 19.2. Until then it stays at V ≥ 20.0.

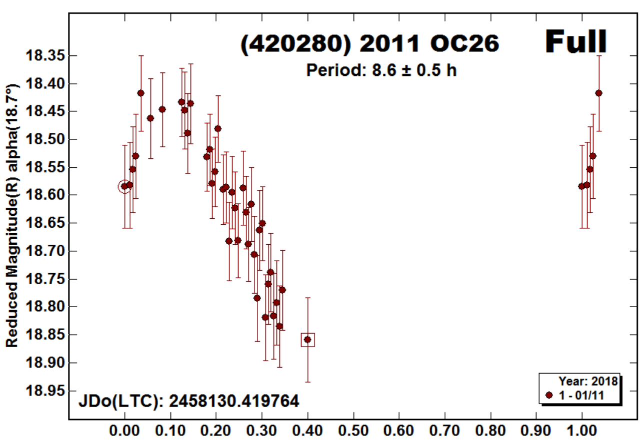


(399912) 2005 XG75. The lightcurve is shown to indicate that data were available and their general quality. The solution is very possibly wrong since it presumes a low-amplitude bimodal lightcurve. 2024 March (V = 19.4) is the next "good" apparition.



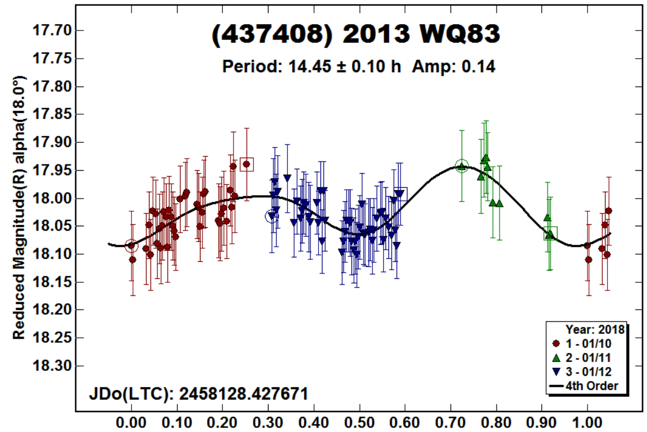
(420280) 2011 OC26. The half-period lightcurve is too asymmetrical to presume a secure solution for the adopted full-period solution of 8.6 hr. However, the monomodal lightcurve helped establish a reasonable estimate of the actual lightcurve amplitude. The next noteworthy apparition is 2024 August (V = 18.6).

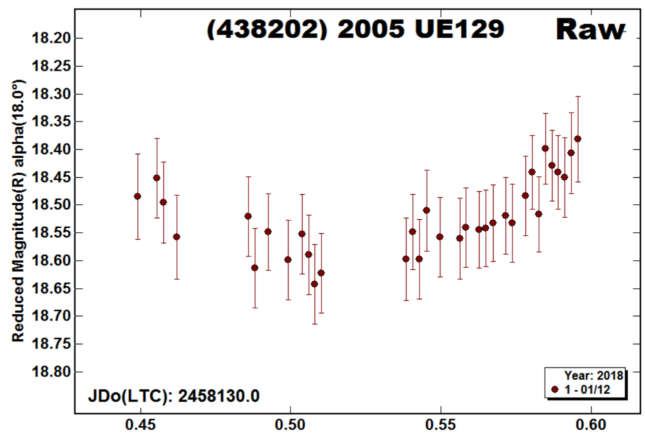


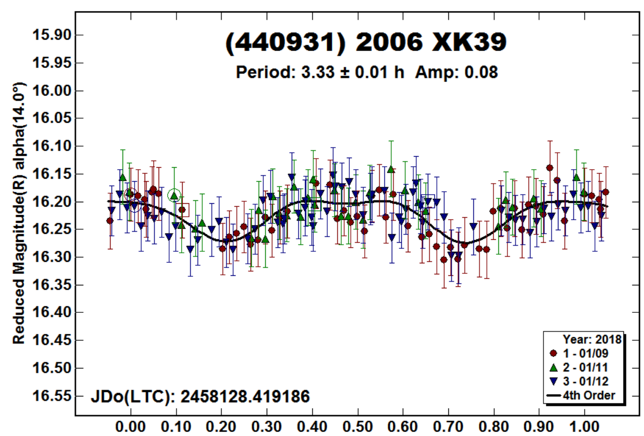


(437408) 2013 WQ83, (438202) 2005 UE129, (440931) 2006 XK39. The solution for 2013 WQ83 could easily be a *fit by exclusion*. However, no other period gave a more plausible result. The data set for 2005 UE129 was too limited to say more than the period is likely >10 hr.

The solution for 2006 XK39 is considered secure. The half-period of 1.66 hr can be safely excluded given the estimated diameter of 4.5 km. The combination would place it too far above the so-called "spin barrier" of about 2.2 hr to be plausible.



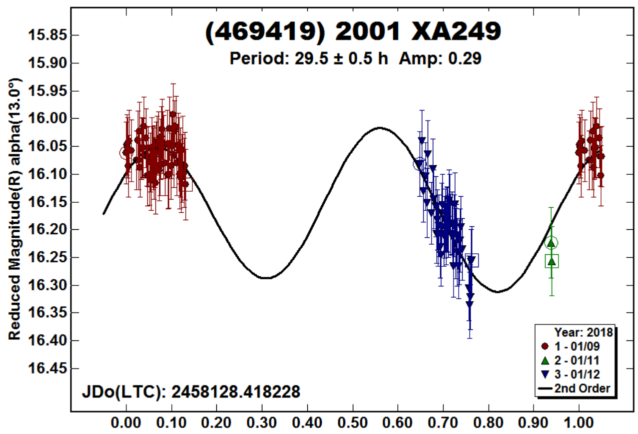


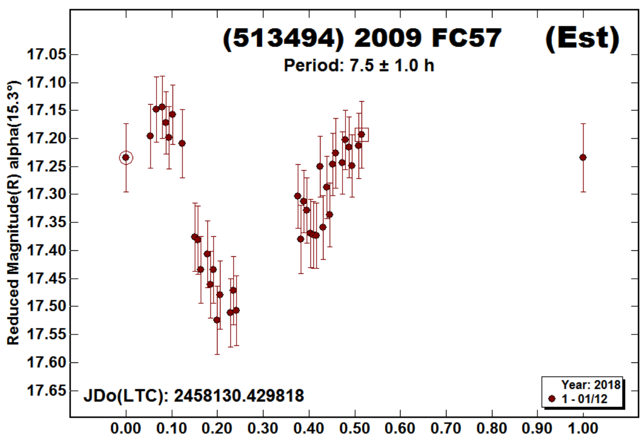


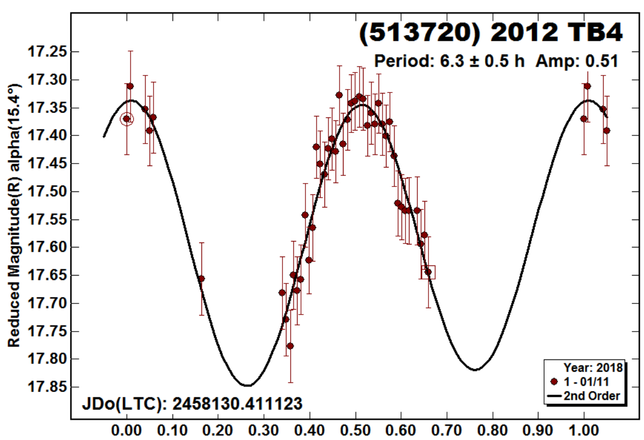
For 2013 WQ83, 2020 October (V = 19.6) is the next apparition with some hope of finding the period, but only with a 1-2 meter telescope. The prospects for 2005 UE129 are even less promising: V = 19.8 is the best it can do, the next time is 2032 December.

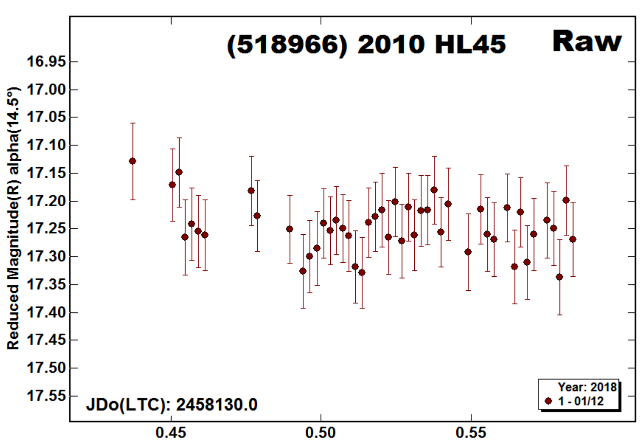
(469419) 2001 XA249, (513494) 2009 FC57, (513720) 2012 TB4, (518966) 2010 HL45. For the first three asteroids, the adopted period is a best estimate based on the slopes of data for the individual nights and a presumed amplitude of about 0.3 mag or larger. For 2010 HL45, no solution could be found and so only a plot of the raw data (mag vs. JD) is given.

2009 FC57 reaches V = 19.2 in 2023 April. The others rarely reach V ≤ 20.0 through 2050.

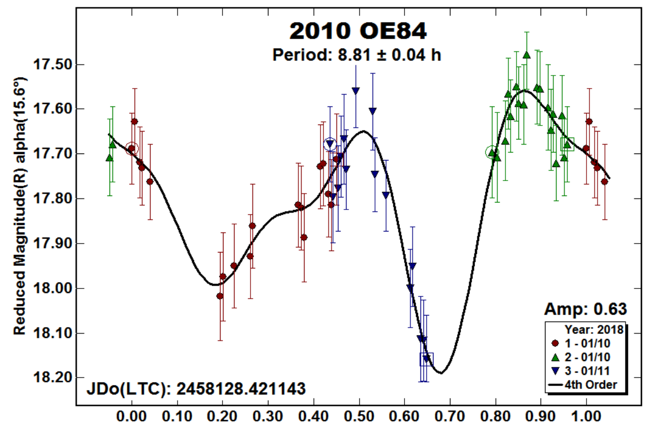




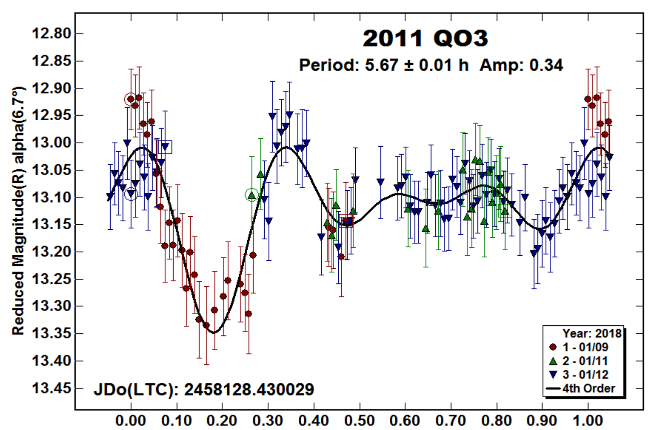




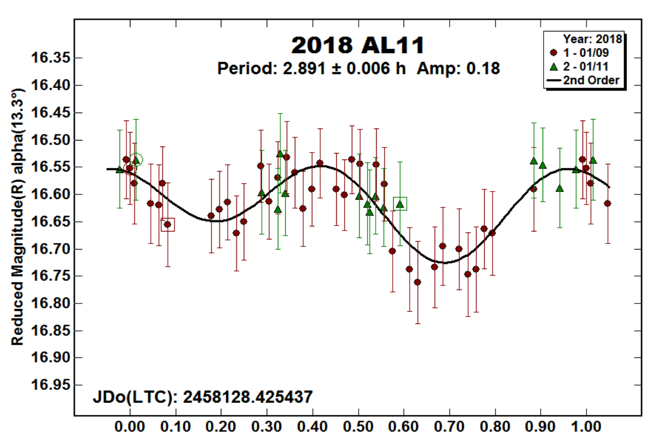
2010 OE84. The period spectrum gave limited guidance when trying to establish the true period. All of the solutions between 6 and 15 hr produced lightcurves that were less than fully convincing. The next good apparition is 2031 February at V = 19.4.



2011 QO3, 2018 AL11. The solution for 2011 QO3 is based on using the full data set. If the data from January 9 are excluded, shorter periods between 2-4 hr become possible, but without nearly as good a fit as with the full data set. In 2022 July, 2011 QO3 brightens to V = 19.0.



The solution for 2018 AL11 is good enough for the period to be used in statistical studies, but it should not be considered definitive. The few apparitions when V < 20 through 2050 are at low galactic latitudes.



Original Data

The data for the 53 asteroids in this paper have been uploaded to the ALCDEF site (*http://alcdef.com*).

Acknowledgements

This research has made use of the KMTNet system operated by the Korea Astronomy and Space Science Institute (KASI) and the data were obtained by observations made at the South African Astronomical Observatory (SAAO). This work is partially supported by the South African National Research Foundation (NRF). Continued work on the asteroid lightcurve database (LCDB; Warner et al., 2009) and ALCDEF database/website (alcdef.org) is supported by NASA grant 80NSSC18K0851.

References

Berthier, J., Vachier, F., Thuillot, W., Fernique, P., Ochsenbein, F., Genova, F., Lainey, V., Arlot, J.-E. (2006). "SkyBoT, a new VO service to identify Solar System Objects." in Astronomical Data Analysis Software and Systems XV. *ASP Conference Series* **351**, 367. Astronomical Society of the Pacific. San Francisco.

Birlan, M., Barucci, M.A., Angeli, C.A., Doressoundiram, A., De Sanctis, M.C. (1996). "Rotational properties of asteroids: CCD observations of nine small asteroids." *Planet. Space Sci.* **44**, 555-558.

Durech, J., Hanus, J., Ali-Lagoa, V. (2018). "Asteroid models reconstructed from the Lowell Photometric Database and WISE data." *Astron. Astrophys.* **617**, A57.

Erasmus, N., McNeill, A., Mommert, M., Trilling, D.E.. Sicakfoose, A.A., van Gend, C. (2018). "Taxonomy and Light-curve Data of 1000 Serendipitously Observed Main-belt Asteroids." *Ap. J. Suppl.* **237**, A19.

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

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

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

Kim, S.-L., Lee, C.-U., Park, B.-G., Kim, D.-J., Cha, S-M., Lee, Y., Han, C., Chun, M.Y., Yuk, I. (2016). "KMTNET: A Network of 1.6 m Wide-Field Optical Telescopes Installed at Three Southern Observatories." J. Korean Ast. Soc. **49**, 37-44.

Mainzer, A.K., Bauer, J.M., Cutri, R.M., Grav, T., Kramer, E.A., Masiero, J.R., Nugent, C.R., Sonnett, S.M., Stevenson, R.A., Wright, E.L. (2016). "NEOWISE Diameters and Albedos V1.0." NASA Planetary Data System.
EAR-A-COMPIL-5-NEOWISEDIAM-V1.0.

Mommert, M. (2017). "PHOTOMETRYPIPELINE: An automated pipeline for calibrated photometry." *Astronomy and Computing* **18**, 47-53.

Pravec, P., Hergenrother, C., Whiteley, R., Sarounova, L., Kusnirak, P. (2000). "Fast Rotating Asteroids 1999 TY2, 1999 SF10, and 1998 WB2." *Icarus* **147**, 477-486.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Number	Name	2018 01/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp	D	p_V
1992	Galvarino	10-11	204	12.8,12.3	146	-8	7.002	0.005	0.60	0.02	EOS	**9.6**	**0.145**
6594	Tasman	09-09	74	12.1	145	-8	3.68	0.03	0.39	0.02	MB-O	**7.0**	**0.365**
15132	Steigmeyer	11-12	81	17.5,17.1	144	-7	115	10	0.62	0.10	V	**1.8**	**0.477**
16364	1979 MA5	10-12	155	12.8,12.3	145	-9	17.59	0.03	0.58	0.03	MB-O	**6.9**	**0.196**
24986	Yalefan	10-11	183	14.4,14.1	145	-8	6.574	0.003	0.43	0.02	FLOR	3.0	0.24
40328	Dow	10-12	158	15.0,14.3	145	-8	–	–	>0.2	–	FLOR	2.3	0.24
44779	1999 TM153	10-11	137	18.2,17.8	144	-8	7.43	0.02	0.11	0.01	FLOR	2.3	0.24
44779	1999 TM153						3.71	0.01	0.11	0.01			
47048	1998 WW18	10-12	223	13.4,12.9	146	-7	17.29	0.07	0.14	0.01	MB-O	**5.1**	**0.244**
47048	1998 WW18						8.61	0.02	0.15	0.01			
52441	1994 RS1	10-10	65	15.3	143	-8	6.36	0.05	0.29	0.02	MB-I	**2.3**	**0.281**
52441	1994 RS1						3.19	0.05	0.29	0.02			
62376	2000 SU153	09-12	194	12.2,11.5	147	-8	17.6	0.2	0.06	0.01	EOS	**3.5**	**0.329**
68414	2001 QZ219	12-12	36	13.5	147	-9	1.36	0.02	0.04	0.01	MB-I	**3.0**	**0.30**
80234	1999 VK195	10-12	160	17.4,16.6	143	-7	4.32	0.01	0.12	0.02	FLOR	1.4	0.24
80623	2000 AE184	09-12	133	16.5,15.4	145	-7	5.057	0.002	0.66	0.03	FLOR	1.6	0.24
81788	2000 JQ81	11-12	132	13.0	145	-8	85	5	0.45	0.10	MB-O	2.6	0.258
107541	2001 DG70	09-11	187	16.7,16.1	144	-8	5.67	0.02	0.07	0.01	EUN	2.6	0.236
107541	2001 DG70						2.85	0.01	0.05	0.01			
114095	2002 VY39	09-11	166	13.7,13.1	145	-8	6.88	0.02	0.21	0.02	MB-O	4.8	0.057
128071	2003 OS9	10-11	103	12.2,12.0	145	-8	17.92	0.05	0.33	0.02	MB-O	**8.1**	**0.052**
128843	2004 RH341	10-11	194	13.2,12.9	146	-8	10.87	0.03	0.33	0.02	MB-O	**4.2**	**0.213**
129437	1978 NG	09-11	143	11.6,11.1	147	-9	6.221	0.004	0.38	0.02	MB-O	**3.3**	**0.301**
132691	2002 NY32	09-12	132	12.9,12.2	147	-9	14.5	0.1	0.13	0.02	EUN	**2.4**	**0.297**
145425	2005 QP39	09-12	142	13.5,12.7	146	-8	200.	15.	0.6	0.1	MB-O	**5.0**	**0.103**
149646	2004 FX34	10-12	140	18.4,17.7	144	-7	3.930	0.004	0.17	0.02	FLOR	1.5	0.24
166342	2002 JV132	12-12	26	12.4	145	-8	3.7	0.3	0.23	0.02	MB-I	**4.0**	**0.041**
177012	2003 BU24	09-11	154	14.1,13.5	145	-9	10.58	0.02	0.45	0.02	MB-O	3.9	0.057
181249	Tkachenko	09-11	116	12.2,11.7	146	-9	2.19	0.02	0.06	0.03	MB-O	**3.5**	**0.089**
181931	1999 TJ138	09-12	136	12.3,11.6	147	.9	3.662	0.002	0.24	0.02	MB-O	**5.1**	**0.074**
188451	2004 HR59	10-12	151	16.5,15.9	145	-8	–	–	–	–	V	1.6	0.20
218827	2006 TJ68	09-12	124	18.2,17.0	143	-7	7.19	0.02	0.13	0.02	FLOR	1.3	0.24
218827	2006 TJ68	09-12					3.60	0.01	0.15	0.02			
237192	2008 UA242	12-12	43	14.2	145	-8	4.2	0.2	0.48	0.03	EUN	1.4	0.21
259650	2003 WH103	12-12	43	16.6	145	-7	3.6	0.2	0.13	0.01	FLOR	1.3	0.24
283691	2002 RH80	10-11	119	14.5,14.2	145	-9	7.98	0.02	0.28	0.02	MB-O	3.3	0.057
300697	2007 VE63	09-11	98	15.0,14.4	145	-7	7.51	0.02	0.21	0.02	MB-O	3.7	0.057
310876	2003 KV33	09-11	79	13.7,13.2	145	-8	2.07	0.01	0.16	0.02	MB-O	3.5	0.057
319017	2005 UU511	09-12	132	13.6,12.8	145	-9	2.45	0.01	0.05	0.01	MB-O	3.9	0.057
321706	2010 GA3	09-11	128	7.6,7.3	149	-8	6.26	0.01	0.17	0.02	TR-J	16.1	0.057
321706	2010 GA3						3.13	0.01	0.15	0.02			
322436	2011 SP247	12-12	38	12.1	146	-8	6.2	0.1	0.21	0.02	MB-O	3.9	0.057
322436	2011 SP247						3.1	0.1	0.21	0.02	MB-O		
342436	2008 UT93	11-12	75	15.8,15.4	144	-9	6.63	0.05	0.22	0.02	MB-M	2.4	0.10
381809	2009 UC135	09-12	121	17.4,16.3	143	-8	2.56	0.01	0.11	0.02	MB-I	**1.5**	**0.109**
387906	2004 XQ	10-11	123	14.5,14.2	145	-8	4.945	0.003	0.38	0.02	EUN	**2.2**	**0.194**
395907	2013 AC78	09-12	96	14.8,14.0	145	-9	5.330	0.002	0.70	0.05	MB-O	3.1	0.057
396929	2005 FQ7	10-10	56	17.1	145	-7	4.03	0.01	0.16	0.02	EUN	1.3	0.21
399912	2005 XG75	09-09	15	13.9	145	-9	3.0	0.1	0.13	0.02	MB-O	4.6	0.057
420280	2011 OC26	11-11	34	19.1	143	-7	8.6	0.5	0.44	0.05	H	0.6	0.30
437408	2013 WQ83	10-12	99	18.0,17.6	143	-8	14.45	0.10	0.11	0.02	FLOR	0.9	0.24
438202	2005 UE129	12-12	33	17.9	143	-7	>14	–	>0.2	–	V	0.9	0.20
440931	2006 XK39	09-11	151	14.7,14.4	159	-8	3.33	0.01	0.08	0.02	MB-O	3.5	0.057
469419	2001 XA249	09-12	109	13.2,12.4	146	-7	29.6	0.5	0.30	0.03	MB-O	4.2	0.057
513494	2009 FC57	12-12	38	15.2	146	-8	7.5	1.0	>0.3		MB-O	2.5	0.057
513720	2012 TB4	11-11	44	16.1	143	-8	6.3	0.5	0.51	0.03	EUN	1.1	0.21
518966	2010 HL45	12-12	47	14.4	145	-8	–	–	–	–	MB-O	**2.9**	**0.027**
	2010 OE84	10-11	51	15.6,15.3	145	-7	8.81	0.04	0.63	0.03	MB-M	**2.3**	**0.083**
	2011 QO3	09-12	116	6.8,6.4	149	-9	5.67	0.01	0.34	0.04	TR-J	15.3	0.057
	2018 AL11	09-11	52	13.5,13.0	145	-8	2.891	0.006	0.18	0.02	MB-O	3.5	0.057

Table I. Observing Circumstances and Results. The numbers and names are those at the time of the observations. The phase angle (α) is given at the start and end of each date range. If there are three values, the middle one is the minimum phase angle over the range of observations. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). If there are two lines for an asteroid, the first line gives the preferred period of ambiguous solution and the second line gives the alternate solution. The Grp column gives the family or group to which the asteroid belongs using the definitions from the LCDB (Warner et al., 2009). EOS: Eos; EUN: Eunomia; FLOR: Flora; H: Hungaria; MB-I/M/O: Main-belt inner/middle/outer; TR-J: Jupiter Trojan; V: Vestoid. D is the diameter (km) and p_V is the visual albedo. Bold text indicates the values came from the literature. Otherwise the diameter and albedo were computed by using the adopted absolute magnitude (*H*) in the LCDB along with the assumed albedo based on orbital position or group membership.

MAIN-BELT ASTEROIDS OBSERVED FROM CS3: 2018 OCTOBER - DECEMBER

Robert D. Stephens
Center for Solar System Studies (CS3)/MoreData!
11355 Mount Johnson Ct., Rancho Cucamonga, CA 91737 USA
rstephens@foxandstephens.com

Brian D. Warner
Center for Solar System Studies (CS3)/MoreData!
Eaton, CO

(Received: 2019 Jan 9)

CCD photometric observations of 18 main-belt asteroids were obtained from the Center for Solar System Studies from 2018 October to December. A pole solution was found for 4910 Kawasato of (λ, β, P_{SID}) = (355°, 35°, 4.66271 h). (31320) 1998 HX2 is a binary asteroid with a P_1 of 2.8149 ± 0.0001 h and P_2 of 47.06 ± 0.05 h.

The Center for Solar System Studies (CS3) has seven telescopes which are normally used in program asteroid family studies. The focus is on near-Earth asteroids, but when suitable targets are not available, Jovian Trojans and Hildas are observed. When a nearly full moon is too close to the family targets being studied, targets of opportunity amongst the main-belt families were selected.

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. Images were unbinned with no filter and had master flats and darks applied. The exposure duration varied depending on the asteroid's brightness and sky motion.

Telescope	Camera
0.30-m f/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/11 Schmidt-Cass	FLI Microline 1001E
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.50-m F8.1 R-C	FLI Proline 1001E

Table I: List of CS3 telescope/CCD camera combinations.

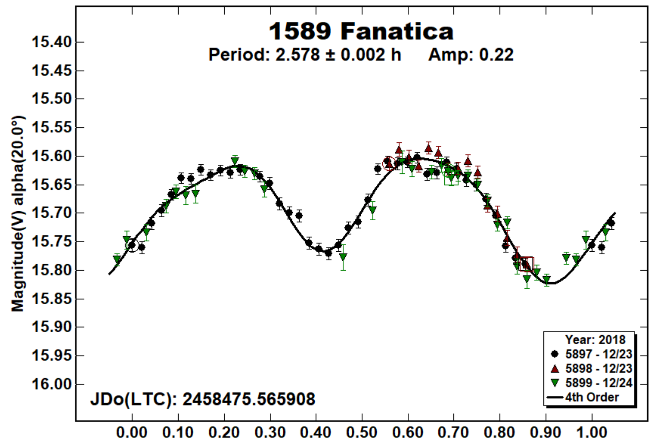
Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Night-to-night calibration (generally < ±0.05 mag) was done using field stars from the CMC-15 or APASS (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 (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.

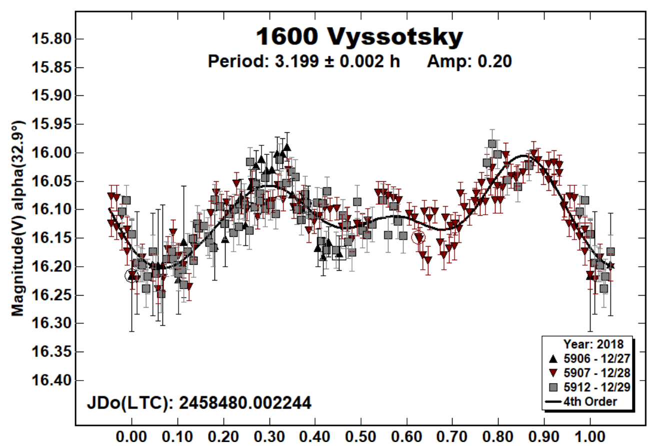
The amplitude indicated in the plots (e.g. Amp. 0.20) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

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).

<u>1589 Fanatica</u>. We previously observed this Vestoid family member (Warner, 2004; Stephens, 2015) finding rotational periods near 2.58 h. This year's result is in good agreement with those previous results.



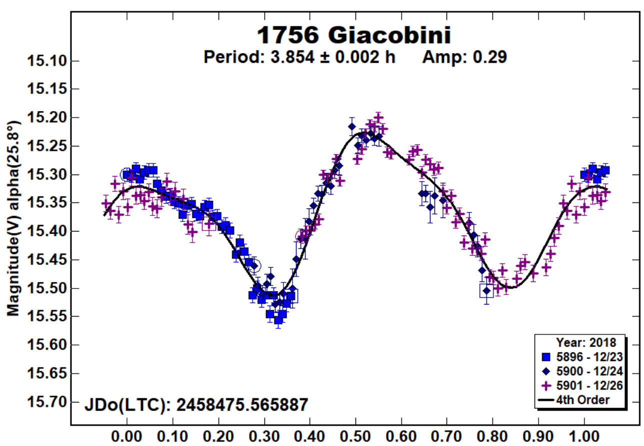
<u>1600 Vyssotsky</u>. We studied this member of the Hungaria family many times in the past (Warner, 2014b; Stephens, 2016) each time finding a rotational period near 3.20 h. The result found this year is consistent with those findings. A previous shape and spin model had been created (Warner et al. 2008) with two possible solutions: (λ, β) = (356°, 7°) and (219°, 54°). For both solutions, the sidereal period was 3.201264 h. It is hoped that this year's data will improve upon that model.



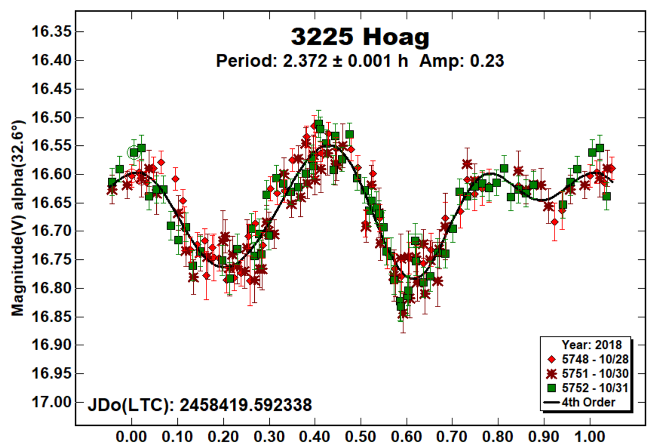
Number	Name	mm\dd	Pts	Phase	LPAB	BPAB	Period	P.E.	Amp	A.E.	Grp
1589	Fanatica	12/23-12/24	85	20.0,20.3	50	-3	2.578	0.002	0.22	0.02	V
1600	Vyssotsky	12/27-12/30	304	32.9,32.7	158	26	3.199	0.002	0.20	0.02	H
1756	Giacobini	12/23-12/26	148	25.8,26.4	43	5	3.854	0.002	0.29	0.02	MB-I
2572	Annschnell	09/29-09/30	114	7.9,7.5	23	0	6.27	0.01	0.70	0.03	V
3225	Hoag	10/28-10/31	182	32.7,32.9	336	9	2.372	0.001	0.23	0.02	H
3299	Hall	10/18-10/21	618	4.2,3.2	30	5	10.45	0.02	0.08	0.02	V
							36.72	0.07	0.14	0.02	V
3704	Gaoshiqi	10/19-10/20	439	3.4,3.8	20	4	9.699	0.001	0.26	0.02	V
3900	Knezevic	11/23-11/26	225	19.9,21.0	27	8	5.260	0.005	0.22	0.02	V
4635	Rimbaud	12/18-01/02	1152	7.7,4.0,4.2	99	7	117.91	0.03	1.08	0.03	V
4910	Kawasato	11/15-11/19	358	4.3,5.9	49	-6	4.659	0.002	0.40	0.02	MC
9873	1992 GH	10/24-10/30	523	25.0,27.3	358	9	2.925	0.001	0.39	0.02	H
13665	1997 GK17	11/15-12/28	519	24.0,3.1	99	3	37.631	0.004	0.92	0.03	FLOR
18842	1999 RB22	11/02-11/02	49	4.4,4.4	48	6	9.6	0.2	0.49	0.03	MB-O
28650	2000 GE8	10/05-10/19	380	11.3,5.3	115	-5	9.625	0.004	0.16	0.02	EOS
31320	1998 HX2	10/03-11/02	549	5.6,3.1,17.5	16	3	2.8149	0.0001	0.16	0.01	H
							47.06	0.05	0.13	0.02	H
65715	1992 WV1	12/05-12/05	50	16.3,16.3	98	3	8.75	0.5	0.36	0.03	MB-I
135690	2002 OO18	10/08-10/09	111	4.4,3.9	23	0	7.61	0.05	0.56	0.05	MB-I
298808	2004 RV33	10/08-10/11	138	5.4,3.5	22	0	3.64	0.01	0.17	0.03	FLOR

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009): H, Hungaria; MB-I/O, main belt inner/outer; MC, Mars-crosser; FLOR, Flora; V, Vestoid.

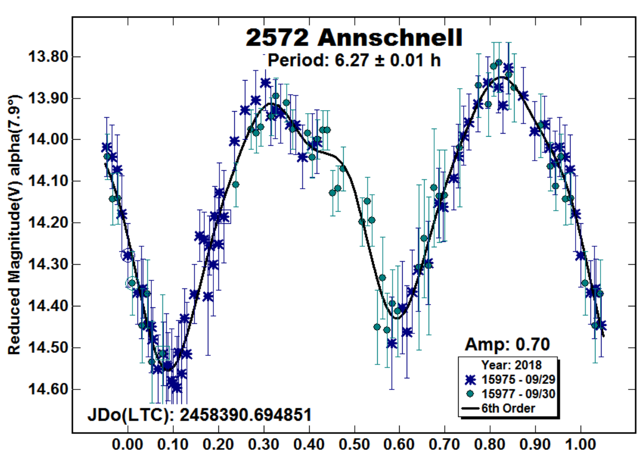
1756 Giacobini. Warner (2007) found a rotational period of 3.8527 h for this inner main-belt asteroid. The rotational period found this year is in good agreement with that result.



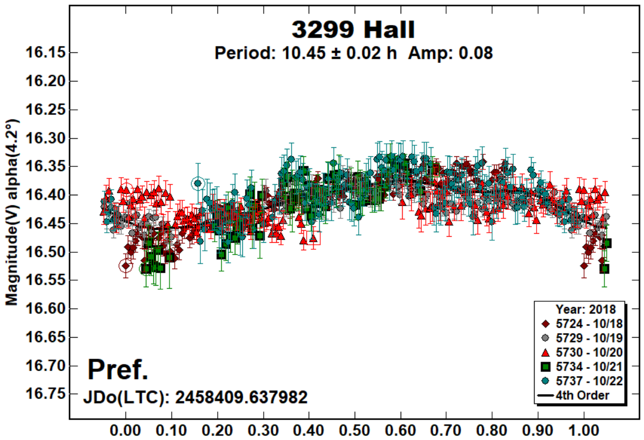
3225 Hoag. Warner (2015) observed this member of the Hungaria family five times in the past, each time reporting periods near 2.37 h. This year's finding is in good agreement with those results.

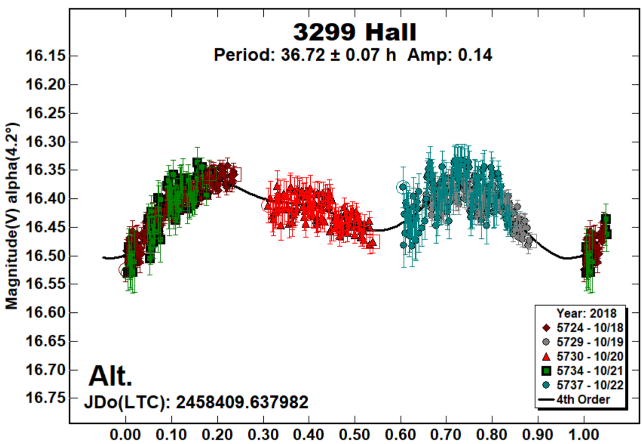


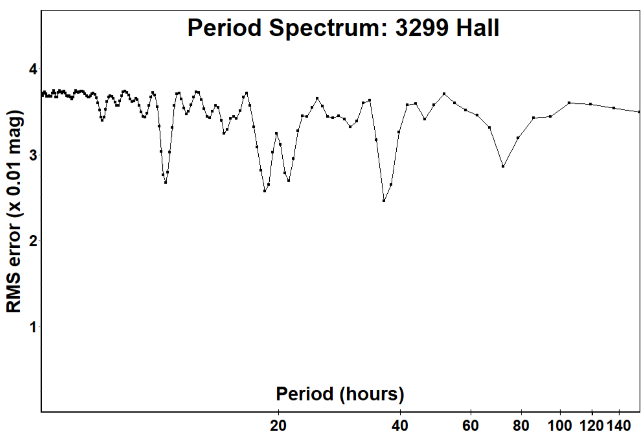
2572 Annschnell. Behrend (2006) and Stephens (2017) reported rotational periods for this member of the Vestoid family in the past of about 6.33 h. The period found this year, based upon two consecutive nights of data, was slightly shorter but consistent with those prior results.



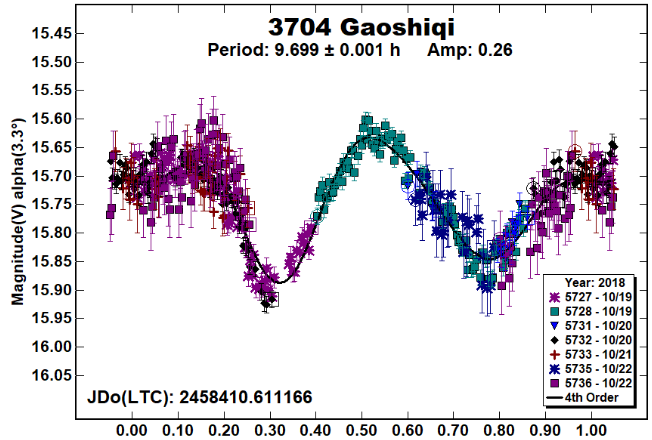
3299 Hall. Anzar (private communication) got two nonconsecutive nights on this member of the Flora family in 2016, reporting a period of 7.2 h on his website. The resulting plot did not cover a complete rotational cycle. It was immediately apparent from the single night slopes that a shorter period of about 7 h would not fit the 2018 data. The best fit on the period spectrum was about 37 h, (Alt. Plot) which resulted in a small amplitude lightcurve. Harris et al. (2014) shows that with a small amplitude, the lightcurve can be monomodal or have three or more extrema. Because of the Azar partial lightcurve with a high amplitude and 7 h period, we are adopting the 10.45 h period (Pref. Plot) as our preferred result, but note that the correct period could be 37 h. The next time this asteroid is observable from the Northern Hemisphere is in August 2021.



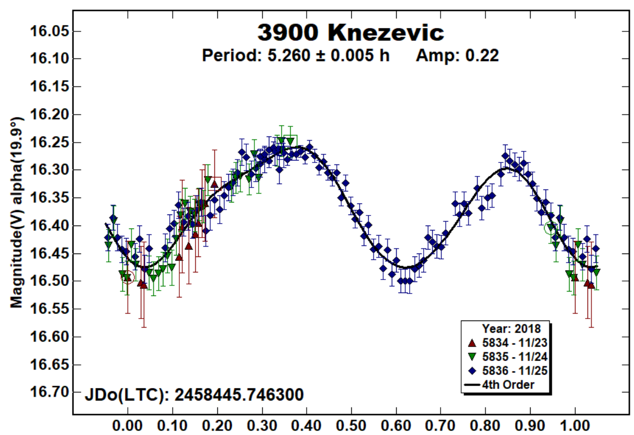




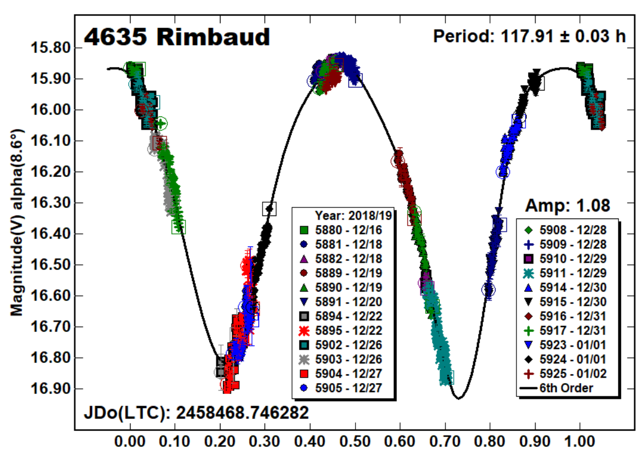
3704 Gaoshiqi. Oey et al. (2014) reported a period of 9.7725 h for this member of the Vestoid family resulting in a lightcurve with a large scatter of observations. Our finding this year is in fair agreement with that result.



3900 Knezevic. This Vestoid family member was observed by Hasegawa et al. (2014) who reported a period of 5.324 ± 0.001 h. That result differs from the period found this year by 0.06 h. Reviewing their plot, their data is somewhat sparse over four nights. About 40% of their lightcurve is covered by just a few datapoints.



4635 Rimbaud. No entry was found in the lightcurve database (LCDB; Warner et al., 2009) for this Vestoid. Tumbling cannot be ruled out but there is no obvious signs of it in the data.



<u>4910 Kawasato</u>. Stephens (2015), Foylan and Salvaggio (2015), and Clark (2015) all reported rotational periods near 4.66 h for this Mars-crosser. This year's result is in good agreement. Because of our prior observations and availability of sparse data from surveys such as from the Catalina Sky Survey in Arizona (*https://catalina.lpl.arizona.edu/*), we attempted a pole/shape model.

The modeling processing using lightcurve inversion has been detailed previously (e.g., Warner et al., 2017, and references therein). Briefly, the idea is to find a shape and its orientation such that its modeled lightcurves closely match the original data. Main-belt asteroids usually require data from at least three oppositions at different phase angle bisector longitudes before a reliable model can be developed. We attempted the shape model because we had a wide range of phase angles for this Mars-crosser.

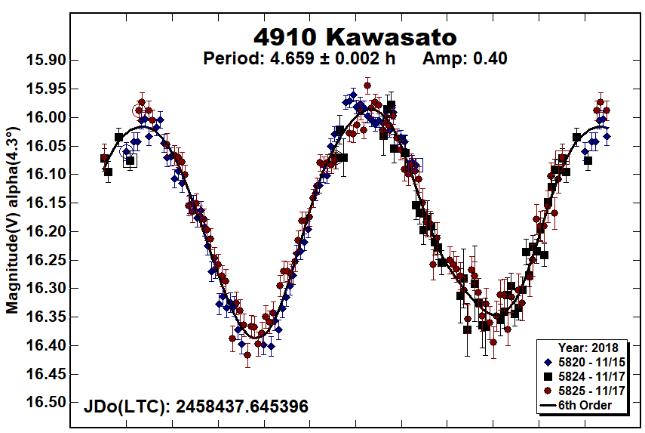
In the PAB longitude plot, green circles represent dense lightcurves while red squares represent sparse data from one or more of the surveys.

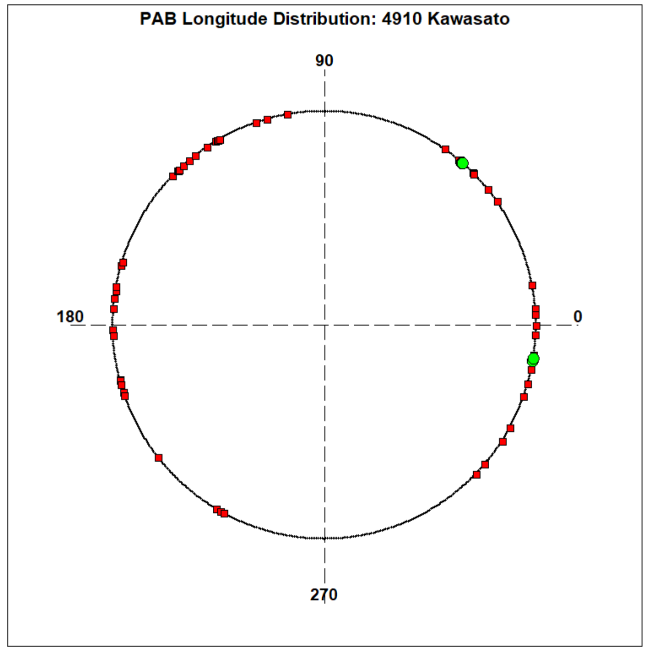
The green line in the period plot lies 10% above the lowest χ^2 value. An ideal solution has a well-defined shape with only one data point below the line. In this case, there are about 10 data points below the line, a good result.

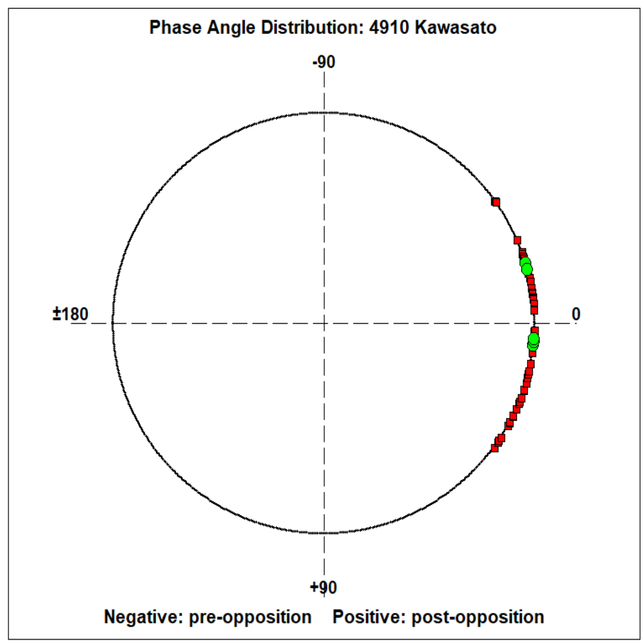
In the pole plot, dark red represents a solution that is more than 10% above the lowest χ^2 value. A "perfect" solution is when there is only one dark blue region and all the others are dark red. This result shows a typical result with competing solutions 180° apart, one a prograde rotation and the other a retrograde rotation. A pole solution often has difficulty distinguishing between the two.

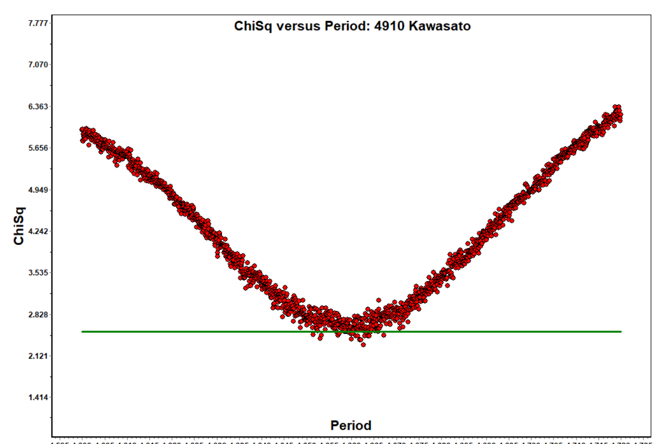
The solid black line in the lightcurve plots is the model lightcurve and the red dots are the original data. The model curves in are from the solution for ecliptic coordinates (355°, 35°, 4.66271 h) although the fits to the model based on (165°, 31°, 4.66271 h) are essentially identical.

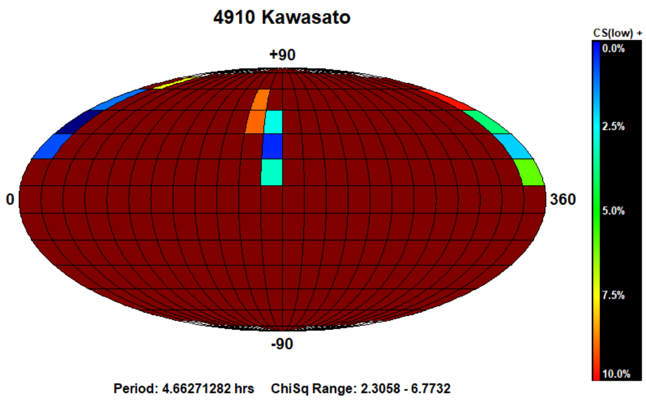
In the end, we chose (355°, 35°, 4.66271 h) because it had the lowest χ^2 value. In both cases, the estimated error for the pole is a circle of about 10° radius and 0.00001 h for the period.

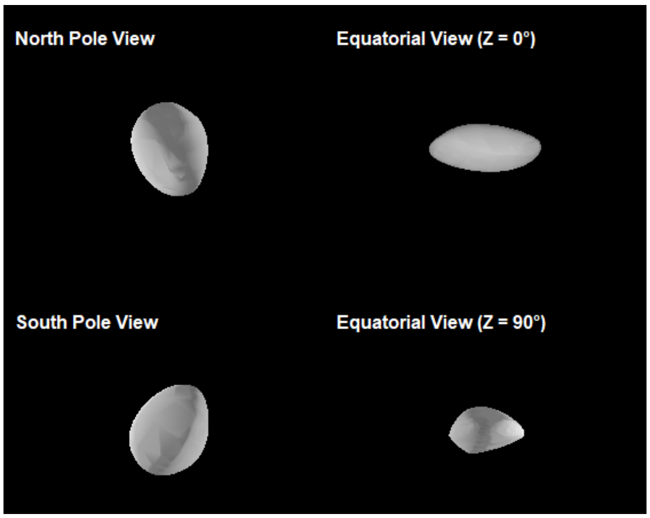


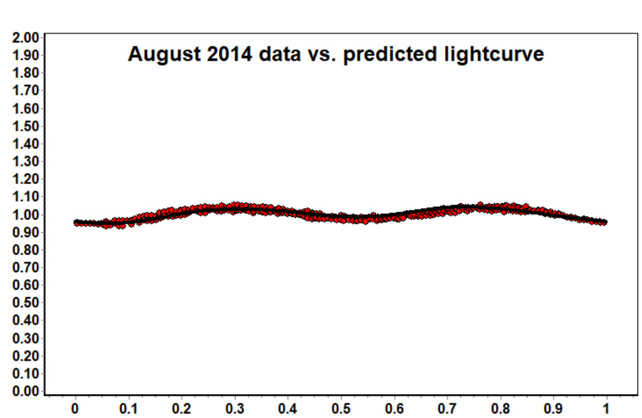


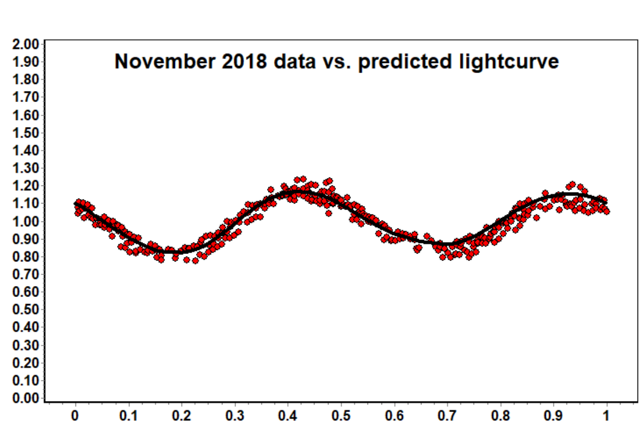




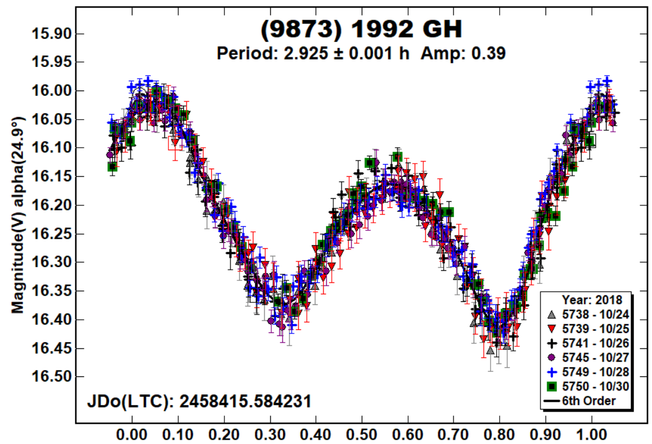




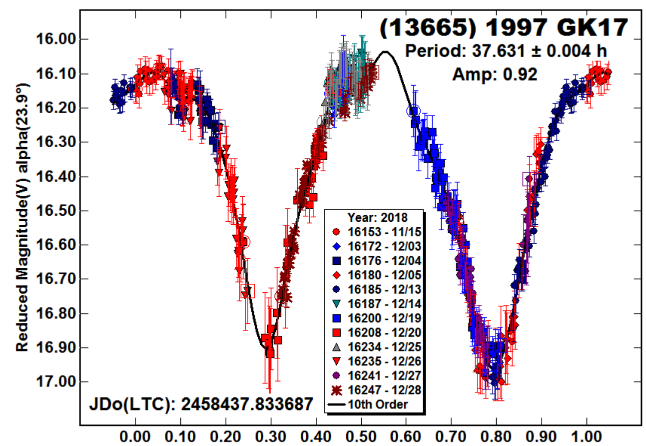




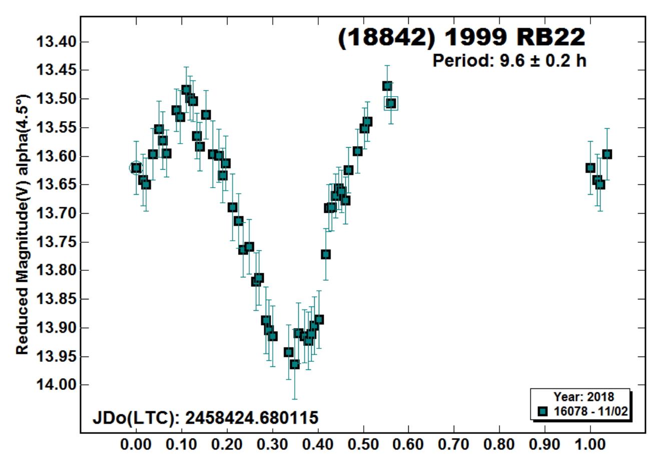
(9873) 1992 GH. Warner (2014a) observed this Hungaria four times in the past, each time finding a rotational period near 2.93 h. This year's result is in good agreement.



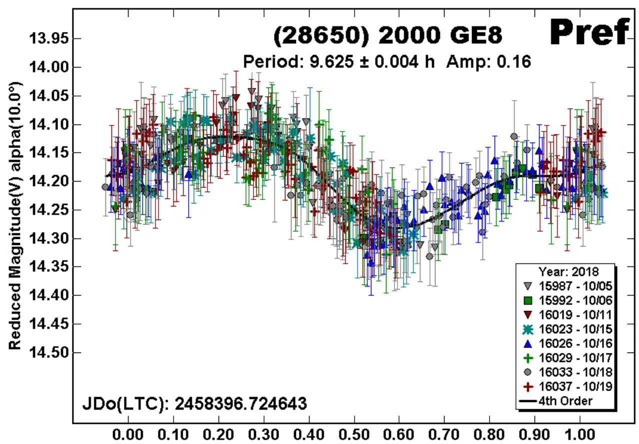
(13665) 1997 GK17. No entry was found in the LCDB for this member of the Flora family.

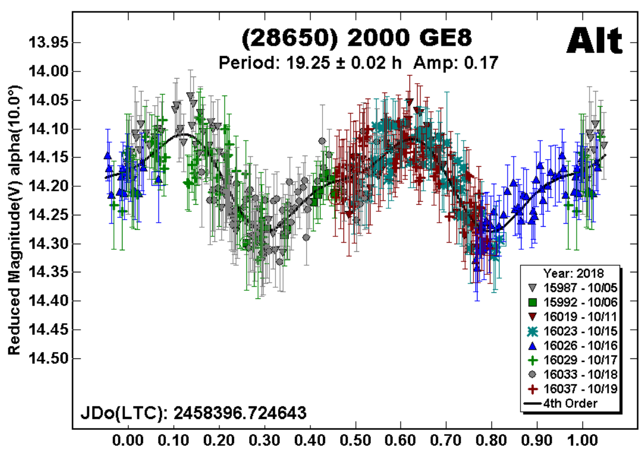


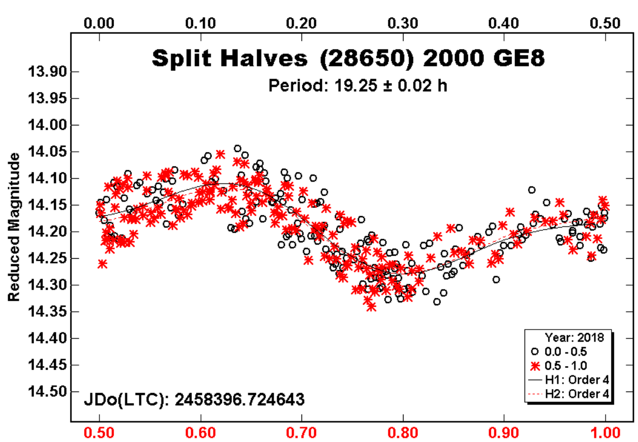
(18842) 1999 RB22. No entry was found in the LCDB for this outer main-belt asteroid. Only a single night of coverage could be obtained. The 9.6 h period was estimated based on the half-period solution. A bimodal solution is assumed because of the ~0.45 mag amplitude and low phase angle (Harris et al., 2014).

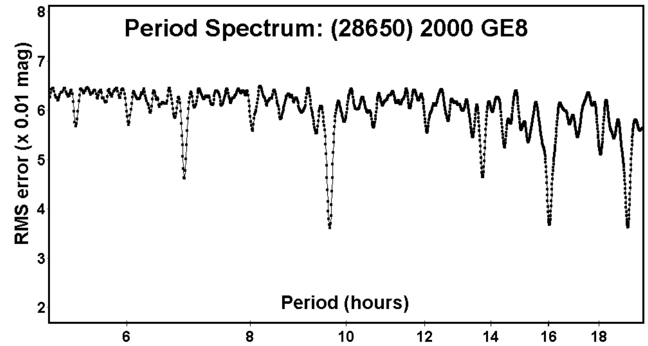


(28650) 2000 GE8. Waszczak et al. (2015) found a period of 9.591 h, rated U = 3. Our observations, when phased to 9.6 h resulted in a single modal lightcurve. Phasing the observations to 19 h created a classic bimodal lightcurve. One reason for rejecting the double period is the split halves plot which shows the bimodal lightcurve to be completely symmetrical. Also, both the Waszczak result and our data have low amplitudes. Harris et al. (2014) show that with a small amplitude, the lightcurve can be monomodal or have three or more extrema. The next favorable opposition to observe this asteroid is in 2021 March.

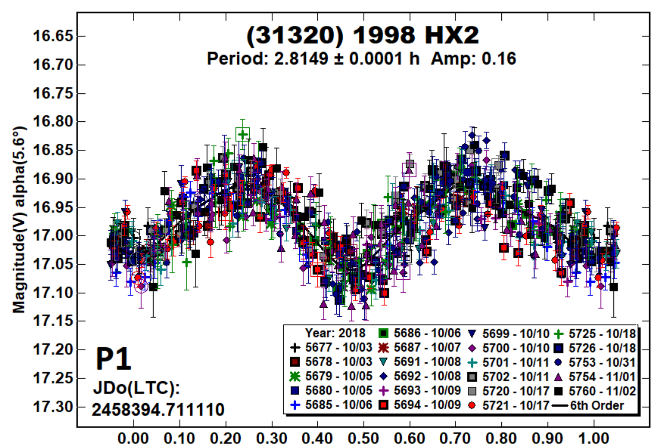


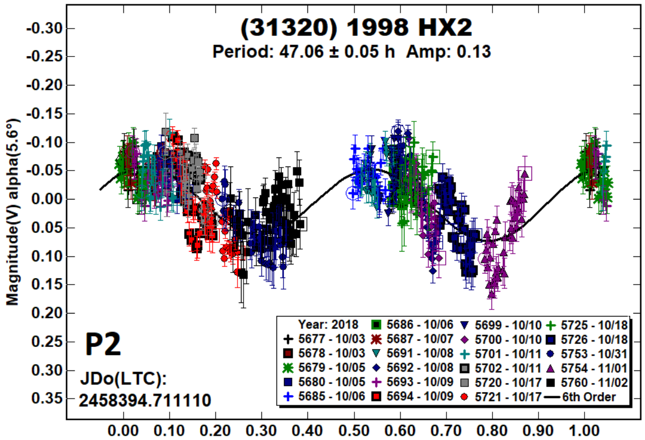


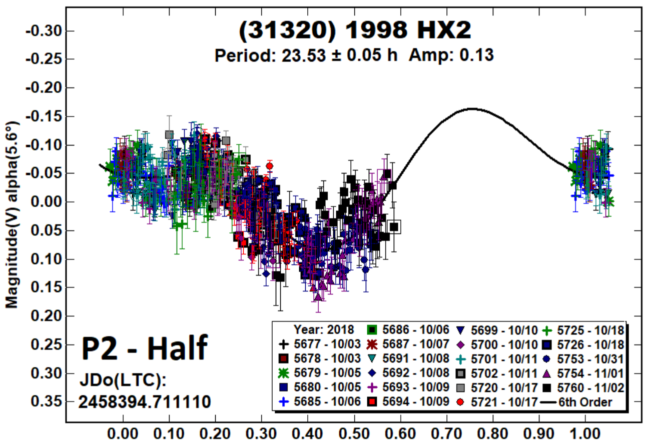


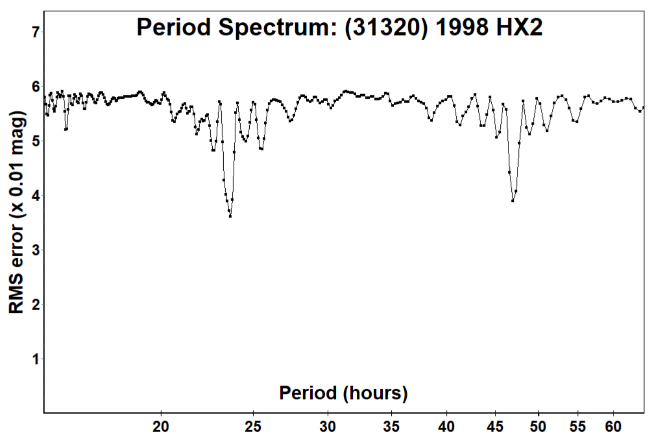


(31320) 1998 HX2. There are no entries in the LCDB for this member of the Hungaria family. The initial observations showed what appeared to be a second frequency indicating a binary asteroid. The dual period analysis found a primary lightcurve of P_1 = 2.8149 ± 0.0001 h, A_1 = 0.16 ± 0.01 mag ("P1" plot). As suspected, subtracting this lightcurve from the data set and doing a period search found a solution that showed what appears to be an *orbital period* due to a satellite ("P2" plot). Two aliases can be seen in the period spectrum. The most likely period of P_2 = 47.06 ± 0.05 h, A_2 = 0.13 mag shows a classic bimodal lightcurve. A half period ("P2 - Half" plot) is also presented showing a monomodal lightcurve plot. Since the asteroid was past opposition when observations commenced, and because P_2 is so close to twice that of an Earth day, the secondary lightcurve could not be completed and it remains a suspected binary. The next opportunity for follow up is in 2022 January when it will only be observable from the Southern Hemisphere. The next opportunity for Northern Hemisphere observers will be in 2023 July when it will just be brighter than V = 18.

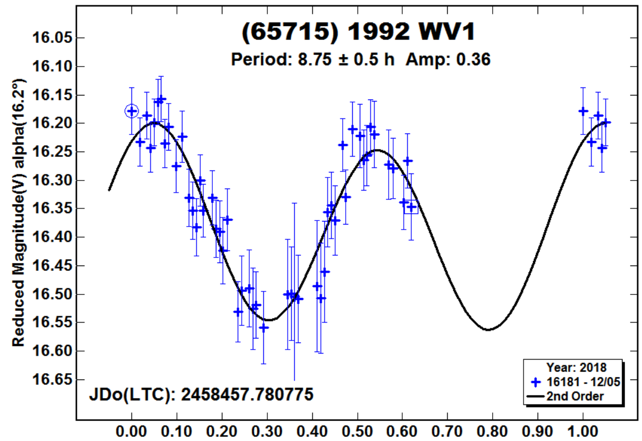




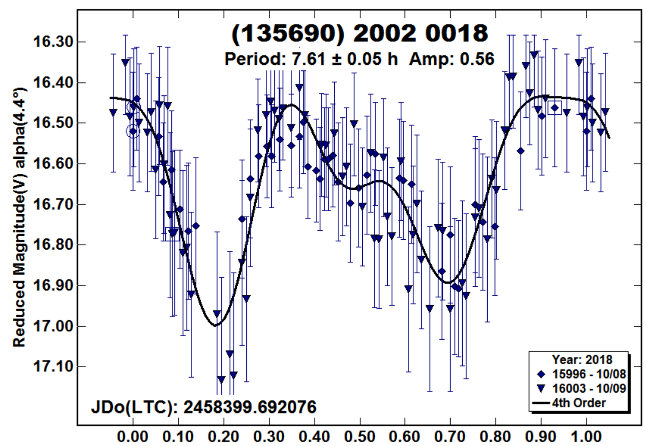




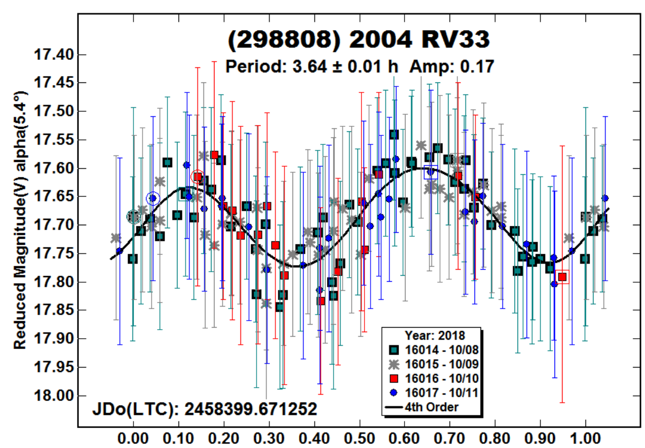
(65715) 1992 WV1. Chang et al. (2016) found a period of 5.89 h, but it was rated U = 1+ in the LCDB. A complete lightcurve was not obtained in the single night it was observed, but a search for the half-period helped find the bimodal solution which, given the amplitude, is probable.



(135690) 2002 OO18. No entry was found in the LCDB for this inner main-belt asteroid. Despite the noise in the observations, the solution is solid since both nights covered the entire curve at the adopted period.



(298808) 2004 RV33. No entry was found in the LCDB for this member of the Flora family. Despite the error bars being larger than the amplitude, the solution is still reasonable, but it needs confirmation at a later date. The next time this asteroid is V < 19.0 is 2025 Nov 2. Most of the time it's V > 20 at brightest in other apparitions.



Acknowledgements

Observations at CS3 and continued support of the asteroid lightcurve database (LCDB; Warner et al., 2009) are supported by NASA grant 80NSSC18K0851. The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. It was also based on data from the CMC15 Data Access Service at CAB (INTA-CSIC) (http://svo2.cab.inta-csic.es/vocats/cmc15/).

References

Behrend, R. (2006). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html*

Chang, C., Lin, H., Ip, W., Prince, T., Kulkarni, S., Levitan, D., Laher, R., Surace, J. (2016). "Large Super-fast Rotator Hunting Using the Intermediate Palomar Transient Factory." *Ap. J.* **227**, A20.

Clark, M. (2015). "Asteroid Photometry from the Preston Gott Observatory." *Minor Planet Bull.* **42**, 15-20.

Foylan, M., Salvaggio, F. (2015). "Lightcurve and Rotation Period Determination for Minor Planet 4910 Kawasato." *Minor Planet Bull.* **42**, 35-36.

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

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

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

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.I. (2009). *http//www.aavso.org/apass*

Hasegawa, S., Miyasaka, S., Mito, H., Sarugaku, Y., Ozawa, T., Kuroda, D., Nishihara, S., Harada, A., Yoshida, M., Yanagisawa, K., Shimizu, Y., Nagayama, S., Toda, H., Okita, K., Kawai, N., Mori, M., Sekiguchi, T., Ishiguro, M., Abe, T., Abe, M. (2014). "Lightcurve survey of V-type asteroids in the inner asteroid belt." *Pub. of Astron. Soc. Japan* **66**, 5415.

Oey, J., Inasaridze, R., Kvaratskhelia, O., Ayvazian, V., Chirony, V., Krugly, Y., Molotov, I., Warner, B., Pravec, P., Kusnirák, P., Higgins, D., Pollock, J., Haislip, J., Ivarsen, K., Reichart, D., Lacluyze, A., Galád, A. (2014). "Lightcurve Analysis in Search of Binary Asteroids." *Minor Planet Bull.* **40**, 169-172.

Stephens, R.D. (2015). "Asteroids Observed from CS3: 2014 July - September." *Minor Planet Bull.* **42**, 70-74.

Stephens, R.D. (2016). "Asteroids Observed from CS3: 2015 July - September." *Minor Planet Bull.* **43**, 52-56.

Stephens, R.D. (2017). "Asteroids Observed from CS3: 2017 April - June." *Minor Planet Bull.* **44**, 321-323.

Warner, B.D. (2004). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory - September-December 2006." *Minor Planet Bull.* **34**, 32-37.

Warner, B.D. (2007). "Lightcurve analysis for numbered asteroids 1351, 1589, 2778, 5076, 5892, and 6386." *Minor Planet Bull.* **31**, 36-39.

Warner, B.D. (2014a). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2013 September-December." *Minor Planet Bull*. **41**, 102-112.

Warner, B.D. (2014b). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 January-March." *Minor Planet Bull*. **41**, 144-155.

Warner, B.D. (2015). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 March-June." *Minor Planet Bull*. **42**, 267-276.

Warner, B.D., Higgins, D., Pray, D., Dyvig, R., Reddy, V., Durech, J. (2008). "A Shape and Spin Model for 1600 Vyssotsky." *Minor Planet Bull*. **35**, 13-14.

Warner, B.D., Pravec, P., Kusnirak, P., Benishek, V., Ferrero, A. (2017). "Preliminary Pole and Shape Models for Three Near-Earth Asteroids." *Minor Planet Bull*. **44**, 206-212.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 Nov. *http://www.minorplanet.info/lightcurvedatabase.html*

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

CALL FOR OBSERVATIONS

Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, NM 88011 USA
fpilcher35@gmail.com

Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar year 2018 are encouraged to report them to this author on or before 2019 April 1. This will be the deadline for receipt of reports, for which results can be included in the "General Report of Position Observations for 2018," to be published in *MPB* Vol. 46, No. 3.

2018RC: A FAST ROTATING TUMBLING ASTEROID

Lorenzo Franco
Balzaretto Observatory (A81), Rome, ITALY
lor_franco@libero.it

Alessandro Marchini
Astronomical Observatory, DSFTA - University of Siena (K54)
Via Roma 56, 53100 - Siena, ITALY

Roberto Bacci
G. Pascoli Observatory (K63), Castelvecchio Pascoli, ITALY

Albino Carbognani
Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA)
Lignan 39, 11020 Nus (Aosta), ITALY

(Received: 2019 Jan 8 Revised: 2019 Feb 24)

Photometric observations of near-Earth asteroid 2018 RC were made in September 2018, few days after its discovery. Lightcurve analysis shows a tumbling nature with a principal rotational period of 0.16548 ± 0.00001 h with an amplitude 0.57 mag and a secondary rotational period 0.26201 ± 0.00001 h with an amplitude 0.20 mag. Multi-band photometric sessions shows color indexes V-R = 0.48 ± 0.07 mag and R-I = 0.40 ± 0.04 mag.

2018 RC is an Aten near-Earth asteroid firstly detected on September 3, 2018, by ATLAS-MLO Survey. Photometric observations of this asteroid were made a few days later (7 and 8 September) at G. Pascoli Observatory (K63) and at the University of Siena Astronomical Observatory (K54) using the instrumentation described in the Table I. Lightcurve analysis was done at the Balzaretto Observatory and at the OAVdA with *MPO Canopus* (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. Corrections for the Rc and the Ic photometric bands were calculated using the transformations by Munari (Munari, 2012). Table II shows the observing circumstances and results.

Observatory (MPC code)	Telescope	CCD	Filter
Univ. Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e(2x2)	V,Rc,Ic
G.Pascoli (K63)	0.40-m NRT f/3.2	QHY22	C

Table I. Observing Instrumentations. MCT: Maksutov-Cassegrain, NRT: Newtonian Reflector.

The lightcurve analysis shows a fast rotational period of P = 0.16548 ± 0.00001 h (Figure 1) with an amplitude A = 0.57 mag and some phase and amplitude variations. This behavior could indicate a tumbling nature of the asteroid. In order to investigate this hypothesis, the first period has been subtracted using the "dual period search" implemented in MPO Canopus. A secondary period was found of P2 = 0.26201 ± 0.00001 h (Figure 3 bottom panel) with an amplitude of A = 0.20 mag. It should be noted that for the tumbling asteroids would be more suitable an analysis software that can analyze multiple periods without a simple additive logic. For this purpose, we are deploying a specific software with Matlab/Scilab.

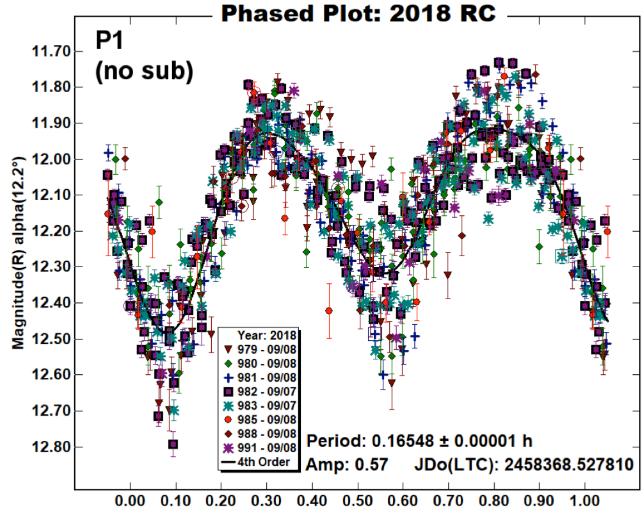


Fig. 1: The lightcurve phased on the principal rotational period.

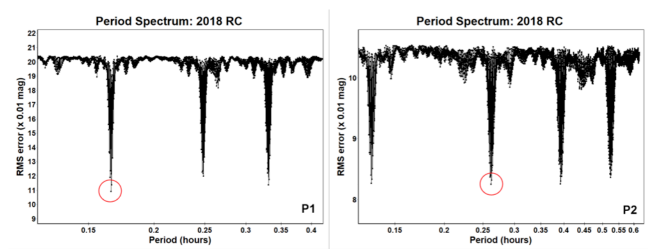


Fig. 2: The period spectrum around the two obtained periods: 0.16548 h (left) and 0.26201 h (right). These are the only periods that produce bimodal solutions for principal and secondary period.

Petr Pravec (personal communication) confirmed the tumbling nature of this asteroid and the first rotational period. However, the second period remains rather uncertain and other solutions are also possible, so we assign PAR = -2 (tending to -3), using the tumbler rating system from Pravec et al. (2005).

Multi-band photometric sessions, acquired at University of Siena (DSFTA, 2018) on 2018 Sept 8, allow us to determine the color indexes V-R = 0.48 ± 0.07 mag and R-I = 0.40 ± 0.04 mag. These color indexes are consistent with a medium albedo S-type taxonomic class (Shevchenko and Lupishko, 1998).

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
	2018 RC	09/07-09/08	812	29.1,14.5	355	-5	0.16548	0.00001	0.57	0.10

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).

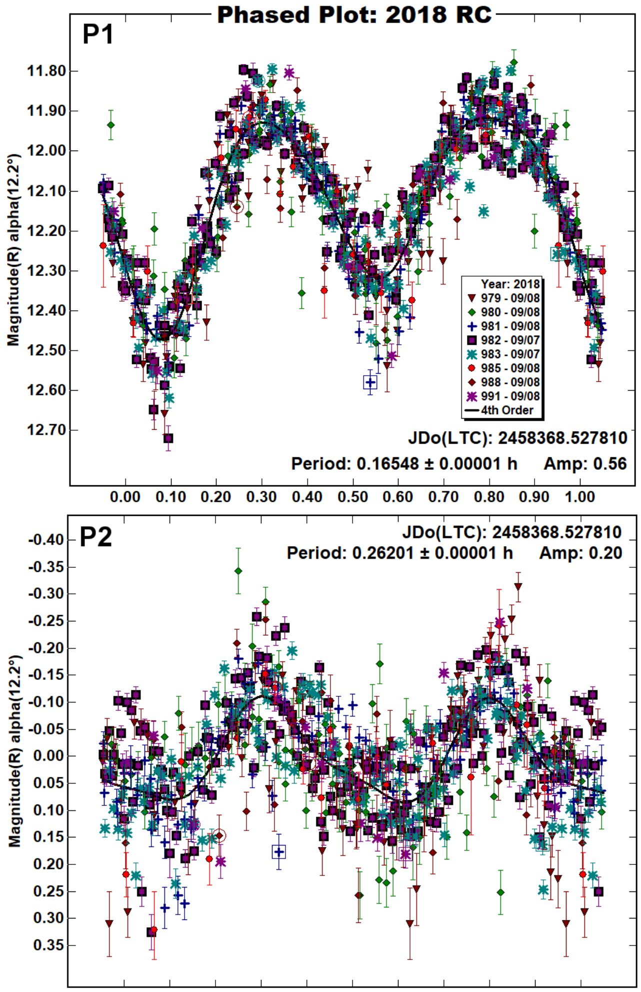


Fig. 3: [Top panel] the lightcurve phased on the first period, after the subtraction of the second period. [Bottom panel] the lightcurve phased on the second period, after the subtraction of the first period.

Acknowledgment

The authors thank Petr Pravec for analyzing our data, confirming the evidence of tumbling.

References

BDW Publishing (2016). *http://www.minorplanetobserver.com/MPOSoftware/MPOCanopus.htm*

DSFTA (2018), Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente – Astronomical Observatory. *https://www.dsfta.unisi.it/en/research/labs-eng/astronomicalobservatory*

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

Munari, U., (2012). "Classical and Recurrent Novae." JAAVSO **40**, 582-597.

Pravec, P., Harris, A.W., Scheirich, P., Kusnirak, P., Sarounova, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G. Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galad, A., Brown, P., Degraff, D. R., Lambert, J. V., Cooney, W.R., Foglia, S. (2005). "Tumbling Asteroids." *Icarus* **173**, 108-131.

Shevchenko V.G., Lupishko D.F. (1998). "Optical properties of Asteroids from Photometric Data." *Solar System Research*, **32**, 220-232.

LIGHTCURVE ANALYSIS FOR 2018 UQ1 AND 2018 UR2

Andy J. López-Oquendo and Desireé Cotto-Figueroa
Department of Physics and Electronics, University of Puerto Rico,
Humacao, Puerto Rico 00792
andy.lopez2@upr.edu

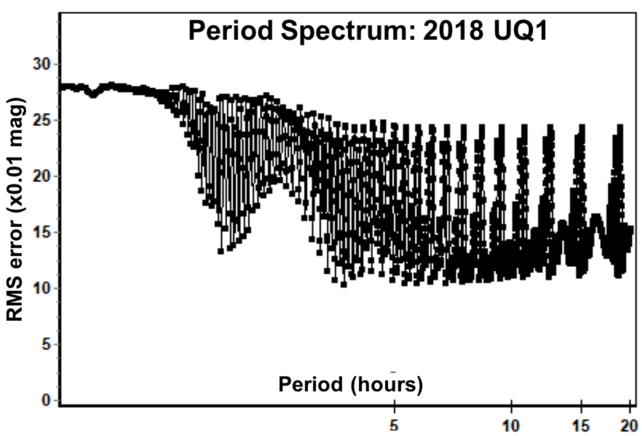
(Received: 2019 Jan 10)

CCD photometric observations of two Near-Earth asteroids (NEAs) were made from 2018 November 6 to 9. Fourier analysis of the data for 2018 UQ1 and 2018 UR2 yielded rotations periods of 3.73 ± 0.01 h and 6.88 ± 0.01 h, respectively.

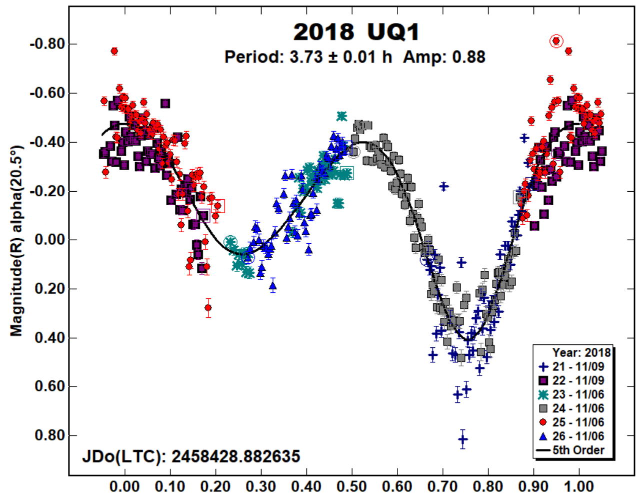
We conducted observations of the near-Earth asteroids (NEA) 2018 UQ1 and 2018 UR2 in 2018 November using the 0.79-m National Undergraduate Research Observatory (NURO) telescope at the Lowell Observatory in Flagstaff, AZ, and the NASAcam CCD camera (2K x 2K pixels) that was thermoelectrically cooled. The asteroids were observed using an R-band filter with an exposure time of 30 seconds. The data reduction and analysis were conducted using the *Image Reduction and Analysis Facility* (*IRAF*) and *MPO Canopus* programs.

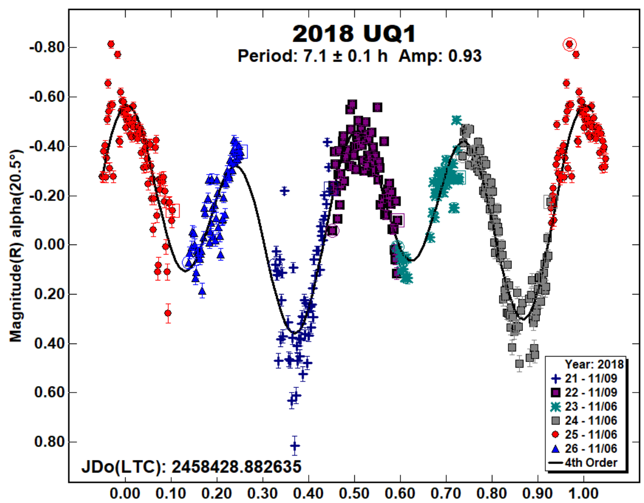
2018 UQ1 is an Apollo-type potentially hazard asteroid (PHA) that was discovered by Catalina Sky Survey on 2018 October 20 (ESA, 2018). The absolute magnitude of 21.8 suggests a diameter of ~180 m. This asteroid made a close to Earth on 2018 November 13, reaching a minimum distance within 0.024 AU. (JPL, 2018)

Photometric observations were made on 2018 November 6 and 9. A total of 6.57 hours of observation produced 415 data points for analysis. No previously reported period was found in a search of the asteroid lightcurve database (LCDB; Warner et al., 2009).



The period spectrum using our data shows two possible solutions: a bimodal lightcurve with a period of 3.73 ± 0.01 h and amplitude of 0.88 mag or a multiple extrema lightcurve with a period of 7.1 ± 0.1 h and amplitude of 0.93 mag. The period of 3.73 ± 0.01 h is favored due to the high amplitude, which suggests a unique period dominated by the second harmonic (Harris et al., 2014). If the period of 7.1 ± 0.1 h is the correct solution, it may suggest the asteroid is "tumbling" (non-principal axis rotation).

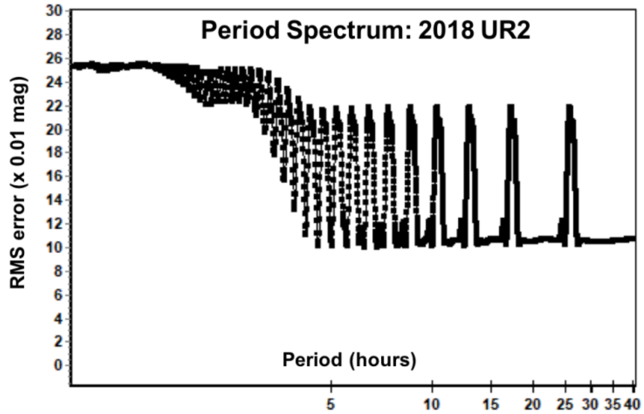


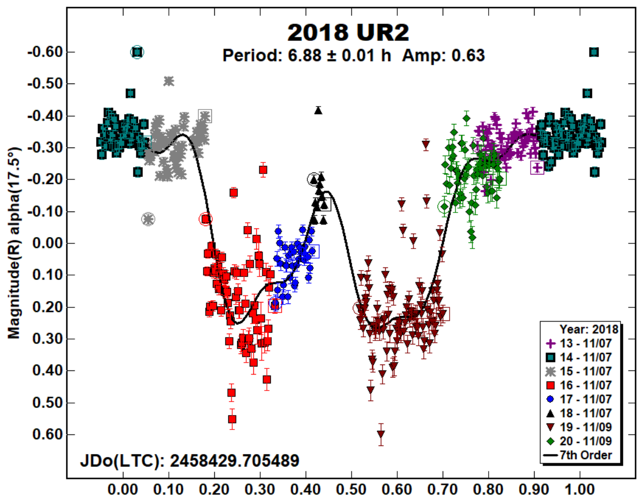


2018 UR2 is an Amor-type NEA discovered by ATLAS-HKO, Haleakala on 2018 October 26. The absolute magnitude of 20.1 suggests a diameter ~400 m (ESA, 2018). This asteroid made it closest approach (~0.085 AU) on 2018 November 4 (JPL, 2018). We observed the asteroid on 2018 November 7 and 9 for a total of 6.68 hours and 455 data points for analysis. We found a period of 6.88 ± 0.01 h and amplitude of 0.63 mag. The LCDB had no previously reported rotation periods.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2018 UQ1	11/06-11/09	415	20.5,30.7	55.7	9.0	3.76	0.01	0.88	0.06	PHA
	2018 UR2	11/07-11/09	455	17.5,28.6	44.9	13.4	6.88	0.01	0.63	0.06	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).





Acknowledgements

This research was made possible through funding by NASA Puerto Rico Space Grant Consortium grant NNX15AI11H. The authors wish to thank Brian Warner and Brian Skiff for their support with the *MPO Canopus* software.

References

European Space Agency (ESA) (2018). *http://neo.ssa.esa.int*

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

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

JPL (2018). Small Body Database Browser. *https://ssd.jpl.nasa.gov/sbdb.cgi*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

CCD PHOTOMETRIC OBSERVATIONS OF ASTEROIDS 2678 AAVASAKSA, 3769 ARTHURMILLER, 4807 NOBORU, (7520) 1990 BV, AND (14510) 1996 ES2

Kenneth Zeigler, Tyler Barnhart, Armand Moser, Tatiana Rockafellow
George West High School
1013 Houston Street, George West, Texas 78022 USA
kzeigler@gwisd.US

(Received: 2019 Jan 16)

CCD photometric observations of asteroids 2678 Aavasaksa, 3769 Arthurmiller, 4807 Noboru, (7520) 1990 BV, and (14510) 1996 ES2, were conducted from the George West ISD Mobile Observatory. The rotational period of 2678 Aavasaksa is 124 ± 2 hours, with an amplitude of 1.3 magnitudes. The rotational period of 3769 Arthurmiller is 8.28 ± 0.01 hours, with an amplitude of 0.82 magnitudes. The rotational period of 4807 Noboru is 4.04 ± 0.02 hours with an amplitude of 0.23 magnitudes. The rotational period of (7520) 1990 BV is 3.83 ± 0.01 hours with an amplitude of 0.28 magnitudes. The rotational period of (14510) 1996 ES2 is 6.24 ± 0.01 hours, with an amplitude of 0.35 magnitudes.

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 and winter break of the 2018-2019 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, which in turn sets upon concrete blocks supported by a thick concrete slab to minimize vibrations. An SBIG STXL 6303 camera thermoelectrically cooled to -35°C was used to make the photometric observations. The photometric exposures were all 120 seconds in length 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 three comparison stars in the same CCD frame. The average instrumental magnitude of the three stars was determined and this average was subtracted from the instrumental magnitude of the asteroid. A constant was then added to approximate the visual magnitude. The instrumental magnitude of the three comparison stars with respect to one another was continuously monitored in the event that one of them was determined to be a short period variable star. The target brightness was determined by measuring a 169 pixel (13 pixel by 13 pixel) sample surrounding the asteroid or star in question. This corresponds to an 8.45 by 8.45 arcsec box. When possible, the same comparison stars were used during consecutive nights of observation. The coordinates of the asteroid were obtained from the online Minor Planet.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 in vertically aligning the photometric data points from different nights in the construction of a composite lightcurve:

$$\Delta m = -2.5 \log_{10}((e2^2/e1^2)(r2^2/r1^2))$$

where Δm is the magnitude correction between night 1 and 2, e1 and e2 are the earth-asteroid distances on nights 1 and 2, r1 and r2 are the sun-asteroid distances on nights 1 and 2

2678 Aavasaksa was discovered on 24 February 1938, by Finnish astronomer Yrjö Väisälä at Turku Observatory in Southwest Finland. It was named for the Aavasaksa hill in Finland. This S-type asteroid is a member of the Flora family and orbits the Sun in the inner main-belt at a distance of 2.1–2.5 AU once every 1,240 days. This asteroid was observed at the George West ISD Mobile Observatory on five separate nights between December 10 and December 18, 2018. A composite lightcurve with a period of 124 ± 2 hours best fit the available data. The lightcurve has an amplitude of 1.3 magnitudes, and displays two maxima and two minima per rotational cycle, as shown in Figure 1.

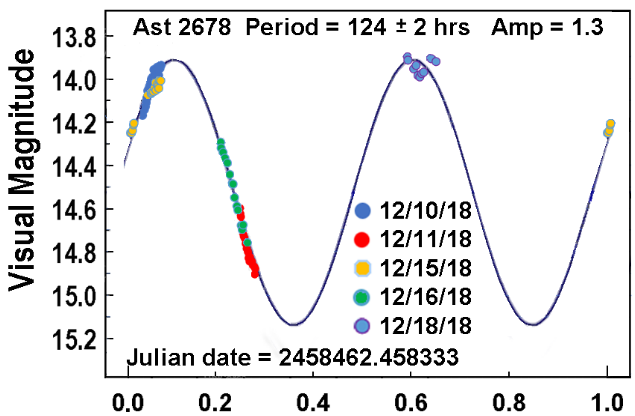


Figure 1.

This is an exceptionally slow rotating asteroid, and despite the fact that it was observed over the course of five nights, only about 30% of its rotational cycle was charted. Its high lightcurve amplitude implies that it is a very elongated object. Although both lightcurve maxima were observed, no actual lightcurve minima were measured during the course of the observations. The relative brightness of the minimum was deduced by fitting a sine curve to the data, as shown in Figure 2.

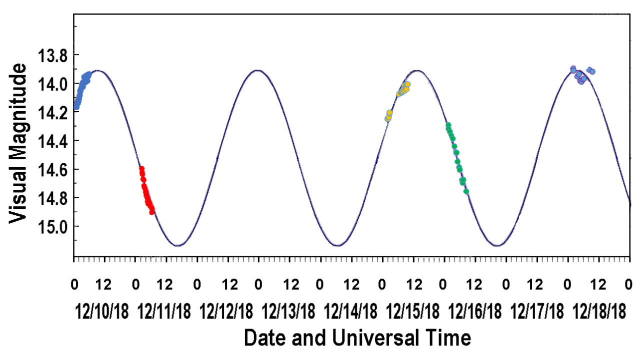


Figure 2.

In January 2009, a fragmentary lightcurve of Aavasaksa was obtained at the Via Capote Observatory in California. Lightcurve analysis gave it a longer than average rotation period of 24 hours or more with a brightness amplitude of 0.4. At the time of this writing, no subsequent photometric observations have been published.

3769 Arthurmiller was discovered on October 30, 1967 by Luboš Kohoutek. It is located in the inner part of the main asteroid belt, with its orbit varying between 2.01 and 2.52 astronomical units from the sun. This asteroid was observed from the George West ISD Mobile Observatory on the nights of November 30, December 1, and December 2, 2018. The asteroid has a rotational period of 8.24 ± 0.01 hours, with a lightcurve amplitude of 0.82 magnitudes. The lightcurve is characterized by two maxima and two minima per rotational cycle. The two maxima are virtually identical, both being of equal brightness, very broad, and symmetrical. The minima are also very similar to each other. However, unlike the maxima, they are very narrow. A graphical representation of these observations is shown in Figure 3. A review of the literature shows that there is currently no published rotational period for this asteroid.

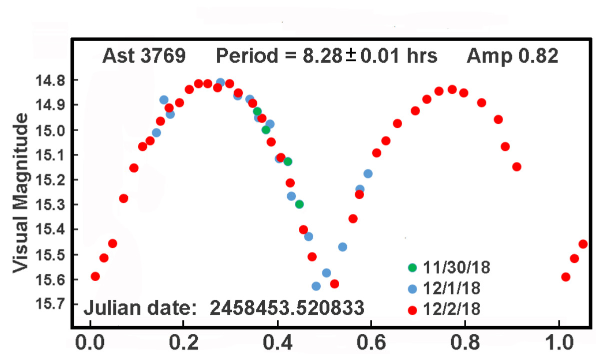


Figure 3.

4807 Noboru, 1991 AO, was discovered on January 10, 1991 by T. Kobayashi. It was named in memory of Noboru Yamada (1950-1989), one of the greatest Japanese mountain climbers. It is an inner main belt asteroid whose orbit ranges between 1.83 to 2.82 astronomical units from the sun. This asteroid was observed from the George West ISD Mobile Observatory on the nights of January 4 and 5, 2019. A rotational period of 4.04 ± 0.02 hours, with a lightcurve amplitude of 0.23 magnitudes best fits the observations. The lightcurve displays two maxima and minima per rotational cycle, as shown in Figure 4. At the time of this writing, there is no published rotational period for this asteroid.

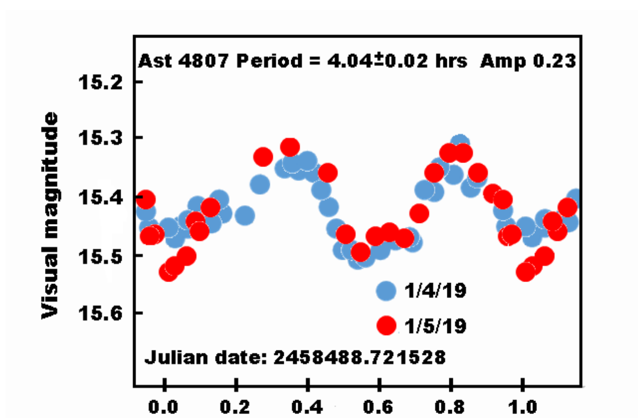


Figure 4

(7520) 1990 BV was discovered on January 21, 1990 by T Hioki and S. Hayakawa. It orbits the sun at a distance between 1.81 and 2.90 astronomical units, making it an inner main belt asteroid. This asteroid was observed on January 5 and 6, 2019. A rotational period of 3.83 ± 0.01 hours was determined. The asteroid displays two maxima and minima per rotational cycle, with an observed amplitude of 0.28 magnitudes. Although the maxima are broad and symmetrical, the minima are brief and narrow. The composite lightcurve for this asteroid is shown in Figure 5.

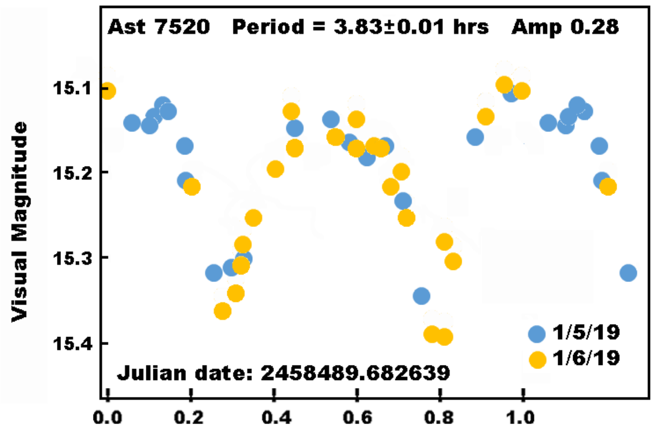


Figure 5

An examination of the most recent Asteroid Lightcurve Database reveals that this asteroid has no published lightcurve.

(14510) 1996 ES2 was discovered on March 15, 1996 by the NEAT Telescope. Asteroid 14510 was observed from the George West ISD Mobile Observatory on October 6 and 7, 2018. A rotational period of 6.24 ± 0.01 hours, with a lightcurve amplitude of 0.35 magnitudes best fits the observations. The lightcurve is characterized by two symmetrical maxima and minima per rotational cycle. According to the Asteroid Lightcurve Database, this asteroid was previously observed by Petr Pravec in 2018. In his as yet unpublished observations, he calculated a rotational period of 6.2443 hours, with a lightcurve amplitude of 0.37 magnitudes, very much in agreement with the observations of the authors. The asteroid was also observed by Pravec in 2018, who obtained similar results. Our lightcurve is displayed in Figure 6.

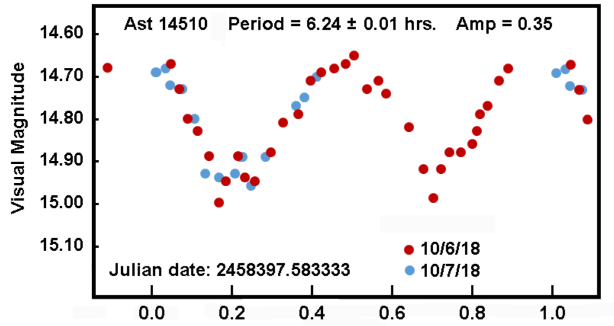


Figure 6

Acknowledgments

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

References

Brinsfield, J.W. (2009). "Asteroid Lightcurve Analysis at the Via Capote Observatory: 2009 1st Quarter." *The Minor Planet Bulletin* **36**(3): 127–128.

Warner, B., Harris, A., Durech, J., Benner, L. (2018). "Lightcurve Photometric Opportunities 2018 October–December." *The Minor Planet Bulletin* **45**, 404–408.

Warner, B., Harris, A., Durech, J., Benner, L. (2019). "Lightcurve Photometric Opportunities 2019 January–March." *The Minor Planet Bulletin* **46**, 100–105.

JPL (2018). Small Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Number	Name	20yy/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2678	Aavasaksa	18/12/10-12/18	166	3.5,8.1	72	2	124	2.0	1.30	0.15	FLOR
3769	Arthurmiller	18/11/30-12/02	58	3.3,4.6	62	1	8.21	0.01	0.81	0.02	FLOR
4807	Noboru	19/01/04-01/05	65	9.5,10.1	90	1	4.04	0.01	0.23	0.02	MB-I
7520	1990 BV	19/01/05-01/06	44	1.0,1.5	103	1	3.83	0.01	0.28	0.01	MB-I
14510	1996 ES2	18/10/06-10/07	47	3.7,3.5	14	5	6.24	0.01	0.35	0.02	BAP

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). FLOR: Flora; MB-I: Inner main belt; BAP: Baptistina.

ROTATIONAL PERIODS AND LIGHTCURVES OF 1475 YALTA AND 7230 LUTZ

Alfonso Noschese
AstroCampania Associazione
and
Osservatorio Elianto (K68)
via V. Emanuele III, 95, 84098
Pontecagnano (SA) ITALY
a.noschese@astrocampania.it

Antonio Vecchione
AstroCampania Associazione, Naples, ITALY

(Received: 2019 Jan 10)

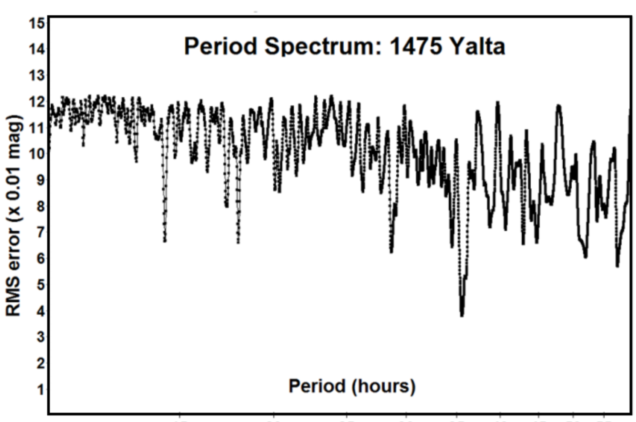
Photometric observations were made from 2018 October 12 to December 18 of the main-belt asteroids 1475 Yalta and 7230 Lutz at the Elianto Observatory located at Pontecagnano, Italy.

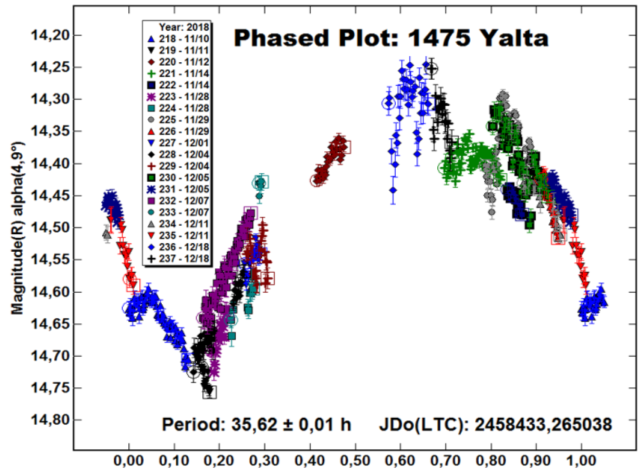
The aim of this research was to find the rotational periods of main-belt asteroids 1475 Yalta and 7230 Lutz. No previous rotation periods were given in the asteroid lightcurve database (LCDB; Warner et al., 2009). CCD photometric observations of the two asteroids were carried out at Elianto Observatory located in the south of Italy (Pontecagnano). We used a 0.3-m Newtonian telescope operating at *f*/4 equipped with a Moravian KAF1603 ME CCD camera (1536x1024x9μ pixels) and a clear filter.

All images were astrometrically aligned and processed with dark and flat-field frames using *Maxim DL* software. The images were measured with *MPO Canopus* (Warner, 2016) using differential photometry. The "comp star selector" feature was used to help with night-to-night zero point calibration by selecting up to five comparison stars with near-solar colors from the CMC15 catalog (Warner, 2007). 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, which employs the FALC Fourier analysis algorithm developed by Harris (Harris, 1989).

Table I gives the observing circumstances and results.

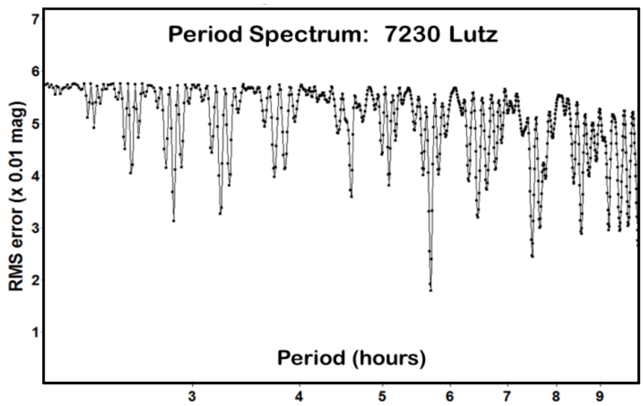
1475 Yalta. CCD photometric observations were performed between 2018 Nov 11 and Dec 18. Twenty observation sessions produced 606 data points for lightcurve analysis. The exposure times ranged from 240 s to 300 s.

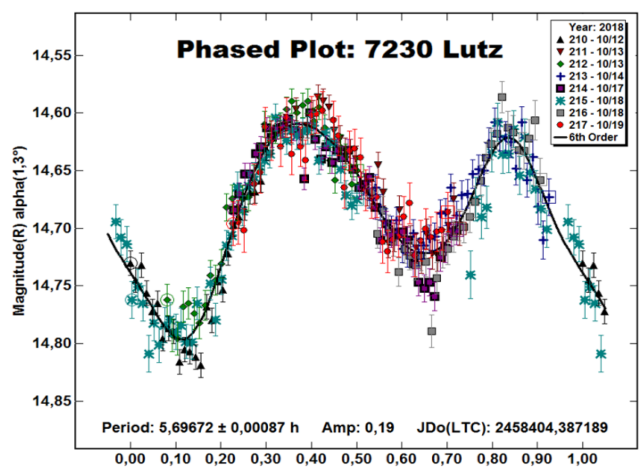




From the data shown, it is clear that the lightcurve is partially sampled. However, although full lightcurve coverage was not achieved, the solution that was favored by the period spectrum gave the best value for 35.62 ± 0.01 h and amplitude of 0.39 mag.

7230 Lutz. A total of 300 lightcurve data points were collected from 2018 October 12-19 in eight observing sessions. Exposure times were 240 s. The period spectrum strongly favored a period of 5.69672 ± 0.00087 h. The data produced a lightcurve with an asymmetrical shape and amplitude of 0.19 mag.





Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Exp
1475	Yalta	11/10-12/18	606	4.9,17.7	56	-4	36.62	0.01	0.39	0.01	240-300
7230	Lutz	10/12-10/19	300	1.3,5.8	18	0	5.69672	0.00087	0.19	0.01	240

Table I. 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, seconds.

References

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

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

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

Warner, B.D. (2016). MPO Software, *MPO Canopus* V10.7.7.0. Bdw Publishing. *http://bdwpublishing.com*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2019 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

LIGHTCURVE AND A SPIN-SHAPE MODEL FOR 16847 SANPOLOAMOSCIANO

Lorenzo Franco
Balzaretto Observatory (A81)
Rome, ITALY
lor_franco@libero.it

Nico Montigiani, Massimiliano Mannucci, Walter Benedetti
Margherita Hack Observatory (A57)
Florence, ITALY

(Received: 2019 Jan 13)

The minor planet 16847 Sanpoloamosciano at the 2018 opposition had a synodic rotation period 8.183 ± 0.001 h and amplitude 0.15 ± 0.02 mag. A lightcurve inversion spin-shape model based on dense and sparse data provides a sidereal period 8.184371 ± 0.000046 h with two mirrored pole solutions at (λ = 90°, β = –39°) and (λ = 286°, β = –20°) with an error of ± 10 deg.

The middle main-belt asteroid 16847 Sanpoloamosciano was discovered on 1997 December 8 by M. Mannucci and N. Montigiani at the San Polo a Mosciano Observatory. Lightcurves were acquired at the 2018 opposition by the discoverers in order to refine the model previously published by Hanus et al. (2013) that used only sparse data.

Photometric data were obtained with four sessions from 2018 December 17-31 at Margherita Hack Observatory with a 0.35-m Schmidt-Cassegrain telescope reduced to *f*/8.3 and SBIG ST10XME (bin 2x2) CCD camera. No filter was used. Lightcurve analysis was done with *MPO Canopus* (BDW Publishing, 2016). All the images were calibrated with dark and flat frames and converted to V magnitudes using solar colored field stars from MPOSC3 catalogue (Warner, 2007). From these data we derived a synodic period of 8.183 ± 0.001 h and amplitude of 0.15 ± 0.02 mag (Figure 1). This period is consistent with the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009). Table II shows the observing circumstances and lightcurve analysis results.

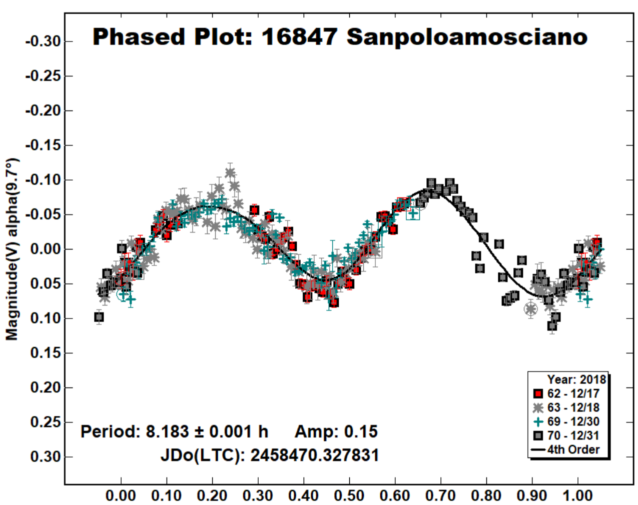


Figure 1. The lightcurve for 16847 acquired at the 2018 apparition.

Lightcurve inversion was performed using *MPO LCInvert* v.11.7.5.1 (BDW Publishing, 2016). For the inversion process, we used the sparse data acquired at the 2009 opposition (Waszczak et al., 2015) and sparse data from (703) Catalina Sky Survey in addition to the new dense data acquired at the 2018 opposition. A weighting of 0.5, 0.2, and 1.0, respectively, were assigned during the analysis. Figure 2 shows the phase angle bisector (PAB) longitude distribution of the dense and sparse data.

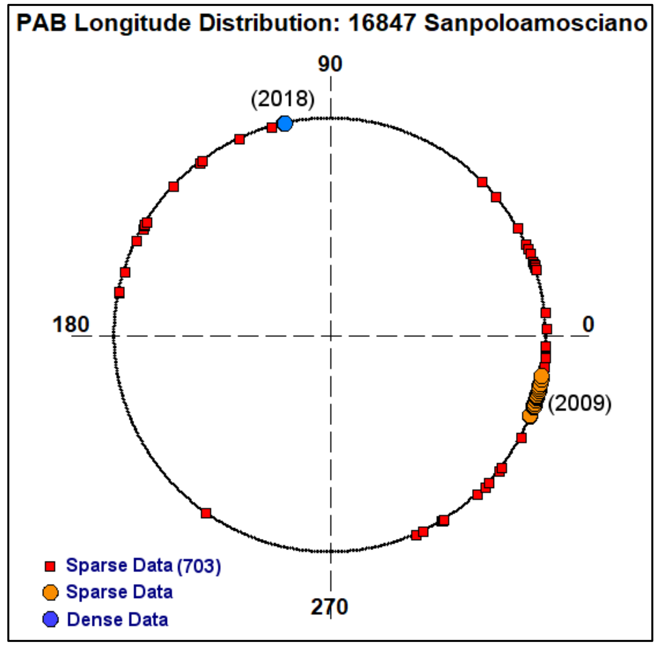


Figure 2. PAB longitude distribution of the dense and sparse data used for the lightcurve inversion model.

Figure 3A plots the sparse data (normalized intensity) from the Catalina survey versus JD Figure 3B shows the same data after being loaded in the *MPO Canopus* H-G calculator. The solution was allowed to float instead of forcing it to fit to the default value of *G* = 0.15 ± 0.2.

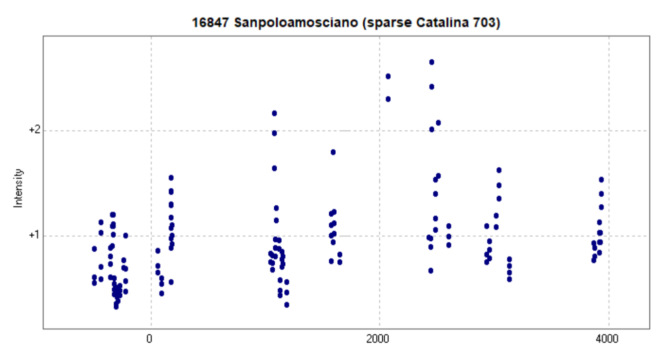


Figure 3A Sparse photometric data point distribution from (703) Catalina Sky Survey with the phase curve (reduced magnitudes vs phase angle).

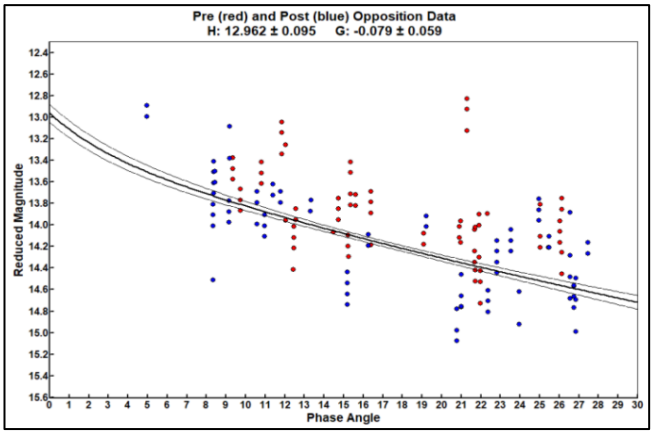


Figure 3B. The sparse data from Catalina (703) were fitted to a "free" solution for *H* and *G*. The outlier data near 21° and lack of data at α < 7° may have contributed to the unusual value for *G*.

The range for the search for the sidereal period was centered on the average of previously published synodic periods. The lowest Chi-Sq corresponded to a period of 8.1844 h (Figure 4).

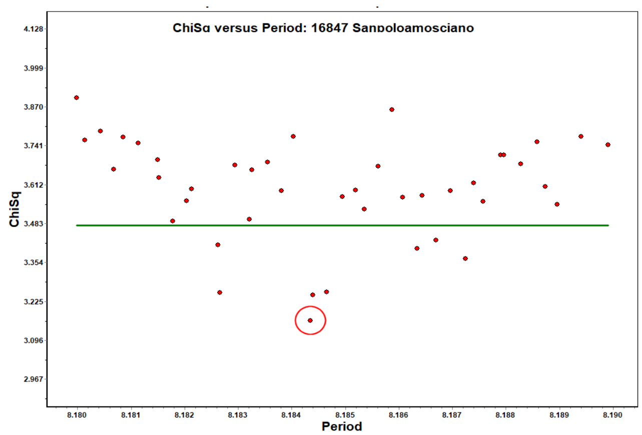


Figure 4. The period search shows one isolated lower chi-sq value.

The initial pole search used the "medium" option. This tests 312 fixed pole solutions but the sidereal period at each position was allowed to float. The required "dark facet" (Kassalien et al., 2001a, 2001b) was set to 0.8. A maximum of 50 iterations were made at each trial position. The search produced two solutions (Figure 5) separated by nearly 180° in longitude at ($\lambda = 88°$, $\beta = -43°$) and ($\lambda = 284°$, $\beta = -20°$).

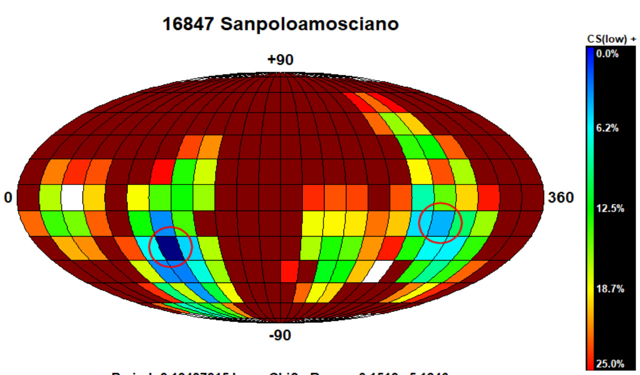


Figure 5. In the pole search plot the Chi-Sq value increases as the colors move from dark blue to dark red.

A secondary search used the "fine" option, which searches a small area about a fixed position, That search found two clustered solutions within 20 degrees in longitude-latitude pairs where with Chi-Sq < 110% of the lowest Chi-Sq (Figure 6 and Table I).

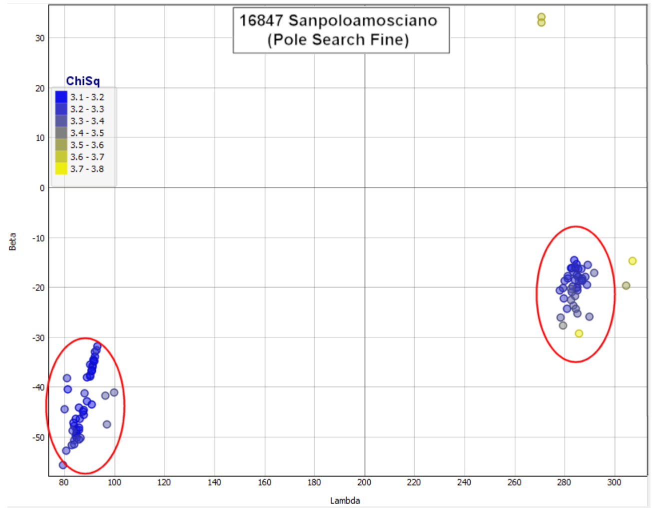


Figure 6. The "fine" pole search shows two clustered solutions centered at the ecliptic longitude/latitude (88°, -43°) and (284°, -20°) with chi-sq values below 10% than the others.

λ °	β °	Sidereal Period (hours)	RMS
90	-39	8.184371 ± 0.000046	0.0819
286	-20		0.0834

Table I. The two spin axis solutions for 16847 Sanpoloamosciano. The sidereal period is the average of the two solutions found in the pole search process.

The sidereal period adopted here is the average of the two solutions from the pole search process. Typical errors in the pole solution are ± 10 degrees and the uncertainty in sidereal period is based on a rotational error of 20 degrees over the total time span from 2009 to 2018 data. Figure 7 shows the shape model for the first solution, which is consistent with Hanus et al. (2013). Figure 8 shows the fit between the model (black line) and two of the 2018 observed lightcurves (red points).

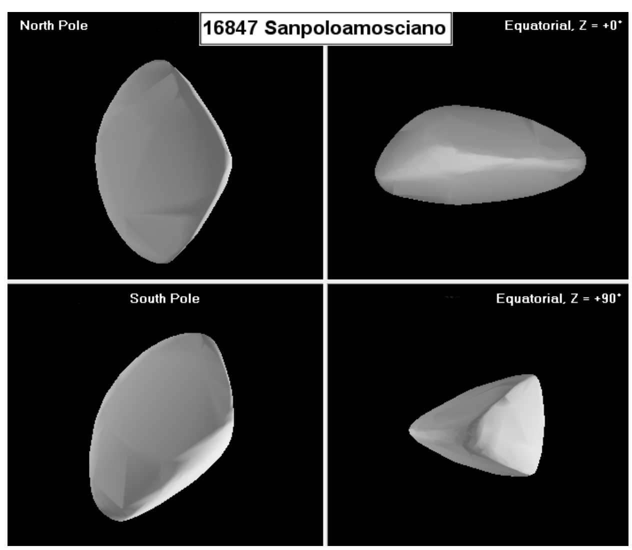


Figure 7: The shape model for 16847 Sanpoloamosciano for the first pole solution of ($\lambda = 90°$, $\beta = -39°$).

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
16847	Sanpoloamosciano	12/17-12/31	242	10.1,5.0	102	-8	8.183	0.001	0.15	0.02

Table II. Observing circumstances and lightcurve analysis results from 2018. Pts is the number of data points. The phase angle values are for the first date and the 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).

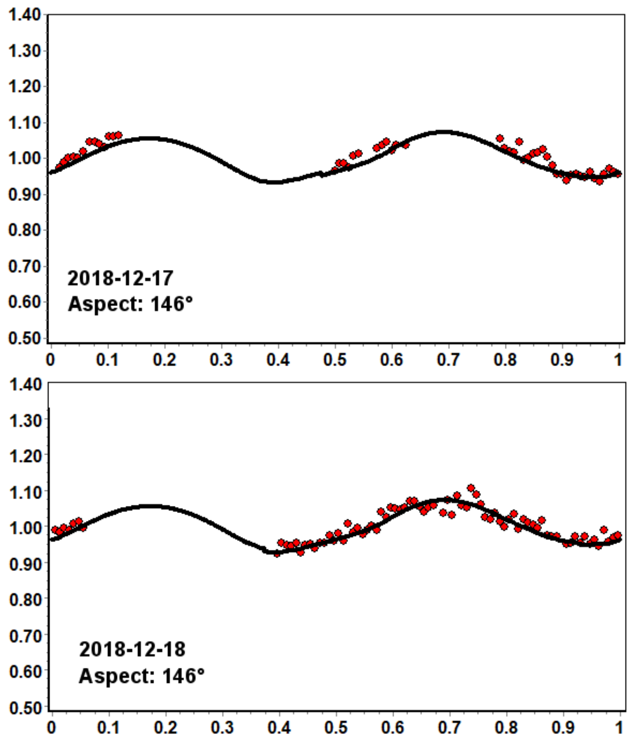


Figure. 8. Model fit (black line) versus observed lightcurves (red points) for the first pole solution (λ = 90°, β = –39°).

References

BDW Publishing (2016). *MPO Canopus* software. *http://bdw publishing.com*

Hanus, J., Durech, J., Broz, M., Marciniak, A., Warner, B.D., Pilcher, F., Stephens, R., Behrend, R., Carry, B., Capek, D., and 110 coauthors (2013). "Asteroids physical models from combined dense and sparse photometry and scaling of the YORP effect by the observed obliquity distribution." *Astron. Astrophys*. **551**, A67.

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

Kaasalainen, M., Torppa, J. (2001a). "Optimization Methods for Asteroid Lightcurve Inversion. I. Shape Determination." *Icarus* **153**, 24-36.

Kaasalainen, M., Torppa, J., Muinonen, K. (2001b). "Optimization Methods for Asteroid Lightcurve Inversion. II. The Complete Inverse Problem." *Icarus* **153**, 37-51.

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." Icarus **202**, 134-146. Updated 2018 November. *http://www.minorplanet.info/lightcurvedatabase.html*

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.

PHOTOMETRIC LIGHTCURVE FOR 4807 NOBORU

Daniel A. Klinglesmith III
Etscorn Campus Observatory
New Mexico Tech
101 East Road
Socorro, NM 87801
dklinglesmith@mro.nmt.edu

(Received: 2019 Jan 14)

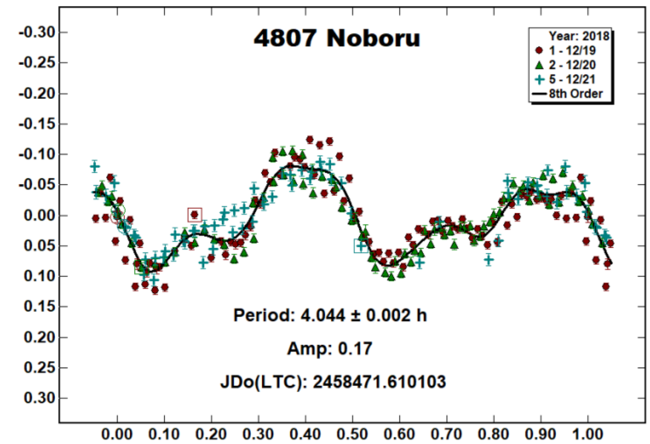
Observations of the main-belt asteroid 4807 Noboru provided a synodic period of 4.044 ± 0.002h with an amplitude of 0.17 mag.

Observations of 4807 Noboru were obtained with two Celestron 0.35-m telescopes equipped with SBIG STL 1001E CCD camera systems at the Etscorn Campus Observatory (Klinglesmith and Franco, 2016). The images were processed and calibrated with MPO Canopus, version 10.7.12.9 (Warner, 2018). Exposure times were 300 seconds through a clear filter. The multi-night data sets were combined with the FALC algorithm (Harris et. al., 1989) within the Canopus software to provide synodic period and amplitude for the asteroid.

Discovery information was obtained from the JPL Small Bodies Node (JPL, 2018). Table I contains the observation circumstances and results. 4807 Noboru is a main-belt asteroid discovered by T. Kobayashi at Oizumi on 1991 Jan 10. It is also known as 1991 AO, 1929 UG, 1961 VM 1961 XF, 1970 QM1 and 1982 RM3. The asteroid was observed on 3 nights between 2018 Dec 19 and Dec 21. A synodic period of 4.044 ± 0.002h with an amplitude of 0.18 mag. No other periods have been found.

Acknowledgements

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Engineering.



References

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

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

JPL (2018). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Klinglesmith III, D.A., Franco, L. (2016). "Lightcurves for 1531Hartmut and 4145 Maximova." *Minor Planet Bull.* **43**, 121.

Warner. B.D. (2018). MPO Canopus software. *http://bdwpublishing.com*

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
4807	Roboru	12/20	229	-1.0,2.0	88	1	4.044	0.002	0.17	0.05

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

ELEVEN MAIN-BELT ASTEROIDS AND ONE NEAR-EARTH ASTEROID LIGHTCURVES AT ASTEROIDS OBSERVERS (OBAS) – MPPD: 2017 MAY- 2019 JAN

Alfonso Carreño
Zonalunar Observatory,Valencia, SPAIN
obas@minorplanet.es

Enrique Arce
Vallbona Observatory, Valencia, SPAIN

Gonzalo Fornas CAAT
Centro Astronómico del Alto Turia, SPAIN

Vicente Mas, CAAT
Centro Astronómico del Alto Turia, SPAIN

(Received: 2019 Jan 14 Revised: 2019 Feb 19)

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

In this paper we publish the results for twelve asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). The data and results were made possible thanks to the collaboration of the Astronomical Center Alto Turia (CAAT) observatory located in Aras de los Olmos and operated by members of the Valencia Astronomy Association (AVA) (*http://www.astroava.org*). This database shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

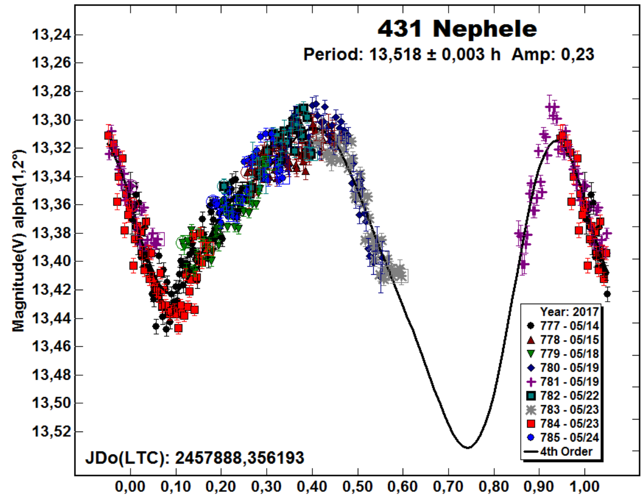
Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.09 R-C	MORAVIAN G2 8300

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

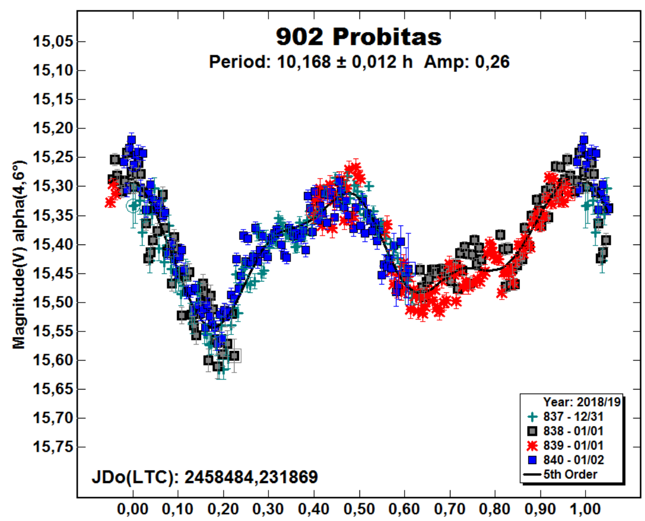
Table I shows the equipment at observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website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

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. Period analysis was also done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris et al., 1989). The comparison stars were restricted to near solar-color to avoid introducing color dependences, especially at larger air masses. The lightcurves give the synodic rotation period. The amplitude (peak-to-peak) that is shown is that for the Fourier model curve and not necessarily the true amplitude.

431 Nephele. This main-belt asteroid was discovered on 1897 Dec 18 by Auguste Honoré Charlois at Niza Observatory. The OBAS group made observations on 2017 May 14-27. From our data we derive a rotation period of 13.518 ± 0.003 h and amplitude of 0.23 mag. Behrend (2002; 2005) found a period of 13.47 h. Wang (2010) found 18.82 h while Pilcher (2017) found 13.53 h.



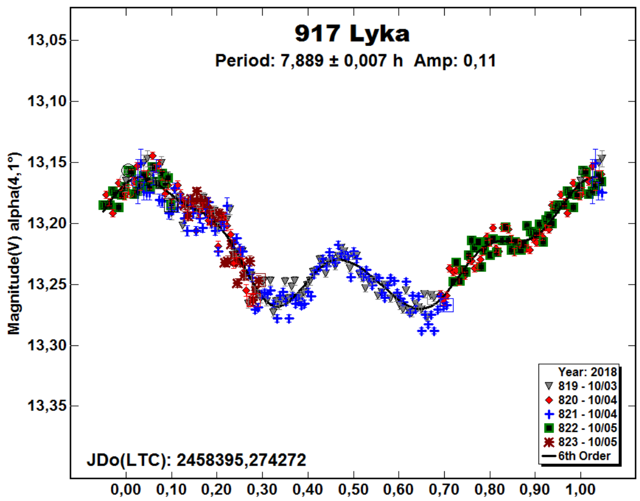
902 Probitas. This main-belt asteroid was discovered on 1918 Sep 3 by Johann Palisa at Vienna Observatory. The OBAS group made observations in 2018 Dec 31 to 2019 Jan 2. We derived a rotation period of 10.168 ± 0.012 h and amplitude of 0.26 mag. Behrend (2006) and Durkee (2011) found a period of 10.12 h.



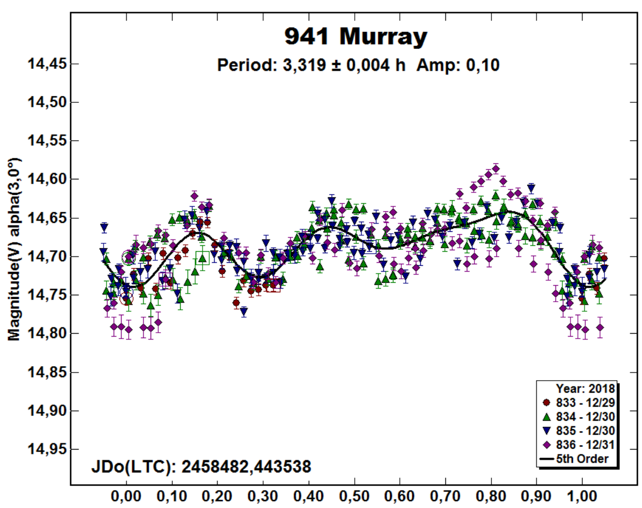
917 Lyka. This main-belt asteroid was discovered on 2015 Sep 5 by Grigori Nikoláievich Neúimin at Crimeiz Observatory. The OBAS group made observations in 2018 Oct 3-5. From our data we derive a rotation period of 7.889 ± 0.007 h and amplitude of 0.11 mag. Behrend (2005) found a period of 7.02 h and Ditteon (2018) found 11.838 h.

Number	Name	yyyy	mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
431	Nephele	2017	05/14-05/24	444	1.2,2.8	236	2	13.518	0.003	0.23	0.04	THM
902	Probitas	2018	12/31-01/02	425	4.7,4.8	98	8	10.168	0.012	0.26	0.03	MB-I
917	Lyka	2018	10/03-10/05	351	3.7,3.3	14	4	7.889	0.007	0.11	0.01	ERI
941	Murray	2018	12/29-12/31	298	3.1,3.4	96	6	3.39	0.004	0.10	0.03	MB-O
1004	Belopolskya	2019	01/02-01/07	699	5.5,6.8	86	3	9.038	0.007	0.09	0.02	MB-O
1006	Lagrangea	2018	09/28-10/03	555	9.7,10.6	2	15	19.797	0.011	0.14	0.01	MB-O
1544	Vinterhansenia	2018	12/06-12/09	569	1.0,1.4	76	1	13.536	0.021	0.11	0.01	MB-I
2162	Anhui	2019	01/07-01/11	532	2.3,0.9	110	-1	8.116	0.006	0.13	0.03	FLOR
3670	Northcott	2019	01/11-01/13	389	1.2,0.7	114	1	6.992	0.008	0.39	0.05	MB-O
7520	1990 BV	2018	01/08-01/12	251	3.3,5.8	104	2	3.83	0.01	0.29	0.05	MB-I
12198	1980 PJ1	2019	01/07-01/11	534	2.7,1.1	110	-1	5.494	0.003	0.23	0.03	MC
18736	1998 NU	2019	01/11-01/13	406	2.4,1.4	113	1	2.473	0.003	0.11	0.03	NEA

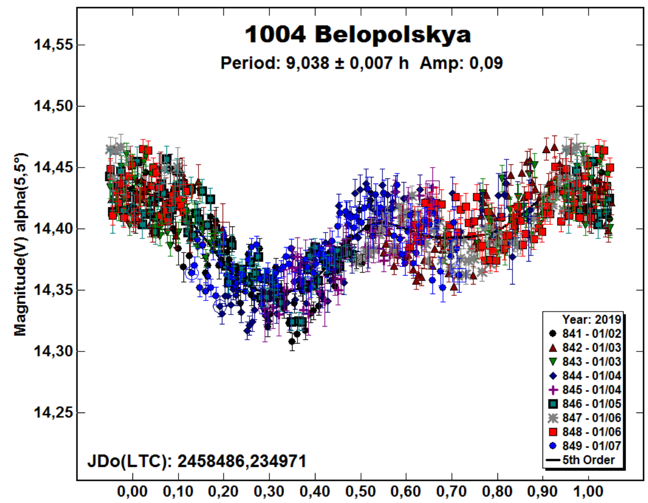
Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group from Warner *et al.* (2009). ERI: Erigone; EUN: Eunomia; MB-I/O: Main-belt inner/outer; MC: Mars-crosser; NEA: near-Earth; THM: Themis; TRJ: Jupiter Trojan.



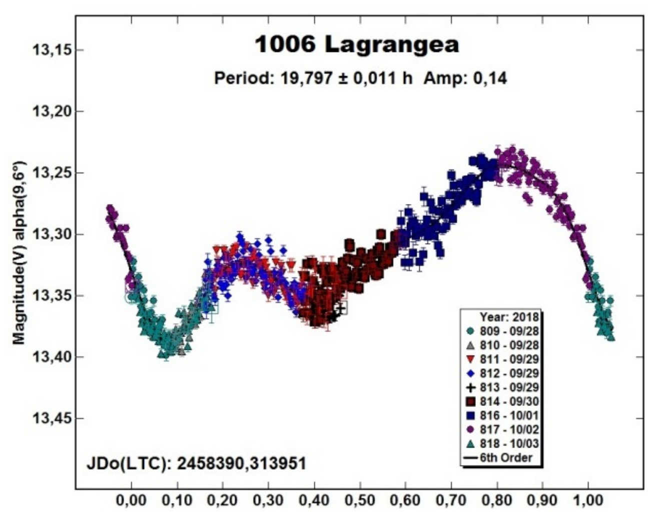
941 Murray. This main-belt asteroid was discovered on 1920 Oct 10 by Johann Palisa at Vienna Observatory. We made observations from 2018 Dec 29-31. Data analysis found a rotation period of 3.319 ± 0.004 h and amplitude of 0.1 mag. The LCDB (Warner et al., 2009) did not list any previous period results.



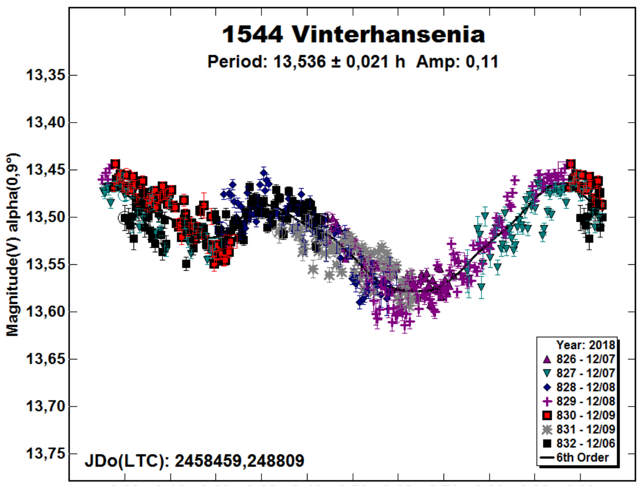
1004 Belopolskya. This main-belt asteroid was discovered on 2015 Sep 5 by Grigori Nikoláievich Neúimin from Crimeiz Observatory. The OBAS group made observations from 2019 Jan 2-7. From our data we derive a rotation period of 9.038 ± 0.007 h and amplitude of 0.09 mag. Behrend (2010) found 9.44 h and amplitude of 0.14 mag.



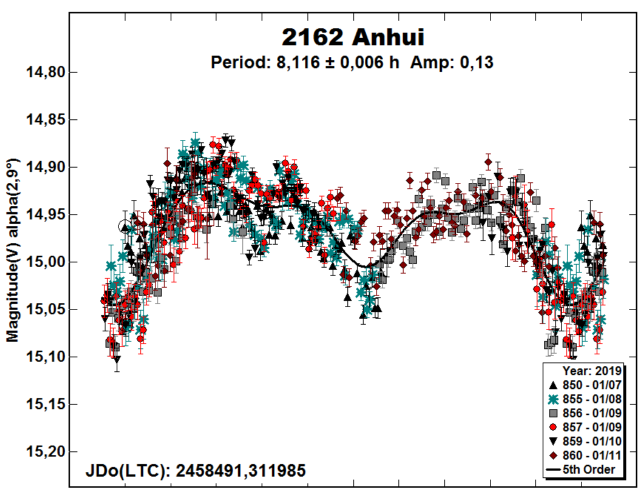
1006 Lagrangea. This main-belt asteroid was discovered on 1923 Sep 12 by Grigori Nikoláievich Neúimin at Crimeiz Observatory. Our observations were made from 2018 Sep 28 to Oct 3. Data analysis found a rotation period of 19.797 ± 0.011 h and amplitude of 0.14 mag. Behrend (2001) found a period of 32.79 h and amplitude of 0.17 mag with a partial lightcurve.



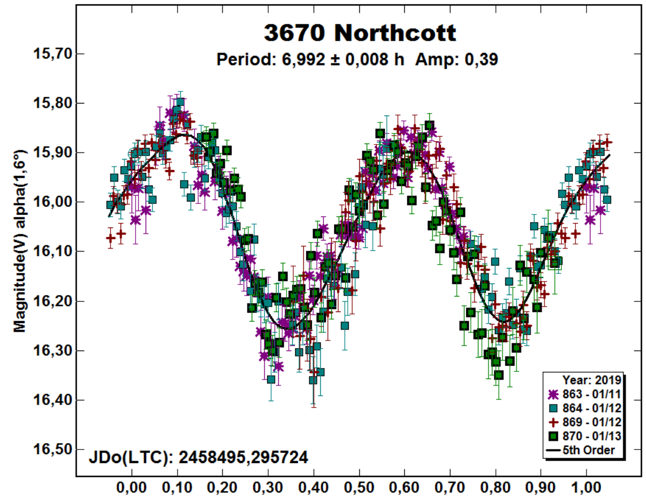
1544 Vinterhansenia. This is a dark inner main-belt asteroid with an estimated diameter of 22 km. It was discovered on 1941 Oct 15 by Liisi Oterma at Turku Observatory in Finland. Our observations were made from 2018 Dec 6-9. From our data we derive a rotation period of 13.536 ± 0.021 h and amplitude of 0.11 mag. Behrend (2001) found a period of 32.79 h and amplitude of 0.17 mag with a partial lightcurve. Ivarsen (2004) found 13.7 h and Behrend (2005) reported 13.77 h.



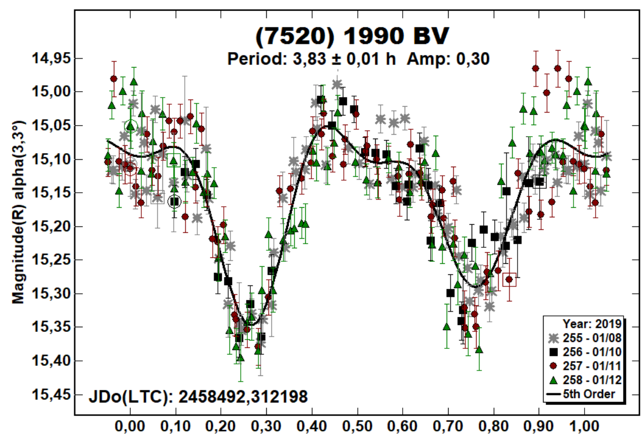
2162 Anhui. This main-belt asteroid was discovered on 1966 Jan 30 at the Purple Mountain Observatory. The OBAS group made observations on 2019 Jan 1-7. From our data we derive a rotation period of 8.116 ± 0.006 h and amplitude of 0.13 mag. Behrend (2018) and Pravec (2018) both reported a period of about 8.11 h.



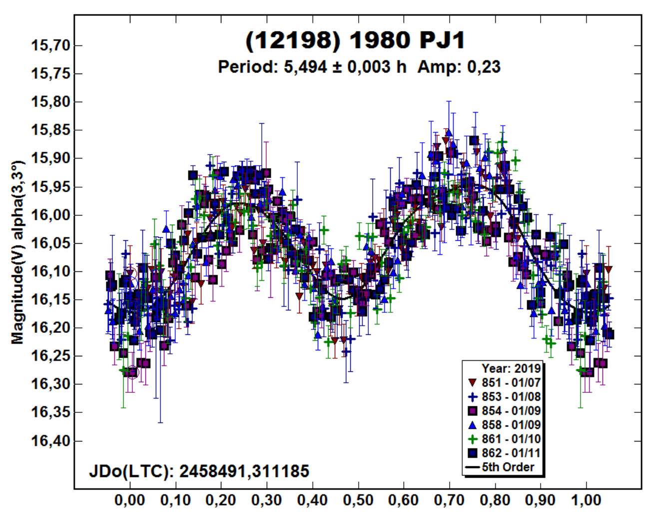
3670 Northcott. This main-belt asteroid was discovered on 1983 Jan 22 by T. Bowell, at Flagstaff (AM). Our observations ran from 2019 Jan 11-13. The data analysis found a rotation period of 6.992 ± 0.008 h and amplitude of 0.39 mag.



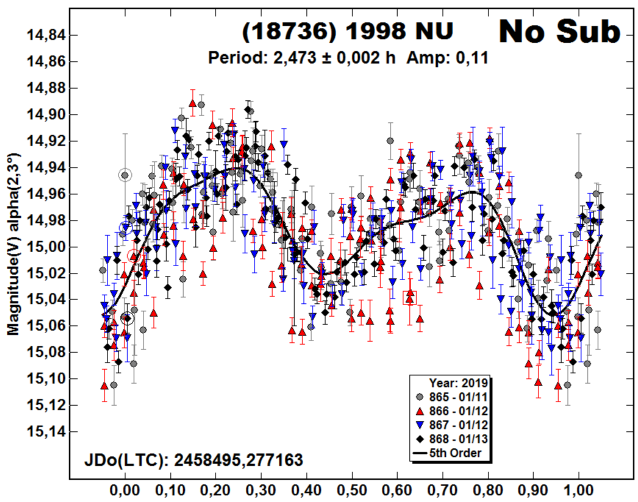
(7520) 1990 BV. This member of the Eunomia group/family was discovered on 1990 Jan 21 by T. Hioki ansd S. Hayakawa at Okutama. Based on data obtained from 2019 Jan 8-12, we found a rotation period of 3.83 ± 0.01 h and amplitude of 0.29 mag.

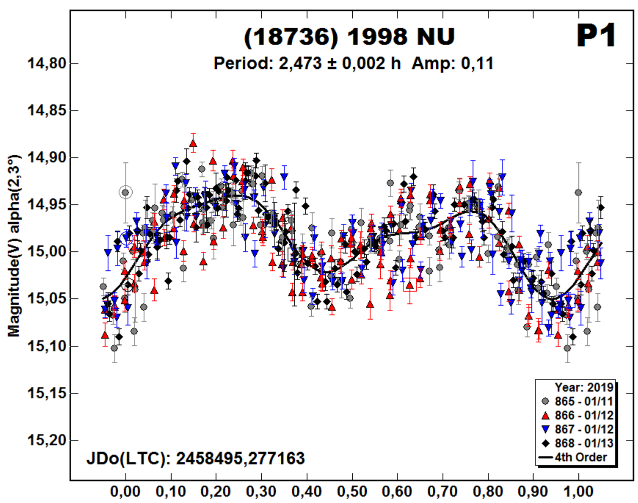


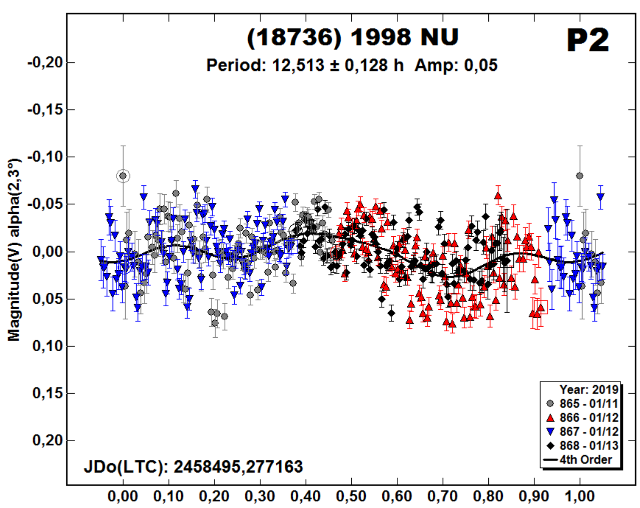
(12198) 1980 PJ1. This is a Mars-crossing asteroid that was discovered on 1980 Aug 6 at La Silla observatory, Chile. The OBAS group made observations from 2019 Jan 1-7. From our data we derive a rotation period of 5.494 ± 0.003 h and amplitude of 0.23 mag.



(18736) 1998 NU. This NEA was discovered on 1988 Jul 2 at Kitt Pick Observatory in Arizona. The OBAS observations in made from 2019 Jan 11-13 led to a rotation period of 2.473 ± 0.003 h and amplitude of 0.11 mag.







Warner and Stephens (2019) reported this to be a suspected binary with a secondary period of 11.95 h. We tried a dual-period search and found a main period of 2.473 ± 0.002 h and amplitude of 0.11 mag and a secondary period of 12.513 ± 0.013 h with a amplitude of 0.05 mag.

Acknowledgements

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

References

Behrend, R. (2001; 2002; 2004; 2005; 2006; 2010; 2018) Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Ditteon, R., Young, J. (2018). “Lightcurve Analysis of Minor Planets Observed at the Oakley Southern Sky Observatory: 2017 March - May.” *Minor Planet Bull.* **45**, 117-119.

Durkee, R.I. (2011). “Asteroids Observed from the Shed of Science Observatory 2010 October - 2011 April.” *Minor Planet Bull.* **38**, 167-168.

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

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

Krugly, Yu.N., Bel’skaya, I.N., Shevchenko, V.G., Chiorny, V.G., Velichko, F.P. Mottola, S., Erickson, A., Hahn G., Nathues, A., Neukum, G., Gaftonyuk, N.M., Dotto, E. (2002). “The Near-Earth Objects Follow-up Program. IV. CCD Photometry in 1996-1999.” *Icarus* **158**, 294-304.

Pilcher, F. (2017). “Rotation Period Determination for 46 Hestia, 118 Peitho, 333 Badenia, 356 Liguria, and 431 Nephele.” *Minor Planet Bull.* **44**, 294-297.

Pravec, P., Wolf, M., Sarounova, L. (2018). *http://www.asu.cas.cz/~ppravec/neo.htm*

Wang, X.-B., Gu, S.-H., Li, X.-J. (2010). “The Rotational Periods of Three C-Type Asteroids 431, 521 and 524.” *Earth, Moon, and Planets* **106**, 97-104.

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146. Updated 2017 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Stephens, R.D. (2019). *CS3 web site. http://www.planetarysciences.org/PHP/CS3_Lightcurves.php*

LIGHTCURVE ANALYSIS OF THREE POTENTIALLY HAZARDOUS ASTEROIDS

Andy J. López-Oquendo and Desireé Cotto-Figueroa
Department of Physics and Electronics, University of Puerto Rico,
Humacao, Puerto Rico 00792
andy.lopez2@upr.edu

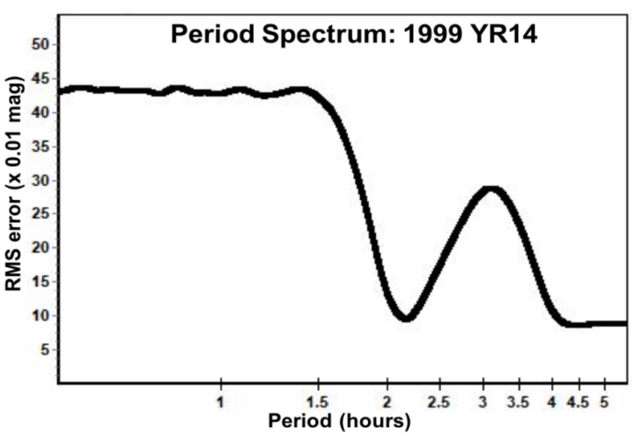
(Received: 2019 Jan 14)

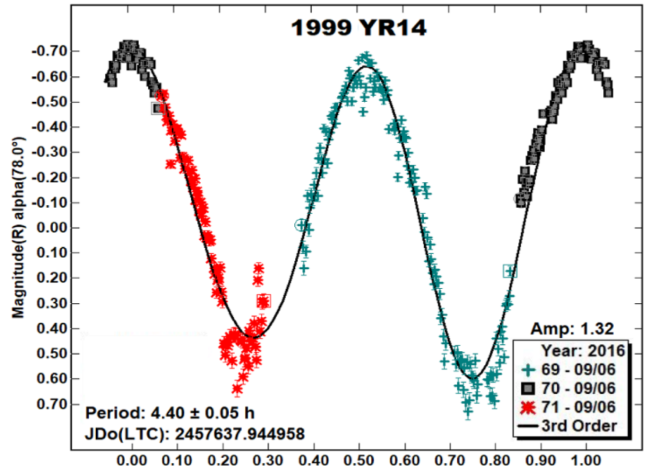
CCD photometric observations of three near-Earth asteroids (NEAs) also listed as potentially hazardous (PHAs) were made during 2016 September and 2018 April. Fourier analysis of the data for the three targets found rotation periods for 1999 YR14, 4.40 ± 0.05 h; 2016 LX48, 2.23 ± 0.06 h; and 2018 BY2, 9.17 ± 0.01 h.

We conducted observations of three near-Earth asteroids (NEA) that are also listed as potentially hazardous (PHA) using the 0.79-m National Undergraduate Research Observatory (NURO) telescope at the Lowell Observatory in Flagstaff, AZ, and the thermoelectrically cooled NASAcam CCD camera (2Kx2K). The asteroids were observed using an R-band filter with exposure times of 30-60 seconds. The data reduction and analysis were conducted using the *Image Reduction and Analysis Facility* (*IRAF*) and *MPO Canopus* programs.

(357024) 1999 YR14 is an Apollo-type discovered by LONEOS on 1999 December 31 with an estimated diameter of 500 m (JPL, 2018). The asteroid made its closest approach to within 0.056 AU of Earth on 2016 September 1. Photometric observations were made on 2016 September 6. A total of 4.03 hours of observation produced 299 data points for analysis.

The asteroid lightcurve database (LCDB; Warner et al., 2009) indicated three previously reported lightcurves: Carbognani (2017), Warner (2017), and Linder (2017) who all reported a period of 4.24 h with amplitudes from 0.9 to 1.38 mag. In this work, we report a period of 4.40 ± 0.05 h and amplitude of 1.32 mag. The large amplitude and symmetry of the lightcurve are an indication of an elongated asteroid.

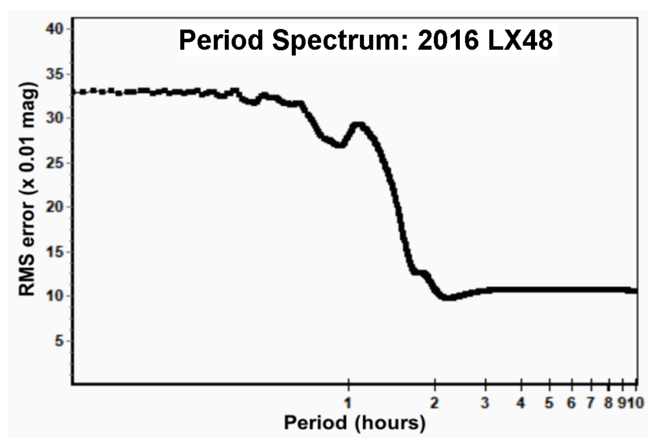




2016 LX48 is an Apollo-type discovered by Pan-STARRS 1 on 2016 June 1. It made its closest approach to within 0.0456 AU of Earth on 2016 September 12 (JPL, 2018). Arecibo radar observations found an estimated diameter of about 735 m, which is consistent with the absolute magnitude of $H = 19.4$.

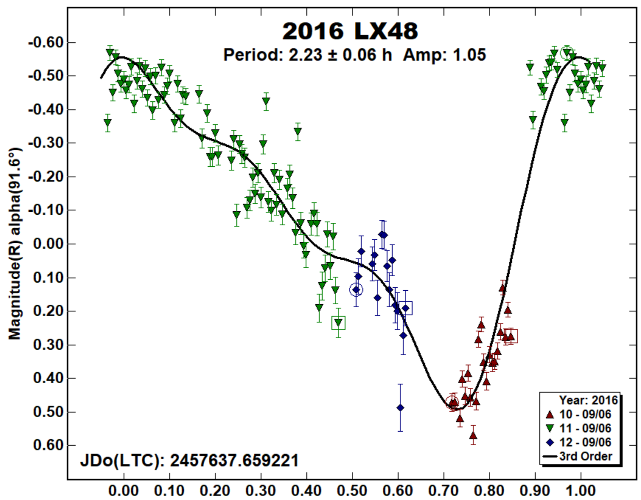
Photometric observations were made on 2016 September 6 for a total of 2.003 hours and a total 122 data points. Our analysis found a period of 2.23 ± 0.06 h and amplitude of 1.05 mag. However, the coverage is not complete, and the true value of the period is suggested to be at least 2x the reported period.

Linder (2017), Sonka (2017), Vaduvescu (2017), Warner (2017), and Benishek (2017) reported a period of about 5.6 h and amplitude of 1.3 mag while Carbognami (2017) reported a period of 3.8 h with an amplitude of 0.55 mag.



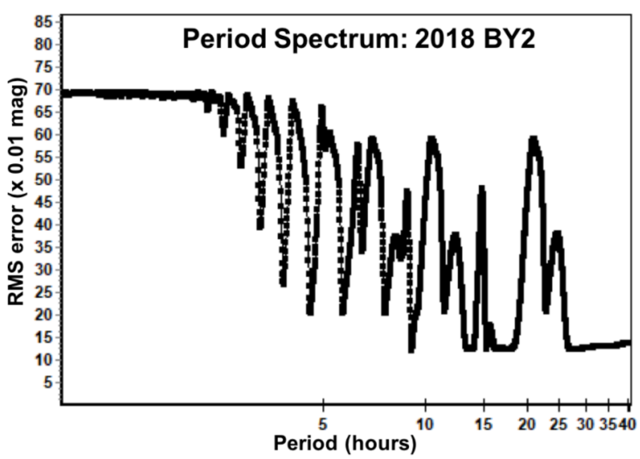
Number	Name	yyyy	mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
357024	1999 YR14	2016	09/06-09/06	299	78	25	-12	4.40	0.05	1.3	0.09	PHA
	2016 LX48	2016	09/06-09/06	122	91.6	296	16	2.23	0.06	1.05	0.04	PHA
	2018 BY2	2018	04/13-04/15	399	40.2,38.2,36.0	182	-1	9.17	0.01	2.18	0.03	PHA

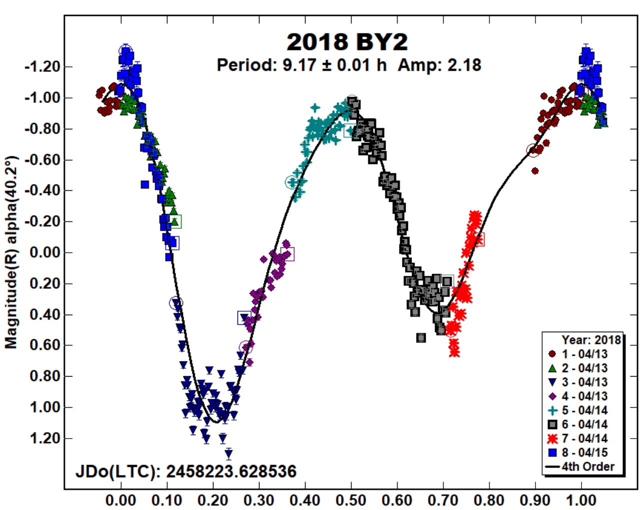
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner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



2018 BY2 is an Apollo-type with an estimated diameter of 211 to 472 meters. This asteroid made its close approach within 0.0456 AU on 2018 April 11 (JPL, 2018).

Photometric observations were performed on 2018 April 13-15. We observed this asteroid for a total of 7.86 hours and 399 data points were obtained for analysis. Here we report a period of 9.17 ± 0.01 h and amplitude of 2.18 mag, which is different from the 7.6 h by Warner et al. (2018) and Pravec et al. (2018).





Acknowledgements

This research was made possible through funding by NASA Puerto Rico Space Grant Consortium grant no. NNX15AI11H.

References

Benishek, V. (2017). "Lightcurves and Rotation Periods for Six Asteroids." *Minor Planet Bull*. **44**, 52-57.

Carbognani, A. (2017). "Asteroids Lightcurves Analysis at OAVDA: 2016 January – October" *Minor Planet Bull.* **44**, 52-57.

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

JPL (2018). Small Body Database Browser. *https://ssd.jpl.nasa.gov/sbdb.cgi*

Linder, R.T., Puckett, A., Holmes, R., Nowinski, M., Hardersen, P., Haislip, J., Reichart, D. (2017). "Near-Earth Asteroids Rotational Analysis by Astronomical Research Institute: 2015 November thru 2016 August." *Minor Planet Bull.* **44**, 96-57.

Pravec, P., Wolf, M., Sarounova, L. (2018). *http://www.asu.cas.cz/~ppravec/neo.htm*

Şonka, A.B., Popescu, M., Nedelcu, D.A, Gherase, R.M, Vass, G. (2017). "Photometric Observations of the Near-Earth Asteroids 326683 (2002 WP) and 2016 LX48." *Minor Planet Bull.* **44**, 176–177.

Vaduvescu, O., Macias, A.A., Tudor, V., Predatu, M., et al. (2017). "The EURONEAR Lightcurve Survey of Near-Earth Asteroids." *Earth, Moon and Planets* **120**, 41-100.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2017). "Near-Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 July-September." *Minor Planet Bull.* **44**, 22-36.

Warner, B.D. (2018). "Near-Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2018 April-June." *Minor Planet Bull.* **45**, 366-379.

LIGHTCURVE ANALYSIS AND ROTATION PERIOD FOR 5321 JAGRAS

M. Mollica
AstroCampania Associazione
via Servio Tullio 101, 80126 Naples (Italy)
m.mollica@astrocampania.it

A. Noschese
AstroCampania Associazione Naples (Italy)
and
Osservatorio Elianto (K68)
via V. Emanuele III, 95, 84098
Pontecagnano (SA) Italy

A. Vecchione
AstroCampania Associazione Naples (Italy)

(Received: 2019 Jan 14 Revised: 2019 Feb 22)

Data for asteroid 5321 Jagras were collected from 2018 October 12th to 2018 November 14th. The lightcurve analysis obtained has led to a trimodal curve with a period of 2.6375 ± 0.0001 hours, with an amplitude equal to 0.06 mag, with a full coverage.

5321 is a main-belt asteroid (middle belt), discovered by Jensen, P. at Brorfelde in 1985. It has a semi-major axis of 2.582 AU, orbital period of 4.15 years, eccentricity of 0.220 and inclination of 13.620 deg. This seven-kilometer-asteroid has an absolute magnitude of 12.6 and a geometric albedo of 0.473 (from NEOWISE Diameters and Albedos V1.0, Mid-IR Photometry). No rotation period and lightcurve were reported for this object at the best of our knowledge. Observations were conducted by using a 0.25 m Ritchey Chrétien telescope operating at f/8, with a KAF 8300M CCD camera and a 5.4-micron pixels 3358x2536 array, unfiltered, a 0.30 m Newtonian telescope at f/4, with a KAF 1603 ME 1536x1024 x 9.0-micron, unfiltered (Elianto Observatory, K68) and iTelescope.net 21, (New Mexico, USA), 0.43 m CDK telescope at f/4.5 with a 9.0-micron pixels 3072x2048 array FLI-PL 6303EA CCD camera, Rc filtered.

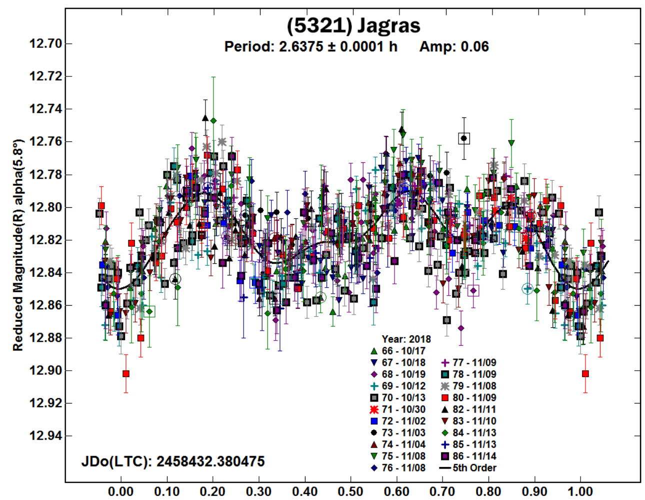
A total of 645 lightcurve data points were collected in seventeen observing sessions from 2018 October 12th, to 2018 November 14th, with exposing times ranging from 180 through 360 s, three of which were divided in two parts (before and after meridian flip). For this reason, the sessions shown are a total of twenty.

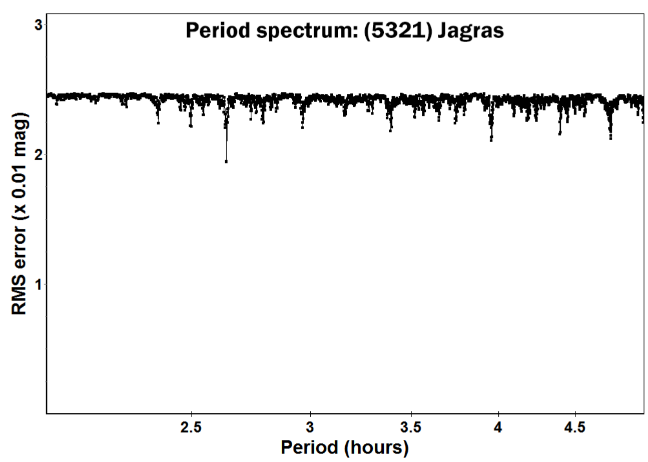
Table I lists the telescope/CCD camera combination used to collect the data. Master dark and flat were obtained using CCD Stack (CCD Ware). MPO Canopus (Warner, 2016) was used to measure the magnitudes with MPOSC3 catalogue. This catalogue is a hybrid one, based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI (Warner, 2007). The Rc derived magnitudes has been reduced for unity Sun-asteroid and Earth-asteroid distances in AU and normalized to the given phase angle of 5.8° and using G=0.15. 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 "starBgone" routine within MPO Canopus was used, as well, in order to subtract stars that occasionally merged with the asteroid during the observations. MPO Canopus was also used for rotation period analysis, adopting FALC method by Harris (Harris, 1989).

We found a period of 2.6375 ± 0.0001 hours. The data shown, indicate a lightcurve amplitude change of 0.06 magnitudes with three peaks. Many attempts have been made in order to find the best solution for this asteroid. During the analysis we had some difficulties in the interpretation of data, especially due to some sessions (67, 68 and 82) for which the corrections in magnitude (compared to others) were higher than usual (from 0.09 to 0.11 mag). In any case, even if these sessions are excluded from the calculation, the proposed result does not change.

The trimodal solution found is unusual to us, but some studies, highlight the fact that, with amplitudes less than 0.15 mag, lightcurves can be dominated by other harmonics (instead of the second) such as the fourth or the sixth (A.W. Harris et al. 2014). In our case, the amplitude found seems to be at least consistent with this situation. Obviously we hope to investigate this asteroid in more detail as soon as possible. In the meantime, this is our best interpretation.

Table II gives the observing circumstances and results. The period spectrum provided, shows that the best solution (thus with lowest RMS) is the one adopted here (1.86).





Site	Ap (m)	Type	f/	Camera	Array	Filter
Pontecagnano,Italy	0.25-m	RC	8.0	KAF8300M	3358x2536x5.4µ	C
Pontecagnano,Italy	0.30-m	N	4.0	KAF1603ME	1536x1024x9.0µ	C
Mayhill, USA	0.43-m	CDK	4.5	PL6303E	3072x2048x9.0µ	Rc

Table I. List of telescope/camera combinations. RC=Ritchey-Chrétien, N= Newton, CDK= Corrected Dall-Kirkham

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	U	Exp
5321	Jagras	10/12-11/14	645	3.7,18.5	16.9	8.6	2.6375	0.0001	0.06	0.01	2	180/360

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). The U rating is our estimate and not necessarily the one assigned in the asteroid lightcurve database (Warner *et al.*, 2009). Exp is average exposure, seconds.

References

JPL (2018). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Warner, B.D. (2016). MPO Software, MPO Canopus version 10.7.7.0 Bdw Publishing. *http://minorplanetobserver.com*

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

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

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." Icarus **202**, 134-146. *http://www.minorplanet.info/lightcurvedatabase.html*

Shevchenko, V.G., Lupishko, D. (1998). "Optical Properties of Asteroids from Photometric Data." *Solar System Research, Vol. 32, No. 3, 220-232.*

ASTEROID LIGHTCURVE AND SYNODIC PERIOD DETERMINATIONS: 2018 OCTOBER-DECEMBER

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA
vlaben@yahoo.com

(Received: 2019 Jan 15)

Results of lightcurve and synodic rotation period determinations from photometric data obtained at Sopot Astronomical Observatory for eight asteroids in the time span 2018 October - December are presented.

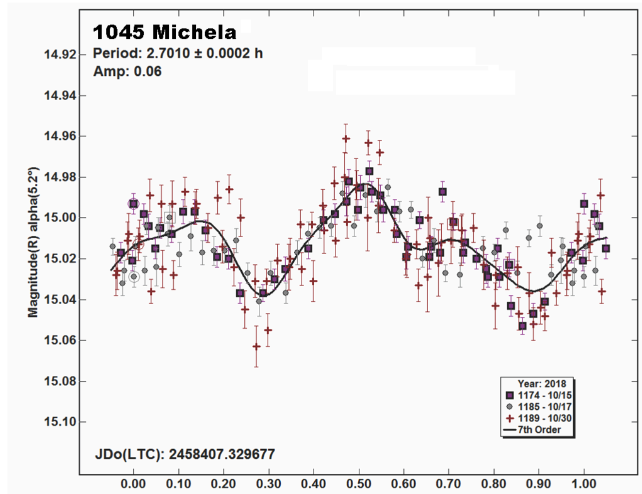
Photometric observations of eight asteroids were conducted at Sopot Astronomical Observatory (SAO) between 2018 October-December in order to determine the asteroids' synodic rotation periods. For this purpose, two 0.35-m *f*/6.3 Meade LX200GPS Schmidt-Cassegrain telescopes were employed. The telescopes are equipped with a SBIG ST-8 XME and a SBIG ST-10 XME CCD cameras. The exposures were unfiltered and unguided for all targets. Both cameras were operated in 2x2 binning mode, which produces image scales of 1.66 arcsec/pixel and 1.25 arcsec/pixel for ST-8 XME and ST-10 XME cameras, respectively. 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, 2018). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq$ B-V ≤ 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, 2018) Sloan r' magnitudes using the formula: R = r' - 0.22 in all cases presented in this paper. In some instances, small zero point adjustments were necessary in order to achieve the best match between individual data sets in terms of minimum RMS residual of a Fourier fit.

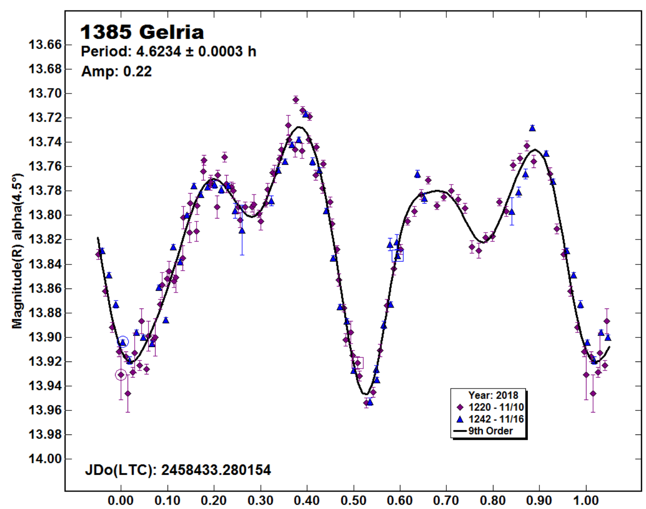
Some of the targets presented in this paper were observed within the Photometric Survey for Asynchronous Binary Asteroids (BinAstPhot Survey) under the leadership of Dr Petr Pravec from Ondřejov Observatory, Czech Republic (Pravec, 2018).

Observations and Results

<u>1045 Michela</u>. No records on previous rotation period determinations have been found for this inner main-belt asteroid. Photometric observations were conducted at SAO over 3 nights in 2018 October. Period analysis yielded a unique result for synodic rotation period of P = 2.7010 ± 0.0002 h despite the small lightcurve amplitude.



<u>1385 Gelria</u>. Another relatively low-numbered target with previously unknown rotation rate. Period analysis upon the data collected on 2 nights in 2018 November led to a bimodal solution for period of P = 4.6234 ± 0.0003 h as the most reliable one. A half-period solution (P/2), also very prominent by its fairly low RMS error has no support in the corresponding lightcurve showing considerably pronounced inconsistencies.

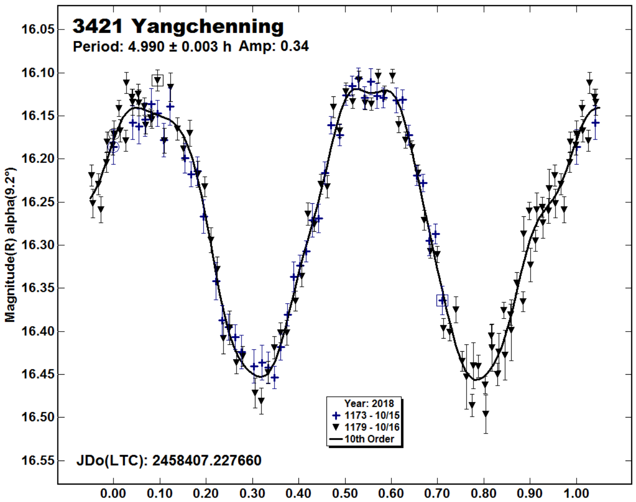


<u>3421 Yangchenning</u>. A Flora family asteroid with no rotation period determination results found prior to the SAO photometry. The data obtained in 2018 October over two consecutive nights at

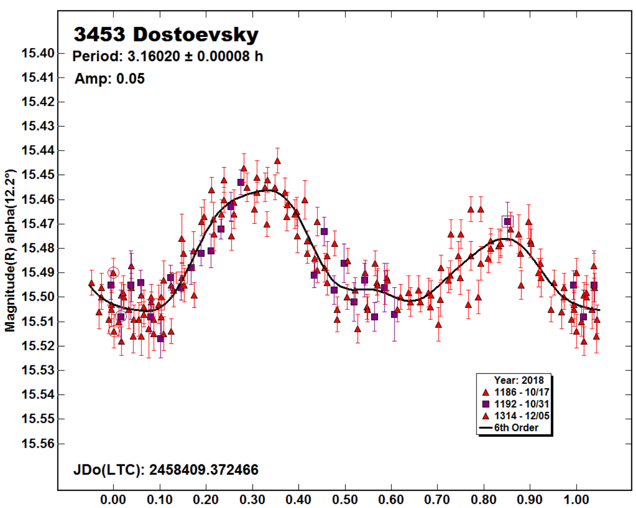
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1045	Michela	10/15-10/30	167	5.1,13.3	14	0	2.7010	0.0002	0.06	0.02	MB-I
1385	Gelria	11/10-11/17	149	4.5,6.1	45	-9	4.6234	0.0003	0.22	0.01	MB-O
3421	Yangchenning	10/15-10/17	138	9.2,9.8	7	3	4.990	0.003	0.34	0.02	FLOR
3453	Dostoevsky	10/17-12/05	160	12.2,2.7,10.7	50	5	3.16020	0.00008	0.05	0.02	MB-I
6540	Stepling	11/05-11/13	272	2.8,5.1	44	4	65.3	0.2	0.53		FLOR
7230	Lutz	10/13-10/15	170	1.9,2.7	18	0	5.690	0.004	0.18	0.01	MB-I
26029	5565 P-L	10/07-10/31	281	8.6,1.3,7.4	26	2	8.48905	0.00009	1.42	0.02	FLOR
136568	1980 XB	12/02-12/07	171	22.2,20.5	95	11	2.7823	0.0001	0.29	0.01	MC

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): FLOR = Flora, MB-I/O = main-belt inner/outer, MC = Mars Crosser.

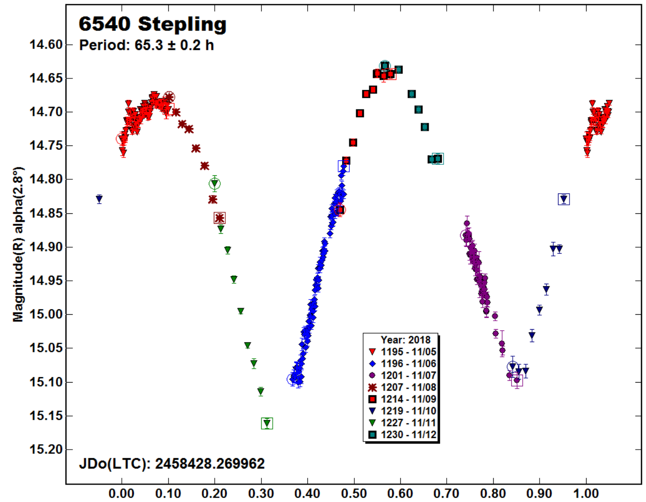
low solar phase angles led to an unequivocal, fairly large amplitude (0.34 mag.) bimodal lightcurve phased to a period of P = 4.990 ± 0.003 h.



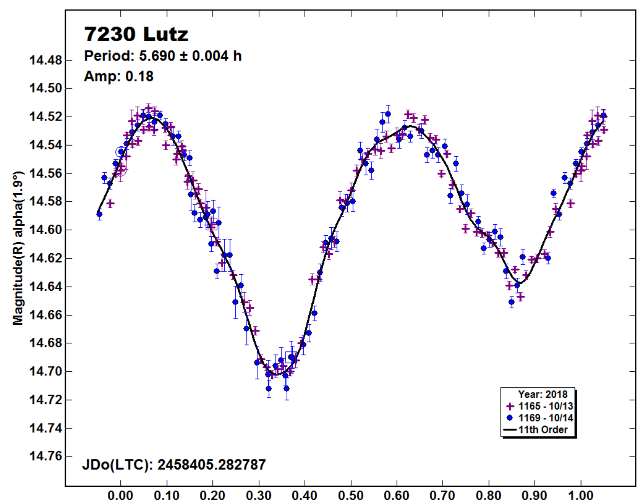
3453 Dostoevsky. A result found for rotation period (P = 3.16020 ± 0.00008 h) from the SAO photometric data collected in 2018 October is fully consistent with two previously obtained results by Carbo et al. (2009; 3.16 h) and Polishook (2009; 3.20 h).



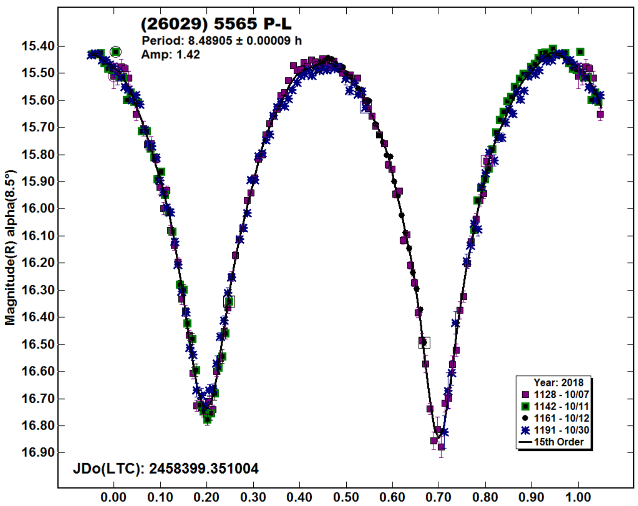
6540 Stepling. This was a BinAstPhot Survey target with no previously known rotation period. Already very first data sets obtained at SAO indicated a slow rotation. The asteroid was followed up persistently on 8 nights in 2018 November over low solar phase angles range and mainly applying a strategy of taking sparse data points (1-2 per hour) in order to save observing time for other more demanding targets. This proved to be sufficient to fairly plausibly establish a solution for period of P = 65.3 ± 0.2 h and a bimodal large-amplitude (A ~ 0.53 mag.) lightcurve containing several small gaps. No doubt that a denser photometry and possible multiple coverage of a full rotation cycle desirable in future apparitions would led to a better determined period value.



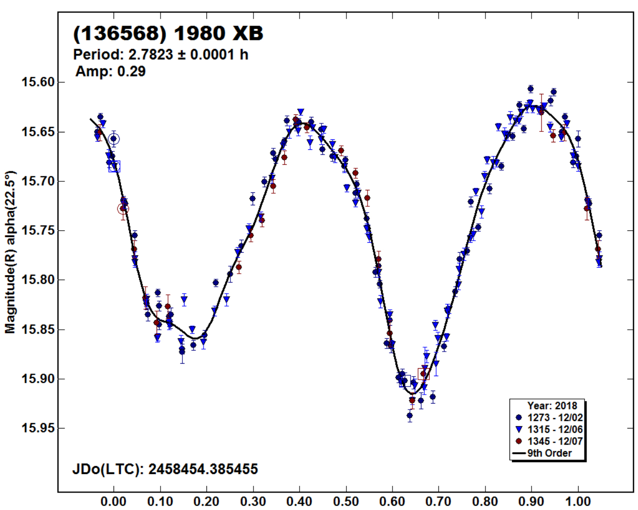
7230 Lutz. Another BinAstPhot Survey main-belt target observed exclusively from SAO during its 2018 apparition. Prior to this work no period determinations were known. Period analysis upon the two dense photometric data sets obtained on consecutive nights in 2018 October show a bimodal lightcurve phased to a period of P = 5.690 ± 0.004 h as a plausible solution. This result is in good agreement with the period value published very recently by Marchini et al. (2019; 5.682 h)



(26029) 5565 P-L. A BinAstPhot Survey program Flora family target. There were no records on previous period determinations. Four dense photometric data sets obtained in 2018 October at low solar phase angles yielded an extremely high amplitude bimodal lightcurve (1.42 mag.) that indicates an elongated shape. A corresponding period value is P = 8.48905 ± 0.00009 h.



(136568) 1980 XB. A Mars-crossing BinAstPhot Survey program target with no previously known rotation period. This one was also observed exclusively at SAO over 3 nights in early December of 2018. Period analysis resulted in a bimodal lightcurve with an amplitude of 0.29 mag. and phased to a period of P = 2.7823 ± 0.0001 h.



Acknowledgements

Observational work at Sopot Astronomical Observatory is supported by a 2018 Gene Shoemaker NEO Grant from The Planetary Society.

References

Carbo, L., Green, D., Kragh, K., Krotz, J., Meiers, A., Patino, B., Pligge, Z., Shaffer, N., Ditteon, R. (2009). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2008 October thru 2009 March." *Minor Planet Bull.* **36**, 152-157.

Marchini, A., Papini, R., Banfi, M., Salvaggio, F. (2019). "Rotation Period Determination for 5351 Diderot and 7230 Lutz." *Minor Planet Bull.* **46**, 90-91.

Polishook, D. (2009). "Lightcurves and Spin Periods from the Wise Observatory: 2008 August - 2009 March." *Minor Planet Bull.* **36**, 104-107.

Pravec, P. (2018). Photometric Survey for Asynchronous Binary Asteroids web site. *http://www.asu.cas.cz/~ppravec/newres.txt*

VizieR (2018). *http://vizier.u-strasbg.fr/viz-bin/VizieR*.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 December 21. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2018). MPO Canopus software, version 10.7.11.3. *http://www.bdwpublishing.com*

ROTATION PERIOD DETERMINATION FOR 3157 NOVIKOV AND 7485 CHANGCHUN

Alessandro Marchini
Astronomical Observatory, DSFTA - University of Siena (K54)
Via Roma 56, 53100 - Siena, ITALY
alessandro.marchini@unisi.it

Riccardo Papini, Massimo Banfi, Fabio Salvaggio
Wild Boar Remote Observatory (K49)
San Casciano in Val di Pesa (FI), ITALY

Mauro Bachini
Osservatorio Astronomico di Tavolaia (A29)
Santa Maria a Monte (PI), ITALY

Charles Galdies
Znith Observatory
Armonie, E. Bradford Street,
Naxxar NXR 2217, MALTA

Stephen M. Brincat
Flarestar Observatory (171)
San Gwann SGN 3160, MALTA

(Received: 2019 Jan 15 Revised: 2019 Feb 27)

Collaborative photometric observations of two main-belt asteroids were conducted from five observatories in order to determine their synodic rotation periods. For 3157 Novikov we found a period of 9.952 ± 0.001 h with an amplitude of 0.31 ± 0.04 mag, for 7485 Changchun we found a period of 10.234 ± 0.001 h with an amplitude of 0.39 ± 0.02 mag.

CCD photometric observations of two main-belt asteroids were carried out in 2018 October-December at the Astronomical Observatory of the University of Siena (K54), a facility inside the Department of Physical Sciences, Earth and Environment (DSFTA, 2019), at Wild Boar Remote Observatory (K49) in San Casciano in Val di Pesa (Florence), at Osservatorio Astronomico di Tavolaia (A29) in Santa Maria a Monte (Pisa), at Znith Observatory in Naxxar and at Flarestar Observatory (171) in San Gwann. Table I shows the main features of the instruments used at the observatories involved in the research while Table II gives the observation circumstances and results.

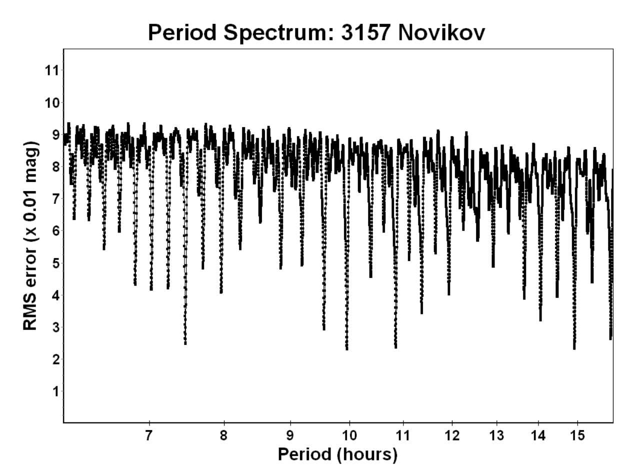
Obs.	Telescope	Filter	CCD
K54	0.30 m f/5.6 MCT	Clear	SBIG STL-6303 2x2 2.3"/pixel
K49	0.24 m f/10 SCT	Clear	SBIG ST8-XME 2x2 1.6"/pixel
A29	0.40 m f/5 NEW	Clear	Kaf-260 1x1 2.1"/pixel
Znith	0.20 m f/10 SCT	Clear	Moravian G2-1600 1x1 1.2"/pixel
171	0.25 m f/10 SCT	Clear	Moravian G2-1600 1x1 1.0"/pixel

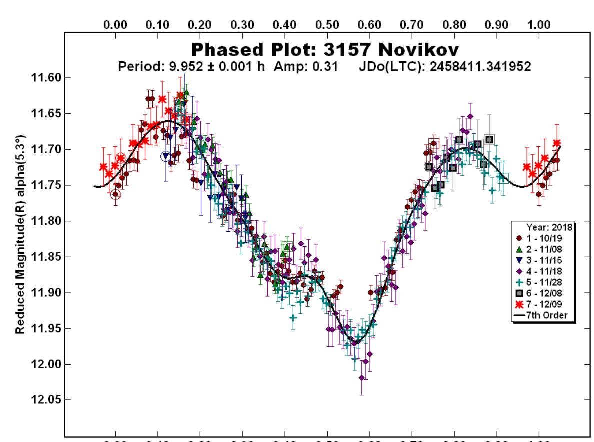
Table 1- Main features of the instruments used at the observatories involved in the research. MCT = Maksutov-Cassegrain; NEW = Newton; SCT = Schmidt-Cassegrain

Data processing and analysis were made with MPO Canopus (Warner, 2018). 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.

A search through the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) indicates that our results may be the first lightcurve observations and results for these objects, reported as lightcurve photometry opportunities in the Minor Planet Bulletin (Warner *et al.*, 2018).

3157 Novikov (1973 SX3) was discovered on 1973 Sept. 25 by L. Zhuravleva at Nauchnyj and it was named in memory of Aleksej Ivanovich Novikov (1916-1986), Soviet aviator and poet [Ref: Minor Planet Circ. 13175]. It is a main-belt asteroid with the semi-major axis of 3.150 AU, eccentricity 0.147, inclination 7.598 degrees and an orbital period of 5.59 years. Its absolute magnitude is H = 11.6 (JPL, 2019; MPC, 2019) while its diameter is D = 30.522 ± 0.306 km (Masiero *et al.*, 2014). Observations of this asteroid were carried on seven nights, collecting 308 data points. The power spectrum analysis shows several peaks with comparable amplitude. We excluded the solution associated at P=7.462 h since it is mono-modal and therefore much less likely; for similar reason we excluded the solution associated with P=14.926 h since it is tri-modal. Nevertheless, due to the bad observing condition which affected overall data quality, two close peaks still remain respectively around P=9.952 h and P=10.856 h. Both periods yield a bi-modal solution. We chose the bi-modal solution for the rotational period P = 9.952 ± 0.001 h with an amplitude A = 0.31 ± 0.04 mag which gives the least square residuals over the Fourier fit model. However further observations in the future would be greatly welcome to refine the proposed period.

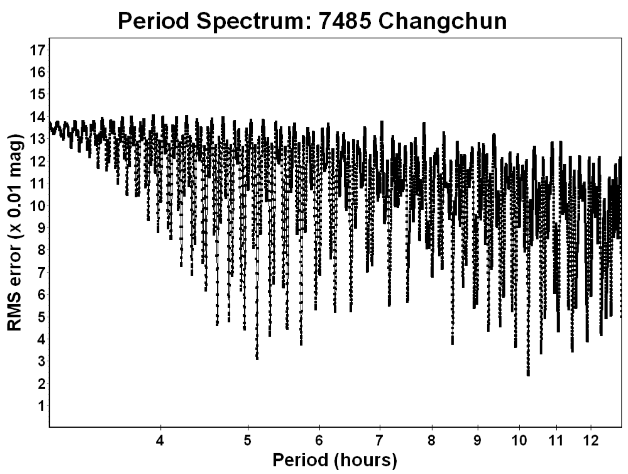


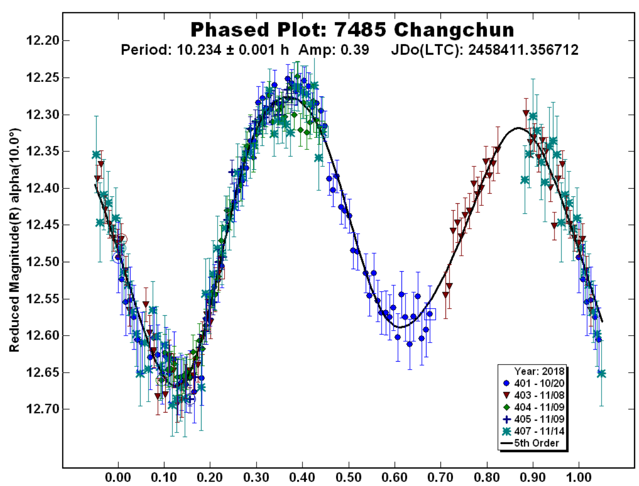


Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3157	Novikov	10/20-12/09	308	4.9,14.5	39	0	9.952	0.001	0.31	0.04
7485	Changchun	10/20-11/14	255	9.8, 9.6	38	-14	10.234	0.001	0.39	0.02

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).

7485 Changchun (1994 XO) was discovered on 1994 Dec. 4 by M. Koishikawa at the Ayashi Station of the Sendai Astronomical Observatory. It was named after the city of Changhun in China, which is the international sister city of Sendai, Japan, affiliated since 1980 [Ref: Minor Planet Circ. 33788]. It is a main-belt asteroid with the semi-major axis of 2.861 AU, eccentricity 0.197, inclination 13.337 degrees and an orbital period of 4.84 years. Its absolute magnitude is H = 12.0 (JPL, 2019; MPC, 2019) while its diameter is D = 10.787 ± 0.169 km (Masiero *et al*., 2011). Observations of this asteroid were conducted on five nights, collecting 255 data points. The period analysis shows a bimodal solution for the rotational period P = 10.234 ± 0.001 h with an amplitude A = 0.39 ± 0.02 mag.





References

Minor Planet Circulars (MPCs) are published by the International Astronomical Union's Minor Planet Center. *https://www.minorplanetcenter.net/iau/ECS/MPCArchive/MPCArchive_TBL.html*

DSFTA (2019). Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente – Astronomical Observatory. *https://www.dsfta.unisi.it/en/research/labs-eng/astronomical-observatory*

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

JPL (2019). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Masiero, J.R., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Dailey, J., Eisenhardt, P.R.M., McMillan, R.S., Spahr, T.B., Skrutskie, M.F., Tholen, D., Walker, R.G., Wright, E.L., DeBaun, E., Elsbury, D., Gautier, T., IV, Gomillion, S., Wilkins, A. (2011). "Main Belt Asteroids with WISE/NEOWISE. I. Preliminary Albedos and Diameters." *Astrophys. J.* **741**, A68.

Masiero, J.R., Grav, T., Mainzer, A.K., Nugent, C.R., Bauer, J.M., Stevenson, R., Sonnett, S. (2014). "Main-belt Asteroids with WISE/NEOWISE: Near-infrared Albedos." *Astrophys. J.* **791**, 121.

MPC (2019). MPC Database. *http://www.minorplanetcenter.net/db_search/*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Harris, A.W., Ďurech, J., Benner, L.A.M. (2018). "Lightcurve photometry opportunities: 2018 October-December." *MPB* **45**, 404-408.

Warner, B.D. (2018). MPO Software, MPO Canopus v10.7.7.0. Bdw Publishing. *http://minorplanetobserver.com*

ROTATION PERIOD DETERMINATION OF THREE MAIN BELT ASTEROIDS: 3769 ARTHURMILLER, 3995 SAKAINO AND (7520) 1990 BV

Alessandro Marchini
Astronomical Observatory, DSFTA - University of Siena (K54)
Via Roma 56, 53100 - Siena, ITALY
alessandro.marchini@unisi.it

Riccardo Papini, Massimo Banfi, Fabio Salvaggio
Wild Boar Remote Observatory (K49)
San Casciano in Val di Pesa (FI), ITALY

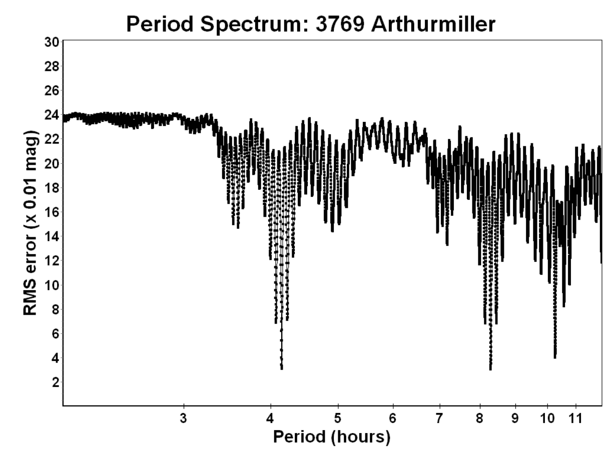
(Received: 2019 Jan 15 Revised: 2019 Feb 24)

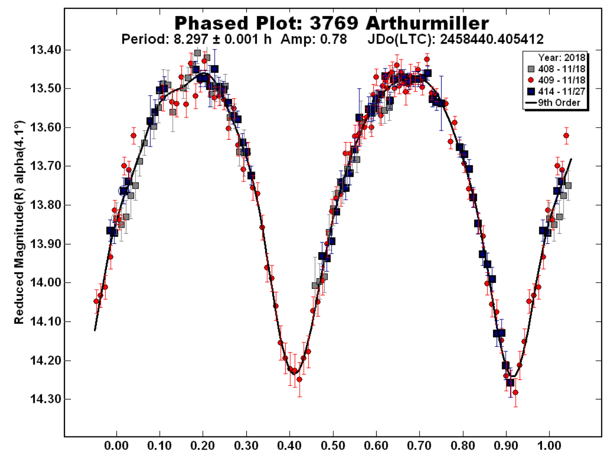
Photometric observations of three main-belt asteroids were conducted from the Astronomical Observatory of the University of Siena (Italy) in order to determine their synodic rotation periods. For 3769 Arthurmiller we found a period of 8.297 ± 0.001 h with an amplitude of 0.78 ± 0.01 mag, for 3995 Sakaino we found a period of 4.552 ± 0.001 h with an amplitude of 0.97 ± 0.02 mag and for (7520) 1990 BV we found a period of 3.828 ± 0.001 h with an amplitude of 0.26 ± 0.04 mag.

CCD photometric observations of three main-belt asteroids were carried on in 2018 November and December at the Astronomical Observatory of the University of Siena (K54), a facility inside the Department of Physical Sciences, Earth and Environment (DSFTA, 2019). 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, 2018). 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 3769 Arthurmiller and for (7520) 1990 BV. The LCDB shows that 3995 Sakaino was observed by Ditteon during 2017; he reported a rotational period of 4.553 h (Ditteon *et al.*, 2018) which is in good agreement with our findings. These objects were reported as lightcurve photometry opportunities in the Minor Planet Bulletin (Warner *et al.*, 2018).

3769 Arthurmiller (1967 UV) was discovered on 1967 Oct. 30 by L. Kohoutek and A. Kriete at Bergedorf. It was named after Arthur Miller (1915-2005), one of the greatest American playwrights and a prolific essayist and author. Miller's second marriage was with the famous actress Marilyn Monroe. The name was suggested by E. Bowell [Ref: Minor Planet Circ. 53952]. It is a main-belt asteroid with the semi-major axis of 2.265 AU, eccentricity 0.115, inclination 4.653 degrees and an orbital period of 3.41 years. Its absolute magnitude is H = 13.4 (JPL, 2019; MPC, 2019) while its diameter is D = 4.839 ± 0.162 km (Masiero *et al.*, 2011). Observations of this asteroid were conducted on three nights, collecting 199 data points. The period analysis shows a bimodal solution for the rotational period P = 8.297 ± 0.001 h with an amplitude A = 0.78 ± 0.01 mag.

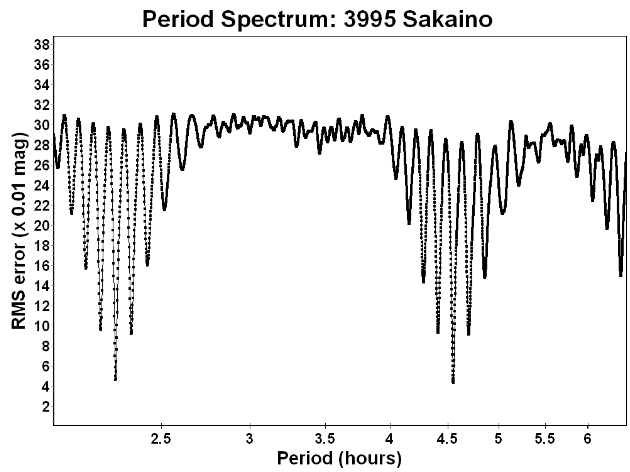


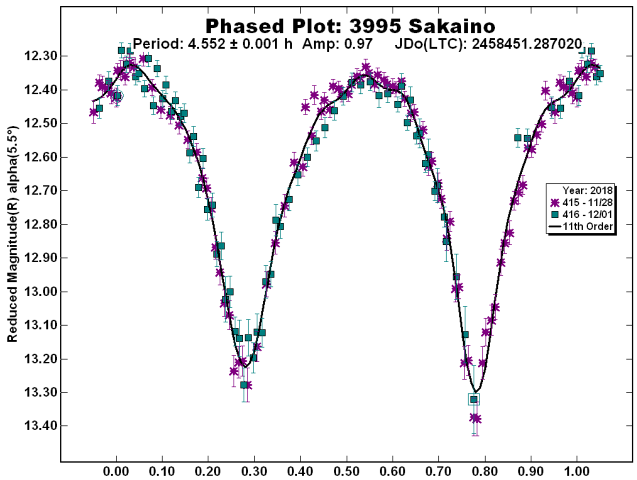


3995 Sakaino (1988 XM) was discovered on 1988 Dec. 5 by T. Kojima at Chiyoda and named in honor of Teruo Sakaino (b. 1917), a glass and ceramics chemist, professor emeritus of the Tokyo Institute of Technology and of the Wuhan (China) University of Engineering, known for his research on amorphous materials. In particular, he developed quantitative methods for estimating the quality of optical glass. He is also an amateur astronomer and a former teacher of the discoverer [Ref: Minor Planet Circ. 28089]. It is a main-belt asteroid with the semi-major axis of 2.635 AU, eccentricity 0.095, inclination 9.299 degrees and an orbital period of 4.28 years. Its absolute magnitude is H = 12.1 (JPL, 2019; MPC, 2019) while its diameter is D = 9.487 ± 0.480 km (Masiero *et al.*, 2012). Observations of this asteroid were conducted on two nights, collecting 159 data points. The period analysis shows a bimodal solution for the rotational period P = 4.552 ± 0.001 h with an amplitude A = 0.97 ± 0.02 mag.

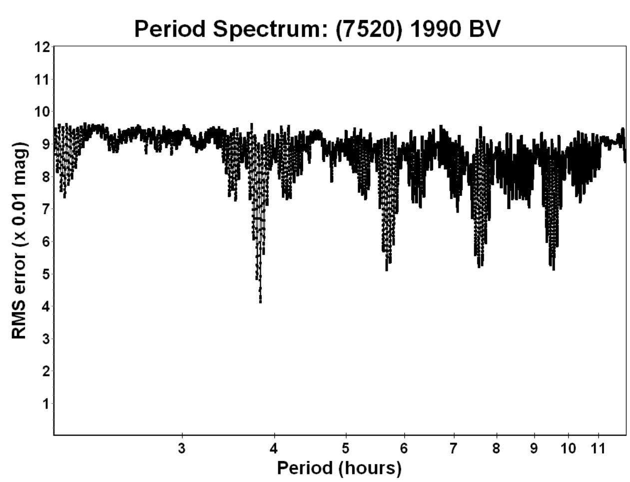
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
3769	Arthurmiller	11/17-11/27	199	4.2,1.5	62	1	8.297	0.001	0.78	0.01
3995	Sakaino	11/28-12/01	159	5.6,4.6	76	-5	4.552	0.001	0.97	0.02
7520	1990 BV	12/18-12/26	186	10.5,5.3	102	0	3.828	0.001	0.26	0.04

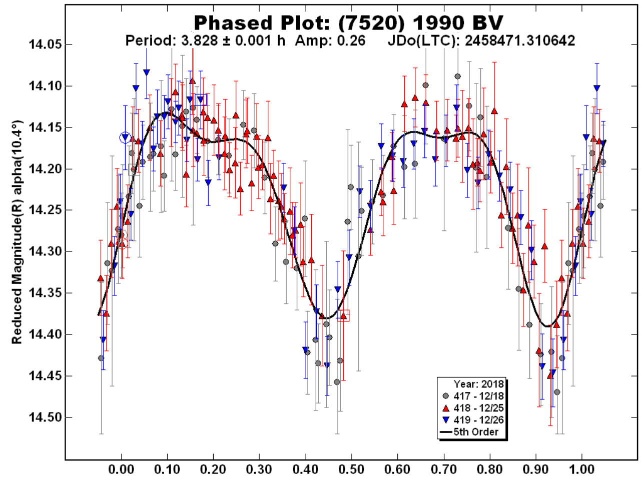
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).





(7520) 1990 BV was discovered on 1990 Jan. 21 by T. Hioki and S. Hayakawa at Okutama. It is a main-belt asteroid with the semi-major axis of 2.365 AU, eccentricity 0.226, inclination 10.563 degrees and an orbital period of 3.64 years. Its absolute magnitude is H = 13.6 (JPL, 2019; MPC, 2019) while its diameter is D = 9.861 ± 0.185 km (Masiero *et al*., 2011). Observations of this asteroid were conducted on three nights, collecting 186 data points. The period analysis shows a bimodal solution for the rotational period P = 3.828 ± 0.001 h with an amplitude A = 0.26 ± 0.04 mag.





References

Minor Planet Circulars (MPCs) are published by the International Astronomical Union's Minor Planet Center. *https://www.minorplanetcenter.net/iau/ECS/MPCArchive/MPCArchive_TBL.html*

Ditteon, R., Trent, L. (2018). "Lightcurve Analysis of Minor Planets Observed at the Oakley Southern Sky Observatory: 2017 June-July" *MPB* **45**, 328-329.

DSFTA (2019). Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente – Astronomical Observatory. *https://www.dsfta.unisi.it/en/research/labs-eng/astronomical-observatory*

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

JPL (2019). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Masiero, J.R., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Dailey, J., Eisenhardt, P.R.M., McMillan, R.S., Spahr, T.B., Skrutskie, M.F., Tholen, D., Walker, R.G., Wright, E.L., DeBaun, E., Elsbury, D., Gautier, T., IV, Gomillion, S., Wilkins, A. (2011). "Main Belt Asteroids with WISE/NEOWISE. I. Preliminary Albedos and Diameters." *Astrophys. J.* **741**, A68.

Masiero, J.R., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Nugent, C., Cabrera, M.S. (2012). "Preliminary Analysis of WISE/NEOWISE 3-Band Cryogenic and Post-cryogenic Observations of Main Belt Asteroids." *Astrophys. J. Letters* **759**.

MPC (2019). MPC Database. *http://www.minorplanetcenter.net/db_search/*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Harris, A.W., Ďurech, J., Benner, L.A.M. (2018). "Lightcurve photometry opportunities: 2018 October-December." *MPB* **45**, 404-408.

Warner, B.D. (2018). MPO Software, MPO Canopus v10.7.7.0. Bdw Publishing. *http://minorplanetobserver.com*

THE ROTATION PERIOD OF (32209) 2000 OW9

Xing Gao
Urumqi No.1 Senior High School
No.192, West Second Street, Kanas Lake Road,
Urumqi, Xinjiang, CHINA PR
webmaster@xjltp.com

Hanjie Tan
Department of Physics
National Central University
No.300 Zhongda Rd., Taoyuan, TAIWAN

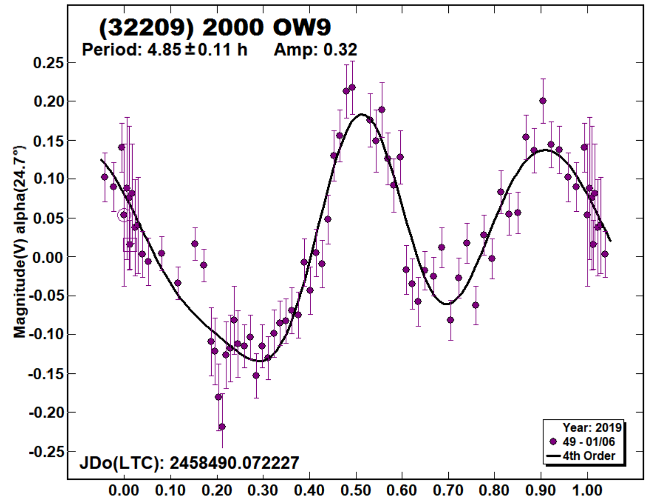
(Received: 2019 Jan 15)

Lightcurve photometry observations of the main-belt asteroid (32209) 2000 OW9 were made at Xingming Observatories on 2019 Jan 6. We find that the asteroid has a synodic rotation period of 4.85 ± 0.11 h and amplitude of 0.32 ± 0.04 mag.

We used the Ningbo bureau of Education and Xinjiang Observatory Telescope (NEXT: 60-cm *f*/8.0 Ritchey-Chretien + LI PL230 CCD) at Xingming Observatory (IAU Code C42) to obtain lightcurves of the main-belt asteroid (32209) 2000 OW9 on 2016 Jan 6. The image scale was 0.64 arcsec/pixel. Exposures with an R-filter were either 90 or 300 sec.

All images were calibrated using standard procedures, including flat-correction and dark and bias frames using *Maxim DL*. *MPO Canopus* was used to analyze the data.

32209 (2000 OW9) was discovered on 2000 Jul 23 by LINEAR. The only previously published lightcurve is by Warner (2010) who reported a period of 4.559 h and amplitude of 0.21 mag. Our data analysis shows a bimodal lightcurve with a synodic rotation period of P = 4.85 ±0.11 h and amplitude of A = 0.32 ± 0.04 mag, which disagrees with Warner (2010). Further observations are needed to confirm an accurate rotation period.



References

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 Nov. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner B.D. (2010). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 June-September." *Minor Planet Bull.* **37**, 24-27.

Number	Name	2019/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
32209	2000 OW9	01/06-01/06	69	24.7,24.8	49	10	4.85	0.11	0.32	0.04	MB-M

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given 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).

MID-INFRARED LIGHTCURVES OF (523806) 2002 WW17

Roc M. Cutri
California Institute of Technology, IPAC MS 100-22
Pasadena, CA 91125
roc@ipac.caltech.edu

Joseph Masiero
NASA Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109
Joseph.Masiero@jpl.nasa.gov

S. Sonnett
Planetary Science Institute, 1700 E. Fort Lowell Rd.
Tucson, AZ 85719-2395
ssonnett@psi.edu

A. Mainzer
NASA Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109
Amy.Mainzer@jpl.nasa.gov

(Received: 2019 Jan 15)

We present 4.6 and 3.4 micron lightcurves of the Amor class near-Earth asteroid (523806) 2002 WW17 constructed from NEOWISE measurements in 2018 October and December. The lightcurve from the December measurements exhibit a 10.51 ± 0.08 hour period with a maximum amplitude of variation of nearly two magnitudes. The October lightcurve has a period consistent with that measured in December, but with an amplitude of approximately 0.8 mag.

Asteroid (523806) 2002 WW17 is an Amor class near-Earth asteroid that was first identified by the NEAT survey on Haleakala (Helin et al. 1997). At the time of this writing, there is no lightcurve for the object in the LCDB (Warner et al. 2009) or a reported period.

The Near-Earth Object Wide-field Infrared Explorer (NEOWISE; Mainzer et al. 2014) observed the position of 2002 WW17 in 2018 October 18-21 and again in 2018 December 15-19. NEOWISE acquires series of images simultaneously in the 3.4 (W1) and 4.6 (W2) micron bands as it scans from pole-to-pole along lines of constant ecliptic longitude. Each fixed point on the sky is imaged 12-15 times with a cadence of 190 minutes as the NEOWISE scan longitude advances along the sky. The number of times a solar system object is observed by NEOWISE varies depending on how the trajectory and angular velocity compare with the survey cadence. A description of NEOWISE data reduction, photometry and calibration is given in Cutri et al. (2015).

During 2018 December, NEOWISE observed 2002 WW17 a total of 38 times when the asteroid was 0.68-0.69 AU from the Earth. The asteroid was detected with high signal-to-noise in the W2 band during each of the 38 observations, and at lower signal-to-noise in the W1 band. A Lomb-Scargle periodogram analysis of the W2 lightcurve yields a rotation period of 10.51±0.08 hours, where the uncertainty is computed from the half-width at the half-maximum of the peak in the power spectrum. The phase-folded W2 curve is shown in the top panel of Figure 1. The W1 lightcurve phased to the same period is shown in the lower panel. The lightcurves are slightly asymmetric with a maximum amplitude of approximately 1.9 mag in both bands, and a secondary amplitude of approximately 1.3 mag. There is no significant variation in the [3.4] – [4.6] micron color of the object over the rotation phase, as illustrated in Figure 2.

2002 WW17 was observed 26 times by NEOWISE during 2018 October when the object was at a distance of approximately 1.3 AU from the Earth, and therefore considerably fainter. The asteroid was detected in the W2 band during each observation, although two of the detections are corrupted by cosmic rays or image artifacts and are not included in this analysis. There were 7 nominal detections in W1, but all have very low signal-to-noise levels (2 to 5). An independent determination of the period is not possible with the much fainter October W2 measurements. However, the W2 lightcurve phased to the period determined from the December observations shown in Figure 3 is consistent with the phased lightcurve from December, but with a much smaller amplitude of variation, approximately 0.7-0.8 mag.

Large lightcurve amplitudes imply a highly elongated and/or binary object with components of similar sizes. A few objects in the LCDB have similar amplitudes to 2002 WW17, for example (1620) Geographos, which radar observations have shown to be extremely elongated (e.g. Hudson and Ostro 1999; Rozitis and Green 2014). However, the lightcurve of 2002 WW17 has a suggestion of a flat bottom at one minimum, which may imply a binary eclipse event.

Acknowledgements

This publication makes use of data products from the Near-Earth Object Wide-field Survey Explorer (NEOWISE), which is a project of the Jet Propulsion Laboratory/California Institute of Technology. NEOWISE is funded by the National Aeronautics and Space Administration.

References

Cutri, R.M. et al. (2015). “Explanatory Supplement to the NEOWISE Data Release Products.” *http://wise2.ipac.caltech.edu/docs/release/neowise/expsup*

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

Helin, E.F, Pravdo, S.H, Rabinowitz, D.L, Lawrence, K.J. (1997). “Near Earth Asteroid Tracking Program.” *NYASA*, **822**, 6.

Hudson, R.S. Ostro, S.J. (1999). “Physical Model of Asteroid 1620 Geographos from Radar and Optical Data.” *Icarus*, **140**, 369.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
523806	2002 WW17	2018 10/18-21	24	37.2,37.8	98.1	3.1	-	-	0.8		Amor
523806	2002 WW17	2018 12/15-19	38	54.5,56.0	145.6	21.1	10.51	0.08	1.9		Amor

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).

Mainzer, A. et al. (2014). “Initial Performance of the NEOWISE Reactivation Mission.” *ApJ*, **792**, 30.

Rozitis, B.. Green, S.F. (2014). “Physical characterization of near-Earth asteroid (1620) Geographos. Reconciling radar and thermal-infrared observations.” *AsAp*, **568**, 11.

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

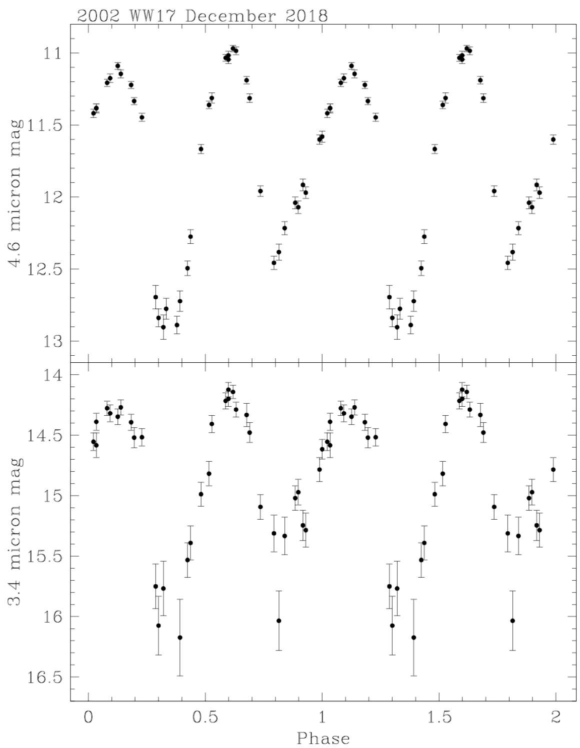


Figure 1 - 4.6 micron (top) and 3.4 micron (bottom) lightcurves for (523806) 2002 WW17 from the 2018 December NEOWISE observations phased to a period of 10.5106 hours.

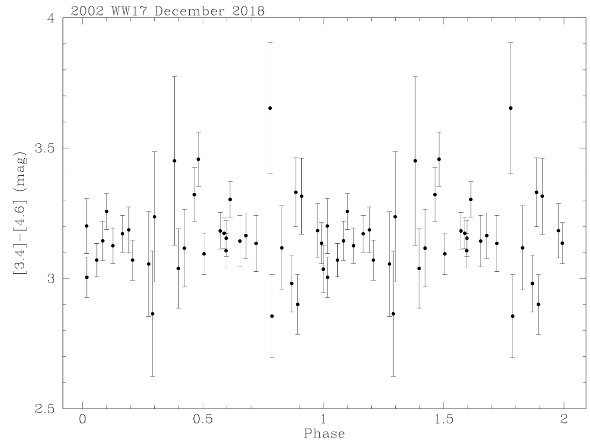


Figure 2 - 3.4 micron - 4.6 micron color curve for (523806) 2002 WW17 from the 2018 December NEOWISE observations phased to a period of 10.5106 hours.

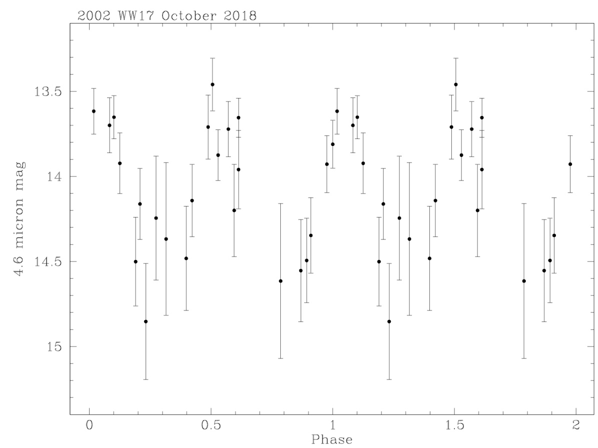


Figure 3 - 4.6 micron lightcurve for (523806) 2002 WW17 from the 2018 October NEOWISE observations phased to a period of 10.5106 hours.

ROTATION PERIOD DETERMINATION OF THE ASTEROID 5321 JAGRAS (1985 VN)

Riccardo Papini, Massimo Banfi, Fabio Salvaggio
Wild Boar Remote Observatory (K49)
via Potente 52, 50026 San Casciano in val di Pesa (FI), ITALY
riccardo.papini@yahoo.it

Alessandro Marchini
Astronomical Observatory, DSFTA - University of Siena (K54)
Via Roma 56, 53100 – Siena, ITALY

Lorenzo Franco
Balzaretto Observatory (A81), Rome, ITALY

(Received: 2019 Jan 15)

Photometric observations were made in 2018 of the main-belt asteroid 5321 Jagras (1985 VN). Analysis of the collected data suggests a period of 2.638 ± 0.001 h.

Photometric observations of the main-belt asteroid 5321 Jagras (1985 VN) were taken at the Astronomical Observatory of the University of Siena (K54), Italy, and at the Wild Boar Remote Observatory (K49), Italy. Exposure time was 300 seconds at both the observatories. Table I shows the main features of the instruments used at the observatories involved in the research while Table II gives the observation circumstances and results.

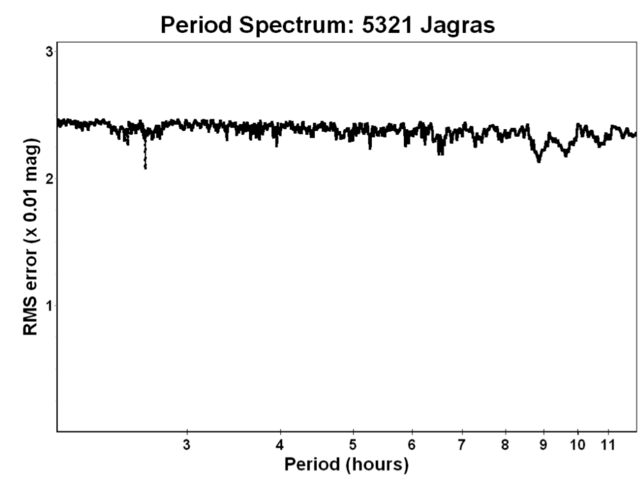
Observatory	Telescope	Filter	CCD
K54	0.30 m f/5.6 MCT	Clear	SBIG STL-6303 2x2 2.3"/pixel
K49	0.24 m f/10 SCT	Clear	SBIG ST8-XME 2x2 1.6"/pixel

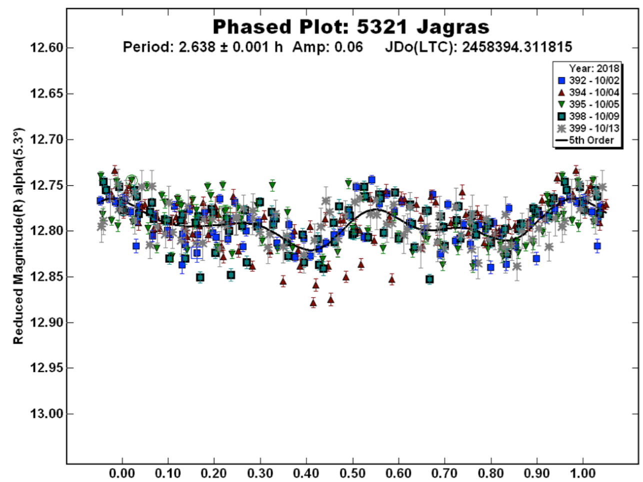
Table 1- Main features of the instruments used at the observatories involved in the research. MCT = Maksutov-Cassegrain; SCT = Schmidt-Cassegrain

The authors performed differential photometry measurements using the Comp Star Selector (CSS) procedure in *MPO Canopus* (Warner, 2018) that allows selecting of up to five comparison stars of near solar color. The magnitudes from the CMC-15 catalog (Munos, 2017) were used for the comparison stars. Period analysis was performed using *MPO Canopus* and its FALC (Fourier Analysis for Light Curves) algorithm (Harris *et al.*, 1989). In the end we carried out additional adjustments of the magnitude zero-points for each data set out in order to reach the minimum RMS value from the Fourier analysis and so achieve the best alignment among lightcurves.

A search of the Asteroid Light Curve Database (LCDB; Warner *et al.*, 2009) and literature found no previous entries.

5321 Jagras (1985 VN) is a middle main-belt asteroid and was discovered at Brorfelde on 1985-11-14 by P. Jensen, K. Augustesen, and H. J. Fogh Olsen. Named in honor of Jakob Grove Rasmussen, fiancé of the daughter of the third discoverer, currently graduating in astronomy at the Copenhagen Observatory. [Ref: Minor Planet Circ. 29144].





Observations were made on five nights from 2018 October, 2nd to October 13th, collecting 394 useful data points. The very low amplitude and the associated high dispersion makes very difficult the period analysis. The low amplitude might be the result from a spheroidal shape of the body or from a polar view caused by the geometrical condition of the orbit at this opposition. However, the period analysis yielded two possible solutions with nearly comparable RMS values. We concluded that the most likely value of the synodic period is associated with a bimodal lightcurve phased to 2.638 ± 0.001 h with an amplitude of 0.06 ± 0.02 mag. Further observations during next opposition would be welcome in order to verify the lightcurve and therefore the rotational period here proposed. In the end, despite of the dispersion, a few attenuations in the lightcurve are visible and they are worth of further observations.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
5321	Jagras (1985 VN)	10/02-12/12	394	5.2,4.0	15	5	2.638	0.001	0.06	0.02

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first date and the 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).

References

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

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

JPL (2018). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Munos, J.L. (2017). Carlsberg Meridian Catalog web site. http://svo2.cab.inta-csic.es/vocats/cmc15/

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2016 Sept. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B. D. (2018). MPO Software, Canopus version 10.7.12.1. Bdw Publishing. *http://minorplanetobserver.com*

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2019 APRIL-JUNE

Brian D. Warner
Center for Solar System Studies / MoreData!
446 Sycamore Ave.
Eaton, CO 80615 USA
brian@MinorPlanetObserver.com

Alan W. Harris
MoreData!
La Cañada, CA 91011-3364 USA

Josef Ďurech
Astronomical Institute
Charles University
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance.benner@jpl.nasa.gov

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 or might be radar targets. 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 2019 April through June.

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

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

The ephemeris generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.0 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 3.2 million observations for more than 13380 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 (sometimes 15.0 when the list has more than 100 objects.

<u>Lightcurve/Photometry Opportunities</u>

Objects with U = 3– or 3 are excluded from this list since they will likely appear in the list 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).

Number	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
3070	Aitken	04 01.5	15.1	-3	6.396	0.38	2
13859	Fredtreasure	04 04.8	15.1	-27			
22262	1980 PZ2	04 05.9	15.4	-26		0.81	
1031	Arctica	04 08.4	13.6	-16	51.	0.22	2
9652	1996 AF2	04 08.8	15.3	-17	4.385	0.10-0.16	2
927	Ratisbona	04 09.2	13.6	-12	12.994	0.12	2
2795	Lepage	04 14.9	15.3	-11			
24473	2000 UK98	04 15.2	15.0	-12			
33933	2000 LE29	04 15.2	15.5	-8	2.447	0.35-0.46	2
3810	Aoraki	04 16.2	15.2	-18	29.807	0.05-0.06	1
1622	Chacornac	04 18.7	13.8	-16	12.206	0.21-0.25	2
1516	Henry	04 24.8	14.4	+3	17.37	0.04-0.54	2
6076	Plavec	04 26.1	15.3	+0			
4408	Zlata Koruna	05 02.1	15.0	-15			
1744	Harriet	05 04.6	15.1	-18			
2433	Sootiyo	05 06.0	13.7	-5	7.2298	0.4-0.54	2+
4675	Ohboke	05 07.1	14.8	-25			
494	Virtus	05 11.6	12.6	-20	5.57	0.03-0.12	2+
4810	Ruslanova	05 11.7	15.1	-18			
4676	Uedaseiji	05 13.8	15.3	-15		0.57	
10226	Seishika	05 13.8	15.2	-25			
9297	Marchuk	05 15.7	14.9	-15	18.09	0.16	2
7514	1986 ED	05 22.4	15.3	-23		0.6	
5486	1991 UT2	05 23.1	15.5	-20	17.9	0.25	2+
9145	Shustov	05 23.4	15.3	-30	3.812	0.29	2
2956	Yeomans	05 23.5	15.4	-17	3.4	0.24-0.28	2
9970	1992 ST1	05 25.8	15.5	-33			
6392	Takashimizuno	05 26.5	15.5	-27	21.81	0.48	2
1068	Nofretete	05 26.9	14.1	-30	6.15	0.04	2
953	Painleva	05 28.5	12.9	-29	7.389	0.05-0.05	2-
4449	Sobinov	05 29.2	15.4	-27			
20423	1998 VN7	05 30.3	14.9	-27			
7319	Katterfeld	05 30.9	15.3	-25			
6094	Hisako	05 31.9	15.2	-12	4.05	0.14-0.22	1+
21923	1999 VT52	06 01.0	15.1	-18			
3167	Babcock	06 02.7	14.2	-45	15.45	0.30	2
3570	Wuyeesun	06 03.5	14.9	-18	15.459	0.45	2
1968	Mehltretter	06 03.8	14.4	-22			
12853	1998 FZ97	06 04.1	15.4	-18			
15276	Diebel	06 08.6	15.5	-6			
6381	Toyama	06 08.8	15.2	-15	27.	0.13	2-
4594	Dashkova	06 08.9	15.5	-13	65.423	0.70	2
40429	1999 RL27	06 09.1	15.4	-40	>24.	0.1	1
3543	Ningbo	06 09.4	15.2	-21			
2145	Blaauw	06 09.6	15.0	-25	12.141	0.18	2+
4654	Gor'kavyj	06 09.6	15.4	-33		0.1	
4795	Kihara	06 11.1	15.2	-14	16.03	0.25	2
897	Lysistrata	06 12.7	12.9	-22	11.26	0.11	2
2784	Domeyko	06 13.0	14.2	-16	5.98	0.15	2
7228	MacGillivray	06 13.4	15.5	-20			
9971	Ishihara	06 14.3	15.3	-28	6.715	1.06	2
2190	Coubertin	06 14.9	15.5	-23			
3837	Carr	06 15.2	15.3	-19			
5445	Williwaw	06 18.4	14.1	-22			
6139	Naomi	06 19.1	15.1	-25	21.35	0.20	2+

(cont'd)

Number	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
26356	Aventini	06 19.8	15.5	-19			
99795	2002 KM6	06 20.4	14.8	-30		0.4	
14000	1993 FZ55	06 23.8	15.5	-14			
4381	Uenohara	06 24.0	15.2	-19			
12268	1990 OY1	06 24.3	15.4	-27			
8160	1990 MG	06 24.6	15.0	-24	3.719	0.38	2
21383	1998 EC9	06 25.1	15.5	-25			
21914	Melakabinoff	06 25.6	15.5	-17			
6898	Saint-Marys	06 26.7	15.1	-22			
10145	***1994 CK1***	***06 27.6***	***14.6***	***-47***			
2081	Sazava	06 28.4	14.0	-27			
1893	Jakoba	06 28.5	15.2	-32	23.9	0.1	1+
2714	Matti	06 28.6	13.9	-15	9.	0.25	2
2281	Biela	06 29.0	14.9	-20	4.929	0.09	2
10212	1997 RA7	06 29.4	15.5	-20	9.154	0.88-1.05	2
2591	Dworetsky	06 29.5	15.1	-26	12.77	0.45	2
1634	Ndola	06 29.6	14.0	-25	64.23	0.4	2

<u>Low Phase Angle Opportunities</u>

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 α > 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
1469	Linzia	04 05.0	0.59	14.4	-04	22.215	0.07-0.09	3
57	Mnemosyne	04 07.7	0.23	11.7	-07	12.463	0.02-0.14	3
904	Rockefellia	04 08.3	0.12	14.4	-07	6.826	0.10-0.18	2
518	Halawe	04 09.3	0.36	14.5	-08	14.310	0.50-0.55	3
229	Adelinda	04 09.8	0.13	14.2	-07	6.60	0.04-0.30	3
444	Gyptis	04 11.9	0.48	12.1	-07	6.214	0.10-0.18	3
1058	Grubba	04 12.3	0.98	14.5	-11	46.30	0.10-0.24	3
572	Rebekka	04 12.5	0.80	14.5	-07	5.6497	0.19-0.40	3
540	Rosamunde	04 13.3	0.20	12.4	-09	9.351	0.40-0.66	3
361	Bononia	04 13.8	0.32	13.9	-10	13.835	0.17-0.25	3
67	Asia	04 14.0	0.08	11.1	-09	15.853	0.22-0.26	3
1204	Renzia	04 20.3	0.55	14.4	-13	7.885	0.42-0.49	3
73	Klytia	04 29.3	0.71	12.6	-16	8.297	0.26-0.35	3
735	Marghanna	05 02.0	0.29	13.7	-14	20.62	0.11-0.13	3-
1289	Kutaissi	05 02.0	0.41	14.4	-14	3.60	0.20-0.42	3

(cont'd)

Num	Name	Date	α	V	Dec	Period	Amp	U
631	Philippina	05 03.0	0.56	12.2	-17	5.899	0.06-0.69	3
438	Zeuxo	05 03.5	0.63	12.6	-14	8.831	0.13-0.14	3
551	Ortrud	05 03.9	0.12	13.9	-16	17.416	0.14-0.19	3
102	Miriam	05 08.0	0.73	13.2	-15	23.613	0.04-0.14	3
957	Camelia	05 08.8	0.69	14.0	-19	150.	0.30	1+
19	Fortuna	05 09.6	0.29	10.7	-17	7.4432	0.23-0.30	3
494	Virtus	05 11.5	0.84	12.6	-20	5.57	0.03-0.12	2+
806	Gyldenia	05 12.7	0.92	14.3	-21	16.852	0.10-0.27	3
68	Leto	05 14.8	0.69	10.6	-21	14.848	0.10-0.53	3
311	Claudia	05 18.6	0.71	13.8	-18	7.532	0.16-0.89	3
936	Kunigunde	05 19.9	0.10	14.2	-20	8.80	0.25	2
20	Massalia	05 20.6	0.28	9.7	-19	8.098	0.17-0.27	3
2582	Harimaya-Bash	05 22.3	0.73	14.5	-22	7.238	0.21-0.24	3
685	Hermia	05 24.0	0.45	13.7	-20	50.40	0.86-0.92	3
823	Sisigambis	05 26.7	0.50	13.8	-22	146.	0.7	2
106	Dione	06 01.8	0.28	12.3	-23	16.210	0.08-0.18	3
1968	Mehltretter	06 03.8	0.13	14.5	-22			
223	Rosa	06 06.9	0.39	14.3	-24	20.283	0.06-0.13	3
514	Armida	06 09.0	0.36	13.2	-24	21.851	0.16-0.27	3
897	Lysistrata	06 12.7	0.66	12.9	-22	11.26	0.11	2
179	Klytaemnestra	06 14.9	0.82	12.1	-21	11.173	0.35-0.55	3
1001	Gaussia	06 15.3	0.32	14.5	-22	20.99	0.11-0.16	3
147	Protogeneia	06 17.1	0.28	12.9	-23	7.8528	0.25-0.28	3
49	Pales	06 17.8	0.44	12.5	-25	20.705	0.17-0.18	3
5445	Williwaw	06 18.5	0.74	14.1	-22			
177	Irma	06 19.0	0.71	13.4	-25	13.856	0.24-0.37	3
517	Edith	06 22.7	0.11	14.2	-24	9.2747	0.08-0.18	3
2013	Tucapel	06 22.8	0.81	13.3	-22	9.028	0.34	3
62	Erato	06 27.9	0.47	13.4	-22	9.2213	0.12-0.22	3
1063	Aquilegia	06 28.2	0.15	13.7	-23	5.792	0.75-0.93	3
586	Thekla	06 30.3	0.57	13.6	-21	13.670	0.24-0.30	3

Shape/Spin Modeling Opportunities

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

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

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

Included in the list below are objects that:

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

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

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

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
295	Theresia	04 03.4	14.3	-9	10.702	0.11-0.22	3
793	Arizona	04 04.0	14.6	+4	7.399	0.22-0.25	3
326	Tamara	04 04.5	12.0	+12	14.445	0.10-0.27	3
905	Universitas	04 05.5	14.8	-3	14.238	0.22-0.33	3
3309	**Brorfelde**	**04 06.0**	**14.8**	**+9**	**2.5041**	**0.09-0.23**	**3**
554	Peraga	04 06.2	12.5	-11	13.7128	0.11-0.28	3
1044	Teutonia	04 08.8	14.0	-3	3.153	0.20-0.32	3
1172	Aneas	04 08.8	15.4	-21	8.705	0.06-0.62	3
1867	Deiphobus	04 08.9	15.4	-37	58.66	0.10-0.27	3-
4580	**Child**	**04 08.9**	**15.1**	**+3**	**4.181**	**0.30-0.50**	**3**
137170	1999 HF1	04 09.6	15.2	+58	2.319	0.12-0.26	3
444	Gyptis	04 12.0	12.1	-7	6.214	0.10-0.18	3
67	Asia	04 14.0	11.1	-9	15.853	0.22-0.26	3
1116	Catriona	04 14.7	14.4	-21	8.832	0.09-0.20	3
772	Tanete	04 16.4	12.5	+20	17.258	0.07-0.18	3
194	Prokne	04 20.7	11.6	+10	15.679	0.08-0.27	3
3451	Mentor	04 21.2	15.4	+4	7.702	0.13-0.63	3
530	Turandot	04 21.9	14.2	+0	19.96	0.10-0.16	3-
788	**Hohensteina**	**04 22.7**	**12.4**	**+0**	**37.137**	**0.10-0.18**	**3**
604	Tekmessa	04 23.0	14.6	-14	5.560	0.43-0.60	3
308	Polyxo	05 01.2	11.7	-11	12.029	0.08-0.15	3-
551	Ortrud	05 03.9	13.9	-16	17.416	0.14-0.19	3
2951	Perepadin	05 05.5	14.3	-24	4.781	0.54-0.76	3
303	Josephina	05 06.9	13.5	-25	12.497	0.12-0.15	3
102	Miriam	05 08.2	13.2	-15	23.613	0.04-0.14	3
806	**Gyldenia**	**05 12.6**	**14.3**	**-21**	**16.852**	**0.10-0.27**	**3**
145	Adeona	05 23.7	11.9	-15	15.071	0.04-0.15	3
11116	**1996 EK**	**05 25.5**	**15.2**	**-3**	**4.4017**	**0.08-0.10**	**3-**
3782	**Celle**	**05 29.0**	**14.8**	**-25**	**3.84**	**0.11-0.17**	**3**
301	Bavaria	05 29.8	13.6	-14	12.253	0.25-0.31	3
375	Ursula	06 03.5	11.8	-45	16.899	0.04-0.17	3
1626	Sadeya	06 05.7	15.5	-40	3.42	0.07-0.22	3
3105	Stumpff	06 05.9	15.2	-11	5.037	0.32-0.46	3
1866	Sisyphus	06 08.1	12.9	-73	2.4	0.02-0.14	3
514	Armida	06 09.1	13.2	-24	21.851	0.16-0.27	3
461	Saskia	06 11.9	15.3	-21	7.348	0.25-0.36	3
91	Aegina	06 14.9	12.6	-26	6.025	0.12-0.27	3
288	Glauke	06 17.8	12.7	-19	1170.	0.36- 0.9	3
177	Irma	06 19.1	13.4	-25	13.856	0.24-0.37	3
2763	Jeans	06 19.6	14.5	-28	7.8	0.13-0.18	3
517	Edith	06 22.8	14.2	-24	9.275	0.08-0.18	3
74	Galatea	06 24.1	12.3	-17	17.268	0.08-0.16	3
5143	Heracles	06 30.0	14.3	+21	2.706	0.05-0.22	3
586	Thekla	06 30.3	13.6	-21	13.67	0.24-0.30	3
5104	Skripnichenko	06 30.9	15.5	+1	2.827	0.21-0.30	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
http://www.naic.edu/~pradar/ephemfuture.txt

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. 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, NPAR for a tumbler, and/or "BIN" to indicate the asteroid is a binary (or multiple) system. "BIN?" means that the asteroid is a suspected 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; "G" is for Goldstone. The calculator SNRs for Arecibo are based on a reduced power of 600 kW to account for problems as of mid-January 2019.

Asteroid	Period	Amp	App	Last	R SNR
(22771) 1999 CU3 NEA	3.782	0.12 1.25	3	2017	A 25 G -
2016 GW221 NEA	**-**	**-**	**-**	**-**	**A 70 G 12**
(152931) 2000 EA107 NEA	**4.137**	**0.28**	**1**	**2010**	**A 45 G -**
(297300) 1998 SC15 NEA	-	-	-	-	A 10 G -
(522684) 2016 JP NEA	**-**	**-**	**-**	**-**	**A 120 G 20**
(250697) 2005 QY151 NEA	-	-	-	-	A 15 G -
(141525) 2002 FV5 NEA	-	-	-	-	A 40 G -
2009 FU23 NEA PHA	**-**	**-**	**-**	**-**	**A 12 G -**
2018 XG5 NEA PHA	**-**	**-**	**-**	**-**	**A 70 G 12**
2008 HS3 NEA PHA	**-**	**-**	**-**	**-**	**A 245 G 40**
(12538) 1998 OH NEA BIN?	5.154	0.10 0.20	3	2018	A 35 G -
(68950) 2002 QF15 NEA PHA	**47**	**0.35**	**2**	**2006**	**A 1490 G 250**
(66391) 1999 KW4 NEA BIN PHA	**2.765**	**0.12 0.14**	**3**	**2018**	**A 12500 G 2080**
2011 HP NEA	**3.942**	**0.33**	**1**	**2011**	**A 575 G 95**
(5604) 1992 FE NEA	5.3375	0.10 0.21	5	2017	A 60 G 10
(494999) 2010 JU39 NEA PHA	**-**	**-**	**-**	**-**	**A 220 G 35**
(441987) 2010 NY65 NEA PHA	**4.973**	**0.16 0.24**	**3**	**2018**	**A 4450 G 745**
(10145) 1994 CK1 NEA	-	-	-	-	A 205 G 35
(418900) 2009 BE2 NEA	-	-	-	-	A 35 G -

Table I. Summary of radar-optical opportunities for the current quarter. Period and amplitude data are from the asteroid lightcurve database (Warner *et al.,* 2009; *Icarus* **202**, 134-146). SNR values are *estimates* that are affected by power output of the radar along with rotation period, size, and distance. They are given for relative comparisons among the objects in the list.

The SNRs were calculated using the current MPCORB absolute magnitude (H), a period of 4 hours (2 hours if $D \leq 200$ m) if it's not known, and the approximate minimum Earth distance during the current quarter.

If the SNR value is in bold text, the object was found on the radar planning pages listed above. Otherwise, the planning 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 is usually placed on the list only if the estimated Arecibo SNR > 10 when using the SNR calculator mentioned above.

(22771) 1999 CU3 (*H* = 16.8)

The estimated diameter is 1.3 km for this NEA. The adopted rotation period in the asteroid lightcurve database (LCDB; Warner et al., 2009) is 3.782 hr. The asteroid is much farther north in June, but the solar elongation is only 45°.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	13 46.0	-56 22	0.20	1.13	15.3	45.5	126	92	-0.17	+6
04/02	13 47.5	-58 54	0.20	1.12	15.3	47.4	124	98	-0.10	+3
04/03	13 49.2	-61 34	0.19	1.11	15.3	49.4	122	103	-0.05	+1
04/04	13 51.4	-64 21	0.19	1.11	15.3	51.6	120	108	-0.02	-2
04/05	13 54.1	-67 15	0.18	1.10	15.3	53.9	118	112	+0.00	-5
04/06	13 57.6	-70 16	0.18	1.09	15.3	56.3	115	114	+0.01	-8
04/07	14 02.5	-73 23	0.17	1.08	15.3	58.9	113	115	+0.03	-11
04/08	14 09.8	-76 35	0.17	1.07	15.3	61.5	110	116	+0.07	-14
04/09	14 21.9	-79 51	0.17	1.06	15.4	64.3	107	116	+0.13	-18
04/10	14 45.8	-83 07	0.17	1.05	15.4	67.1	104	115	+0.21	-21

2016 GW221 (*H* = 24.8)
The time when this asteroid is V < 19 is short: about 10 days in mid-April. There was no period in the LCDB. The estimated diameter is only 30 meters, which greatly increases the chances that the period is *P* << 2 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/11	15 37.1	+11 06	0.03	1.02	18.7	38.9	140	134	+0.31	+48
04/12	15 12.7	+10 58	0.03	1.03	18.5	33.2	146	117	+0.41	+53
04/13	14 48.2	+10 42	0.03	1.03	18.4	27.9	151	99	+0.53	+58
04/14	14 24.2	+10 18	0.03	1.03	18.3	23.4	156	81	+0.64	+62
04/15	14 01.2	+09 48	0.03	1.03	18.3	20.1	159	62	+0.75	+66
04/16	13 39.6	+09 14	0.03	1.03	18.3	18.5	161	43	+0.84	+69
04/17	13 19.7	+08 37	0.03	1.03	18.4	18.8	161	24	+0.92	+70
04/18	13 01.5	+07 59	0.03	1.04	18.5	20.4	159	9	+0.97	+71
04/19	12 45.1	+07 21	0.04	1.04	18.7	22.8	156	16	+1.00	+70
04/20	12 30.5	+06 45	0.04	1.04	18.9	25.7	153	32	-0.99	+69

(152931) 2000 EA107 (*H* = 16.1)
The first ten days of April will be the only chance to work this NEA: it moves rapidly towards a solar conjunction afterwards. The estimated diameter is 1.79 km. The LCDB gives a period of 4.137 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	17 42.8	+44 00	0.36	1.10	16.3	64.1	97	81	-0.17	+30
04/02	17 46.8	+44 36	0.35	1.10	16.3	65.0	97	86	-0.10	+30
04/03	17 51.1	+45 13	0.34	1.09	16.3	65.9	96	90	-0.05	+29
04/04	17 55.7	+45 52	0.33	1.08	16.2	66.8	96	95	-0.02	+28
04/05	18 00.5	+46 32	0.32	1.08	16.2	67.8	95	98	+0.00	+28
04/06	18 05.7	+47 13	0.31	1.07	16.1	68.9	94	101	+0.01	+27
04/07	18 11.3	+47 56	0.30	1.06	16.1	70.1	93	104	+0.03	+26
04/08	18 17.3	+48 39	0.29	1.06	16.1	71.3	93	106	+0.07	+25
04/09	18 23.9	+49 25	0.28	1.05	16.0	72.6	92	107	+0.13	+25
04/10	18 31.0	+50 11	0.28	1.04	16.0	74.0	91	107	+0.21	+24

(297300) 1998 SC15 (*H* = 19.2)
There was no period in the LCDB for this 430 m NEA. The size should make it safe to assume a period about *P* > 2.2 hr. The second half of April is the only good opportunity in Q2 2019.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/15	06 54.2	+18 10	0.14	0.98	18.2	93.4	78	42	+0.75	+9
04/17	07 27.2	+21 13	0.14	1.00	18.0	88.1	84	63	+0.92	+17
04/19	08 01.2	+23 50	0.14	1.01	17.9	82.8	89	84	+1.00	+25
04/21	08 34.9	+25 53	0.15	1.03	17.8	77.6	94	105	-0.97	+33
04/23	09 07.1	+27 19	0.15	1.04	17.8	72.9	99	125	-0.85	+41
04/25	09 36.8	+28 11	0.16	1.05	17.8	68.6	103	143	-0.68	+47
04/27	10 03.7	+28 36	0.17	1.07	17.8	65.0	106	159	-0.49	+53
04/29	10 27.4	+28 40	0.19	1.08	17.9	61.8	109	165	-0.31	+58
05/01	10 48.2	+28 29	0.20	1.10	18.0	59.2	111	154	-0.15	+63
05/03	11 06.5	+28 08	0.22	1.11	18.2	56.9	113	135	-0.04	+67

(522684) 2016 JP (*H* = 16.8, PHA)
The best observing circumstances are from mid-April to early May. The size is about 180 meters, so this might be a super-fast rotator (*P* < 2.2 hr). Keep exposures as short as possible, sky motion notwithstanding, until an initial period estimate can be made.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	19 58.3	+19 36	0.05	1.00	17.9	93.0	84	87	-0.99	-5
04/22	18 57.2	+24 14	0.05	1.01	17.4	78.8	98	58	-0.92	+10
04/24	18 02.0	+26 55	0.06	1.03	17.3	66.9	110	49	-0.77	+22
04/26	17 16.8	+28 02	0.07	1.04	17.3	57.7	119	62	-0.59	+32
04/28	16 41.4	+28 13	0.07	1.05	17.5	51.0	126	83	-0.40	+40
04/30	16 14.1	+27 54	0.08	1.06	17.6	46.2	130	106	-0.22	+45
05/02	15 52.9	+27 22	0.10	1.08	17.8	42.8	133	126	-0.09	+50
05/04	15 36.3	+26 44	0.11	1.09	18.0	40.5	136	139	-0.01	+53
05/06	15 23.1	+26 04	0.12	1.10	18.3	38.8	137	138	+0.01	+56
05/08	15 12.4	+25 23	0.13	1.11	18.5	37.8	138	122	+0.11	+58

(250697) 2005 QY151 (*H* = 17.8)
This NEA follows the general rule that Southern Hemisphere observers have the advantage a month or so before and after the summer solstice. The estimated size is 820 m, so the period is very likely greater than 2 hr. There was no rotation period in the LCDB.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	20 17.0	-49 35	0.20	1.04	17.0	74.8	94	82	-0.99	-34
04/25	19 53.5	-54 31	0.22	1.07	17.0	66.1	103	34	-0.68	-31
04/30	19 26.2	-58 28	0.23	1.11	17.0	58.4	110	63	-0.22	-27
05/05	18 54.3	-61 26	0.25	1.15	17.0	51.5	117	115	+0.00	-24
05/10	18 18.6	-63 21	0.27	1.18	17.1	45.5	124	136	+0.28	-21
05/15	17 41.4	-64 13	0.29	1.22	17.1	40.2	129	89	+0.82	-17
05/20	17 06.1	-64 07	0.32	1.25	17.2	35.8	134	45	-0.98	-14
05/25	16 35.3	-63 14	0.34	1.29	17.4	32.3	137	64	-0.66	-11
05/30	16 10.6	-61 48	0.37	1.32	17.5	29.7	140	110	-0.20	-7
06/04	15 51.9	-60 01	0.40	1.35	17.7	28.1	141	138	+0.01	-5

(141525) 2002 FV5 (*H* = 17.9)
All of April will be a good time to observe this 780-m NEA. There was no rotation period given in the LCDB.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	15 45.9	+15 09	0.48	1.36	18.4	34.4	130	94	-0.17	+48
04/04	15 42.5	+16 24	0.43	1.33	18.1	33.9	132	125	-0.02	+49
04/07	15 37.6	+17 53	0.39	1.30	17.8	33.4	134	147	+0.03	+51
04/10	15 30.7	+19 40	0.34	1.27	17.5	33.0	136	136	+0.21	+53
04/13	15 20.9	+21 50	0.30	1.24	17.1	32.8	138	102	+0.53	+56
04/16	15 06.7	+24 31	0.26	1.21	16.7	33.1	139	63	+0.84	+60
04/19	14 45.9	+27 54	0.22	1.18	16.4	34.4	139	37	+1.00	+65
04/22	14 14.0	+32 07	0.18	1.14	16.0	37.8	136	57	-0.92	+71
04/25	13 23.2	+36 57	0.15	1.11	15.8	44.8	129	98	-0.68	+78
04/28	12 03.4	+40 53	0.13	1.07	15.7	56.9	117	139	-0.40	+73

2009 FU23 (*H* = 20.0, PHA)
With an estimated diameter of 100 m, this is another potential super-fast rotator. There was no rotation period in the LCDB for 2009 FU23.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	18 57.7	+14 20	0.16	1.04	18.6	72.0	99	72	-0.99	+5
04/22	19 07.3	+14 21	0.15	1.04	18.5	73.2	99	54	-0.92	+3
04/24	19 18.3	+14 20	0.14	1.03	18.4	74.7	98	41	-0.77	+1
04/26	19 30.9	+14 16	0.13	1.03	18.2	76.6	96	36	-0.59	-2
04/28	19 45.5	+14 08	0.12	1.02	18.1	78.9	95	41	-0.40	-5
04/30	20 02.5	+13 53	0.11	1.02	18.0	81.7	92	51	-0.22	-9
05/02	20 22.7	+13 30	0.10	1.01	18.0	85.1	89	64	-0.09	-13
05/04	20 46.5	+12 55	0.09	1.01	17.9	89.3	86	79	-0.01	-18
05/06	21 14.6	+12 03	0.08	1.00	18.0	94.5	81	94	+0.01	-24
05/08	21 47.3	+10 49	0.08	0.99	18.1	100.5	75	111	+0.11	-31

2018 XG5 (*H* = 20.2, PHA)
Minimum distance from Earth is about May 3.2 for this NEA. There was no rotation period in the LCDB but, with an estimated size of 275 m, the period is likely greater than 2 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/25	07 02.5	+07 10	0.10	0.98	18.8	102.1	73	165	-0.68	+6
04/28	07 49.9	+12 24	0.08	1.00	18.1	95.4	80	156	-0.40	+19
05/01	08 59.7	+18 50	0.07	1.01	17.4	84.1	92	137	-0.15	+37
05/04	10 30.6	+24 13	0.07	1.03	16.8	69.6	107	119	-0.01	+58
05/07	12 00.7	+25 58	0.07	1.05	16.7	56.3	120	98	+0.05	+79
05/10	13 09.1	+24 52	0.09	1.07	16.9	47.2	129	75	+0.28	+85
05/13	13 55.1	+22 52	0.11	1.09	17.2	41.6	134	49	+0.61	+75
05/16	14 25.8	+20 53	0.13	1.11	17.5	38.1	137	29	+0.90	+68
05/19	14 47.2	+19 09	0.15	1.13	17.9	35.8	139	39	-1.00	+62
05/22	15 02.6	+17 38	0.18	1.15	18.2	34.1	140	66	-0.89	+58

2008 HS3 (H = 21.7, PHA)

Southern observers get the bulk of observing opportunities for 2008 HS3 but, in late May, northern observers get their chance. The diameter is about 140 m, so this could be a super-fast rotator. There was no rotation period in the LCDB for guidance.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/10	11 39.7	-47 50	0.10	1.08	18.5	40.8	135	112	+0.21	+13
04/15	11 56.1	-48 06	0.09	1.07	18.2	40.1	137	70	+0.75	+14
04/20	12 21.5	-47 39	0.07	1.06	17.7	38.2	139	46	-0.99	+15
04/25	12 59.3	-45 47	0.06	1.06	17.1	34.0	144	74	-0.68	+17
04/30	13 52.1	-40 59	0.05	1.05	16.4	26.2	153	115	-0.22	+20
05/05	14 57.3	-30 49	0.04	1.05	15.7	14.4	165	161	+0.00	+25
05/10	16 03.9	-14 40	0.04	1.05	15.5	13.8	166	129	+0.28	+27
05/15	16 59.8	+02 21	0.04	1.05	16.1	30.2	149	70	+0.82	+26
05/20	17 41.3	+14 53	0.05	1.05	16.9	43.1	135	37	-0.98	+22
05/25	18 10.4	+22 44	0.06	1.05	17.6	50.6	127	61	-0.66	+19

(12538) 1998 OH (H = 15.8)

There will plenty of time to work this NEA. The diameter is about 2 km and the LCDB gives a period of 5.154 hr. Because of orbital geometry, the date of minimum distance – May 16.4, 0.187 AU – is about a week before the date of maximum brightness.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	04 57.0	-17 48	0.48	0.93	17.0	84.1	67	102	-0.17	-33
04/11	05 26.1	-14 58	0.40	0.92	16.8	90.2	66	37	+0.31	-25
04/21	06 02.8	-09 58	0.32	0.92	16.6	95.8	66	133	-0.97	-15
05/01	06 54.2	-00 43	0.25	0.94	16.2	99.2	67	106	-0.15	+0
05/11	08 14.0	+15 13	0.19	0.97	15.6	96.4	73	7	+0.38	+25
05/21	10 13.2	+32 58	0.19	1.01	15.2	85.0	84	119	-0.95	+55
05/31	12 17.2	+40 40	0.24	1.06	15.4	72.6	94	129	-0.13	+75
06/10	13 42.6	+40 19	0.31	1.11	15.8	63.7	100	45	+0.47	+73
06/20	14 35.3	+37 30	0.39	1.17	16.2	57.4	104	97	-0.93	+66
06/30	15 10.4	+34 06	0.48	1.23	16.6	52.8	105	128	-0.10	+59

(68950) 2002 QF15 (H = 16.4, PHA)

The estimated size is 1.56 km and the rotation period about 47 hr. Since this is very closely commensurate with an Earth day, a campaign of at least two observers at well-separated locations in longitude is recommended.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/20	09 06.8	+01 49	0.09	1.00	14.5	94.5	80	114	-0.98	+31
05/30	12 21.9	+20 47	0.13	1.06	14.5	66.1	107	156	-0.20	+81
06/09	13 43.4	+23 54	0.22	1.12	15.4	57.5	112	49	+0.36	+78
06/19	14 22.0	+23 35	0.31	1.17	16.2	54.1	111	84	-0.97	+69
06/29	14 46.4	+22 21	0.41	1.21	16.8	52.2	109	144	-0.17	+64
07/09	15 05.4	+20 42	0.51	1.26	17.3	50.9	106	39	+0.45	+59
07/19	15 22.4	+18 50	0.61	1.30	17.7	49.8	103	98	-0.96	+54
07/29	15 38.8	+16 51	0.70	1.33	18.1	48.9	100	133	-0.13	+50
08/08	15 55.3	+14 49	0.79	1.36	18.4	48.0	96	30	+0.53	+46
08/18	16 12.3	+12 48	0.89	1.38	18.6	47.1	93	112	-0.94	+41

(66391) 1999 KW4 (H = 16.5, PHA)

This well-known and well-studied NEA (see Ostro et al., 2006, *Science*) should be a relatively easy target despite the solar elongation hovering near 100°. The rotation period of the primary is 2.765 hr while the satellite's orbital period is about 17.44 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/20	09 06.8	+01 49	0.09	1.00	14.5	94.5	80	114	-0.98	+31
05/27	11 38.0	+17 41	0.11	1.04	14.2	71.7	102	167	-0.47	+71
06/03	13 03.5	+22 52	0.16	1.08	14.8	61.4	110	116	+0.00	+85
06/10	13 48.5	+23 57	0.23	1.12	15.5	57.0	112	39	+0.47	+77
06/17	14 15.9	+23 45	0.29	1.16	16.0	54.6	112	64	+1.00	+71
06/24	14 35.2	+23 02	0.36	1.19	16.5	53.1	110	131	-0.63	+66
07/01	14 50.5	+22 03	0.43	1.22	16.9	51.9	109	128	-0.04	+63
07/08	15 03.6	+20 52	0.50	1.25	17.3	51.0	107	48	+0.34	+59
07/15	15 15.8	+19 36	0.57	1.28	17.6	50.2	104	58	+0.96	+56
07/22	15 27.4	+18 15	0.63	1.31	17.8	49.5	102	126	-0.78	+53

2011 HP (H = 22.1)

The LCDB gives a rotation period of P = 3.942 hr. The estimated diameter for the NEA is 110 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/10	14 20.2	-15 22	0.11	1.12	18.2	9.9	169	106	+0.28	+42
05/13	14 28.5	-13 54	0.09	1.10	17.9	11.4	168	65	+0.61	+43
05/16	14 40.1	-11 53	0.08	1.09	17.5	12.7	166	24	+0.90	+43
05/19	14 56.8	-09 00	0.07	1.08	17.1	14.1	165	15	-1.00	+43
05/22	15 22.0	-04 39	0.05	1.06	16.7	16.5	163	50	-0.89	+42
05/25	16 01.5	+02 13	0.04	1.05	16.4	22.2	157	79	-0.66	+38
05/28	17 05.3	+12 44	0.03	1.04	16.3	35.0	144	98	-0.38	+29
05/31	18 41.1	+25 02	0.03	1.03	16.6	55.2	123	103	-0.13	+13
06/03	20 28.2	+32 32	0.03	1.02	17.5	75.0	103	103	+0.00	-4
06/06	21 50.3	+34 04	0.04	1.02	18.4	87.8	90	113	+0.09	-15

(5604) 1992 FE (H = 17.2)

The solar elongation drops quickly below 90° starting early June. Southern observers should make this a priority. The size is about 1 km and the LCDB gives P = 5.3375 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/01	19 35.1	-34 25	0.44	1.23	17.7	50.5	110	64	-0.15	-23
05/04	19 44.5	-34 38	0.42	1.22	17.6	50.8	111	99	-0.01	-25
05/07	19 54.5	-34 50	0.39	1.21	17.5	51.1	111	135	+0.05	-27
05/10	20 05.1	-35 01	0.37	1.20	17.3	51.5	112	165	+0.28	-29
05/13	20 16.5	-35 12	0.34	1.18	17.1	52.1	113	143	+0.61	-32
05/16	20 29.0	-35 20	0.32	1.17	17.0	52.8	113	104	+0.90	-34
05/19	20 42.7	-35 25	0.29	1.16	16.8	53.7	113	67	-1.00	-37
05/22	20 58.0	-35 25	0.27	1.14	16.6	54.9	112	33	-0.89	-40
05/25	21 15.3	-35 18	0.25	1.13	16.5	56.6	112	17	-0.66	-44
05/28	21 35.0	-35 01	0.23	1.11	16.3	58.6	110	38	-0.38	-48

(494999) 2010 JU39 (H = 19.6, PHA)

The observing window is a short 10 days at the end of June. For those with larger telescopes, the start of the period can be pushed back to early June. There was no rotation period in the LCDB; the diameter is 360 m, so the period is likely $P > 2.2$ hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/20	18 11.5	+24 24	0.12	1.10	17.0	43.2	132	53	-0.93	+19
06/21	17 58.0	+24 27	0.11	1.10	16.8	43.5	132	62	-0.87	+22
06/22	17 41.6	+24 24	0.10	1.09	16.5	44.0	132	72	-0.80	+26
06/23	17 21.7	+24 10	0.09	1.08	16.3	45.0	131	85	-0.72	+30
06/24	16 57.4	+23 38	0.08	1.07	16.1	46.7	130	99	-0.63	+35
06/25	16 27.9	+22 39	0.08	1.06	16.0	49.4	127	114	-0.54	+41
06/26	15 52.5	+20 57	0.07	1.06	15.9	53.4	123	130	-0.44	+48
06/27	15 11.5	+18 21	0.06	1.05	15.8	59.2	118	147	-0.35	+57
06/28	14 26.8	+14 45	0.06	1.04	15.9	66.4	110	157	-0.25	+65
06/29	13 41.3	+10 23	0.06	1.03	16.2	74.7	102	148	-0.17	+70

(441987) 2010 NY65 (H = 21.5, PHA)

The rotation period in the LCDB is 4.973 hr. You'll have only a few days at the end of June to confirm that. With a 1-meter or larger telescope, the window is open for another 10 days into July.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/25	11 48.8	+61 48	0.02	1.01	17.3	112.1	67	123	-0.54	+54
06/26	14 11.3	+55 10	0.02	1.02	16.5	93.0	86	123	-0.44	+58
06/27	15 21.1	+45 19	0.03	1.02	16.3	78.4	100	125	-0.35	+55
06/28	15 55.9	+37 17	0.03	1.03	16.4	68.4	110	129	-0.25	+50
06/29	16 15.9	+31 21	0.04	1.03	16.6	61.4	117	133	-0.17	+46
06/30	16 28.7	+26 59	0.04	1.04	16.8	56.5	121	136	-0.10	+42
07/01	16 37.6	+23 42	0.05	1.05	17.0	52.9	125	136	-0.04	+39
07/02	16 44.2	+21 09	0.06	1.05	17.2	50.2	127	134	-0.01	+37
07/03	16 49.2	+19 07	0.06	1.06	17.4	48.2	129	128	+0.00	+35
07/04	16 53.2	+17 28	0.07	1.06	17.6	46.6	131	120	+0.02	+34

(10145) 1994 CK1 (*H* = 16.8)

There was no rotation period in the LCDB for 1994 CK1, which has an estimated diameter of 1.3 km. Minimum distance from Earth is 0.099 AU on July 6.7, or about 10 days after the date of brightest (June 27.6, 14.6)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/10	17 15.5	-34 39	0.62	1.56	17.7	21.0	146	147	+0.28	+2
05/16	17 13.6	-35 51	0.54	1.50	17.3	18.8	151	65	+0.90	+2
05/22	17 09.2	-37 13	0.46	1.45	16.8	16.4	156	24	-0.89	+2
05/28	17 01.2	-38 49	0.39	1.39	16.3	14.4	160	91	-0.38	+2
06/03	16 48.4	-40 41	0.33	1.33	15.8	14.0	161	157	+0.00	+3
06/09	16 28.4	-42 49	0.27	1.27	15.4	17.0	159	101	+0.36	+4
06/15	15 56.9	-45 12	0.22	1.21	15.0	24.1	151	31	+0.94	+6
06/21	15 05.2	-47 25	0.17	1.15	14.7	35.9	139	74	-0.87	+10
06/27	13 39.1	-47 31	0.13	1.09	14.5	54.1	120	136	-0.35	+15
07/03	11 37.6	-40 01	0.10	1.03	14.8	81.6	93	90	+0.00	+21

(418900) 2009 BE2 (*H* = 19.2)

The estimated size is 430 m for the asteroid with no rotation period. It's very likely *P* > 2.2 hr.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/10	13 35.6	+56 38	0.17	1.03	18.3	81.8	89	54	+0.47	+59
06/14	13 46.9	+48 53	0.15	1.03	17.9	79.0	93	61	+0.88	+66
06/18	13 58.3	+38 01	0.12	1.04	17.4	74.2	99	85	-1.00	+72
06/22	14 09.8	+23 08	0.11	1.05	16.9	67.1	107	118	-0.80	+72
06/26	14 21.6	+04 41	0.10	1.07	16.5	58.8	116	156	-0.44	+59
06/30	14 34.0	-14 12	0.11	1.08	16.4	52.2	123	159	-0.10	+42
07/04	14 47.2	-29 54	0.12	1.09	16.7	48.9	126	110	+0.02	+27
07/08	15 01.4	-41 22	0.15	1.11	17.0	48.0	126	64	+0.34	+15
07/12	15 16.5	-49 23	0.17	1.12	17.4	47.8	125	35	+0.77	+7
07/16	15 32.6	-54 59	0.20	1.14	17.8	47.8	124	50	+0.99	+1

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
250162	2002 TY57	36	144
259650	2003 WH103	58	166
283691	2002 RH80	58	166
298808	2004 RV33	72	180
300697	2007 VE63	58	166
310876	2003 KV33	58	166
319017	2005 UU511	58	166
321706	2010 GA3	58	166
322436	2011 SP247	58	166
342436	2008 UT93	58	166
357024	1999 YR14	1	109
381809	2009 UC135	58	166
387906	2004 XQ	58	166
395907	2013 AC78	58	166
396929	2005 FQ7	58	166
399912	2005 XG75	58	166
420280	2011 OC26	58	166
437408	2013 WQ83	58	166
438202	2005 UE129	58	166
440931	2006 XK39	58	166
442742	2012 WP3	45	153
443923	2002 RU25	36	144
457260	2008 RY24	36	144
468481	2004 TP20	36	144
469419	2001 XA249	58	166
496018	2008 NU	1	109
512245	2016 AU8	36	144
513494	2009 FC57	58	166
513720	2012 TB4	58	166
518635	2008 HO3	36	144
518735	2009 JL1	36	144
518966	2010 HL45	58	166
523604	2004 QB17	45	153
523631	2009 SX1	36	144
523806	2002 WW17	108	216
523815	2009 HW44	36	144
	1999 YR14	96	204
	2003 NW1	36	144
	2005 YY36	36	144
	2007 UL12	36	144
	2007 YQ56	36	144
	2009 SV17	36	144
	2010 OE84	58	166
	2011 QO3	58	166
	2014 YC15	1	109
	2016 LX48	96	204
	2018 AL11	58	166
	2018 BY2	96	204
	2018 QN1	36	144
	2018 RC	80	188
	2018 RL	45	153
	2018 TF3	36	144
	2018 UQ1	82	190
	2018 UQ2	36	144
	2018 UR2	36	144
	2018 UR2	82	190
	2018 VX	36	144
	2018 XR	36	144

THE MINOR PLANET BULLETIN (ISSN 1052-8091) is the quarterly journal of the Minor Planets Section of the Association of Lunar and Planetary Observers (ALPO). Current and most recent issues of the *MPB* are available on line, free of charge from:

http://www.minorplanet.info/MPB/mpb.php

Nonmembers are invited to join ALPO by communicating with: Matthew L. Will, A.L.P.O. Membership Secretary, P.O. Box 13456, Springfield, IL 62791-3456 (will008@attglobal.net). The Minor Planets Section is directed by its Coordinator, Prof. Frederick Pilcher, 4438 Organ Mesa Loop, Las Cruces, NM 88011 USA (fpilcher35@gmail.com, assisted by Lawrence Garrett, 206 River Rd., Fairfax, VT 05454 USA (LSGasteroid@msn.com). Dr. Alan W. Harris (Space Science Institute; awharris@spacescience.org), and Dr. Petr Pravec (Ondrejov Observatory; ppravec@asu.cas.cz) serve as Scientific Advisors. The Asteroid Photometry Coordinator is Brian D. Warner, Palmer Divide Observatory, 446 Sycamore Ave., Eaton, CO 80615 USA (brian@MinorPlanetObserver.com).

The Minor Planet Bulletin is edited by Professor Richard P. Binzel, MIT 54-410, 77 Massachusetts Ave, Cambridge, MA 02139 USA (rpb@mit.edu). Brian D. Warner (address above) is Associate Editor, and Dr. David Polishook, Department of Earth and Planetary Sciences, Weizmann Institute of Science (david.polishook@weizmann.ac.il) is Assistant Editor. The *MPB* is produced by Dr. Robert A. Werner, 3937 Blanche St., Pasadena, CA 91107 USA (rawerner@polygrav.org) and distributed by Derald D. Nye. Direct all subscriptions, contributions, address changes, etc. to:

Mr. Derald D. Nye - Minor Planet Bulletin
10385 East Observatory Drive
Corona de Tucson, AZ 85641-2309 USA
(nye@kw-obsv.org) (Telephone: 520-762-5504)

Effective with Volume 38, the *Minor Planet Bulletin* is a limited print journal, where print subscriptions are available only to libraries and major institutions for long-term archival purposes. In addition to the free electronic download of the *MPB* noted above, electronic retrieval of all *Minor Planet Bulletin* articles (back to Volume 1, Issue Number 1) is available through the Astrophysical Data System

http://www.adsabs.harvard.edu/.

Authors should submit their manuscripts by electronic mail (rpb@mit.edu). Author instructions and a Microsoft Word template document are available at the web page given above. All materials must arrive by the deadline for each issue. Visual photometry observations, positional observations, any type of observation not covered above, and general information requests should be sent to the Coordinator.

* * * * *

The deadline for the next issue (46-3) is April 15, 2019. The deadline for issue 46-4 is July 15, 2019.