THE MINOR PLANET BULLETIN

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

VOLUME 45, NUMBER 4, A.D. 2018 OCTOBER-DECEMBER

FILTERED PHOTOMETRIC MONITORING OF 1591 BAIZE

Misty C. Bentz, Caleb Abbott, Steven Agudelo, Steven Dassing, Wyatt Flynn, Austin Gibbs, Louis Gonzalez, Bokyoung Kim, Leonardo Paredes, Christopher Toben, Eliot Halley Vrijmoet, Alexandra Yep
Department of Physics and Astronomy
Georgia State University
25 Park Place, Suite 605
Atlanta, GA 30303 USA
bentz@astro.gsu.edu

(Received: 2018 May 11)

Broad-band BVR photometry of asteroid 1591 Baize was obtained over four nights in 2017 February and March. We determined a rotation period of 7.788 ± 0.003 hours and typical colors of B-V = 0.9 and V-R = 0.5. The amplitude of color variations is small, ~0.02 mag. These characteristics support the classification of 1591 Baize as an S-type asteroid.

The main-belt asteroid (a = 2.39 AU) 1591 Baize was discovered by the Belgian astronomer Sylvain Arend on 1951 May 31. It has an eccentric (e = 0.176) and inclined (i = 24.8°) orbit that places it among the Phocaea group of asteroids (JPL, 2018). Based on a single night of observations, Barucci et al. (1994) estimated a rotation period of ~10 hours. Over a period of two nights, Garlitz (2013) refined the period estimate to 7.78 ± 0.04 hours. Mas et al. (2018) monitored the asteroid on four nights in 2017 Jan-Feb and determined a rotation period of 7.794 ± 0.001 hours.

Photometric monitoring of 1591 Baize was carried out at Georgia State University's Hard Labor Creek Observatory in Rutledge, GA, as part of the course work for ASTR 4100 and ASTR 6100, *Observing Methods and Instrumentation*. Observations were conducted with the 0.6-m Miller telescope, an *f*/6.5 Planewave Corrected Dall-Kirkham Astrograph, equipped with an Apogee Alta camera with 15-micron pixels in a 2048x2048 array. The resultant field of view is 26.3x26.3 arcmin and a scale of 0.77 arcsec/pixel. Broad-band photometry through Johnson B, V, and R filters was obtained on the calendar nights of 2017 Feb 25, Mar 3, and Mar 4. Photometry in V and R was also obtained on 2017 Feb 10, but observations in B were omitted because of the full Moon. Exposure times were generally 2-4 mins, and the observing sequence cycled through each of the filters, performed a small dither, and then cycled through the filters again. The process was repeated for as long as possible and achieved a total of 5-8 hours of coverage each night.

Data were reduced with *IRAF* following standard procedures. Aperture photometry of 1591 Baize and several field stars was carried out in *IRAF* with a circular aperture of radius 8 pixels. Absolute calibrations were determined using photometry of field stars from the APASS catalog (Henden et al., 2009) for the B and V filters. The transformation equations of Jordi et al. (2006) for Population I stars were used to determine the effective R magnitudes for field stars using the Sloan r′ magnitudes and the g′-r′ colors from APASS.

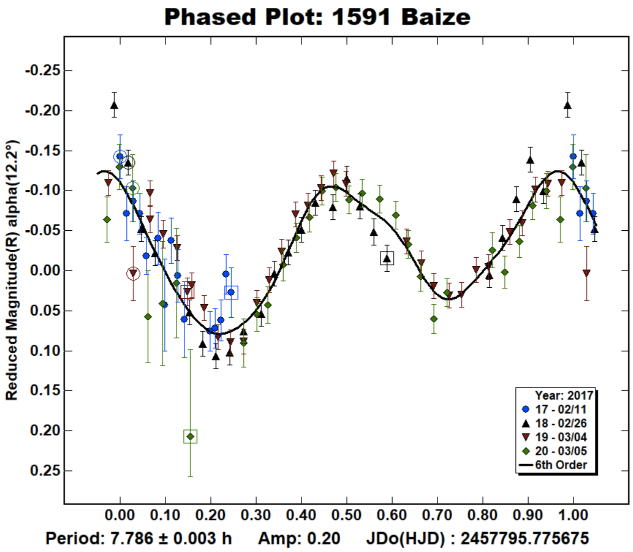
MPO Canopus, which implements the Fourier Analysis of Light Curves (FALC) algorithm of Harris (Harris et al., 1989), was used to determine the rotation period of the asteroid. The best-fit periods and the amplitudes of variation are listed below for each filter. In the summary table, we report the weighted average of these individual fits and the standard deviation as the uncertainty, which are in agreement with the periods determined by Garlitz (2013) and Mas et al. (2018). Below, we show the phased R-band light curve with a 6th order polynomial overlaid.

Filter	Pts	Period (hr)	Amp. (mag)
B	79	7.791 ± 0.006	0.20
V	127	7.788 ± 0.002	0.18
R	98	7.786 ± 0.003	0.20

The photometric colors were found to be B-V = 0.9 and V-R = 0.5. These colors are usual for S-type, or silicaceous, asteroids (Dandy et al., 2003) and agree with the reported membership of 1591 Baize in the Phocaea family. The amplitude of color variations is quite small, only ~0.02 mag, which is typical of most asteroids (e.g., Szabo et al., 2004).

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1591	Baize	02/10-03/04	304	12.15,16.46	140	26	7.788	0.003	0.19	0.02	PHO

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

IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy (AURA) under cooperative agreement with the National Science Foundation. This research was made possible in part based on data from the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

References

Barucci, M.A., di Martino, M., Dotto, E., Fulchignoni, M., Rotundi, A., Burchi, R. (1994). "Rotational Properties of Small Asteroids: Photoelectric Observations of 16 Asteroids." *Icarus* **109**, 267-273.

Dandy, C.L., Fitzsimmons, A., Collander-Brown, S.J. (2003). "Optical colors of 56 near-Earth objects: trends with size and orbit." *Icarus* **163**, 363-373.

Garlitz, J. (2013). Posting on CALL website. *http://www.minorplanet.info/call.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.

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*

Jordi, K., Grebel, E.K., Ammon, K. (2006). "Empirical color transformations between SDSS photometry and other photometric systems." *Astron. Astrophys*. 460, 339-347.

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

Mas, V., Fornas, G., Lozano, J., Rodrigo, O., Fornas, A., Carreño, A., Arce, E., Brines, P., Herrero, D. (2018). "Twenty-One Asteroid Lightcurves at Asteroids Observers (OBAS) – MPPD: Nov 2016 – May 2017." *Minor Planet Bull*. **45**, 76-82.

Szabo, Gy.M., Ivezic, Z., Juric, M., Lupton, R., Kiss, L.L. (2004). "Colour Variability of Asteroids in the Sloan Digital Sky Survey Moving Object Catalog." *Mon. Not. Royal Ast. Soc.* **348**, 987-998.

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*

ROTATION PERIOD FOR (138847) 2000 VE62

Stephen C. Percy
The Studios Observatory (Z52)
31 Ipswich Gardens, Grantham, NG31 8SE, U.K.
mail@opussoftware.co.uk

(Revised: 2018 May 13)

Photometric observations of the Amor class asteroid (138847) 2000 VE62 were performed by the author over five nights from 2018 April 22 to May 10. The rotation period was found to be 7.601 ± 0.001 h with an amplitude of 0.30 ± 0.03 mag.

(138847) 2000 VE62 is an Amor class Near-Earth Object (NEO) discovered at Socorro on 2000 November 3 by LINEAR. Photometric observations were performed by the author over five nights between 2018 April 22 and May 10. More than 21.6 hours of observations produced 1677 data points for analysis. The rotation period was found to be 7.601 ± 0.001 h with an amplitude of 0.30 ± 0.03 mag.

A search of the asteroid lightcurve database (LCDB, Warner et al., 2009) indicated one previously reported lightcurve: Monteiro et al. (2017; *P* = 6.469 h, *A* = 0.36 mag). Their observations included about 200 data points obtained in 12 hours of observation spread over 5 nights during a 3-month period in 2016 (March into May). The observations and data analysis reported here resulted in a longer rotation period and a less-regular sinusoidal lightcurve shape. The new phased plot reveals a plateau in the lightcurve that was not evident in the previous research. The data were checked against the period of 6.469 h found by Monteiro et al. (2017); this produced an unconvincing fit. One possible solution at 6.563 ± 0.001 h did present itself. However, it was less convincing than the 7.601 h fit.

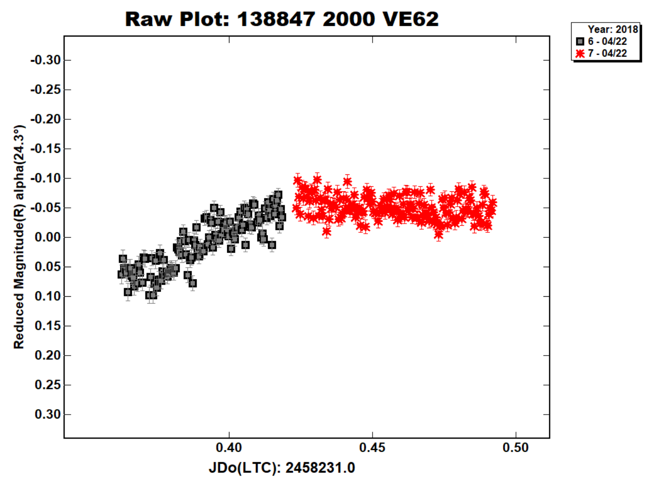
All observations were performed at The Studios Observatory (Z52) using a Meade 0.36-m LX200 ACF OTA operating at *f*/7. The OTA was mounted on a Paramount MEII robotic mount and equipped with Moonlite CSL motorized focuser, Astro Physics AP CCDT67 focal reducer, and a QSI 683 cooled CCD camera (binned 2x2). An Astrodon Clear (UV blocking only) filter was used for all observations. The CCD is based on an 8.3 Mp (3326x2504) Kodak KAF-8300 sensor with 5.4 µm square pixels. The image scale after 2x2 binning was 0.86 arcsecs/pixel.

TheSkyX Professional software by Software Bisque (2018) was used for all telescope, focuser, and camera control. This software was also later used to calibrate all science images using dark, dark-for-flat, and flat field frames. All flat field images were taken at the end of the observing sessions using a wall-mounted whiteboard illuminated by an A4-size electroluminescent (EL) panel. A library of dark and dark-for-flat frames was used in the calibration process, no scaling of dark frames was necessary.

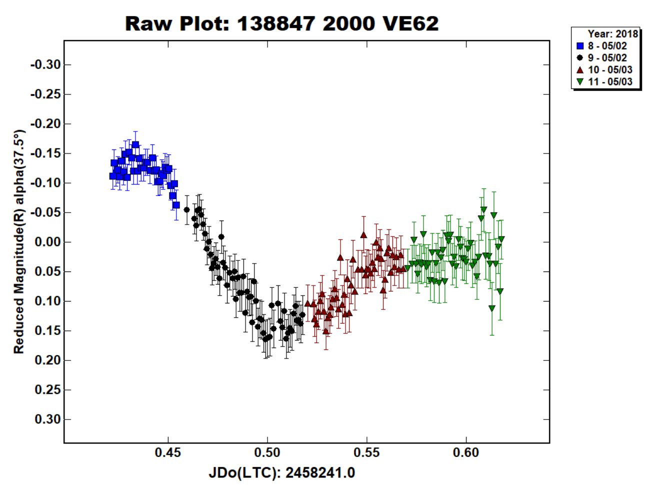
All data processing of the calibrated images and subsequent period analysis was performed using *MPO Canopus* (Warner, 2018a). Differential photometry measurements were performed using the Comp Star Selector (CSS) and Star-B-Gone procedures of *MPO Canopus*. The asteroid and four or five solar-like stars were used for all photometric comparisons.

On three (possibly four) nights of observation, the raw data plots showed a plateau in the lightcurve. This plateau was not evident in the Monteiro et al. (2017) data, which may explain why a different rotational period was determined.

Table I provides an overview of the observed results. The observing schedule and calibrated data are summarized below.



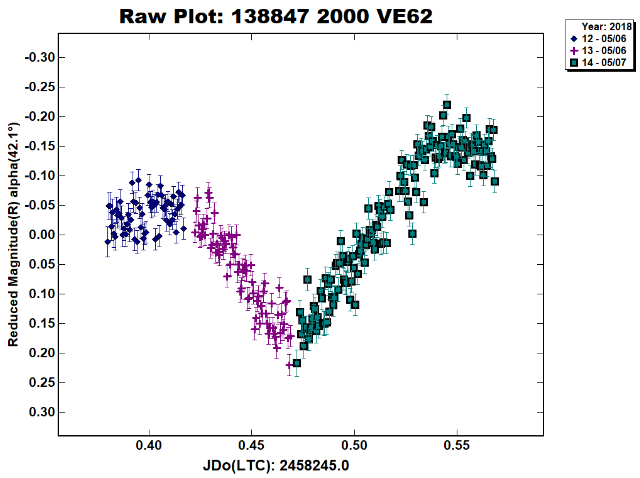
2018 April 22 (Phase 24.3, L_{PAB} 196.3, B_{PAB} 2.0). A total of 207 data points (30 s exposures) was acquired over a 3 h 4 min period.



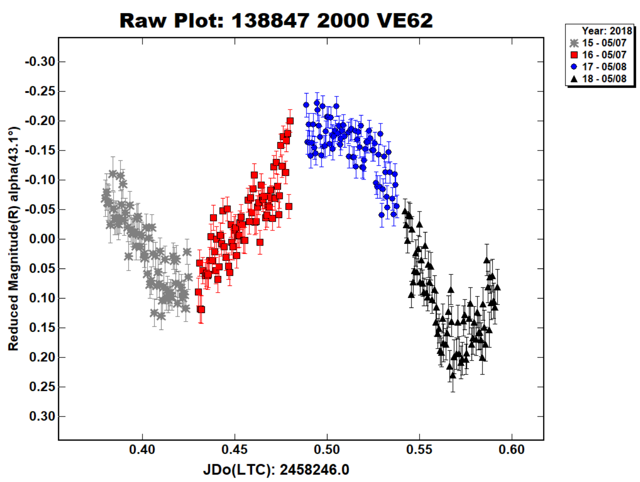
2018 May 2 (Phase 37.6, L_{PAB} 201.0, B_{PAB} 14.5). A total of 400 data points (30 s exposures) was acquired over a 4 h 29 min period.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
138847	2000 VE62	04/22-05/10	1677	24.3,45.9	201.2	12.2	7.601	0.001	0.30	0.03	NEA

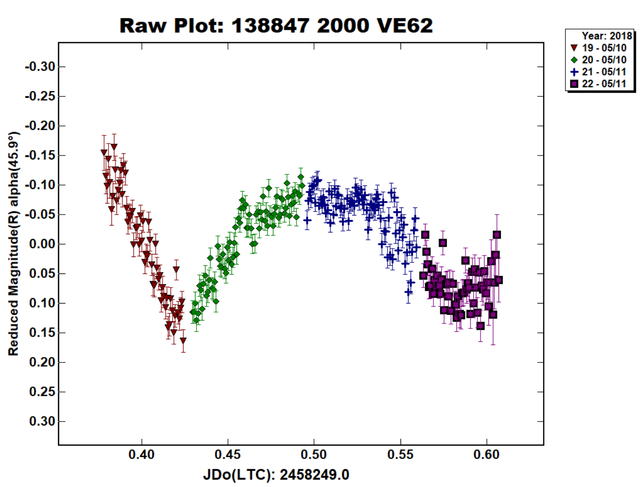
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner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



2018 May 6 (Phase 42.1, L_{PAB} 203.4, B_{PAB} 18.6). A total of 285 data points (45 s exposures) was acquired over a 4 h 20 min period.

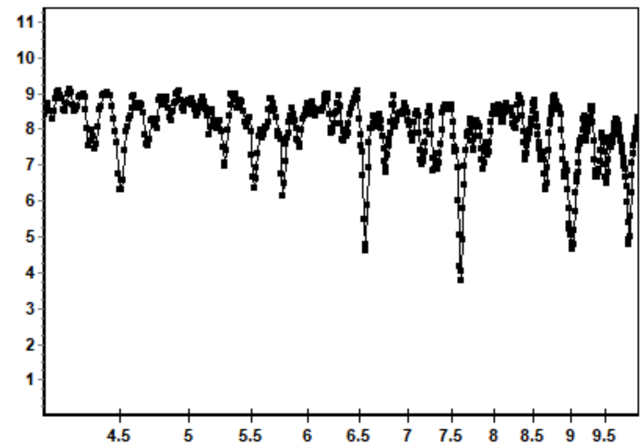


2018 May 7 (Phase 43.2, L_{PAB} 204.1, B_{PAB} 19.6). A total of 312 data points (45 s exposures) was acquired over a 4 h 39 min period.

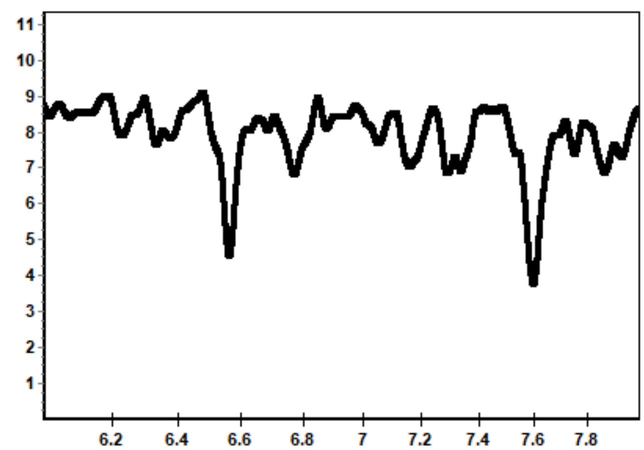


2018 May 10 (Phase 46.0, L_{PAB} 206.2, B_{PAB} 22.3). A total of 473 data points (60 s exposures) was acquired over a 5 h 10 min period.

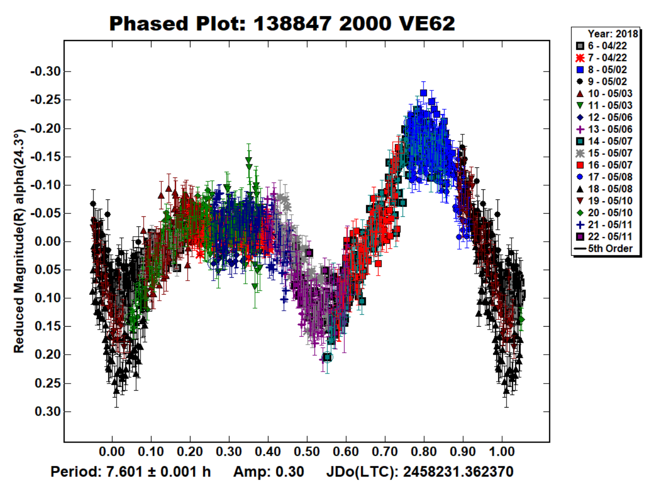
Two example period spectrums for (138847) 2000 VE62 are shown below. A range of periods was checked, first ranging from 4 to 10 hours, and then from 6 to 8 hours. In all cases, a period of 7.601 h proved to be the optimum rotation period.



Period Spectrum for (138847) 2000 VE62, Period 4 to 10 Hours



Period Spectrum for (138847) 2000 VE62, Period 6 to 8 Hours



The final phased plot for (138847) 2000 VE62 showing the matched 7.601 h rotation period.

All new data were uploaded to the ALCDEF database (Warner, 2018b).

Acknowledgements

This research was made possible in part based on data from the MPCOSC3-2MASS catalog (a product of the Two Micron All Sky Survey), UCAC4 (the fourth U.S. Naval Observatory CCD

Astrograph Catalog), and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

The author would like to express his gratitude to Brian D. Warner for his *MPO Canopus* software and support, along with the 2nd edition of his book, *A Practical Guide to Lightcurve Photometry and Analysis* (Warner, 2006). Both have been invaluable in this research.

The Lincoln Near-Earth Asteroid Research (LINEAR) project is a collaboration of the United States Air Force, NASA, and the MIT's Lincoln Laboratory for the systematic detection and tracking of near-Earth objects.

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.

Monteiro, F., Silva, J.S., Lazzaro, D., Arcoverde, P., Medeiros, H., Souza, R., Rodrigues, T. (2017). "Lightcurve Analysis for Ten Near-Earth Asteroids." *Minor Planet Bull*. 44, 20-22.

Software Bisque (2018). *TheSkyX Professional* software. *http://www.bisque.com/sc/pages/TheSkyX-Professional-Edition.aspx*

Warner, B.D. (2006). *A Practical Guide to Lightcurve Photometry and Analysis (2nd edition)*. pp 268. Springer, New York.

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

Warner, B.D. (2018a). MPO Software, *MPO Canopus* v10.7.11.1. *http://www.bdwpublishing.com*

Warner, B.D. (2018b) Asteroid Lightcurve Photometry Database (ALCDEF) website. *http://www.minorplanet.info/alcdef.html*

PHOTOMETRIC OBSERVATIONS OF NEAR-EARTH ASTEROID 2018 GE3

Andreea Ioana Gornea
Astronomical Institute of the Romanian Academy
5 Cuţitul de Argint, 040557 Bucharest, ROMANIA
Technical University of Civil Engineering Bucharest
Lacul Tei Bvd. 122 - 124, 020396 Bucharest, ROMANIA
andreea.gornea@astro.ro

Adrian Bruno Sonka
Astronomical Institute of the Romanian Academy
Faculty of Physics, University of Bucharest,
405 Atomistilor, 077125 Magurele, Ilfov, ROMANIA

Mirel Birlan
Astronomical Institute of the Romanian Academy
IMCCE, Observatoire de Paris
77 av Denfert Rochereau, 75014 Paris Cedex, FRANCE

Simon Anghel
Astronomical Institute of the Romanian Academy

(Received: 2018 May 22)

On 2018 April 14, we observed as a target of opportunity the near-Earth asteroid (NEA) 2018 GE3 from the Astronomical Institute of the Romanian Academy (IAU code 073). Analysis of our data found a synodic period of 0.304 ± 0.001 h based on data obtained over one hour prior to the asteroid's closest approach to Earth.

The near-Earth asteroid (NEA) 2018 GE3 was discovered 2018 April 11 (JPL, 2018). It made its closest approach to Earth (193.000 km) on Apr 15 at 06:41 UT (Tichy et al., 2018). Unfiltered CCD images were taken at the Astronomical Institute of the Romanian Academy, Bucharest, Romania, on the night of 2018 April 14 between 22:44–23:43 UT. The observations were made with a 0.38-m *f*/8 Ritchey-Chretien telescope and SBIG STL-11000M CCD camera (Sonka et al., 2017).

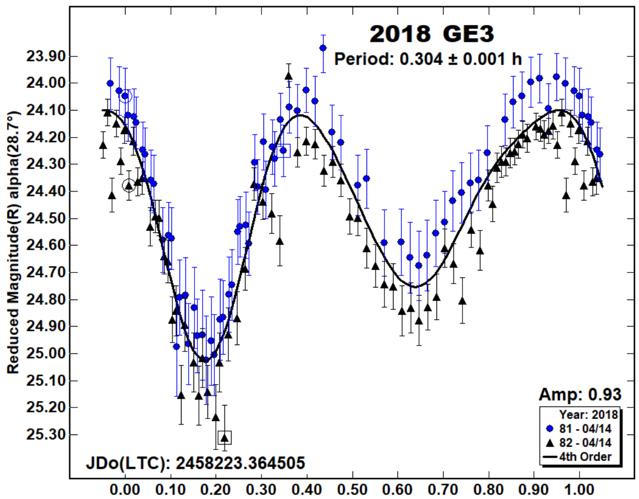
The asteroid was observed when it was at 0.005 AU from Earth. In order to keep a point-like source for 2018 GE3, we tracked it at half of its differential sky motion. Exposures were 10 sec. The raw science images were calibrated with bias, flats, and darks using the standard procedures of *Maxim DL* (2016) software. Data processing and period analysis were made using *MPO Canopus* software (Warner, 2015). Differential photometric measurements were performed using the Comp Star Selector (CSS) procedure in *MPO Canopus*, which allows selecting up to five comparison stars with a near-solar color. The comp star magnitudes were taken from the CMC-15 catalog (Munos, 2017).

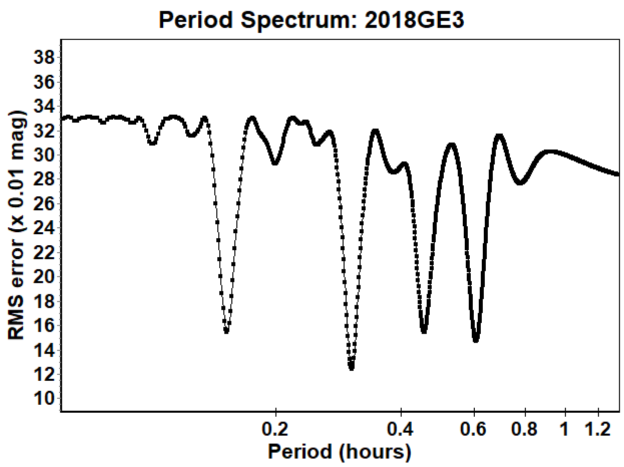
Our data fit a period of 0.304 ± 0.001 h. The lightcurve amplitude is 0.93 ± 0.05 mag. A fourth-order fit showed an asymmetric bimodal lightcurve. A period spectrum between 0.1 h and 1.2 h indicated that the most probable solution was 0.3 h. The folded lightcurve points are slightly shifted; this could be due to a slightly

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2018 GE3	04/14	138	28.4,30.1	216	8	0.304	0.001	0.93	0.05	NEA

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

different calibration in absolute magnitude or to a small change in the viewing aspect.





Acknowledgements

This work was supported by a grant of the Ministry of National Education and Scientific Research, RDI Programe for Space Technology and Advanced Research - STAR, project number 513 and ARGOSS MCI Contract No. 11 PS/2017.

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.

JPL (2018). NASA Horizons web site. *https://ssd.jpl.nasa.gov/horizons.cgi*

MaxIm DL (2016). Maxim DL software manual. *https://diffractionlimited.com/help/maximdl/MaxIm-DL.htm*

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

Sonka, A.B., Gornea, A.I., Anghel, S., Birlan, M. (2017). “Photometric observations of Near Earth Asteroid 2012 TC4.” *Romanian Astronomical Journal* **27**, 223-231.

Tichy, M., Ticha, J., Fumagalli, A., Sicoli, P., Testa, A., Montanar, U., Pettarin, E., Gibbs, A.R., Africano, B.M., Christensen, E.J., Fuls, D.C., Grauer, A.D., Johnson, J.A., Kowalski, R.A., Larson, S.M., Leonard, G.J., Seaman, R.L., Shelly, F.C., Dangl, G., Sato, H., Birtwhistle, P., Kalup, C., Sarneczky, K., Denisenko, D., Kachalin, P., Larin, I. (2018). “2018 GE3.” *Minor Planet Electronic Circulars* **2018,** G94**.**

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. (2015). *MPO Canopus* software v10.7.0.6. Bdw Publishing. *http//www.bdwpublishing.com*

A LIGHTCURVE OF 1090 SUMIDA

R. M. Blake
Dept. Physics and Earth Science
University of North Alabama
Florence, Alabama, USA 35630
rmblake@una.edu

K. Himeno
Dept. Physics and Earth Science
University of North Alabama
Florence, Alabama, USA

(Received: 2018 May 24 Revised: 2018 Aug 20)

We used the 0.36-m telescope of the Virtual Telescope Project to obtain three hours of photometry of the main-belt asteroid 1090 Sumida. The robotic telescope provided 120 sixty-second exposures.

Asteroid 1090 Sumida was discovered by Oikawa on 1928 Feb 20 and independently by Reinmouth four days earlier. Lightcurves were obtained by Behrend et al. (2004, 2015). Wisniewski (1991) determined a period of 2.70 h with amplitude of 0.22 magnitudes for Sumida. Behrend et al. (2004) obtained a rotation period of 2.7194 h and amplitude of 0.28 magnitudes. Warner and Megna (2012) obtained observations of Sumida from the Palmer Divide Observatory and the Center for Solar System Studies. The rapid spin period and 8 km size suggested Sumida could be a binary asteroid, but no secondary period was reported. The work of Warner and Megna (2012) suggested the possibility of discontinuities in the smoothly changing lightcurve of Sumida that could indicate a transit of a companion object and encouraged further observations of the object.

We selected Sumida for study because it was listed by Warner et al. (2015) as a good candidate for photometry in between January to March, 2015. Our major objective was to attempt a shape modeling of the object, and to obtain a very tightly spaced dataset with no observational gaps over the entire rotation period of the asteroid.

Our data were obtained on the night of 2015 Feb 18 with the Virtual Telescope operated by Gianluca Masi. The data consisted of 60-second exposures obtained over about 3 hours. The data were pre-processed using *IRAF* and the *IRAF Phot* package was used to measure instrumental magnitudes of Sumida and five comparison stars. We then took the average value of the magnitude difference between the asteroid and the comparison stars. The lightcurve of Sumida contributed for future modeling efforts for this object.

No formal period analysis was done. However, if assuming a bimodal lightcurve, the estimated period is 3.0 ± 0.3 h and the lightcurve amplitude 0.28 ± 0.03 mag.

Acknowledgements

We thank the staff at the Virtual Telescope Project for their help in planning and conducting our service-observing request that made this project possible.

References

Behrend R. (2004, 2015). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page3cou.html#001090*

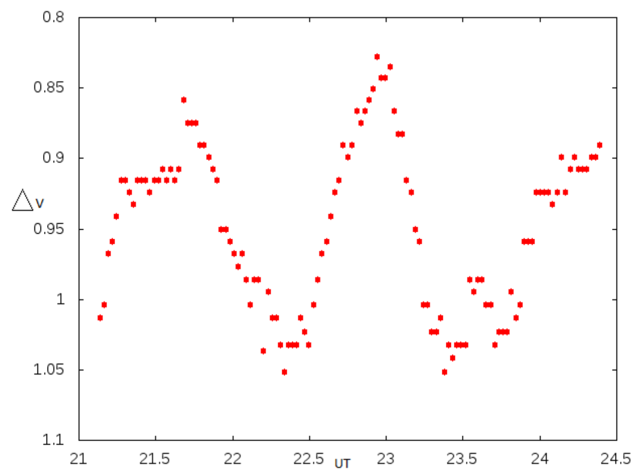
Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

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

Warner, B.D. Megna, R. (2012). "Lightcurve for 1090 Sumida." *Minor Planet Bull.* **39**, 231.

Warner, B.D., Harris, A.W., Durech, J., Benner, L.A.M., (2015). "Lightcurve Photometry Opportunities: 2015 January-March." *Minor Planet Bull.* **42**, 83-86.

Wisniewski, W.Z. (1991). "Physical studies of small asteroids. I - Lightcurves and taxonomy of 10 asteroids." *Icarus* **90**, 117-122.



Number	Name	2015 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1090	Sumida	02/18-02/18	120	7.4	158	4	3.0	0.3	0.28	0.03	PHO

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 average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). PHO: Phocaea.

PHOTOMETRIC OBSERVATIONS OF 1856 RUZENA

Melissa N. Hayes-Gehrke, Brandon Stoeckel, Suteerth Vishnu, Dallas Rhoades, Daniel Yang, Alex Pham, Andrew Gingerich, Gi Yoon Woo
Department of Astronomy
University of Maryland
College Park, MD 20742
mhayesge@umd.edu

Stephen M. Brincat
Flarestar Observatory (MPC 171)
FL5/B, George Tayar Street
San Gwann SGM 3160, MALTA
stephenbrincat@gmail.com

Charles Galdies
Znith Observatory
Armonie, E. Bradford Street
Naxxar NXR 2217, MALTA
charles.galdies@um.edu.mt

Winston Grech
Antares Observatory
76/3, Kent Street
Fgura FGR 1555, MALTA
win.grech@gmail.com

(Received: 2018 May 25)

CCD photometric observations of asteroid 1856 Růžena were taken over a span of 10 nights in April 2018, yielding a lightcurve with a rotation period of 5.960 ± 0.003h and an amplitude of 0.65 mag.

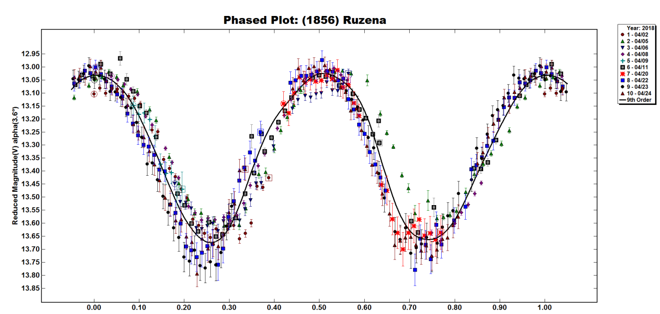
The main-belt asteroid 1856 Růžena was discovered on 1969 Oct 8 by the Russian astronomer Lyudmila Chernykh at the Crimean Astrophysical Observatory in Nauchnyj on the Crimean Peninsula. The asteroid was named in honor of Růžena Petrovičová who was a staff member of the Klet Observatory who observed comets and minor planets. The name was proposed by the discoverer of Růžena, Lyudmila Chernykh. Růžena has an orbital period of 3.35 years and an absolute magnitude of 12.8 (The International Astronomical Union Minor Planet Center. 2018). The geometric albedo of Růžena is 0.335 and SMASSII spectral classification is S-type (JPL, 2018).

One set of observations was obtained from iTelescope's New Mexico observatory (MPC code H06), located in Mayhill, New Mexico (32° 54'N, 105° 31'W). These observations took place on 2018 Apr 5, Apr 8, and Apr 11. We utilized the T21 telescope, a 0.43-m f/6.8 Corrected Dall-Kirkham (CDK) telescope with a FLI-PL6303E CCD (iTelescope, 2018). The CCD has an array of 3062 x 2048 pixels. Images were obtained with a clear filter and an exposure time of 300 seconds. All images were mid-exposure time light-time corrected using MPO Canopus 10.7.11.3 (Warner, 2017).

We took 175 images and discarded 36 images. A total of 139 images were used in the analysis, while the remaining images were discarded due to bad weather and the presence of a cloud cover. We performed differential photometry using MPO Canopus. We selected five comparison stars and used the lightcurve analysis feature to calculate the period. In addition, we also used the "Lightcurve Analysis" tool that uses the Fourier analysis calculation developed by Harris (Harris *et al.* 1989).

Following registration of preliminary periodic information of Růžena asteroid on MPO's CALL website by the US team, additional support came from the Malta team by means of additional observations of this asteroid. This resulted in a set of observations obtained from Flarestar Observatory - MPC Code: 171 (14° 28m 12.4s E, 35° 54' 37.2" N) through a 0.25-m f/6.3 Schmidt-Cassegrain (SCT) equipped with a Moravian G2-1600 CCD camera, and from Antares Observatory (14° 30m 46.7s E, 35° 52' 13.0" N) through a 0.28- m SCT coupled to a SBIG ST-11000 CCD Camera. All images were taken through a clear filter and auto-guided for the duration of the exposure. Flarestar Observatory used the camera in 1x1 binning mode with a resultant pixel scale of 0.99 arcsec per pixel while Antares Observatory used its camera in 2x2 binning mode with a resultant pixel scale of 1.32 arcsec per pixel. Both cameras were operated at sensor temperature of –15°C and images were calibrated with dark and flat-field frames. Both telescopes and cameras were controlled remotely from a nearby location via Sequence Generator Pro (Main Sequence Software). Photometric reduction, lightcurve construction, and period analyses were done using MPO Canopus software (Warner, 2017). Differential aperture photometry was used, and photometric measurements were based on the use of comparison stars of near solar color that were selected by the Comparison Star Selector (CSS) utility available through MPO Canopus. Asteroid magnitudes were based on MPOSC3 catalog supplied with MPO Canopus.

We consolidated all of our nights of data to get a single phased lightcurve with period 5.960 ± 0.003h. The lightcurve has typical peaks and troughs with a magnitude spanning 0.65 mag. We adjusted the order and the number of steps to ensure the data were fitted correctly.



Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1856	Ruzena	04/02-04/24	445	3.0,14.5	187	0.3	5.960	0.003	0.65		MBA

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

We would like to thank the University of Maryland Astronomy Department and the College of Computer, Mathematical, and Natural Sciences for their support. We would also like to thank iTelescope.net for their telescope services.

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.

The International Astronomical Union Minor Planet Center. (n.d.). *https://www.minorplanetcenter.net/db_search/show_object?object_id=1856*

iTelescope (2018) iTelescope.Net - Remote Internet Telescope Network - Online Image & Telescope Hosting Services. *http://www.itelescope.net/*

JPL (2018). Small-Body Database Browser - JPL Solar System Dynamics web site. *http://ssd.jpl.nasa.gov/sbdb.cgi*

Warner, B.D. (2017). MPO Software, MPO Canopus version 10.7.11.3, Bdw Publishing. *http://www.minorplanetobserver.com/*

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*

ROTATION PERIOD DETERMINATION FOR 418 ALEMANNIA AND 4911 ROSENZWEIG

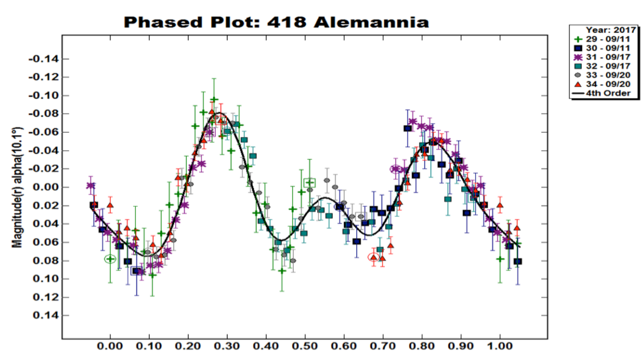
Richard D. Gorby, Adam W. Rengstorf, Jacob Pavel
Northwest Indiana Robotic Observatory
Purdue University Northwest
Department of Chemistry and Physics
2200 169th St.
Hammond, IN 46323
adamwr@pnw.edu

(Received: 2018 May 29)

Fourier analysis of data taken of asteroid 418 Alemannia determined a rotational period of 4.670 ± 0.006 h with an amplitude of 0.16 ± 0.02 mag. 4911 Rosenzweig's analysis shows a period of 9.75 ± 0.01 h with an amplitude of 0.08 ± 0.02 mag.

418 Alemannia was observed over 6 nights between 2017 Sep 11 and Sep 20. 4911 Rosenzweig was observed over 6 nights between 2017 Sep 25 and Oct 20. All data were taken at Purdue University Northwest's Northwestern Indiana Robotic Observatory (NIRo, MPC W11) in Lowell, Indiana. The two asteroids were selected from the MPC quarterly bulletin as good observation candidates. Data were collected using a 0.5-m f/8.1 Ritchey-Chretien telescope equipped with an *FLI ProLine PLO9000* camera housing a KAF-09000 CCD image sensor. Images were corrected for bias, dark current, and flat-field artifacts using accepted data reduction practices. Rotation periods for both asteroids were determined via Fourier analysis using *MPO Canopus* (Warner, 2017).

418 Alemannia is an M-class main-belt asteroid discovered on 1896 Sep 7 by Max Wolf at the Heidelberg Observatory. Originally designated as 1896 CV, the German astronomer Adolf Berberich named this asteroid after the fraternity Alemannia in Heidelberg, Germany. The JPL Small-Bodies Database lists the orbital period as 4.18 yrs along with an albedo of 0.201, a diameter of 40.330 km, and an absolute magnitude of H = 9.77 mag (JPL, 2017).



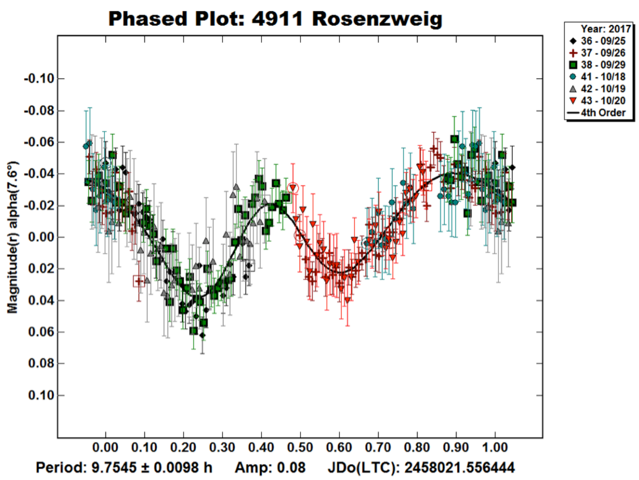
The first published period for 418 Alemannia was 5.82 h (Lagerkvist et al., 1987). Wetterer et al. (1999) published a period

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
418	Alemannia	09/11-09/20	153	7.5,17.0	332	9	4.760	0.006	0.16	0.02	MB-I
4911	Rosenzweig	09/25-10/20	162	7.5,8.8	355	10	9.75	0.01	0.08	0.03	EUN

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).

of 4.680 h. Most recently, Klinglesmith and Hendrickx (2018a) and Pilcher (2018) report a period of 4.67 h. Our analysis found a period of 4.670 ± 0.006 h with an amplitude of 0.16 ± 0.02 mag, which agrees with the most recent data to within our uncertainty.

4911 Rosenzweig is in the Eunomia family of S-type asteroids in the intermediate asteroid belt. Discovered on 1953 Oct 16, 4911 Rosenzweig is one of the 119 asteroids discovered by the Indiana Asteroid Program between 1949 and 1966. This asteroid is named for Jack and Marcelle Rosenzweig. The JPL Small-Bodies Database lists the orbital period as 4.28 yrs; along with an albedo of 0.309, a diameter of 9.97 km, and an absolute magnitude of H = 12.1 mag (JPL, 2017).



Recently, Klinglesmith and Hendrickx (2018b) reported a period of 12.71 ± 0.02 h, while Rowe (2018) reported a period of 28.6 ± 0.1 h. Our analysis found a period of 9.75 ± 0.01 h with an amplitude of 0.08 ± 0.02 mag. All three rotation periods differ at a statistically significant level. Attempts to fit our data to the other rotation periods resulted in unconvincing fits. Further observations of 4911 Rosenzweig are necessary.

Acknowledgements

The authors wish to thank Daniel A. Klinglesmith III at Etscorn Observatory for his advice and assistance throughout this work.

References

JPL (2017). Small Body Database Search Engine. *http://ssd.jpl.nasa.gov/sbdb_query.cgi*

Klinglesmith, D.A. III, Hendrickx, S. (2018a). “Asteroid Lightcurves from Etscorn Observatory.” *Minor Planet Bull,* **45**, 61–63.

Klinglesmith, D.A. III, Hendrickx, S. (2018b). “Asteroid Lightcurve Observations at Etscorn Observatory.” *Minor Planet Bull*. **45**, 162–165.

Rowe, B. (2018). “Lightcurve Analysis of Ten Asteroids from RMS Observatory.” *Minor Planet Bull.* **45**, 203-207

Lagerkvist, C.-I., Hahn, G., Magnusson, P. (1987). “Physical studies of asteroids XVI – Photoelectric Photometry of 17 Asteroids.” *Astron. Astrophys. Suppl. Ser*. **70**, 21-32.

Pilcher, F. (2018). “Rotation Period Determination for 418 Alemannia, 646 Kastalia and 876 Scott.” *Minor Planet Bull.* **45**, 55–56.

Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). “Lightcurves and phase relations of the asteroids 82 Alkeme 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 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

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

Wetterer, C.J., Saffo, C.R., Majcen, S. (1999). “CCD Photometry of Asteroids at the US Air Force Academy Observatory During 1998.” *Minor Planet Bull.,* **26,** 30.

LIGHTCURVE ANALYSIS OF MAIN-BELT ASTEROID (9899) 1996 EH

Melissa N. Hayes-Gehrke, Chris Nakamura, Erin Estes,
Keona Holden, Justin Vo, Leonel Ramos, Chanh Tran,
Jeffrey Sweeney, Jack Sigler
Department of Astronomy
University of Maryland
College Park, MD 20740 USA
mhayesge@umd.edu

(Received: 2018 May 25)

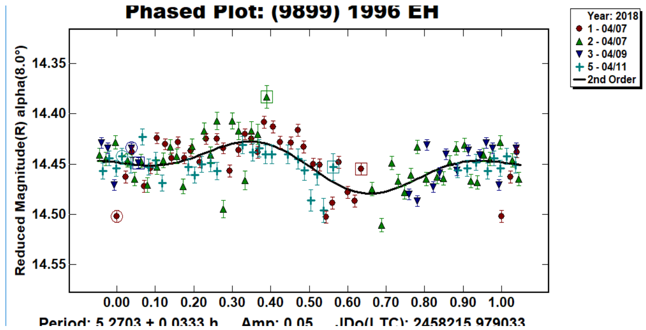
We obtained multiple sessions of observations of the main belt asteroid (9899) 1996 EH, using the iTelescope Observatory in Siding Spring, Australia. After analysis, we were unable to determine a conclusive period.

Our observations of (9899) 1996 EH were performed using iTelescope T27, a 700-mm telescope in Siding Spring, Australia with a FLI PL09000 CCD, and a 'clear' glass filter, using 300-s exposures. The CCD has an array of 3056 x 3056 pixels, where each pixel has an angular resolution of 0.53 arc-seconds. Data were collected from four observing sessions over three days, for a total of 16 hours of observations. Lightcurve analysis was done using MPO Canopus.

Our phased lightcurve shows no well-defined peaks or troughs and remains mostly flat throughout the plotted data. The change in magnitude over time is small enough (with a differential magnitude ranging from 14.5 to 14.4) that these variations could be due to noise sources. This lack of variation in magnitudes leads us to believe that 1996 EH fits one or more of the following criteria.

1. It has a nearly spherical shape and a uniform albedo. This would greatly reduce the change in brightness over time, preventing us from discerning a pattern in the lightcurve.
2. The rotation period may be abnormally long, causing a lack of detectable change of brightness throughout four days of observation.
3. 1996 EH may have an axis of rotation orthogonal to Earth, meaning no changes in brightness due to rotation would be visible until its position relative to Earth has changed.

In a search of the Asteroid Lightcurve Database, there is no currently published period of 1996 EH.



The displayed lightcurve has a period of 5.27 ± 0.03h, with an amplitude of only 0.05 magnitudes. This amplitude is not significantly larger than the variations in brightness due to the noise; therefore, this is not a definitive period, but it satisfactorily displays the data we collected.

Acknowledgements

This research was made possible through funding by the Astronomy Department and the College of Mathematical and Natural Sciences at the University of Maryland, College Park. We would like to thank iTelescope (accessible at iTelescope.net) for providing the use of their telescopes. We would also like to thank Brian Warner for his assistance in data analysis problems that we encountered using MPO Canopus.

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.

JPL(2017). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

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

Warner, B.D. (2017). MPO Software, MPO Canopus v10.7.7.0. Bdw Publishing. *http://minorplanetobserver.com*

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
9899	1996 EH	04/07, 04/09, 4/11	115	7.9-6.3	206.5	-7.8	N/A	N/A	N/A	N/A	MB

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).

TWO POSSIBLE ROTATION PERIODS FOR (86401) 2000 AF143

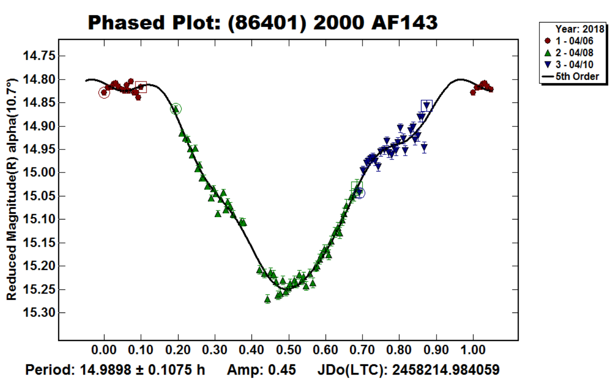
Melissa N. Hayes-Gehrke, Suhas Amireddy, Daniel Choi,
Kyle Collins, Christian Nguyendinh, Kiwon Park, Nisarg Patel,
Michael Toscano, Haotian Wang
Department of Astronomy
University of Maryland
College Park, MD 20742 USA
mhayesge@umd.edu

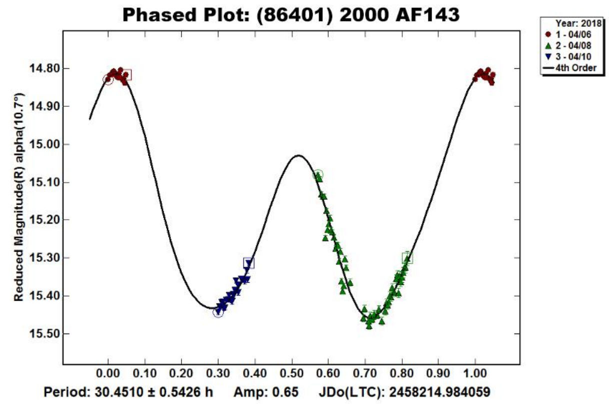
(Received: 2018 May 25)

The minor planet (86401) 2000 AF143 was observed remotely using the T27 telescope located in Siding Spring, Australia. Two aliasing periods are potential rotation periods: 15.0 ± 0.3 h and 30 ± 2 h.

The asteroid was observed from 2018 Apr 6 to 2018 Apr 10. Observations were made using iTelescope's T27 telescope located in Siding Spring, Australia. The telescope is a 0.70-m f/6.6 reflector with a FLI PL09000 CCD. All images were taken with a luminance filter with a 300-second exposure time. The camera operated at a temperature of -35°C with a focal length of 4531 mm and a resolution of 0.53" per pixel.

Photometric reduction and rotation period analyses were performed using the MPO Canopus software, yielding the differential magnitudes shown in the figures. The rotation period was fitted by *MPO Canopus* using the Fourier analysis algorithm developed by Harris (Harris *et al.* 1989).





(86401) 2000 AF143 was discovered by the LINEAR project at Socorro, New Mexico on 2000 Jan 5 (JPL, 2018). A search for the asteroid in the Asteroid Lightcurve Database (Warner *et al.*, 2009) yielded no results. Due to observational constraints, there are several gaps in the data, contributing to the lack of a conclusive result. Two aliasing rotation periods for the asteroid are presented: 15.0 ± 0.3 h and 30 ± 2 h. While a 2-peak lightcurve is more common in the literature, thus the 30 h period is preferred, we cannot rule out the 15 h scenario.

Acknowledgements

Funding and resources were provided by the University of Maryland's Astronomy Department and by the College of Computer, Mathematical, and Natural Sciences. We thank the iTelescope for providing the telescopes used for observations.

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*

Warner, B.D., Harris, A.W., Pravec, P. (2009). *Icarus* **202**, 134-146. Updated 2018 March 19. *http://www.MinorPlanet.info/lightcurvedatabase.html*

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	Grp
86401	2000 AF143	04/06-04/10	103	10.9,9.1	206.3	-8.5	15.0	0.3	0.45	MC
86401	2000 AF143	04/06-04/10	93	10.9,9.1	206.3	-8.5	30	2	0.65	MC

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 average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). MC = Mars-crossing asteroid. For a more conservative estimate, reported period error is three times that calculated by *MPO Canopus*.

THE ROTATION PERIOD OF 3394 BANNO AND THE RAW LIGHTCURVE OF (48697) 1996 HX14

Melissa N. Hayes-Gehrke, Cory Hannon, Isaac Lockwood, Justin Lee, Richard Moyer III, Adrian Hidayat, Steve Moore, Michael Newman, Olivier Toujas-Bernate
Department of Astronomy
University of Maryland
College Park, MD 20742
mhayesge@umd.edu

(Received: 2018 May 25)

Over the course of five nights of observations, we observed asteroid 3394 Banno using iTelescope facilities in New Mexico and Australia. Using the software MPO Canopus, we analyzed and plotted our data to find a rotation period of 7.321 ± 0.025 hours. Additionally, we present raw data for the asteroid (48697) 1996 HX14 found in one night of our observations.

3394 Banno was observed via photometric systems from both Siding Spring, Australia and Mayhill, New Mexico. Images were taken by the T30 and T21 telescopes from iTelescope.net, respectively, over a nine-day period between 2018 April 11 and 2018 April 18 with a clear filter and 300-s exposures. The T30 telescope is a 0.50-m f/6.8 reflector + CCD + f/4.5 focal reducer telescope, and the T21 is a 0.43-m f/6.8 reflector + CCD + f/4.5 focal reducer. The 160-plus images taken were processed via MPO Canopus to yield a lightcurve. Within MPO Canopus, the magnitude of 3394 Banno was compared to comparison stars, which were selected based on their lack of proximity to the edges of the images and signal-to-noise ratio. The generated lightcurves were then phased using Fourier analysis to identify the period of 7.321 ± 0.025 h.

Consulting the Asteroid Lightcurve Database, it was found that no prior rotation period for 3394 Banno has been recorded, so we are unable to compare the period found against prior analysis.

(48697) 1996 HX14 was found while performing data analysis on images for 3394 Banno. (48697) 1996 HX14 is markedly dimmer than 3394 Banno, with apparent magnitudes of 18.15 and 14.6, respectively on 2018 April 11, and (48697) 1996 HX14 only appeared in one set of images taken. Because of this, no phased lightcurve for (48697) 1996 HX14 was generated, but raw data have been provided for future analysis.

Acknowledgements

We thank the Astronomy Department and the College of Computer, Mathematical, and Natural Sciences at the University of Maryland, College Park for their continued support of our research.

We thank the iTelescope network (*https://www.iTelescope.net*) for allowing us to use their telescopes for observation.

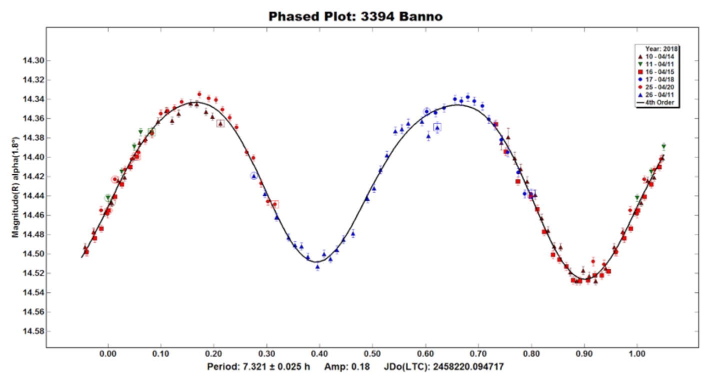
References

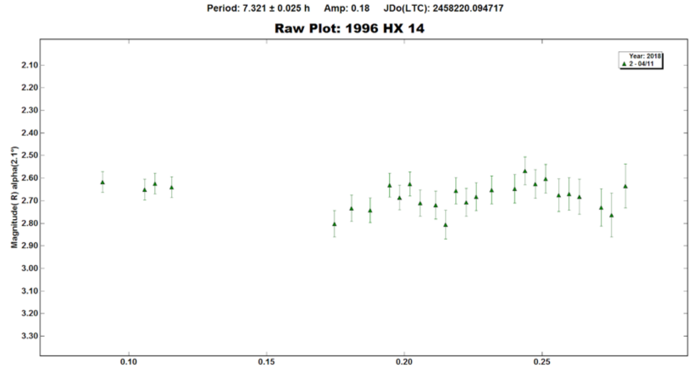
Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

iTelescope.net. "iTelescope."

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). MPO Software, *MPO Canopus* version 10.7.11.3. Bdw Publishing. *http://www.minorplanetobserver.com/*





Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3394	Banno	04/11-04/20	160	13.5	207.2	3.8	7.321	0.025	0.21	0.016	MB
48697	1996 HX14	04/11	27	9.8	205.4	1.7	---	---	---	---	MB

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).

4767 SUTOKU LIGHTCURVE DETERMINATION

Melissa N. Hayes-Gehrke, Matthew Dolinka, Ian Ihde, Albert Liu, Kevin Souders, Saira Umar, Carl Xiong, Sydney Gholson, Dustin Brashear
Department of Astronomy
University of Maryland College Park, MD 20742
mhayesge@umd.edu

(Received: 2018 May 25 Revised: 2018 Aug 11)

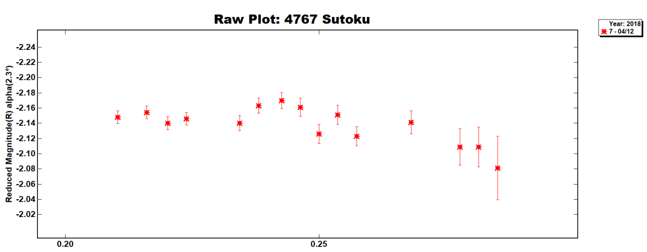
Images from three nights of observing 4767 Sutoku were analyzed using aperture photometry. The asteroid's raw data did not yield a definitive periodic trend.

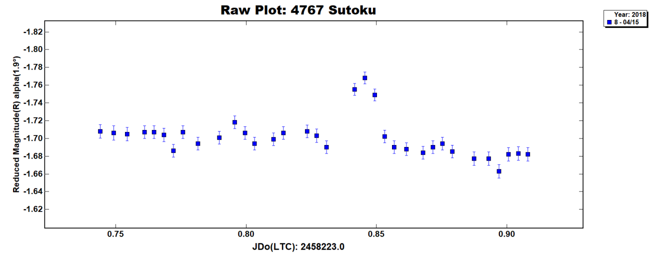
Named in honor of the 75th emperor of Japan, 4767 Sutoku is a main-belt asteroid discovered in 1953. It has a diameter of 8.36 km and a semi-major axis of 2.69 AU.

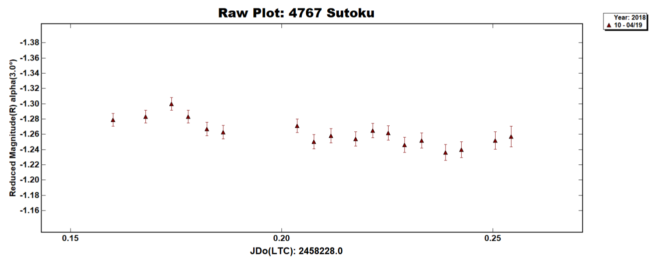
Two different telescopes were used for our observations, both provided and maintained by iTelescope.net. The first telescope was T30, in the Siding Spring Observatory in Australia. The T30 telescope uses an FLI Proline PL6303 CCD, with a 3072 x 2048 array of 9-µm pix. The telescope has a field of view of 27.8 x 41.6 arcminutes and an angular resolution of 0.81 arcsec/pix. The second telescope used was iTelescope's T21, in Mayhill, New Mexico. This telescope is also fitted with an FLI Proline PL6303E CCD. It has a resolution of 0.96 arcsec/pix and a field of view of 32.8 x 49.2 arcminutes. These telescopes were both used to take images with an exposure of 300 seconds and a luminance filter.

4767 Sutoku was successfully observed on 2018 April 12, 15, and 19. Over the nights of observation, Sutoku's brightness varied very little. As such, Sutoku's rotation period could not be determined. This could be a result of Sutoku having one or more of the following properties: nearly spherical shape, extremely long rotation period, or rotation pole pointed towards the observer.

The three figures display the raw data plots for the three nights of observation.







It was difficult to identify any periodic trends in the raw plots. The highest fluctuation measured was a mere 0.1 magnitude. Additionally, some of the changes that did occur in the data are difficult to explain. Particularly, on April 15th there is an anomalous peak around a date of 0.8. The data for this night have been reanalyzed several times and this feature has appeared each time.

Overall, we did not acquire sufficient data to propose a reasonable phased lightcurve and rotation period for 4767 Sutoku. Due to the lack of prior research and low quantity of images analyzed, additional research will be necessary in order to determine a model for the rotation period of Sutoku. These three proposed scenarios regarding Sutoku can serve as a basis to guide future observations and analyses.

Acknowledgements

The observations were made possible by funding from the University of Maryland Astronomy Department and the College of Computer, Mathematical, and Natural Sciences. Telescopes used were T17 in Mayhill, New Mexico and T30 in Siding Spring, Australia through iTelescope.net.

References

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

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

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). MPO Software. MPO Canopus v10.7.7.0. Bdw Publishing. *http://minorplanetobserver.com*

Number	Name	2018 05/04	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4767	Sutoku	04/12-04/19	67	8.6,9.6	350.3	-22.2					MB

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

LIGHTCURVE ANALYSIS FOR 19911 RIGAUX

Melissa N. Hayes-Gehrke, Owen Raman, Diarre Ibrahim,
Jonathan Isolato, Kyle Strouth, Emery Bacon, Danielle Haslup,
Eni Awowale, Neema Valizadeh
Department of Astronomy
University of Maryland
College Park, MD 20742 USA
mhayesge@umd.edu

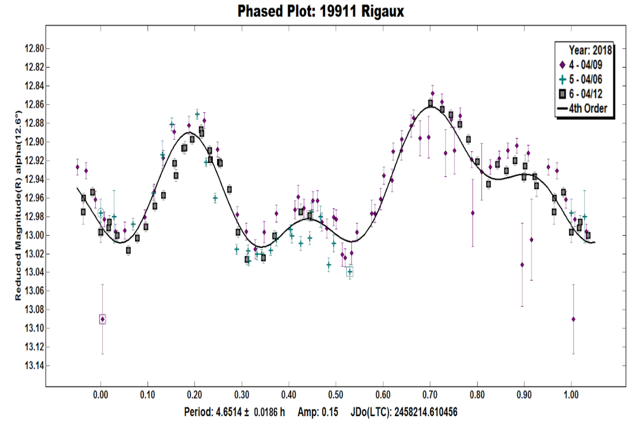
(Received: 2018 May 25)

Using *MPO Canopus*, we analyzed the lightcurve of asteroid 19911 Rigaux. The rotation period was previously unknown, and we determined it to be 4.65 ± 0.02 hours.

19911 Rigaux was discovered on 1933 March 26 by astronomer Fernand Rigaux (JPL, 2018). It has an orbital period of 5.32 years. It is a main belt asteroid with an absolute magnitude of 12.4 and a diameter of 18.341 km (JPL, 2018).

The observations took place on 2018 April 5, 8, and 11 remotely from iTelescope.net. The telescope used was T21 in Mayhill, New Mexico. It has a diameter of 0.43 m and focal length of 1940 mm, with the FLI-PL6303E CCD which has a 3072 x 2048 pixel array and a pixel size of 9 microns (Telescope, 2018). With CCD and telescope resolution combined, final images have a resolution of 0.96 arcsec/pixel (Telescope, 2018). The coordinates of the telescope are 32.9° North, and 105.5° West (Telescope, 2018). We used a luminance filter with an exposure time of 300 seconds.

The Asteroid Lightcurve Database did not contain any previously recorded data on the rotation period of the asteroid, however the data from the three observing sessions overlapped well in the phased lightcurve, yielding a convincing result. The rotation period of the asteroid was determined to be 4.65 ± 0.02 hours. The phased lightcurve also suggests that the asteroid has an irregular shape, evidenced by an unusual rise in the trough as well as after the second peak.



Acknowledgements

Observations were funded by the Astronomy Department and College of Computer, Mathematical and Natural Sciences at the University of Maryland. ITelescope was also very gracious enough to allow us to use their services and facilities to make observations of our asteroid.

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.

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

Telescope (2018). iTelescope.Net-Remote Internet Telescope Network- Online Image & Telescope Hosting Services. *http://www.itelescope.net/*

Warner, B.D., Harris, A.W., Pravec, P. (2009). *Icarus* **202**, 134-146. Updated 2018 March 19. *http://www.MinorPlanet.info/lightcurvedatabase.html*

Warner, B.D. (2016). MPO Software, MPO Canopus version 10.7.7.0, Bdw Publishing. *http://www.minorplanetobserver.com/*

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	Grp
19911	Rigaux	04/5-04/11	143	11.1,12.8	181	13	4.65	0.02	0.15	MB

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 average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). MC = Mars-crossing asteroid. For a more conservative estimate, reported period error is three times that calculated by *MPO Canopus*.

ROTATION PERIOD FOR 4221 PICASSO

Stephen C. Percy
The Studios Observatory (Z52)
31 Ipswich Gardens, Grantham, NG31 8SE, U.K.
mail@opussoftware.co.uk

(Received: 2018 June 11)

CCD photometric observations of the main-belt asteroid 4221 Picasso ware made at the Studios Observatory over five nights from 2018. The rotation period was found to be 3.111 ± 0.001 h with a lightcurve amplitude of 0.31 ± 0.05 mag.

The main-belt asteroid 4221 Picasso (previous designations: 1954 GD, 1984 JH1, and 1988 EJ) was discovered at Palomar on 1988 March 13 by J. Alu. CCD photometric observations were made from The Studios Observatory, Grantham, U.K. (Z52) over five nights between 2018 May 26 and June 10.

The observations were made using a Meade 0.36-m LX200 ACF OTA operating at *f*/7. The OTA was mounted on a Paramount MEII robotic mount and equipped with a Moonlite CSL motorized focuser, Astro Physics AP CCDT67 focal reducer, and a QSI 683 cooled CCD camera (binned 2x2). All measurements were unfiltered due to the faint magnitude of the target, V = 15.7-15.9. The CCD is based on an 8.3 Mpix (3326x2504) Kodak KAF-8300 sensor with square 5.4 µm pixels. The image scale after 2x2 binning was 0.86 arcsec/pixel.

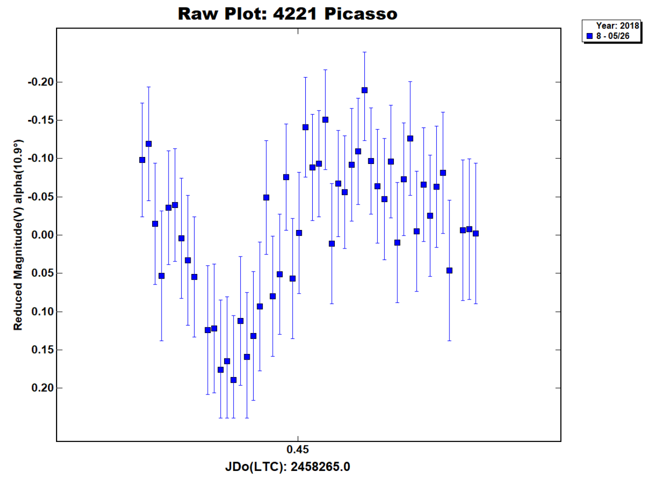
TheSkyX Professional software (Software Bisque, 2018) was used for all telescope, focuser, and camera control. This software was also used to calibrate all science images using dark, dark-for-flat, and flat field frames. All flat field images were taken at the end of the observing sessions using a wall-mounted whiteboard illuminated by an A4-size electroluminescent (EL) panel. A recent library of dark and dark-for-flat frames was used in the calibration process; no scaling of dark frames was necessary.

All data processing of the calibrated images and subsequent period analysis was performed using *MPO Canopus* (Warner, 2018). Differential photometry measurements were performed using the Comp Star Selector (CSS) and Star-B-Gone procedures of *MPO Canopus*. The asteroid and five solar-like stars were used for all photometric comparisons. Period analysis was performed using the Fourier analysis algorithm (FALC) of *MPO Canopus* developed by Alan Harris (Harris et al., 1989).

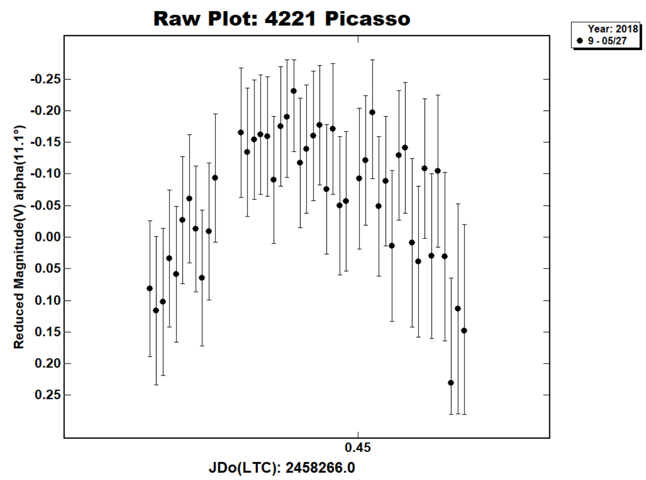
More than 11 hours of observations produced 393 data points for analysis. All likely periods between 2 and 10 hours were examined. The rotation period was found to be 3.111 ± 0.001 h with a lightcurve amplitude of 0.31 ± 0.05 mag. A search of the asteroid lightcurve database (LCDB; Warner et al., 2009) indicated no previously reported lightcurve data for this asteroid.

The first two observing sessions on May 26 and 27 were plagued by poor seeing and terminated early due to clouds. The final three observing sessions benefited from improved seeing, although the June 8 session was still hampered by occasional cloud cover.

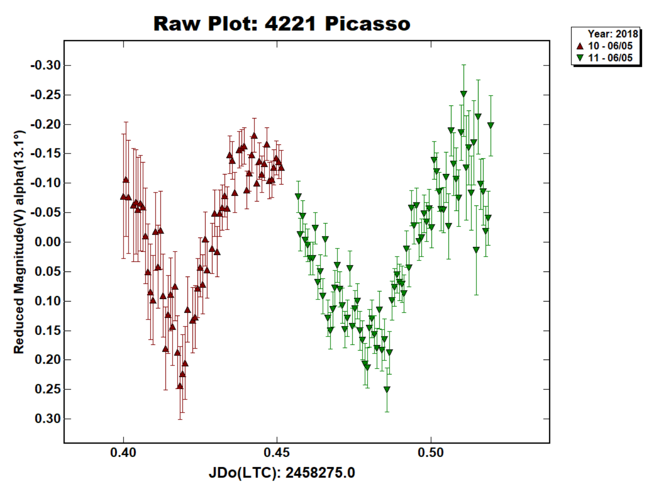
Table I provides an overview of the observed results. The observing schedule and calibrated data are summarized below.



2018 May 26 (Phase 10.92, L_{PAB} 240, B_{PAB} 19). A total of 50 data points (90 s exposures) was acquired over a 1 h 25 min period.



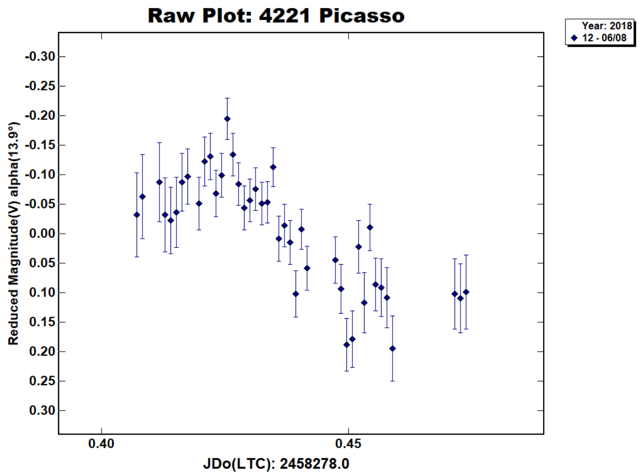
2018 May 27 (Phase 11.08, L_{PAB} 240, B_{PAB} 19.3). A total of 42 data points (90 s exposures) was acquired over a 1 h 19 min period.



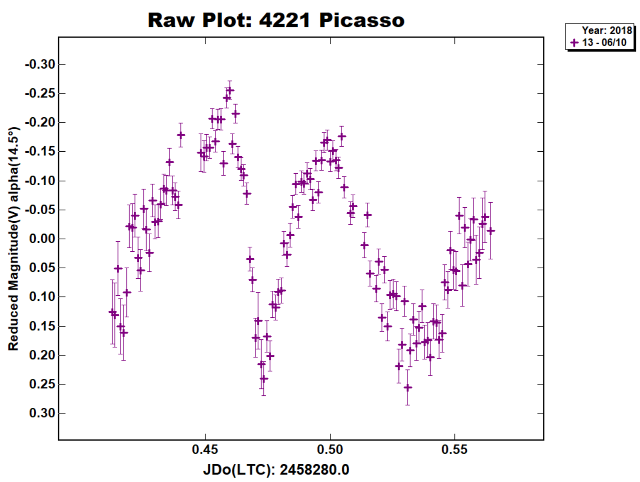
2018 June 5 (Phase 13.08, L_{PAB} 240, B_{PAB} 20). A total of 138 data points (60 s exposures) was acquired over a 2 h 47 min period.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
4221	Picasso	05/26-06/10	393	10.9,14.5	240	20	3.111	0.001	0.31	0.05	MB-M

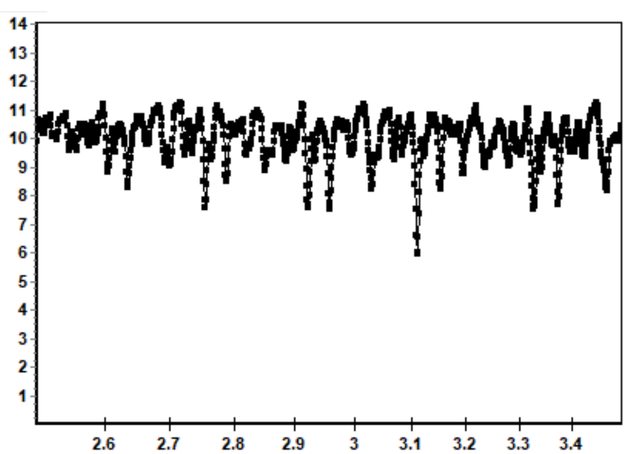
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner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

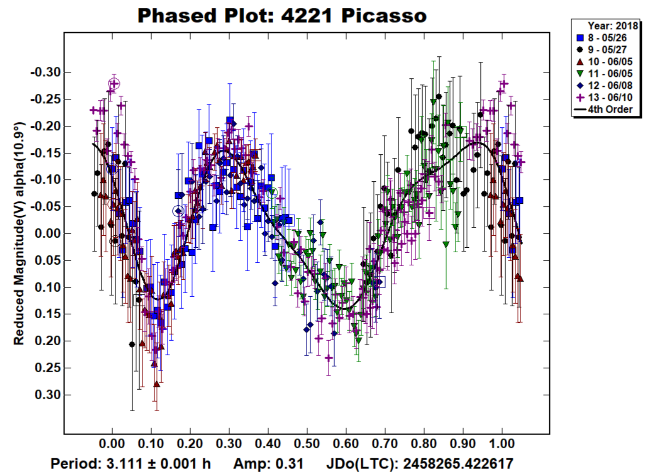


2018 June 8 (Phase 13.89, L_{PAB} 241, B_{PAB} 20). A total of 42 data points (90 s exposures) was acquired over a 1 h 33 min period.



2018 June 10 (Phase 14.47, L_{PAB} 241, B_{PAB} 20). A total of 121 data points (90 s exposures) was acquired over a 4 h 14 min period.





The period spectrum for 4221 Picasso covered all likely solutions between 2 and 10 hours. The Fourier analysis consistently indicated an optimum period of 3.111 h. The lightcurve shows the data phased to the solution of 3.111 h. Its amplitude is 0.31 mag.

All new data were uploaded to the ALCDEF database (*http://alcdef.org*).

Acknowledgements

This research was made possible in part based on data from the MPCOSC3-2MASS catalog (a product of the Two Micron All Sky Survey), UCAC4 (the fourth U.S. Naval Observatory CCD Astrograph Catalog), and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. The author would like to express his gratitude to Brian D. Warner for his *MPO Canopus* software and support, along with the 2nd edition of his book, *A Practical Guide to Lightcurve Photometry and Analysis* (Warner, 2006). Both have been invaluable in this research. The author would also like to express his gratitude to his neighbor Brian J. Shortland for kindly chopping down his tree adjacent to the observatory, the direct result of which allowed this asteroid to be imaged and its rotation period determined.

[EDITOR'S NOTE: The readers of the *Minor Planet Bulletin* also convey their thanks to Mr. Shortland.]

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., Bowel, 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.

Software Bisque (2018). *TheSkyX Professional* software. *http://www.bisque.com*

Warner, B.D. (2006). *A Practical Guide to Lightcurve Photometry and Analysis (2nd edition)*. pp 268. Springer, New York.

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. (2018). *MPO Canopus* v10.7.11.3. BDW Publishing. *http://www.bdwpublishing.com*

LIGHTCURVE ANALYSIS OF MINOR PLANETS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2017 JUNE–JULY

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

(Received: 2018 June 11)

From 2017 June 20 to July 25, images of nine minor planets were collected to investigate their rotational lightcurve periods. The minor planets observed were 1049 Gotho, 1184 Gaea, 1737 Severny, 1887 Virton, 2672 Pisek, 3995 Sakaino, 6358 Chertok, (13538) 1991 ST, and 14339 Knorre.

We used an STX-16803 camera with 3x3 binning and a luminance filter attached to a 0.5-m Planewave telescope operating at *f*/6.7 (plate scale 1.63 arcseconds) to collect images on the nights of 2017 June 20–23, 25, 26, 29, 30, July 11–18, 20–25. The targeted minor planets were 1049 Gotho, 1184 Gaea, 1737 Severny, 1887 Virton, 2672 Pisek, 3995 Sakaino, 6358 Chertok, (13538) 1991 ST, and 14339 Knorre. The images were processed using standard techniques with *MaxIm DL*. The images were measured and lightcurves generated with *MPO Canopus*.

Table I lists the targets, range of dates, phase angle, phase angle bisector longitude, and latitude as well as the period if we were able to determine one. Unfortunately, we were not able to determine periods for 1887 Virton, 2672 Pisek, or 6358 Chertok, so only an estimate of the amplitude is given.

1049 Gotho. Our period of 8.468 ± 0.002 h is in close agreement with the Albers *et al*. (2010) period of 8.470 ± 0.007 h.

1184 Gaea. The period of 2.8735 ± 0.0005 h we found is just outside the uncertainty range of the period of 2.94 ± 0.06 h found by Behrend (2011). We tried the 2.94 h period on our data and it does not fit.

1737 Severny. Behrend (2005) gives a period of 14.11 ± 0.07 h while Waszczak et al. (2015) lists 9.25 ± 0.06 h. We tried to fit our data with both periods, and derived a good fit with a period of 9.223 ± 0.004 h.

References

Albers, K., Kragh, K., Monnier, A., Pligge, Z., Stolze, K., West, J., Yim, A., Ditteon, R. (2010). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2009 October thru 2010 April." *Minor Planet Bull.* **37**, 152-158.

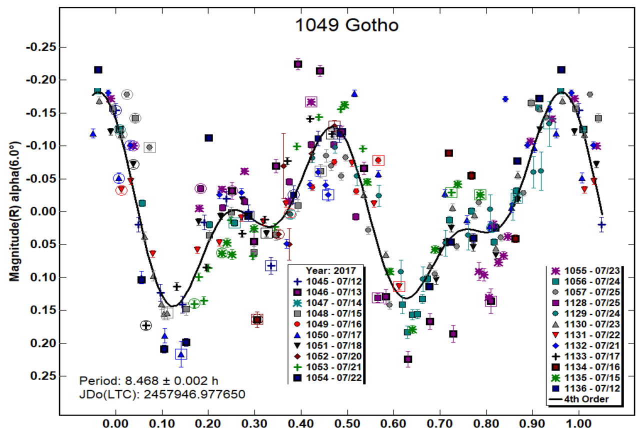
Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.
1049	Gotho	07/12-07/25	227	6.1, 5.5, 6.0	296	-14	8.468	0.002	0.35	0.05
1184	Gaea	07/11-07/25	250	7.4, 6.7, 7.3	295	-13	2.8735	0.0005	0.15	0.05
1737	Severny	07/12-07/25	154	4.4, 2.2, 2.4	299	-6	9.223	0.004	0.10	0.05
1887	Virton	07/12-07/25	190	4.7, 4.0, 4.7	296	-10			0.5	0.1
2672	Pisek	06/20-06/30	81	13.2, 16.3	251	15			0.04	0.04
3995	Sakaino	07/12-07/25	201	5.6, 2.1, 2.3	300	-4	4.5529	0.0002	0.75	0.05
6358	Chertok	07/11-07/25	175	5.7, 5.1, 6.9	294	-9			0.06	0.04
13538	1991 ST	07/12-07/25	211	9.6, 6.4, 6.6	300	-7	12.3206	0.0014	0.82	0.03
14339	Knorre	06/20-06/30	166	13.2, 16.3	251	15	3.7963	0.0003	0.20	0.06

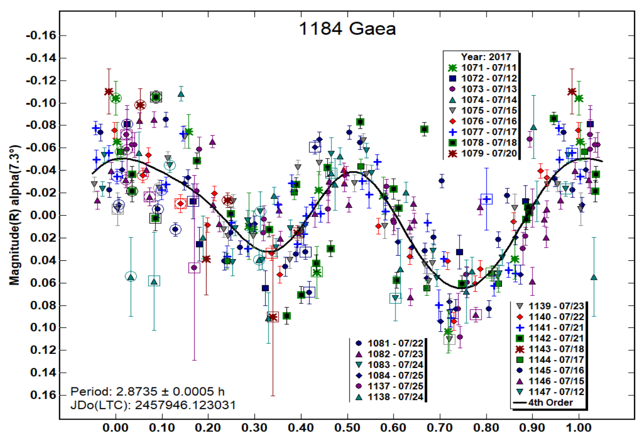
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al, 1984).

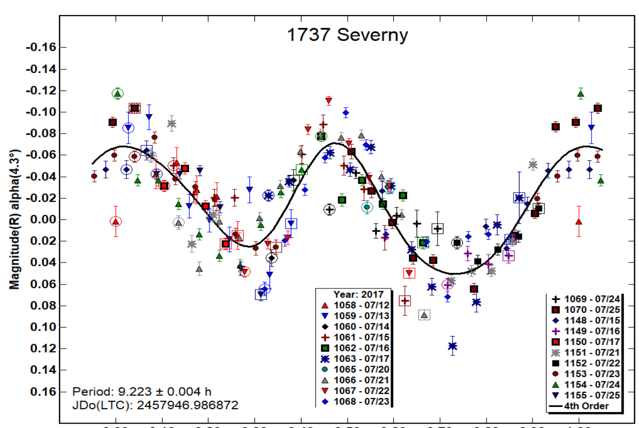
Behrend, R. (2011, 2015). Observatoire de Genève web site. *http://obswww.unige.ch/~behrend/page_cou.html*

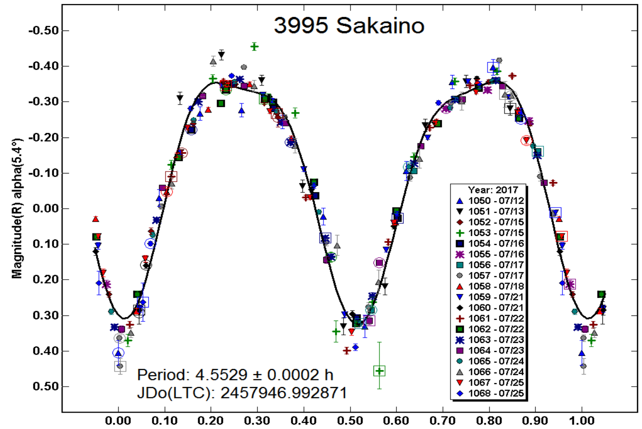
Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

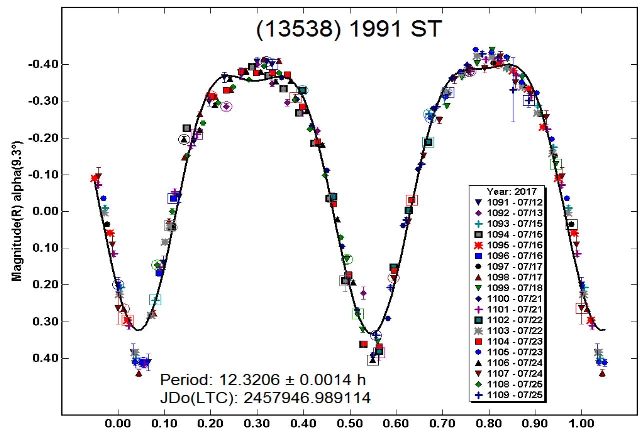
Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry."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

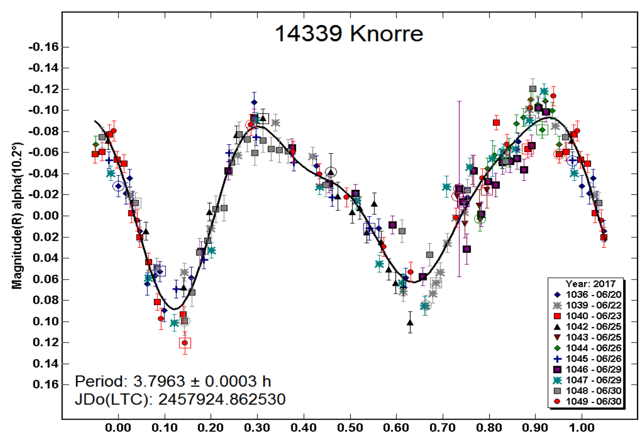












LIGHTCURVE ANALYSIS AND ROTATION PERIOD FOR (3394) BANNO

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: 2018 Jun 11)

Photometric data for asteroid 3394 Banno were collected from 2018 April 19-25. The analysis obtained led to a good multiple coverage lightcurve that fit to a period of 7.324 ± 0.002 hours and amplitude of 0.24 mag.

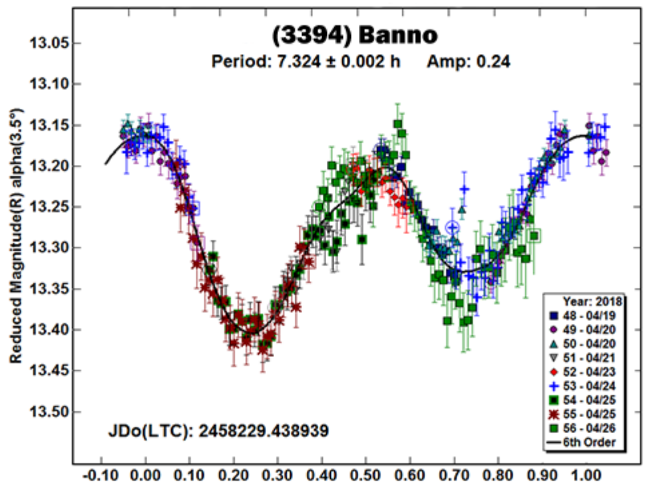
The main-belt asteroid 3394 Banno (1986 DB) was discovered by S. Inoda and T. Urata, at Karasuyama in 1986. It orbit has a semi-major axis of 2.317 AU, period of 3.53 years, eccentricity of 0.197, and inclination of 7.093 deg. The SMASS catalog (Bus and Binzel, 2002) classifies the asteroid as type S. With H = 13.1 and p_V = 0.271 (JPL, 2018) the estimated diameter is 6 km. Marchini et al. (2018) previously reported the rotation period to be 7.324 h.

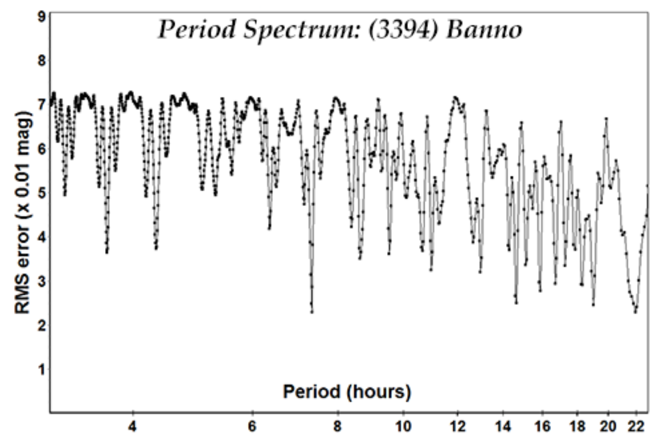
Observations were conducted from Elianto observatory (MPC K68) using an *f*/4 0.30-m Newtonian telescope. The CCD camera had a KAF-1603 chip with 9-micron pixels in a 1536x1024 array. No filter was used. Exposures were 240 seconds. Master dark and flat fields were obtained using *CCD Stack*. *MPO Canopus* (Warner, 2016) was used to measure the magnitudes with MPOSC3, a hybrid catalog 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 were reduced to unity Sun-asteroid and Earth-asteroid distances and normalized to a phase angle of 3.5° 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.

A total of 294 lightcurve data points were collected in five observing sessions from 2018 April 19-25. *MPO Canopus* was used to find the rotation period from the data using the FALC method by Harris (Harris et al., 1989). The individual sessions were divided into two parts (except on April 23), one before and one after the asteroid crossed the meridian. We found a period of 7.324 ± 0.002 hours. The bimodal lightcurve amplitude is 0.24 mag. Table I gives the observing circumstances and results.

It is clear that the phased curve covers the adopted period multiple times. The whole process was quite straightforward, providing a result without any particular ambiguity. The period spectrum shows that the best solution (with the lowest RMS) is the one adopted here.





References

Bus, S.J. and Binzel, R.P. (2002). "Phase II of the Small Main-Belt Asteroid Spectroscopic Survey." *Icarus* **158**, 106-145.

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 and444 Gyptis." *Icarus* **57**, 251-258.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	U	Exp
3394	Banno	04/19-04/25	294	3.5,6.9	206	3	7.324	0.002	0.24	0.01	2	240

Table II. Observing circumstances and results. 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). 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.

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

Marchini, A., Bucalo, E., Cocchiarella, D., Nardi, B., Papini, R., Salvaggio, F. (2018). "Rotation Period Determination for 2079 Jacchina and 3394 Banno." *Minor Planet Bull.* **45**, 276-277.

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

Warner, B.D. (2016). MPO Software, *MPO Canopus* version 10.7.7.0 Bdw Publishing. *http://bdwpublishing.com*

FIVE LIGHTCURVES FROM THE SHED OF SCIENCE: 2017 NOVEMBER - 2018 APRIL

Brigitte Montminy, Katherine McDonald
Minnetonka High School Minnetonka, MN 55345, USA

Russell I. Durkee
Shed of Science Observatory Minneapolis, MN 55410, USA
russdurkee1@gmail.com

(Received: 2018 Jun 14)

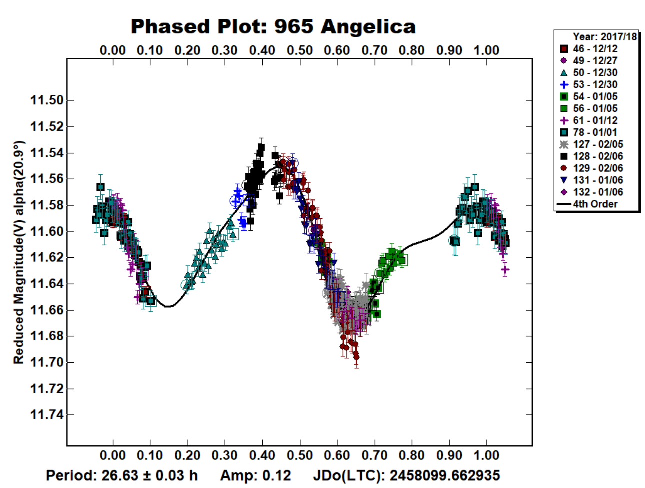
CCD observations of five asteroids were made between 2017 November and 2018 April. Analysis of the data found the period and lightcurve amplitudes for 965 Agnelica (P = 26.63 ± 0.03 h, A = 0.12 mag), 1266 Tone (P = 15.55 ± 0.03 h, A = 0.19 ± 0.05 mag), 3210 Lupishko (P = 14.255 ± 0.03 h, A = 0.74 ± 0.05 mag), 4435 Holt (P = 2.867 ± 0.002 h, A = 0.18 ± 0.05 mag), and 5133 Phillipadams (P = 6.665 ± 0.005 h, A = 0.43 mag).

CCD Photometry observations of five asteroids took place from the Shed of Science Observatory between 2017 November and 2018 April in partnership with Minnetonka High School in Minnetonka, Minnesota.

The observations used a 0.5-m Planewave corrected Dall-Kirkham telescope using a focal reducer, which resulted in a focal ratio of *f*/5.3 and a plate scale of 1.24 arcsec/pixel. An SBIG ST-10XME CCD camera was used and all exposures were made through a Celestron UHC LPR filter.

All images were dark and flat-field corrected. Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. The *MPO Canopus* Comp Star Selector was used to link sessions. The data were light-time corrected. Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris et al., 1989).

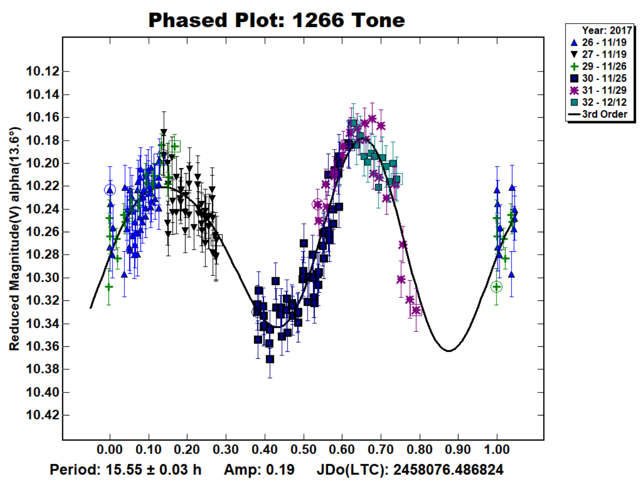
965 Angelica. Observations were made over nine nights between 2017 Dec 12 and 2018 Feb 6. Data analysis indicates a synodic period of P = 26.63 ± 0.03 h, A = 0.12 mag. This is in agreement with earlier observations by Polakis (2018).



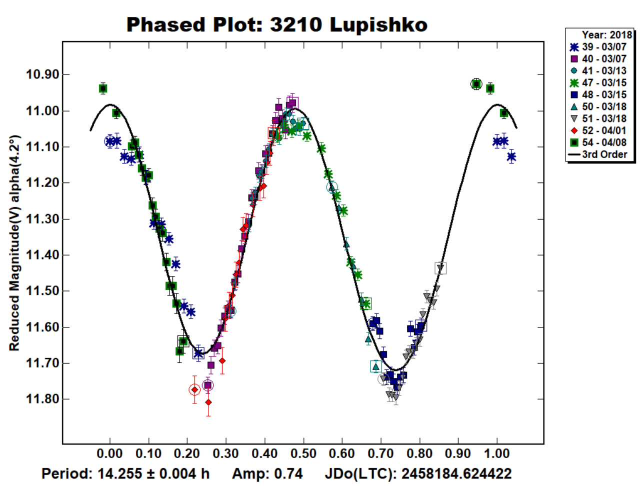
Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
965	Angelica	17/12/12-18/02/06	15.3,13.1,19.0	100	24	26.63	0.03	0.12	0.02	MB-O
1266	Tone	17/11/19-17/12/12	13.5,16.3	12	16	15.55	0.03	0.19	0.05	MB-O
3210	Lupishko	18/03/07-18/04/08	4.1,12.8	164	10	14.255	0.004	0.74	0.05	MB-O
4435	Holt	17/11/19-17/11/29	30.3,32.9	29	31	2.867	0.002	0.18	0.05	MC
5133	Phillipadams	17/12/12-17/12/27	4.7,11.4	72	-3	6.665	0.005	0.43	0.05	MB-O

Table II. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are, respectively, the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). The Group column gives the orbital group to which the asteroid belongs. The definitions are those used in the LCDB (Warner et al., 2009). MB-O: Main-belt outer, MC: Mars-crosser.

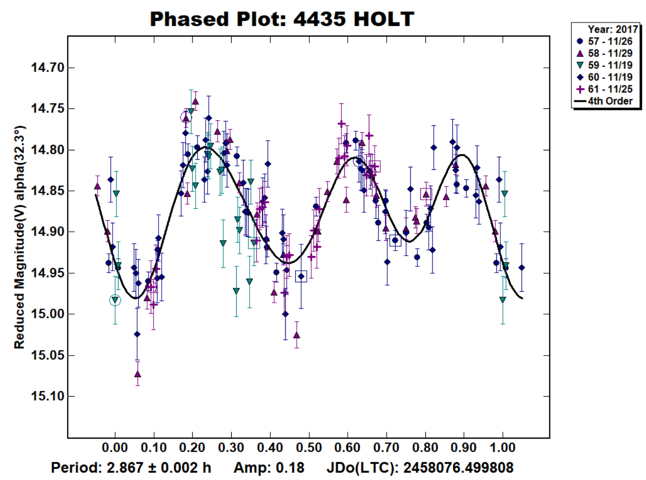
1266 Tone. Analysis of observations over five nights between 2017 Nov 18 and Dec 29 indicates a synodic period of P = 15.55 ± 0.03 h, A = 0.19 ± 0.05 mag. Earlier observations indicated a period of P = 11.38 ± 0.05 h based on data over two nights (Warner, 2003).



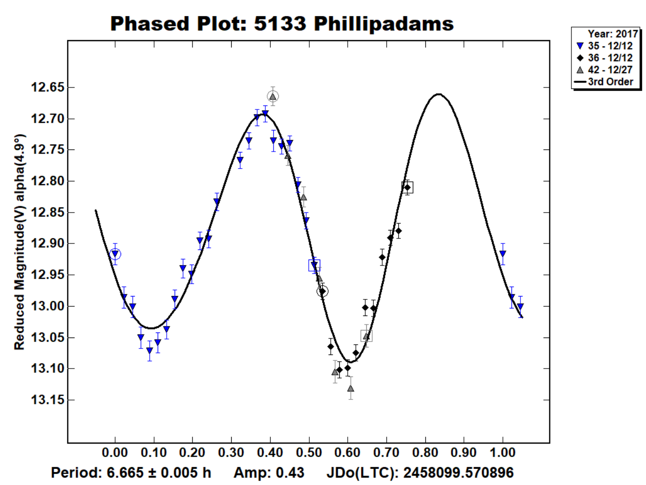
3210 Lupishko. Observations were made over six nights between 2018 Mar 7 and April 8. Our analysis indicates a synodic period of P = 14.25 ± 0.03 h, A = 0.74 ± 0.05 mag.



4435 Holt. Observations made over four nights between 2017 Nov 19-27 led to a synodic period of P = 2.867 ± 0.002 h, A = 0.18 ± 0.05 mag. Earlier work by J. Ruthroff indicated a period of 2.71 h ± 0.002 h based on data over two nights (Ruthroff, 2017). Additional work on this object was completed in 2018 January by the Ondrojev Asteroid Photometry Project, which identified it to be a binary and possibly ternary system (Stephens, et. al., 2018). Our data supports the primary period found. However, our data set was not sufficient to confirm their findings of a binary or ternary system.



5133 Phillipadams. Analysis of observations over two nights between 2017 Dec 12-27 indicates a period of P = 6.665 ± 0.005 h, A = 0.40 mag. Our results do not have sufficient coverage for a unique solution. However, our result does agree with earlier work (Carbo et. al, 2009; Behrend, 2009).



Acknowledgements

Thank you to Brian Warner for regular support throughout this project. Partial funding for work at the Shed of Science Observatory is provided by 2009 and 2010 Shoemaker NEO Grants from the Planetary Society.

References

Behrend, R. (2009). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

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.

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.

Polakis, T. (2018). "Lightcurve analysis for eleven main-belt asteroids." *Minor Planet Bull*. **45**, 199-203.

Ruthroff, J. (2018). "Rotational Study of Mars-crossing Asteroid 4435 Holt." *Minor Planet Bull*. **45**, 130.

Stephens, R., Pray, D., Pravec, P., Kusnirak, P., Kucakova, H., Hornoch, K., Benishek, V. (2018). "(4435) Holt." *CBET* **4480**.

Warner, B. (2003). "Lightcurve analysis of asteroids 331, 795, 1266, 2023, 3285, and 3341." *Minor Planet Bull*. **30**, 61-64.

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*

[Editor's Note: Congratulations to high school students Montminy and McDonald on their work and a salute to their mentor Durkee for guiding them.]

NEGLECTED LIGHTCURVES FROM THE SHED OF SCIENCE

Russell I. Durkee
Shed of Science Observatory Minneapolis, MN 55410 USA
russdurkee1@gmail.com

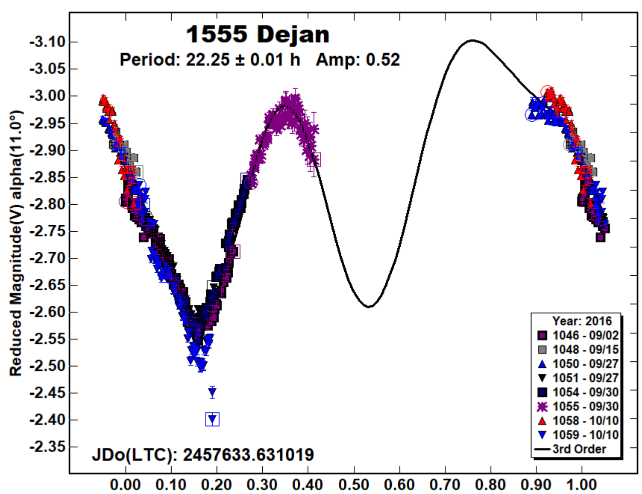
(Received: 2018 Jun 16)

CCD observations of five asteroids made between 2016 July and November led to finding synodic periods and lightcurve amplitudes for 1555 Dejan (P = 22.25 ± 0.01 h, A = 0.52 ± 0.05 mag), 4488 Tokitada (P = 34.25 ± 2.25 h, A = 0.58 ± 0.07 mag), 5996 Julioangel (P = 9.74 ± 0.01 h, A = 0.34 ± 0.07 mag), 8083 Mayeda (P = 11.75 ± 0.05 h, A = 0.76 ± 0.05 mag), and (20447) 1999 JR85 (P = 4.925 ± 0.015 h, A = 0.24 ± 0.05 mag).

CCD photometry observations of five asteroids were made at the Shed of Science Observatory between 2016 July and November. The observations used a 0.5-m Planewave corrected Dall-Kirkham telescope with a focal reducer, which gave a focal ratio of *f*/5.3 and plate scale of 1.24 arcsec/pixel. An SBIG ST-10XME CCD camera and Celestron UHC LPR filter were used for all exposures.

All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique and its Comp Star Selector to link sessions. The data were light-time corrected. Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989).

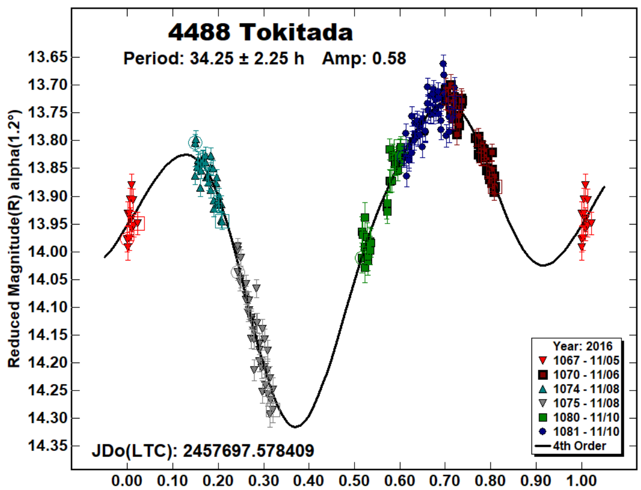
1555 Dejan. Analysis of observations over five nights between 2016 Sep 2 and Oct 10 indicates P = 22.25 ± 0.01 h, A = 0.52 ± 0.05 mag. Earlier observations indicated a period of 16.960 ± 0.002 h (Brines et al., 2017). However, our data do not support their period near 17 hours but instead the longer period near 22 h.



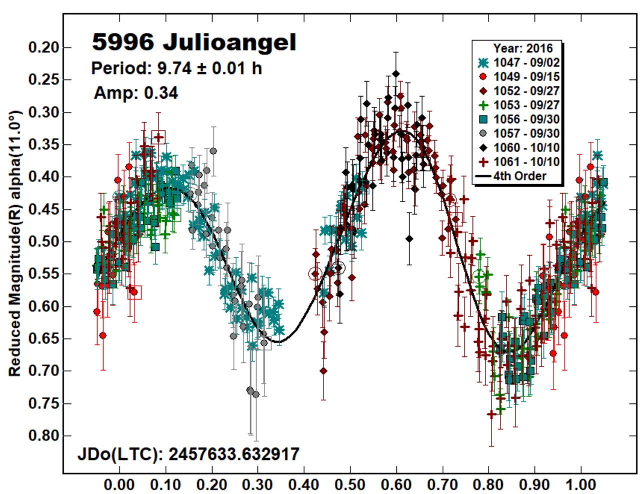
Number	Name	2016/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1555	Dejan	09/02-10/10	8.1,3.5,14.7	352	5	22.25	0.01	0.52	0.05	MB-M
4488	Tokitada	11/05-11/10	1.0,4.3	41	-1	24.25	2.25	0.58	0.07	FLOR
5996	Julioangel	09/02-10/10	11.1,7.9,13.0	356	15	9.74	0.01	0.34	0.07	EUN
8083	Mayeda	11/06-11/10	0.9,3.6	41	0	11.75	0.05	0.76	0.05	MB-O
20447	1999 JR85	07/31-08/04	13.6,14.3	303	17	4.925	0.015	0.24	0.05	MB-M

Table II. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. If three values are given, the phase angle reached a minimum. L_{PAB} and B_{PAB} are, respectively, the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). The Group column gives the orbital group to which the asteroid belongs. The definitions are those used in the LCDB (Warner *et al.*, 2009). MB-M/O: Main-belt middle/outer; FLOR: Flora; EUN: Eunomia.

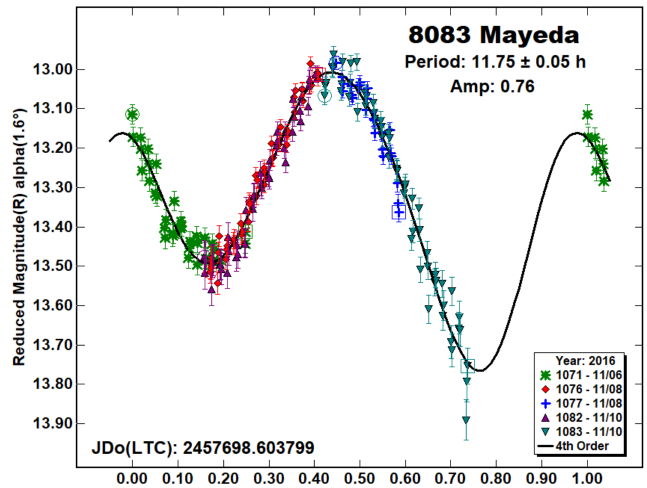
4488 Tokitada. Observations were made over four nights between 2016 Nov 5-10. Data analysis found a synodic period of P = 34.25 ± 2.25 h, A = 0.58 ± 0.07 mag.



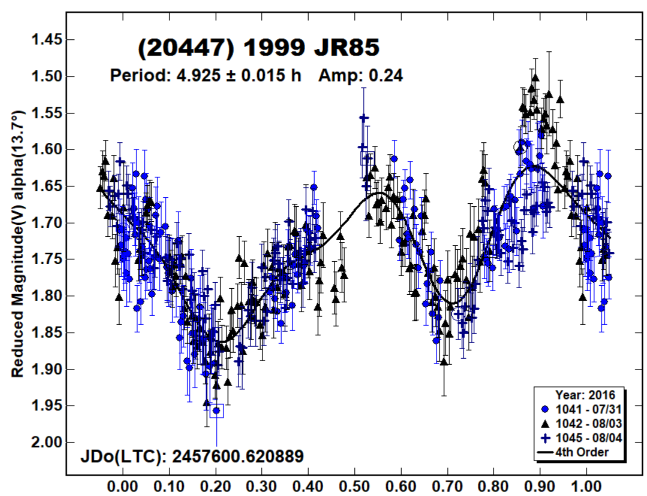
5996 Julioangel. Data obtained over five nights between 2016 Sep 2 and Oct 10, led to a synodic period of P = 9.74 ± 0.01 h, A = 0.34 ± 0.07 mag.



8083 Mayeda. Analysis of our data, obtained over three nights between 2016 Nov 6-10 indicates a synodic period of P = 11.75 ± 0.05 h, A = 0.76 ± 0.05 mag.



(20447) 1999 JR85. Observations over three nights between 2016 Jul 31 and Aug 4 led to a synodic period of P = 4.925 ± 0.015 h, A = 0.24 ± 0.05 mag.



Acknowledgements

Partial funding for work at the Shed of Science Observatory is provided by 2009 and 2010 Shoemaker NEO Grants from the Planetary Society.

References

Brines, P., Lozano, J., Rodrigo, O., Fornas, A., Herrero, D., Mas, V., Fornas, G., Carreño, A., Arce, E. (2017). "Sixteen Asteroids Lightcurves at Asteroids Observers (OBAS) - MPPD: 2016 June-November." *Minor Planet Bull*. **44**, 145-149.

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. Updated 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

A PHOTOMETRIC STUDY OF 1144 ODA

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

(Received: 2018 Jun 20)

Minor planet 1144 Oda is a tumbling asteroid with periods probably near 648 hours and 553 hours, maximum amplitude 0.55 ± 0.05 magnitudes

Minor planet 1144 Oda, a = 3.754 AU, e = 0.096, i = 9.74°, is the only large diameter asteroid (D ~ 55 km) with an orbit lying between the outer edge of the Cybele zone near 3.65 AU and the inner edge of the Hilda 3:2 Jupiter resonators near 3.88 AU.

Previously published rotation periods for 1144 Oda are 14.4 hours from a very sparse lightcurve (Behrend, 2006) and by Waszczak et al. (2015) who made 1 to 4 measurements on each of 11 nights from 2011 May 11 through June 20 for a total of 26 data points to derive a period of 44.023 hours and amplitude 0.41 magnitudes.

A more comprehensive survey was made at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. Exposures were 120 seconds, unguided, with a clear filter. All measurements were calibrated from CMC15 Sloan r′ values converted to Cousins R magnitudes using R = r′–0.22 for solar-colored field stars. Photometric measurement was with *MPO Canopus* software.

Sixty sessions were obtained from 2018 Feb 8 through May 21. A raw lightcurve prepared by *MPO Canopus* including data from all sessions features a quasi-periodic variation with the usual two maxima and minima per cycle in a period near 615 hours, but with an amplitude varying from near zero to a maximum of about 0.55 magnitudes. To reduce the number of points on this lightcurve and make it easier to read, data points have been binned in sets of 3 with a maximum time difference of 6 minutes between points in each bin.

The author thanks Petr Pravec (personal communication) for the application of simultaneous dual-period software to the complete data set. Tumbling behavior is confirmed. However, a period solution is not very clear. The most likely periods may be about 648 and 553 hours, but other values are also possible. It is not determined which period is rotation and which is precession. There are also signals for periods around 51.8 and 44.1 h, but they appear to be aliases with Earth rotation: Note that 1/51.8 = 1/48 – 1/648 and 1/44.1 = 1/48 + 1/553. A lightcurve phased to 648 hours with the dual period software illustrates very different successive cycles.

The raw lightcurve is analogous to beat phenomena of two acoustic signals of slightly unequal frequency or period, in which the tumbling periods of 553 hours and 648 hours combine for an

Number	Name	2018/mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
1144	Oda	02/08-05/21	3979	9.9,1.2,13.2	179	5	648	10	0.55	0.05
	P2						553			

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

intermediate period of 615 hours with the amplitude varying as the signals arise alternately in phase and out of phase. The 44.023 hour period published by Waszczak et al. (2015) is the identification with the Earth alias period of 44.1 hours described above.

Acknowledgements

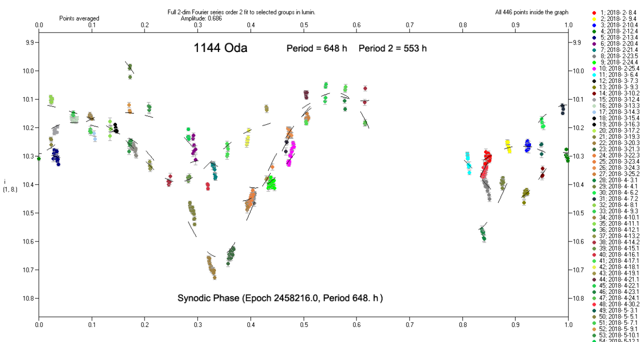
The author thanks Petr Pravec for analyzing the data with simultaneous dual period software that showed conclusively that 1144 Oda was tumbling and found two separate periods.

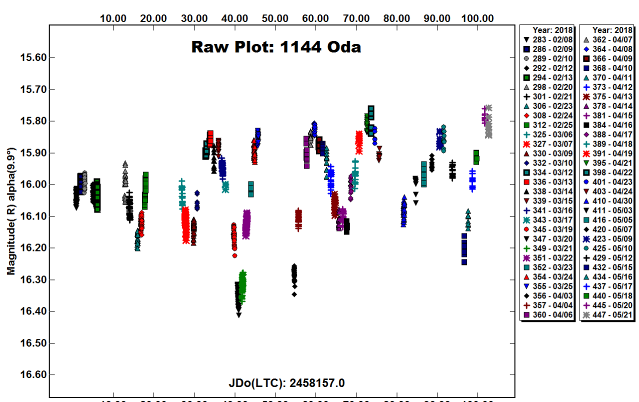
References

Behrend, R. (2006). 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.

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.





REDETERMINED ORBITAL PERIOD FOR THE NEWLY DISCOVERED NEAR-EARTH BINARY ASTEROID 15745 YULIYA

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA
vlaben@yahoo.com

Petr Pravec
Astronomical Institute
Academy of Sciences of the Czech Republic
Fricova, CZ-25165 Ondřejov, CZECH REPUBLIC

(Received: 2018 Jul 14)

A photometric observing campaign conducted in 2018 April and May by Aznar et al. revealed the near-Earth asteroid 15745 Yuliya as a binary system with an orbital period of 15.63 h. Later analysis by Pravec using the dense photometric data obtained in 2018 June by Benishek yielded a different orbital period of 11.735 h, or nearly commensurate with an Earth day.

15745 Yuliya is a relatively large, $D \sim 1$ km, Amor-type near-Earth asteroid discovered at La Silla in 1991 by E.W. Elst. On 2018 June 9, it was announced as being a binary system (Aznar et al., 2018) for which Pravec established a primary period of 3.2486 ± 0.0003 h and an orbital period of 15.63 ± 0.02 h.

Having no information about the possible binary nature of this target, Benishek launched independent photometric observations at Sopot Astronomical Observatory (SAO) on 2018 June 3 using a 0.35-m Schmidt-Cassegrain telescope operating at *f*/6.3 and an SBIG ST-8 XME CCD camera with no filters. A total of eight densely-sampled independent data sets (*sessions*) was obtained by 2018 June 22.

Photometric reduction was performed in *MPO Canopus* software (Warner, 2018) applying differential photometry with up to five field comparison stars of near solar color (0.5 ≤ B-V ≤ 0.9). To ensure satisfactory quality of night-to-night magnitude zero-point calibration, all comparison stars were calibrated using the Cousins R magnitudes derived from the CMC15 Sloan r´ magnitudes (VizieR, 2018) by the formula: R = r´ - 0.22.

Certain deviations closely resembling attenuations typical of binary asteroids were seen in early data sets. A rough preliminary analysis by Benishek found a period of about 11.74 h but it was not possible to distinguish whether it was a rotational period or an orbital period of a possible binary system.

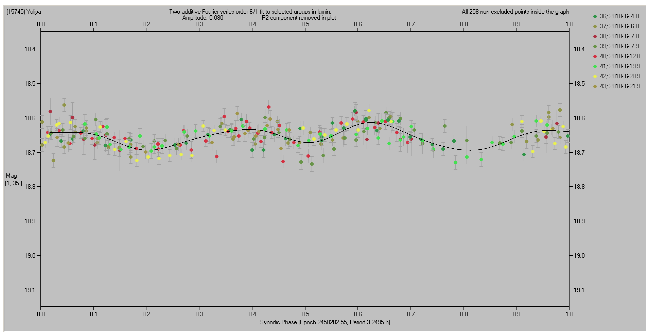
Suspecting that 15745 Yuliya could be a binary system, Benishek sent his data to Pravec for a detailed analysis on 2018 June 23. At that point, the report on 15745 Yuliya as a binary asteroid (Aznar et al., 2018) had already been published. The announced system parameters had been found from the period analysis done by Pravec as part of the discovery team. Nevertheless, he agreed to

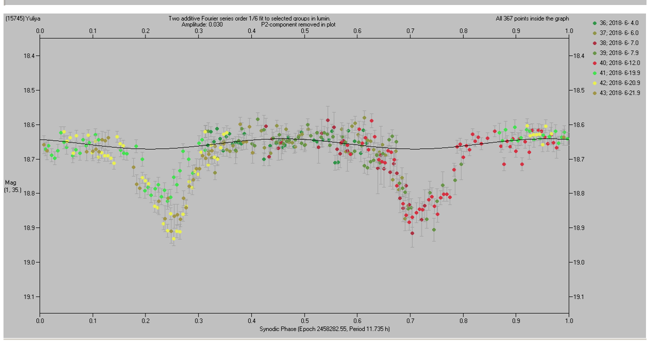
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
15745	Yuliya	06/03-06/21	258	35.6,35.1	255	29	3.2495	0.0002	0.08	0.02	NEA
	P_{ORB}						11.735	0.003	0.21-0.26		

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. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009): NEA = near-Earth asteroid analyze Benishek's data independently by using his custom period analysis software that is capable of solving for multiple periods simultaneously.

The new analysis led to a period for the primary of 3.2495 ± 0.0002 h, nearly identical to the Aznar et al. (2018) result. On the other hand, the orbital period was revised to 11.735 ± 0.003 h. Pravec strongly suggests that the new orbital period is correct after taking into account the longer observing runs by Benishek. This is important for finding a unique solution, especially when the period is nearly commensurate with an Earth day. The Aznar et al. (2018) orbital period is 4/3 of the revised period.

A lower limit of the satellite mean diameter (D_s) to primary body mean diameter (D_p) is estimated to be $D_s / D_p \geq 0.46$ on the basis of the SAO data.





It should be noted that one of the attenuation events showed an obvious depth and shape change over just one day (see 2018-06-19.9 and 2018-06-20.9 data sets on the orbital lightcurve plot). With the data set limited to a very small solar phase angle range, it was not possible to find a valid explanation of the observed effect. Repeated quality checks of the relevant images and photometric reduction discard the possibility of a systematic origin of this change. Due to the asteroid's fast fading and frequent bad weather, further follow-up of the possible attenuation events changes was not possible.

Acknowledgements

Observational work at Sopot Astronomical Observatory is supported by a 2018 Gene Shoemaker NEO Grant from The Planetary Society.

References

Aznar, A., Vaduvescu, O., Wilson, T., Zegmott, T., Pravec, P. (2018). "(15745) Yuliya." *CBET* **4523**.

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.

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

Warner, B.D. (2018). *MPO Canopus* software v10.7.11.3. *http://www.bdwpublishing.com*

LIGHTCURVE ANALYSIS OF MINOR PLANETS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2017 AUGUST–SEPTEMBER

Richard Ditteon, Sydney Black,
Zachary Masner, Joshua Osborne, Lee Trent
Rose-Hulman Institute of Technology
5500 Wabash Ave., Terre Haute, IN 47803, USA
ditteon@rose-hulman.edu

(Received: 2018 Jun 21)

From 2017 July 26 to September 28, images of 19 minor planets were collected: 820 Adriana, 1326 Losaka, 1594 Danjon, 2021 Poincare, 2164 Lyalya, 2353 Alva, 2558 Viv, 2623 Zech, 3341 Hartmann, 4522 Britastra, (10113) 1992 PX2, 11434 Lohnert, (11889) 1991 AH2, (14892) 1991 VE5, (15549) 2000 FN, (21893) 1999 VL4, (23621) 1996 PA, (30769) 1984 ST2, and (42284) 2001 TV8.

The Oakley Southern Sky Observatory is equipped with an STX-16803 camera attached to a 0.5-m Planewave telescope operating at *f*/6.7. For minor planet photometry we use a luminance filter and bin the camera 3x3 to get a plate scale of 1.63 arcseconds.

From 2017 July 26 to August 5, we targeted six minor planets: 820 Adriana, 2558 Viv, 2623 Zech, 4522 Britastra, (10113) 1992 PX2, and (42284) 2001 TV8. Beginning on August 23, we targeted an additional six minor planets: 2164 Lyalya, 11434 Lohnert, (15549) 2000 FN, (21893) 1999 VL4, (23621) 1996 PA, and (30769) 1984 ST2. Finally, from September 19-30, we observed another seven minor planets: 1326 Losaka, 1594 Danjon, 2021 Poincare, 2353 Alva, 3341 Hartmann, (11889) 1991 AH2, and (14892) 1991 VE5. All images were processed using standard techniques with *MaxIm DL*. The processed images were then measured and lightcurves generated with *MPO Canopus*.

Table I lists the targets, range of dates, phase angle, phase angle bisector longitude and latitude as well as the period if we were able to determine one. We were unable to find periods for 1326 Losaka, 1594 Danjon, 2353 Alva, (23621) 1996 PA, and (30769) 1984 ST2.

2164 Lyalya. Our period of 7.705 ± 0.003 h does not agree with the period of 11.566 h (no uncertainty given) found by Chang *et al*. (2016). However, note that 7.705 h is approximately two thirds of 11.566 h.

2623 Zech. We found a period of 2.740 ± 0.002 h, which agrees within experimental uncertainty with the period of 2.7401 ± 0.0002 h found by Pray et al. (2014).

4522 Britastra. Chang et al. (2016) reported a period of 2.767 h (no uncertainty given). We could not fit our data to this period. Instead we found a period of 11.919 ± 0.011 h.

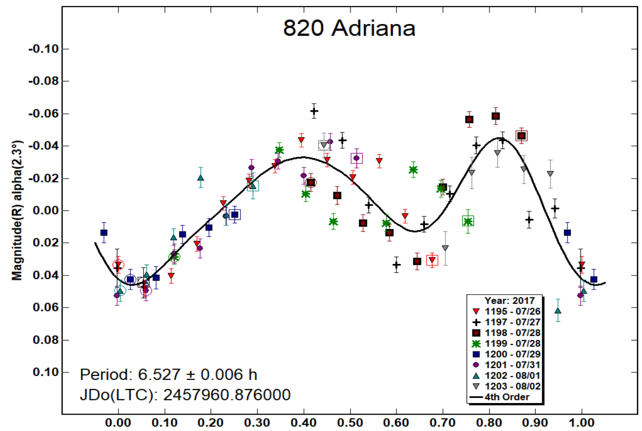
(10113) 1992 PX2. Our period of 6.775 ± 0.003 h falls just outside the uncertainty range with the period of 6.768 ± 0.002 h found by Waszczak et al. (2015).

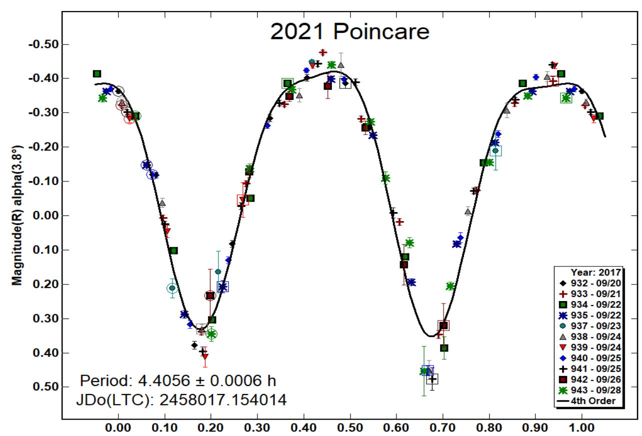
References

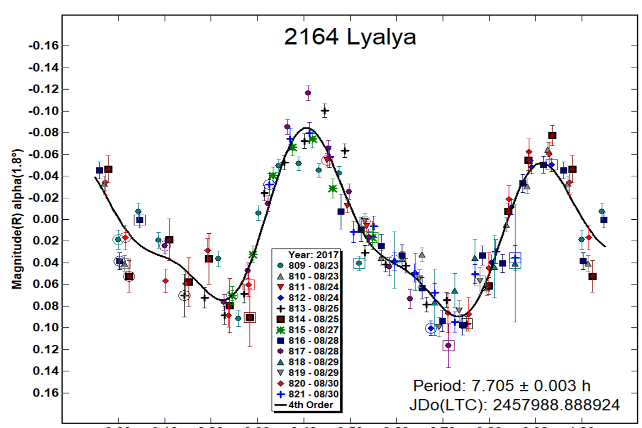
Chang, C.-K., Lin, H.-W., Ip, W.-H., Prince, T.A., Shrinivas, R.K., Levitan, D., Laher, R., Surace, J. (2016). "Large Super-Fast Rotator Hunting Using the Intermediate Palomar Transient Factory." *Astrophys. J. Sup. Ser*. **227**, A20.

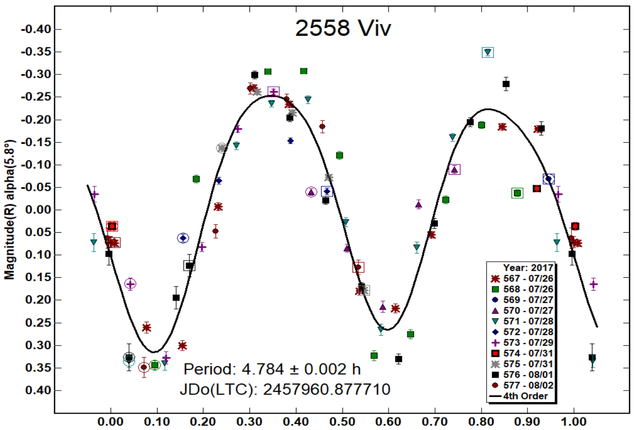
Pray, D., Pravec, P., Chiorny, V., Krugly, Yu.N., Benishek, V., Pollock, J., Caton, D.B., Smith, A.B., Hawkins, R.L., Inasaridze, R., Montaigut, R., Leroy, A., Reichart, D.E., Haislip, J.B., LaCluyze, A.P. (2014). "(2623) Zech." *CBET* **4012**.

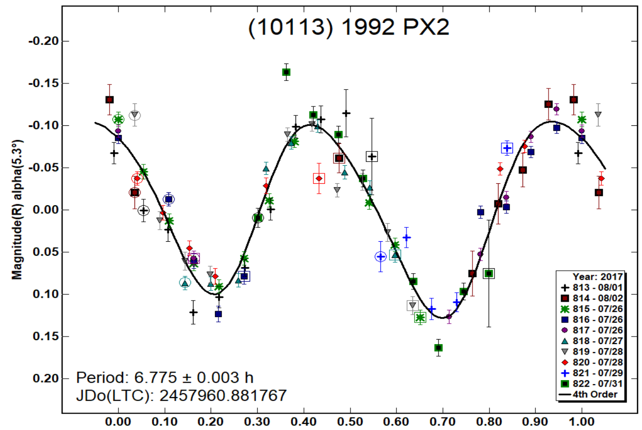
Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry."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

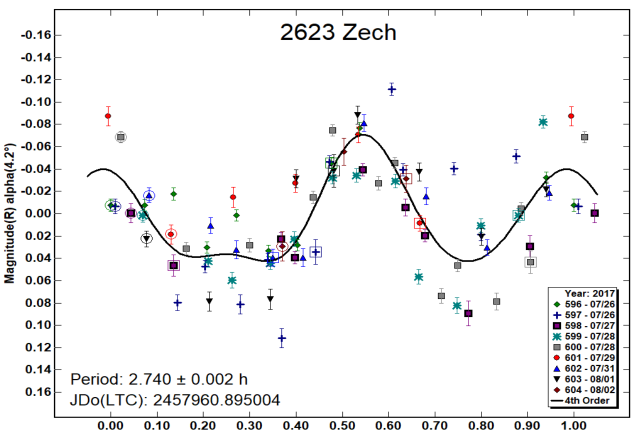


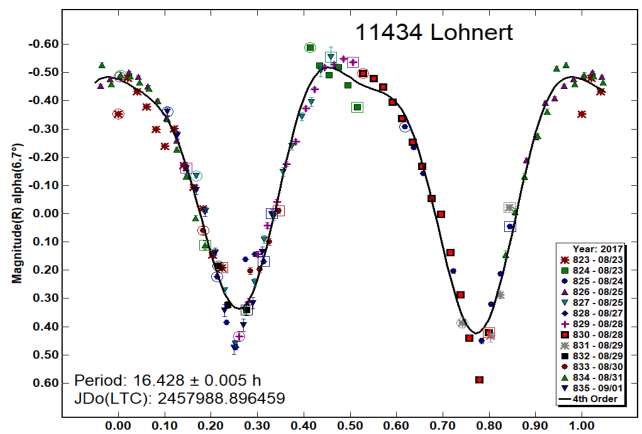


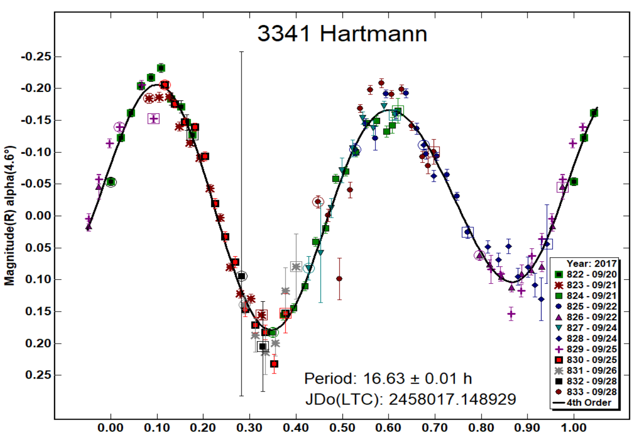


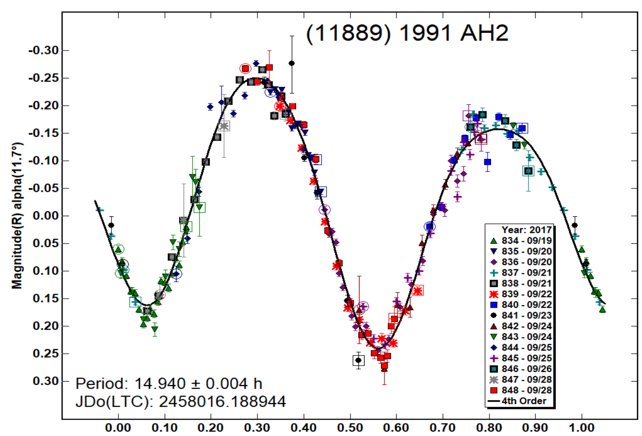

2558 Viv
Magnitude(R) alpha(5.8°)
Period: 4.784 ± 0.002 h
JDo(LTC): 2457960.877710

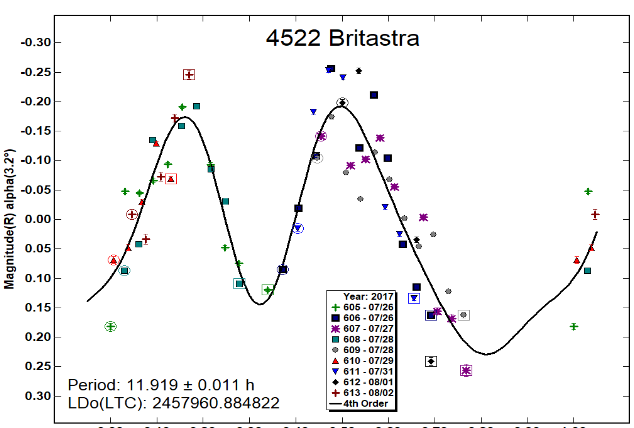

(10113) 1992 PX2
Magnitude(R) alpha(5.3°)
Period: 6.775 ± 0.003 h
JDo(LTC): 2457960.881767

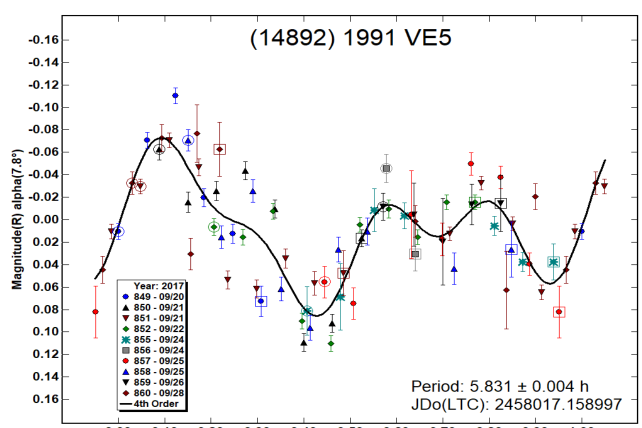

2623 Zech
Magnitude(R) alpha(4.2°)
Period: 2.740 ± 0.002 h
JDo(LTC): 2457960.895004


11434 Lohnert
Magnitude(R) alpha(6.7°)
Period: 16.428 ± 0.005 h
JDo(LTC): 2457988.896459


3341 Hartmann
Magnitude(R) alpha(4.6°)
Period: 16.63 ± 0.01 h
JDo(LTC): 2458017.148929

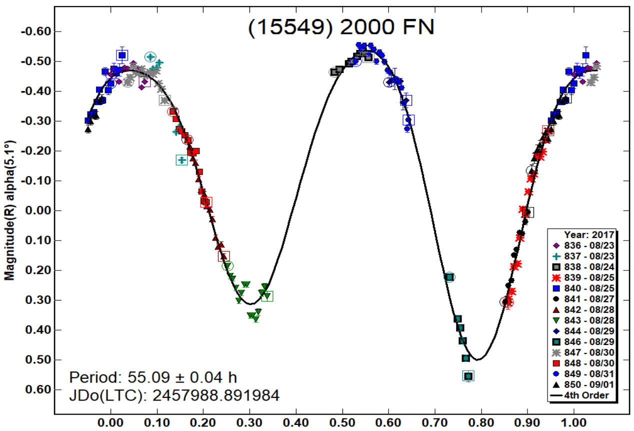

(11889) 1991 AH2
Magnitude(R) alpha(11.7°)
Period: 14.940 ± 0.004 h
JDo(LTC): 2458016.188944

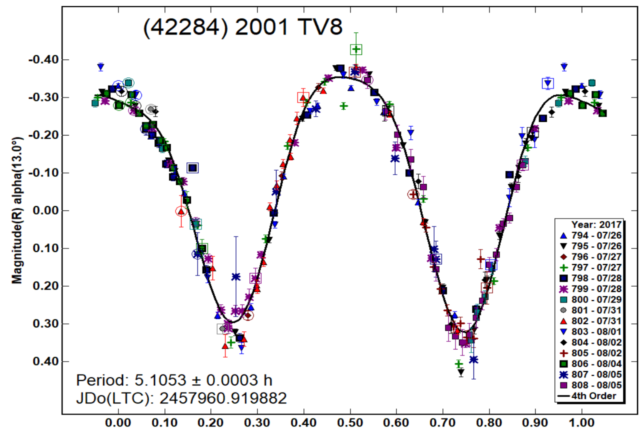

4522 Britastra
Magnitude(R) alpha(3.2°)
Period: 11.919 ± 0.011 h
LDo(LTC): 2457960.884822

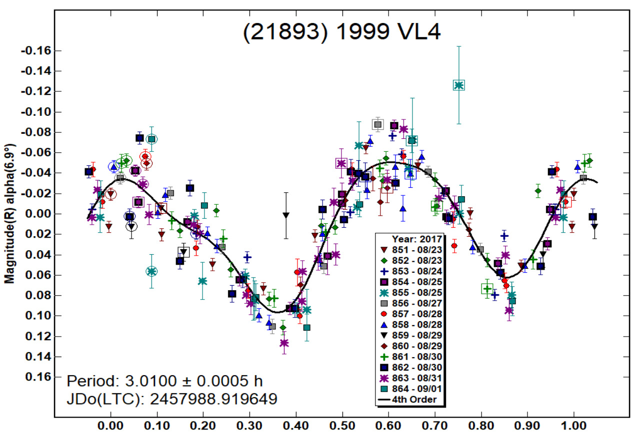

(14892) 1991 VE5
Magnitude(R) alpha(7.8°)
Period: 5.831 ± 0.004 h
JDo(LTC): 2458017.158997

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.
820	Adriana	07/26-08/02	71	2.0, 4.7	298	0	6.527	0.006	0.10	0.03
1326	Losaka	09/19-09/30	197	13.2, 14.9	354	-22			0.05	0.03
1594	Danjon	09/20-09/30	129	9.1, 11.9	352	-13			0.15	0.05
2021	Poincare	09/20-09/28	101	3.4, 8.0	354	-3	4.4056	0.0006	0.80	0.05
2164	Lyalya	08/23-08/30	125	1.6, 4.3	327	-2	7.705	0.003	0.20	0.03
2353	Alva	09/20-09/30	92	2.7, 6.9	353	-3			0.08	0.03
2558	Viv	07/26-08/02	76	5.7, 7.1	303	-8	4.784	0.002	0.58	0.03
2623	Zech	07/26-08/02	84	4.0, 7.4	300	-4	2.740	0.002	0.15	0.05
3341	Hartmann	09/20-09/28	122	4.4, 6.6	356	-8	16.63	0.01	0.40	0.05
4522	Britastra	07/26-08/02	69	3.0, 6.1	299	3	11.919	0.011	0.40	0.06
10113	1992 PX2	07/26-08/02	86	2.5, 5.4	300	4	6.775	0.003	0.22	0.03
11434	Lohnert	08/23-09/01	131	6.5, 9.8	322	-5	16.428	0.005	0.90	0.05
11889	1991 AH2	09/20-09/28	192	11.7, 13.1	352	-21	14.940	0.004	0.45	0.03
14892	1991 VE5	09/20-09/28	77	7.4, 11.8	350	-5	5.831	0.004	0.15	0.05
15549	2000 FN	08/23-09/01	168	4.8, 10.0	326	-4	55.09	0.04	1.00	0.05
21893	1999 VL4	08/23-09/01	172	6.6, 11.5	327	-5	3.0100	0.0005	0.14	0.04
23621	1996 PA	08/23-09/01	113	7.5, 15.6	325	-5			0.12	0.05
30769	1984 ST2	08/23-09/01	130	4.6, 10.1	325	-2			0.07	0.05
42284	2001 TV8	07/26-08/05	198	12.9, 14.2	302	-21	5.1053	0.0003	0.70	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.







2207 ANTENOR: A SUSPECTED JOVIAN TROJAN BINARY

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

Petr Pravec, Hana Kučáková, Peter Kušnirák and Kamil Hornoch
Academy of Sciences of the Czech Republic
Ondřejov, CZECH REPUBLIC

Vladimir Benishek
Belgrade Astronomical Observatory
Belgrade, SERBIA

Amadeo Aznar Macias
APT Observatories Group (Z95, J42)
Valencia, SPAIN

Brian D. Warner
Center for Solar System Studies – Palmer Divide Station
Eaton, CO USA

(Received: 2018 June 28)

We report that asteroid 2207 Antenor is a very likely binary asteroid candidate. If confirmed, it would be the fifth known binary Jovian Trojan asteroid. The primary lightcurve has a period of 7.96436 ± 0.00006 h and an amplitude 0.22 to 0.23 mag. A secondary orbital period could not be determined.

The Jovian Trojan 2207 Antenor was initially observed by Stephens on 2018 January 23 as part of an ongoing study of the Jovian Trojan family. Deviations from the lightcurve suggestive of mutual events from a binary system were quickly found. Help was sought from Aznar and Benishek who are at significantly different latitudes. Table I gives the telescopes and CCD cameras used for observations. Exposures were unfiltered and ranged from 240 to 300 seconds.

Observer	Telescope	Camera
Stephens	0.40m SCT	FLI Proline 1001E
Aznar	0.35m SCT	SBIG 10XME
Benishek	0.35m SCT	SBIG ST-8 XME
Kučáková, Kusnirak Hornoch	0.65m Reflector	MI G2-3200

Table I. Observers and equipment. SCT: Schmidt-Cassegrain.

Antenor has been observed several times in recent years, each time with a reported rotational period near 7.9645 h (Mottola et al., 2011; Stephens et al., 2016, 2017; Waszczak et al., 2015). The raw images were flat-field and dark subtracted before being measured. For the Stephens, Aznar and Benishek observations, night-to-night linkage was aided by the Comp Star Selector utility which helps find near solar-color comparison stars. Stars were chosen from the APASS (Henden et al., 2009) or CMC-15 catalog (*http://svo2.cab.inta-csic.es/vocats/cmc15/*), or the MPOSC3 catalog which is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*). Generally, needed zero points adjustments are within ±0.05 mag of one another, but larger adjustments can be required to minimize the RMS value from the Fourier analysis. The Kučáková, and Hornoch observations were calibrated in the Cousins R band.

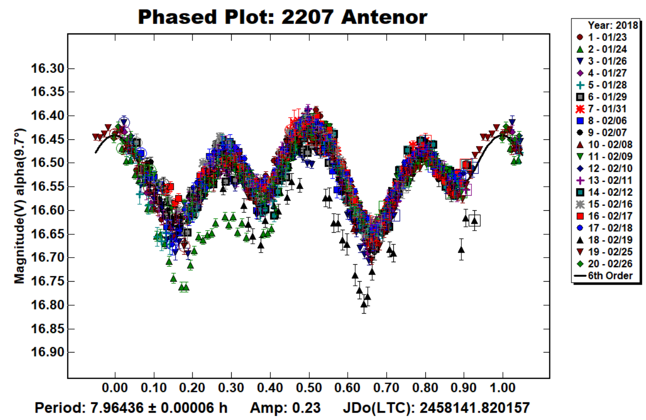


Figure 1. The raw lightcurve over the observing run between 2018 Jan 23 to Feb 26. During this period, Antenor passed from phase angle 10° to 5°. The first attenuation event was seen on 24 Jan 2018.

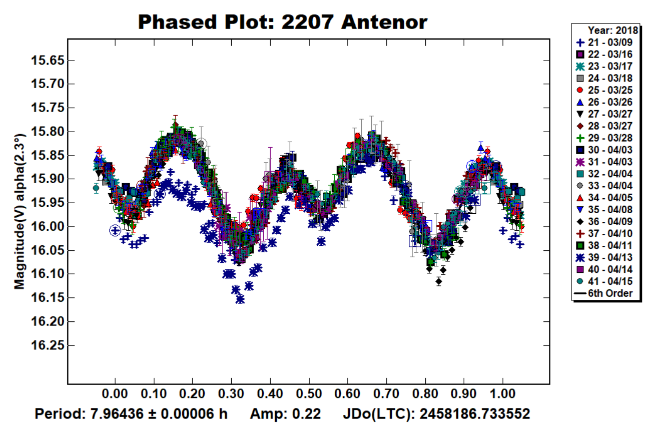


Figure 2. The raw lightcurve over the observing run between 2018 Mar 9 to 28. During this period, Antenor passed from phase angle 2° to 6°.

Number	Name	2018/mm/dd	Pts.	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
2207	Antenor	01/23-05/22	3,041	10,1,11	179	2-3	7.96450	0.00007	0.19-0.24	0.02

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

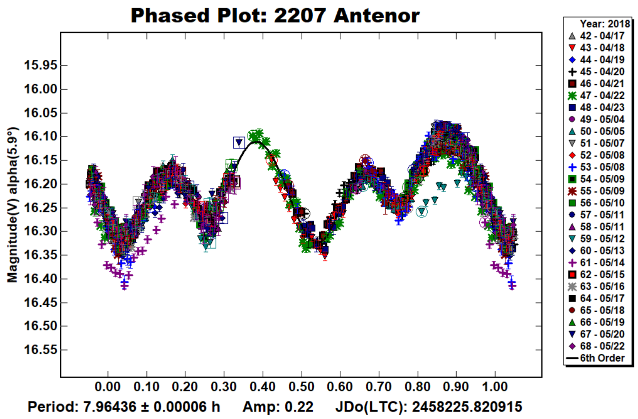


Figure 3. The raw lightcurve over the observing run between 2018 Apr 14 to May 22. During this period, Holt passed from phase angle 6° to 11°.

Period Analysis

All data were sent to Petr Pravec, whose software solves for the primary and secondary period simultaneously. The dual period analysis found a primary lightcurve of 7.96436 ± 0.00006 h (Figures 1, 2, and 3). The amplitude changed from 0.19 to 0.24 mag over the course of the observing run.

The mean H_R of the whole system (outside events) is 8.58 ± 0.04 was determined from the Ondřejov Cousins R Data assuming G = 0.12 ± 0.08, which is the mean G for CGBFPTD types (Warner et al., 2009). Since Antenor has been determined to be a D type, we get H = 9.04 ± 0.05 using the mean color index (V - R) = 0.455 ± 0.033 for D types (Pravec et al. 2012). Using Antenor's effective diameter of D_{eff} = 91 km, which is the mean of the three diameter estimates obtained by AKARI, SIMPS and WISE, we obtain and albedo of p_V = 0.052. The uncertainty is about ± 0.010, which is dominated by the uncertainty of D_{eff}, not H.

As many as five prominent events and a few shallower ones were observed. The orbital period is likely on the order of a few hundred hours, but we could not get all of the five events to line up with any secondary period. Either there are multiple satellites or some of the five prominent events might be spurious.

Antenor is a very strong binary candidate, but without having derived its orbital period, it is not a complete detection of a binary asteroid. Its binary status will be confirmed only when its orbital period can be resolved in the future.

Because of the unusual nature of this Trojan, and because there are only four other known Trojan binaries, Antenor should be a prime candidate for future observations. It will be well placed for observations from the Northern Hemisphere in 2019 and for the Southern Hemisphere in 2020 through 2022. With a relatively bright magnitude (V~16), it can be easily observed with small telescopes.

Acknowledgements

The purchase of Stephens' FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grants AST-1210099 and AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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

References

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

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.

Mottola, S., Di Martino, M., Erikson, A., Gonano-Beurer, M., Carbognani, A., Carsenty, U., Hahn, G., Schober, H., Lahulla, F., Delbò, M., Lagerkvist, C. (2011). "Rotational Properties of Jupiter Trojans. I. Light Curves of 80 Objects." *Astron. J.* **141**, A170.

Pravec, P., Harris, A.W., Kušnirák, P., Galád, A., Hornoch, K., (2012). "Absolute magnitudes of asteroids and a revision of asteroid albedo estimates from WISE thermal observations." Icarus 221, 365-387.

Stephens, R.D., Coley, D.R., French, L.M. (2016). "A Report from the L5 Trojan Camp - Lightcurves of Jovian Trojan Asteroids from the Center for Solar System Studies." *Minor Planet Bull.* **43**, 265-267.

Stephens, R.D., Coley, D.R., (2017). "Lightcurve Analysis of Trojan Asteroids at the Center for Solar System Studies 2017 January – March." *Minor Planet Bull.* **44**, 252-257.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2018 July. *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.

LIGHTCURVE ANALYSIS OF L5 TROJAN ASTERIODS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 APRIL TO MAY

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: 2018 June 28)

Lightcurves of four Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2018 April to May. One of the Trojans observed was 617 Patroclus to time the start of mutual events in support of NASA's Lucy mission.

CCD Photometric observations of four Trojan asteroids from the L_5 (Trojan) Lagrange point were obtained at the Center for Solar System Studies (CS3, MPC U81). For several years, CS3 has been conducting a study of Jovian Trojan asteroids. This is another in a series of papers reporting data being accumulated for family pole and shape model studies. It is anticipated that for most Jovian Trojans, two to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed and can be supplemented with reliable sparse data for the brighter Trojan asteroids. For most of these targets, we were able to get preliminary pole positions and create shape models from sparse data and the dense lightcurves obtained to date. These preliminary models will be improved as more data are acquired at future oppositions and will be published at a later date. A special target selected this observing season was the Patroclus-Menoetius binary Trojan asteroid in support of NASA's Lucy mission.

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

Telescope	Camera
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.35-m f/11 Schmidt-Cass	FLI Microline 1001E

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

Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Night-to-night calibration (generally < ±0.05 mag) was done using field stars from the CMC-15 or APASS (Henden *et al.*, 2009) catalogs. The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

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

The amplitude indicated in the plots (e.g. Amp: 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

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

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

To evaluate the quality of the data obtained to determine how much more data might be needed, preliminary pole and shape models were created for some of these targets. These will be published at a later date. Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (*http://hamilton.dm.unipi.it/asdys2/*). These sparse data were combined with our dense data as well as any other dense data found in the ALCDEF asteroid photometry database (*http://www.alcdef.org/*) using *MPO LCInvert*, (Bdw Publishing). This Windows-based program incorporates the algorithms developed by Kassalainen et al. (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values.

<u>617 Patroclus</u>. The Patroclus-Menoetius system is the first known Jovian Trojan binary. It has a mutual orbit of 4.283 ± 0.004 days (Marchis et al. 2005). NASA's Lucy probe is planned for a visit to the Patroclus-Menoetius system in 2033, creating a desire to refine its orbital properties. The Lucy program put out a call for supporting observations (*https://lucyebo.space.swri.edu/news/*) and a prediction of mutual event times was published (Grudy et al., 2018).

Observations were planned beyond the predicted mutual events to allow measurement of the primary lightcurve. With each mutual event lasting approximately 4 hours, it would be difficult for any single station to capture an entire mutual event given the unpredictable winter weather in the Northern Hemisphere. Indeed, from CS3, mutual events were only detected twice.

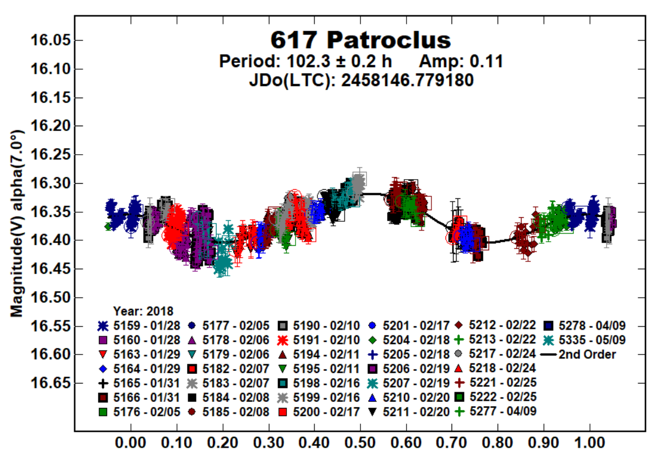


Figure 1. All observations of the Patroclus-Menoetius system without mutual events.

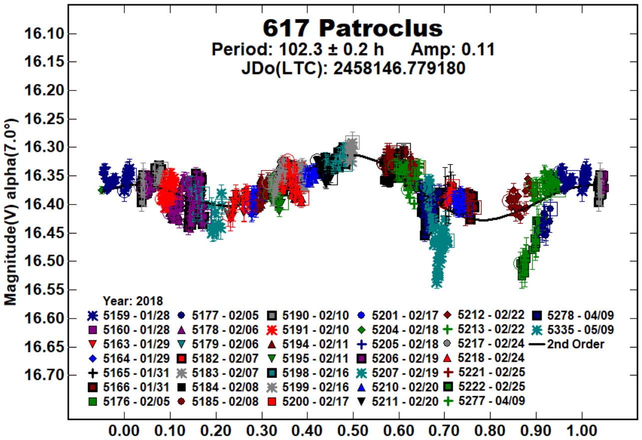


Figure 2. All observations of the Patroclus-Menoetius system including mutual events.

The purpose of the project was to measure the start and end of mutual events against their predicted times in order to reduce the orbital uncertainties. Precise predictions of the mutual events cannot be made due to the elapsed time from the original Marchis et al. (2005) predictions. In addition, the orbit could be changing over time due to perturbations.

Because of the 300 second exposures, it is unlikely the start of any single mutual event could be measured with an accuracy exceeding 10 minutes. An additional complication for the April 9 mutual event was that the German Equatorial mounted 0.35-meter SCT was crossing the meridian at the start of the mutual event, which caused further delay in the time sequence as the telescope reacquired the target field. This mutual event seemed to be about 60 minutes after its predicted start time, but this could be off by as much as 30 minutes due to the meridian flip. The session did not last long enough to reliably measure the end of the mutual event.

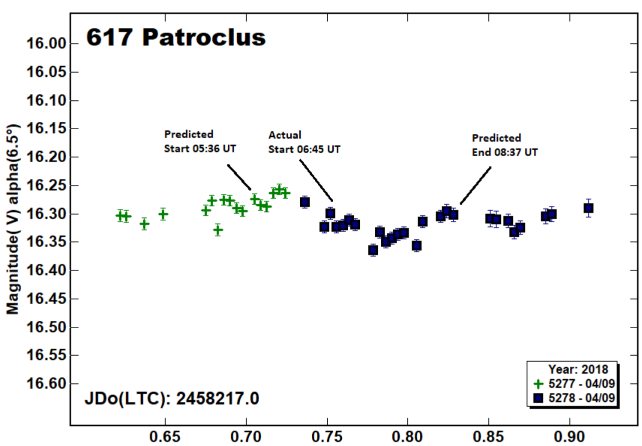


Figure 3. The mutual event on 2018 April 9. The actual start of the mutual event was about an hour after the predicted time.

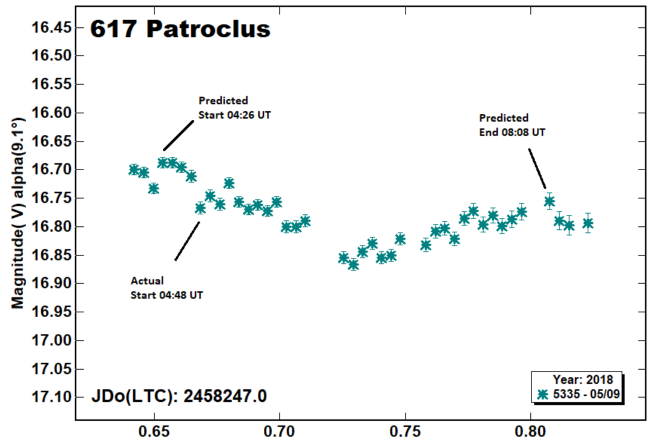


Figure 4. The mutual event on 2018 May 9. The actual start of the mutual event was about a half hour after the predicted time.

For the May 9 mutual event, the first drop in magnitude for the start of the mutual event was 22 minutes after the predicted time. However, that first data point might be an outlier, and the actual start of the mutual event could be about 30 minutes after the predicted time. Again, the session was not quite long enough to measure the end of the mutual event.

2895 Memnon. The synodic period we found this year agrees with previous synodic results (Binzel and Sauter, 1992; Mottola et al., 2011; French 2011; Stephens et al., 2015; 2016a; 2017). These data were combined with available sparse data to find a preliminary shape model with a sidereal rotational period of 7.519792 ± 0.00001 h.

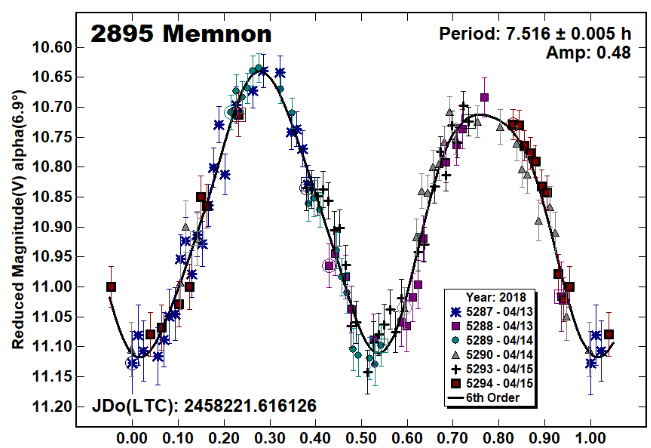


Figure 5. The lightcurve of 2895 Memnon for 2018.

4348 Poulydamas. Rotational periods have been determined five times in the past (Mottola et al., 2011; Stephens et al., 2015; 2016b; 2017; and Waszczak et al., 2015), each time finding a synodic period near 9.9 h. This year's result is in good agreement. The new and previous data were combined with available sparse data to find a preliminary shape model with a sidereal rotational period of 9.92006 ± 0.00001 h.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
617	Patroclus	01/28-05/11	920	7.0,4.0,9.3	166	21	102.8	0.1	0.05	0.01
2895	Memnon	04/13-04/15	123	7.0,7.2	171	20	7.516	0.005	0.48	0.02
4348	Poulydamas	04/04-04/11	101	5.1,6.2	167	-7	9.937	0.004	0.29	0.02
16070	1999 RB101	04/17-05/13	200	8.4,10.4	160	-12	9.6	0.002	0.13	0.02

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

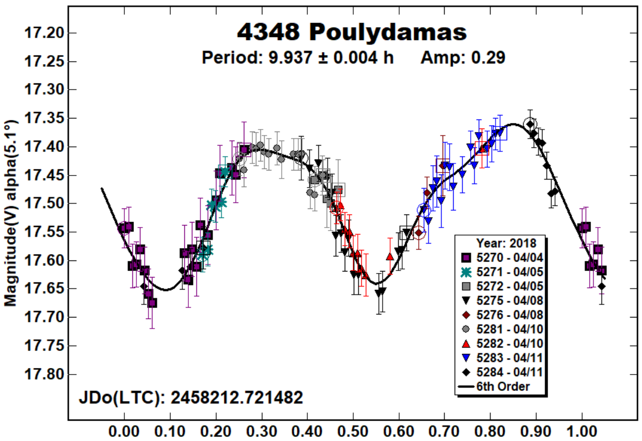


Figure 6. The synodic lightcurve of 4348 Poulydamas in 2018 April.

(16070) 1999 RB101. Due to its low amplitude and presumed spheroidal shape, this Trojan has always been a difficult case over the years. The tendency in evaluating rotational periods is to fit the Fourier curve to a bimodal solution. However, with an amplitude under 0.1 magnitudes, it is possible that a lightcurve could have only a single extremum, or three or more extrema (Harris et al., 2014). We observed it four times in the past, first in 2011 (French et al., 2012) finding a synodic period of 31.74 h. In 2015, we observed it again finding a synodic period of 20.27 h while creating a very low amplitude single-modal lightcurve (Stephens et al., 2016a). In 2017, (Stephens et al., 2017) we again found a low amplitude lightcurve with a best fit synodic period of 20.205 h. However, the short runs each night and shape of the lightcurve did not by itself present a convincing case. In 2018, we were again presented with a low amplitude lightcurve, which, when phased to a period near 20 h, presented four extrema. However, the best fit in this range was just over 19 h. The data from the other years could not be phased to match this period.

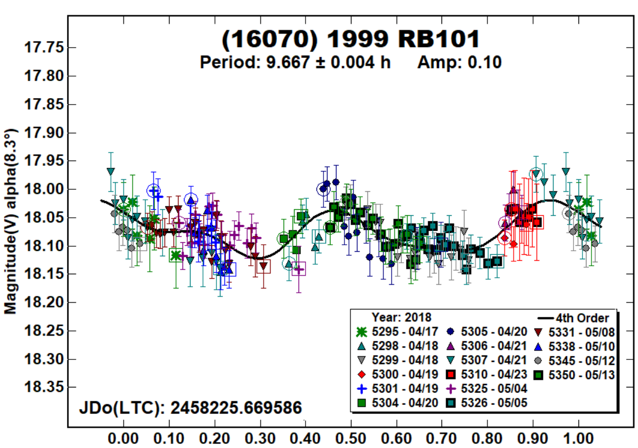


Figure 7. The lightcurve of (16070) 1999 RB101 in 2018 phased to 9.667 h.

The period spectrum for each year was reexamined to see if a common period presented itself. Each data set had several aliases present and minor zero point adjustments could make a difference. Like a Sherlock Holmes mystery, impossible solutions not present in all four datasets were eliminated leaving just one common solution near 9.7 h. Ultimately, this solution remains unsatisfactory since it is not a great fit to the 2011 dataset. It is possible some other physical process (e.g., tumbling) could be a factor contributing to the inability to find a repeatable rotation period.

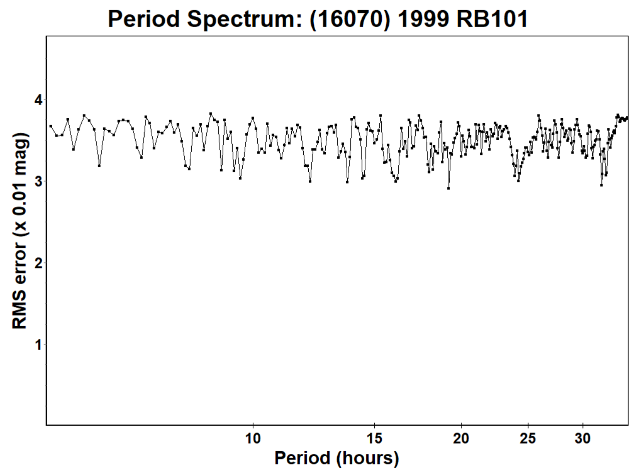


Figure 8. The period spectrum of (16070) 1999 RB101 in 2018 shows that no single period differentiates itself, but periods near 9.7 h, 19 h, and 24 h are possible.

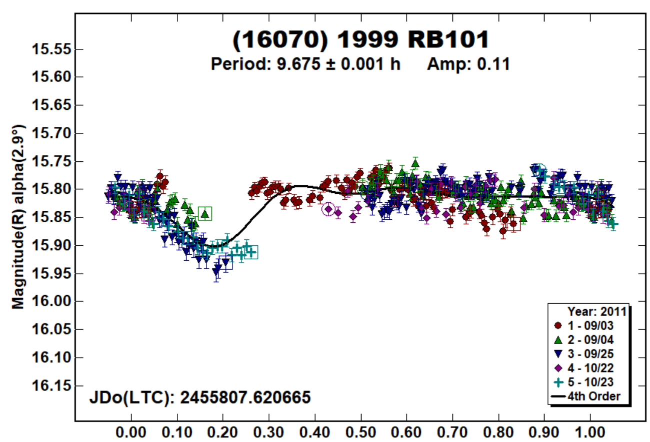


Figure 9. The dataset of (16070) 1999 RB101 in 2011 rephased to the 9.7 h period found in 2018. The dataset was originally fit to a period of 30,7 h, then to 19.06 h, both resulting in asymmetric bimodal lightcurves.

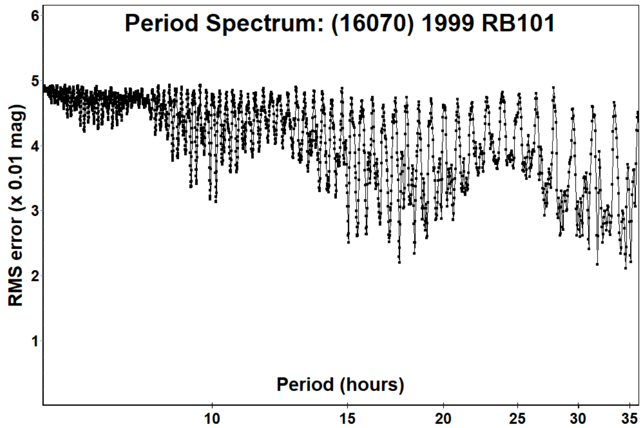


Figure 10. The Period Spectrum for the 2011 dataset of (16070) 1999 RB101 showing the 9.7 h, an 18 h, 19 h, and 34 h possible solutions.

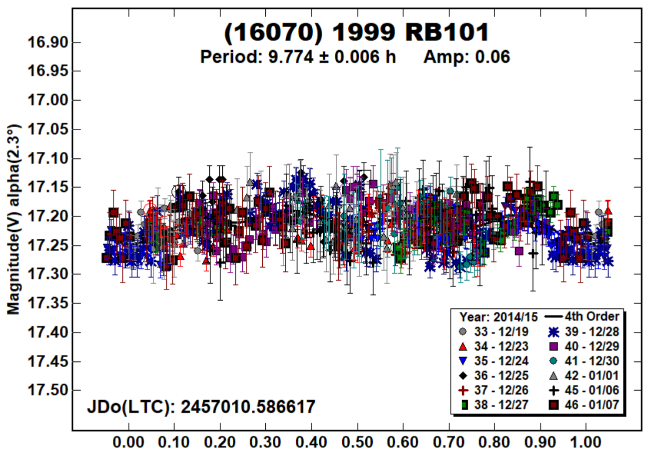


Figure 11. The dataset of (16070) 1999 RB101 in 2014/15 which has a very small amplitude. Combined with the noise in the observations almost equal to the amplitude, this dataset could fit a number of solutions.

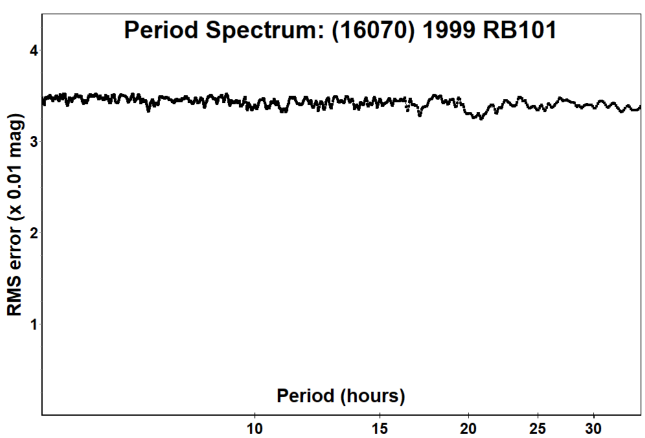


Figure 12. The Period Spectrum for the 2014/15 dataset which shows that no single solution stands out.

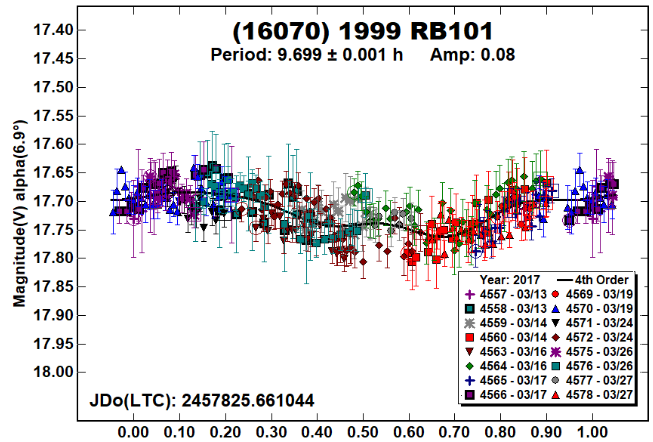


Figure 13. The dataset of (16070) 1999 RB101 in 2017 rephased to the 9.7 h period found in 2018. Originally the dataset was fitted to an asymmetric lightcurve with a 20.2 h period.

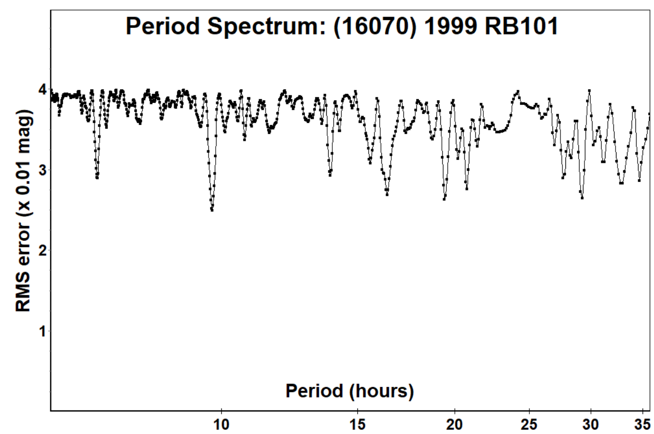


Figure 14. The Period Spectrum for the 2017 dataset of (16070) 1999 RB101 showing the 9.7 h, an 18 h, 20 h, and 30 h possible solutions.

Acknowledgements

This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*) The purchase of two FLI-1001E CCD cameras was made possible by 2013 and 2015 Gene Shoemaker NEO Grants from the Planetary Society.

References

Binzel, R.P., Sauter, L.M. (1992). "Trojan, Hilda, and Cybele asteroids - New lightcurve observations and analysis." *Icarus* **95**, 222-238.

French, L.M., Stephens, R.D., Lederer, S.M., Coley, D.R., Rohl, D.A. (2011). "Preliminary Results from a Study of Trojan Asteroids." *Minor Planet Bul.* **38**, 116-120.

French, L.M., Stephens, R.D., Coley, D.R., Megna, R., Wasseman, L.H. (2012). "Photometry of 17 Jovian Trojan Asteroids." *Minor Planet Bull.* **39**, 183-187.

Grundy, W.M., Noll, K.S., Buie, M.W., Levison, H.F. (2018). "The upcoming mutual event season for the Patroclus-Menoetius Trojan binary." *Icarus* **305**, 198-202.

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.

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

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

Marchis, F., Hestroffer, D., Descamps, P., Berthier, J., Bouchez, A.H., Campbell, R.D., Chin, J.C.Y., van Dam, M.A., Hartman, S.K., Johansson, E.M., Lafon, R.E., Le Mignant, D., de Pater, I., Stomski, P.J., Summers, D.M., Wizinovitch, P.L., Wong, M.H. (2005). "The Orbit of 617 Patroclus Binary Trojan System from Keck LGS AO observations." *Bull. Amer. Astron. Soc.* **37**, 637.

Mottola, S., Di Martino, M., Erikson, A., Gonano-Beurer, M., Carbognani, A., Carsenty, U., Hahn, G., Schober, H., Lahulla, F., Delbò, M., Lagerkvist, C. (2011). "Rotational Properties of Jupiter Trojans. I. Light Curves of 80 Objects." *Astron. J.* **141**, A170.

Stephens, R.D., Coley, D.R., French, L.M. (2015). "Dispatches from the Trojan Camp - Jovian Trojan L5 Asteroids Observed from CS3: 2014 October - 2015 January." *Minor Planet Bull.* **42**, 216-224.

Stephens, R.D., Coley, D.R., French, L.M. (2016a). "Large L5 Jovian Trojan Asteroid Lightcurves from the Center for Solar System Studies." *Minor Planet Bul.* **43**, 15-22.

Stephens, R.D., Coley, D.R., French, L.M. (2016b). "A Report from the L5 Trojan Camp - Lightcurves of Jovian Trojan Asteroids from the Center for Solar System Studies." *Minor Planet Bull.* **43**, 265-270.

Stephens, R.D., Coley, D.R. (2017). "Lightcurve Analysis of Trojan Asteroids at the Center for Solar System Studies 2017 January - March." *Minor Planet Bull.* **44**, 252-257.

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.

LIGHTCURVE ANALYSIS FOR FOURTEEN MAIN-BELT MINOR PLANETS

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

(Received: 2018 June 30)

Synodic rotation periods were determined for fourteen main-belt asteroids: 424 Gratia, 20.075 ± 0.008 h; 504 Cora, 7.58 ± 0.01 h; 791 Ani, 11.174 ± 0.004 h; 821 Fanny, 238.9 ± 0.8 h; 866 Fatme, 5.800 ± 0.002 h; 874 Rotraut, 14.297 ± 0.009 h; 896 Sphinx, 21.038 ± 0.008 h; 1097 Vicia, 100.5 ± 0.3 h; 1237 Genevieve, 16.48 ± 0.03 h; 1315 Bronislawa, 9.578 ± 0.002 h; 1329 Eliane, 137.8 ± 0.3 h; 1334 Lundmarka, 6.2497 ± 0.0008 h; 1793 Zoya, 5.750 ± 0.002 h; and 4142 Dersu-Uzala, 276.0 ± 1.0 h. All the data have been submitted to the ALCDEF database.

CCD photometric observations of fourteen main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe. Images at V02 were taken using a 0.32-m *f*/6.7 Modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a 'clear' glass filter. Exposure time for all the images was 2 minutes. The image scale after 2x2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results. All of the images for these fourteen asteroids were obtained during 2018 May and June, when southern Arizona enjoyed 35 photometric nights.

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

Comp star magnitudes were derived from a combination of CMC15 (Muiñoz et al. 2014), APASS DR9 (Munari et al. 2015), and 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.

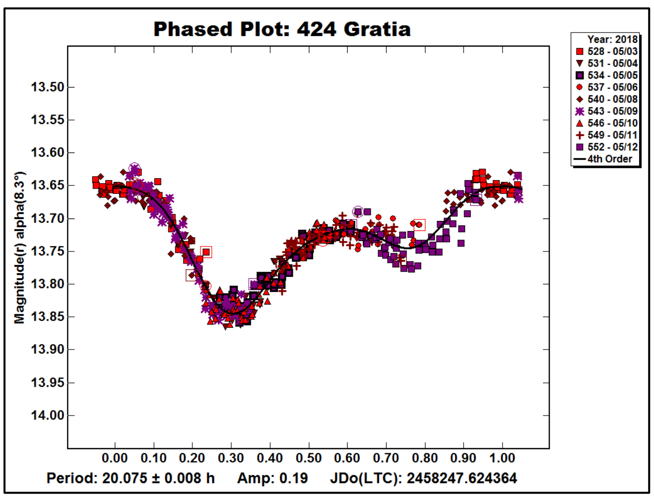
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall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

In most cases, asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude greater than 14.5 and quality of results, U, less than 3-.

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

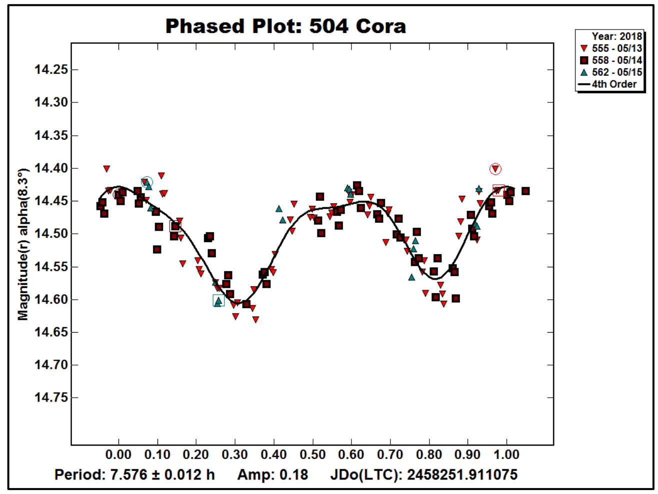
<u>424 Gratia.</u> This outer-belt asteroid was discovered by Auguste Charlois at Nice in 1896. Only one rotation period appears in the LCDB (Florczak et al., 1997), whose result is 19.47 ± 0.01 h.

A total of 516 data points were obtained over the course of nine nights. The period spectrum showed a good solution of 20.075 ± 0.008 h, roughly agreeing with Florczak's result. The amplitude is 0.19 ± 0.02 mag, and the RMS scatter on the fit shown in the phased plot is 0.015 mag.



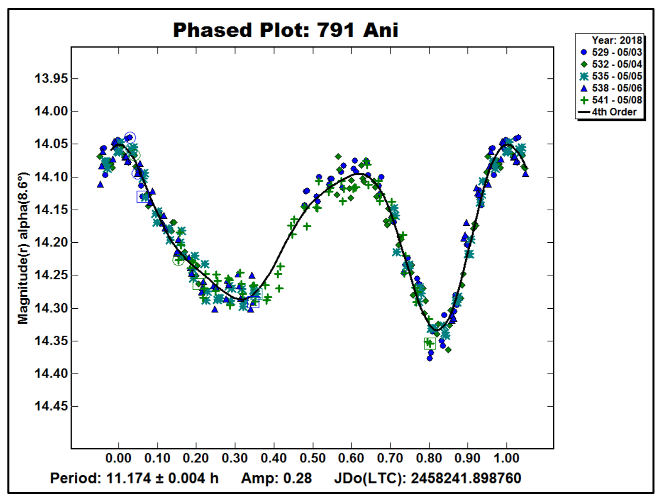
<u>504 Cora</u> is an outer-belt asteroid in a moderately eccentric orbit. It was discovered at Arequipa in 1902 by Solon Irving Bailey. Among the three published periods are those of Waszczak et al. (2015) and Higgins (2011), who both calculated 7.588 h.

Only three nights and 127 images were sufficient to compute a period solution of 7.58 ± 0.01, agreeing with previously determined periods. The amplitude is 0.18 ± 0.03 mag. The RMS scatter on the fit is 0.025 mag.



<u>791 Ani.</u> Gregory Neujmin discovered this asteroid in a high-inclination orbit from Simeis in 1914. Sauppe et al. (2007) computed a synodic period of 16.72 ± 0.03 h, while Behrend (2004 and 2009) calculated 22.85 h in both cases.

Due to its short period, this asteroid required only five nights and 294 data points to ascertain an unambiguous solution of 11.174 ± 0.004 h. This result is very close to half of Behrend's, suggesting that theirs may be an alias. The full amplitude is 0.28 ± 0.02 mag; the RMS scatter of the fit is 0.019 mag.

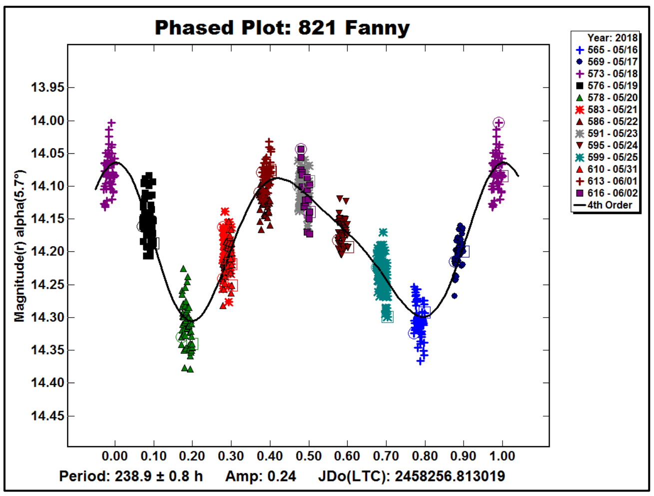


<u>821 Fanny</u> was discovered by Max Wolf at Heidelberg in 1916. The LCDB shows only one period solution: Behrend (2013) with 5.44 ± 0.05 h and a quality rating, U = 1.

It became apparent after several nights that the period would in fact be much longer than one day. During 13 nights, 669 images were secured, producing a period solution of 238.9 ± 0.8 h. Data points separated by 10 nights overlaid closely on the phased curve, showing no evidence of tumbling. The amplitude of the lightcurve is 0.24 ± 0.03 mag, with an RMS error on the fit of 0.027 mag.

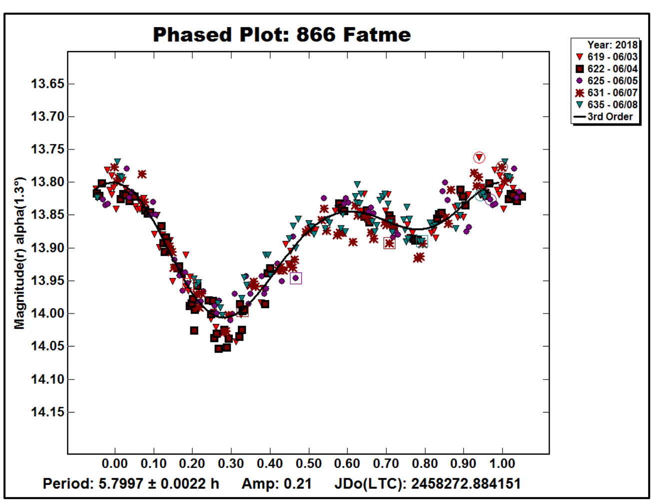
Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
424	Gratia	05/03-05/12	516	8.3,11.0	204	10	20.075	0.008	0.19	0.02	MB-O
504	Cora	05/13-05/15	127	8.2,8.7	216	14	7.58	0.01	0.18	0.03	MB-O
791	Ani	05/03-05/08	294	8.6,9.6	205	19	11.174	0.004	0.28	0.02	MB-O
821	Fanny	05/16-06/02	669	5.6,13.8	226	3	238.9	0.8	0.24	0.03	MB-O
866	Fatme	06/03-06/08	293	1.3,1.9	253	3	5.800	0.002	0.21	0.02	MB-O
874	Rotraut	05/09-05/12	288	9.4,8.5	249	11	14.297	0.009	0.29	0.03	MB-O
896	Sphinx	06/06-06/23	651	8.8,3.1	268	3	21.038	0.008	0.16	0.03	MB-I
1097	Vicia	06/09-06/25	758	11.6,2.9	276	2	100.5	0.3	0.14	0.03	MB-M
1237	Genevieve	05/19-05/24	310	6.3,8.3	224	2	16.48	0.03	0.11	0.03	MB-M
1315	Bronislawa	06/03-06/12	451	1.6,2.8	255	3	9.578	0.002	0.17	0.02	MB-O
1329	Eliane	05/03-05/18	859	11.3,15.7	208	19	137.8	0.3	0.43	0.04	MB-M
1334	Lundmarka	05/13-05/15	323	6.8,6.7	235	15	6.2497	0.0008	0.72	0.02	MB-O
1793	Zoya	05/31-06/02	201	9.8,10.8	234	1	5.750	0.002	0.44	0.03	FLOR
4142	Dersu-Uzala	05/20-06/10	731	12.7,21.5	223	7	276.0	1.0	0.52	0.08	H

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).



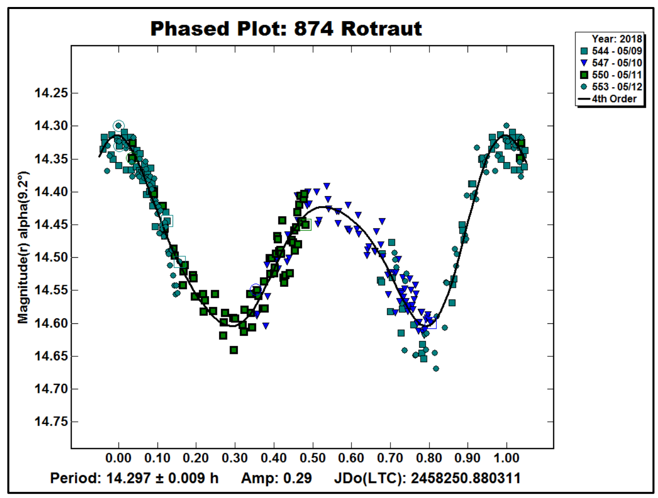
866 Fatme is an outer-belt asteroid discovered at Heidelberg by Max Wolf in 1917. *Several entries appear in the LCDB. Behrend (2004 and 2012) obtained a period of roughly 9.4* h in both instances. Stephens (2002) computed 20.03 ± 0.01 h, and Aznar et al. (2016) shows 20.7 ± 0.1 h.

The asteroid was observed on five nights, during which 293 images were obtained. The period solution of 5.800 ± 0.002 h differs from previously published values. The RMS scatter on the fit is 0.021 mag. The amplitude is 0.24 ± 0.02 mag.



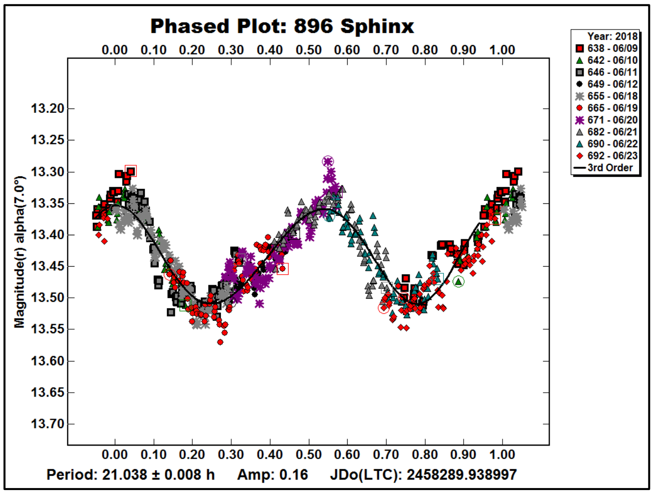
874 Rotraut. Another of Max Wolf's 1917 discoveries, this asteroid has only one published period. Behrend (2004) computed a result of 14.586 ± 0.003 h.

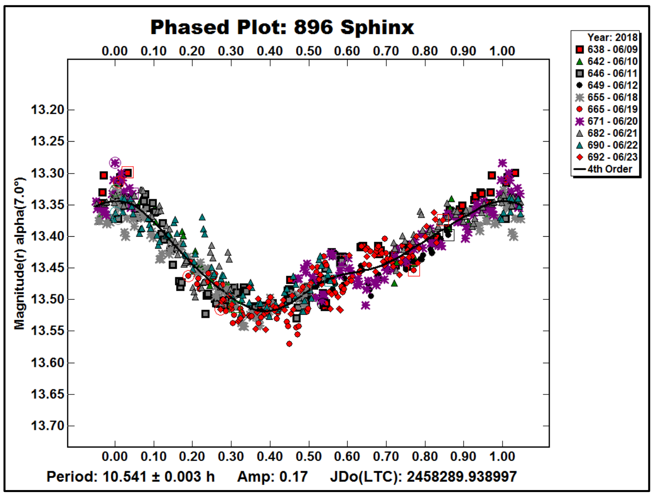
A total of 288 images were taken during four nights. The derived period of 14.297 ± 0.009 h is in good agreement with Behrend's determination. The amplitude is 0.29 ± 0.03 mag, and the RMS error on the fit is 0.026 mag.



896 Sphinx is again a Max Wolf discovery from 1917. Behrend (2001) provided the only published period: 26.27 ± 0.02 h.

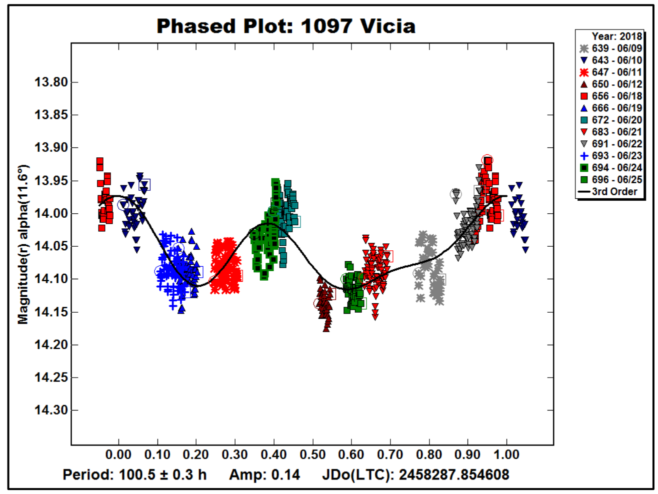
Due to its opposition location near the galactic center, this asteroid presented difficulties with unreliable comparison star magnitudes, and required extensive star subtraction. After ten nights, 651 images had been obtained. The bi-modal curve fit produces a period of 21.038 ± 0.008 h, which disagrees with published results. While this is the preferred solution, the "Split Halves" feature in Canopus showed that the mono-modal solution of 10.541 ± 0.003 h is possible. For the bi-modal solution, the amplitude is 0.16 ± 0.03 mag, with an RMS scatter of the fit of 0.026 mag. For the mono-modal solution, these values are 0.17 ± 0.02 mag, and 0.022 mag. Both lightcurves are presented.





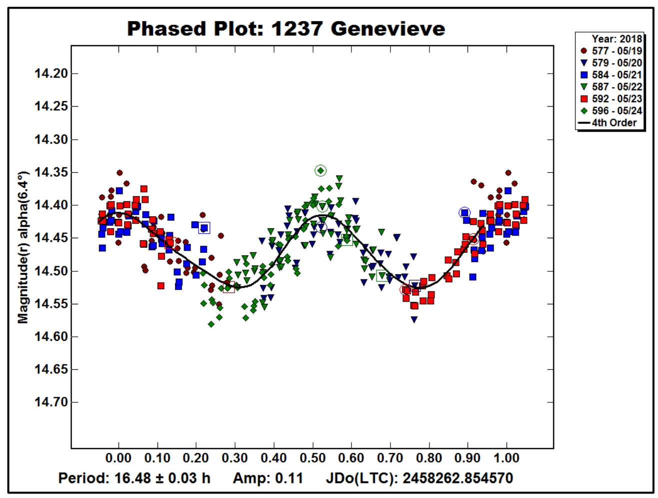
1097 Vicia is a Main Belt asteroid with a high eccentricity of 0.29. It was identified by Karl Reinmuth at Heidelberg in 1928. The only period determination was made by Gartrelle (2012), who published 26.5 ± 0.1 h.

Observations and reductions for 1097 Vicia were again complicated by its location near the Galactic center. After accumulating 758 data points in 12 nights, the synodic period remained ambiguous. The best result is 100.5 ± 0.3 h which disagrees with Gartrelle's solution. The amplitude of the lightcurve is 0.14 ± 0.03 mag. with the curve fit having an RMS scatter of 0.030 mag.



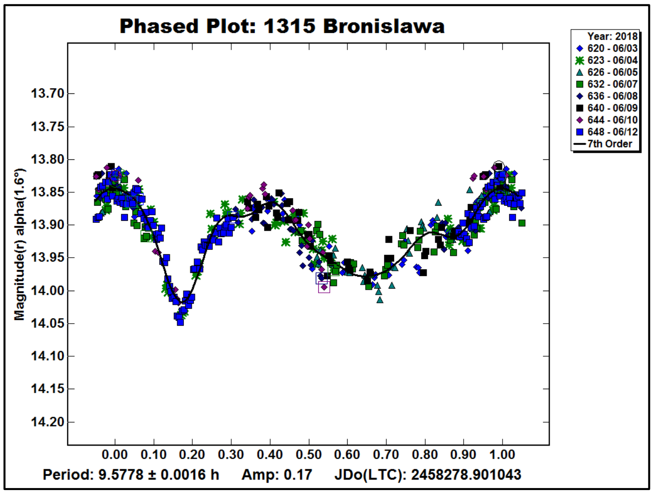
1237 Genevieve was discovered by Guy Reiss in 1931 at Algiers. Behrend (2005) found a period of 24.82 ± 0.07 h, while Binzel (1987) computed 16.37 ± 0.10 h.

During six nights, 310 data points were acquired. The period is 16.48 ± 0.03 h, agreeing with Binzel's determination. The amplitude is 0.11 ± 0.03 mag, with an RMS scatter on the fit of 0.030 mag.



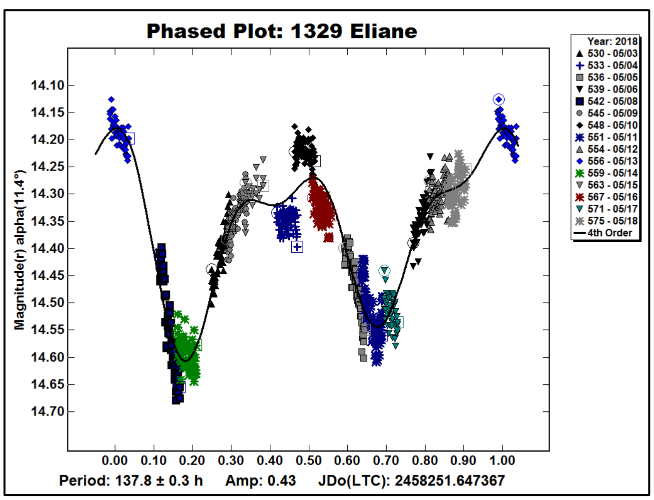
1315 Bronislawa. Sylvain Arrend discovered this outer-belt asteroid at Uccle in 1933. The two periods in the LCDB are those of Ditteon and West (2011), who found 9.565 ± 0.006 h, and Moravec et al. (2013), which is 10.01 ± 0.03.

A total of 451 images were gathered during eight nights, resulting in a synodic period of 9.578 ± 0.002 h., which agrees closely with Ditteon. The lightcurve's amplitude is 0.17 ± 0.02, and RMS scatter of the fit is 0.019 mag.



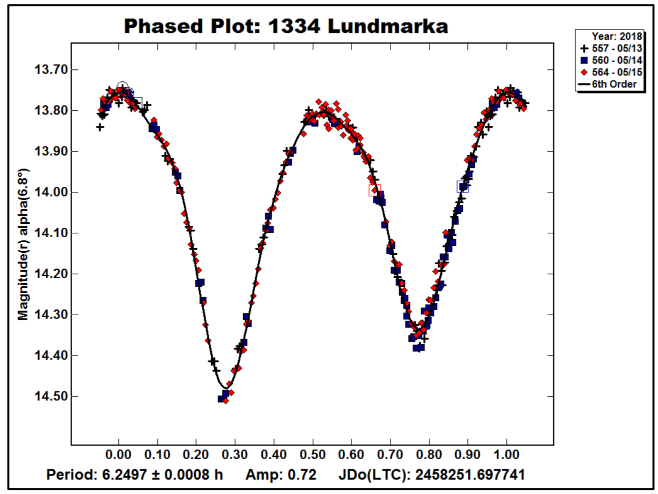
1329 Eliane. This asteroid was discovered in 1933 by Eugene Delporte at Uccle. Behrend (2005) shows a period of 72 ± 2 h. More recently, Warner (2010) published a period of 106 ± 25 h.

After 15 nights during which 859 data points were taken, the period of 1329 Eliane remained ambiguous. The best match for a bi-modal lightcurve in the period spectrum appears at 137.8 ± 0.3 h, differing from published values. The nature of the lightcurve suggests that the minor planet is tumbling, although inadequate data exists to determine the tumbling period. The amplitude of the lightcurve is 0.57 ± 0.04 mag. RMS scatter of the fit is 0.038 mag.



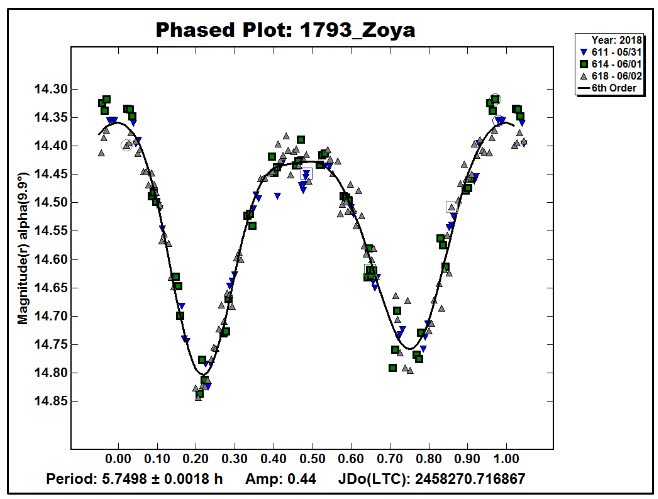
1334 Lundmarka. Karl Reinmuth identified this outer-belt asteroid at Heidelberg in 1934. The two published periods are consistent with each other. Bohn et al. (2015) shows 6.250 ± 0.003 h, and Durech et al. (2016) computed 6.25033 ± 0.00001 h.

On three consecutive nights, 323 images were sufficient to define the lightcurve, and compute a synodic period of 6.2497 ± 0.0008, in line with published solutions. The amplitude is 0.72 ± 0.02 mag, with an RMS error on the fit of 0.018 mag.



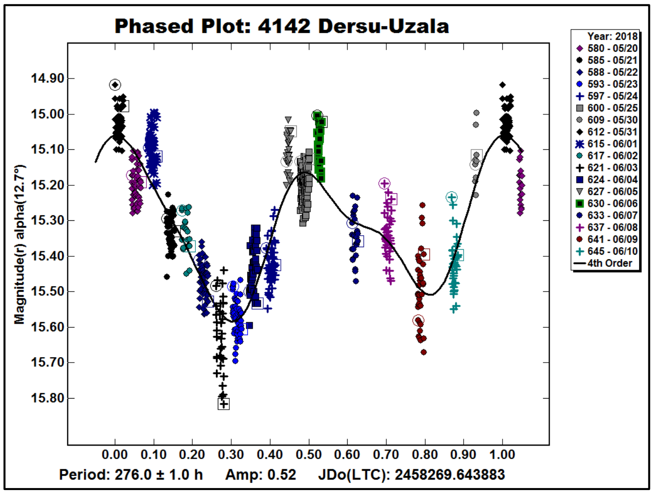
1793 Zoya is a Flora-family asteroid, discovered in 1968 by Tamara Smirnova at Nauchnyj. Three recent period solutions in the literature are as follows: Brinsfield (2008) 5.753 ± 0.001 h, Durech et al. (2016) 5.75187 ± 0.00001, Hanus et al. (2016) 5.751872 ± 0.000005 h.

On three nights, 201 images were obtained, resulting in a period of 5.750 ± 0.002 h, agreeing with previous solutions. The asteroid's amplitude is 0.44 ± 0.03 mag, with an RMS scatter of 0.027 mag.



4142 Dersu-Uzala. This Hungaria asteroid has an inclination of 26°. Its discovery was made by Zdenka Vavrova at Klet in 1981. Warner (2009) showed a period of 140 ± 3 h, which he revised (Warner 2015) to 71 ± 3 h.

Beginning at magnitude 15 and fading during the observing interval, signal-to-noise for this minor planet was low from my urban site. After obtaining 731 images in 18 nights, a rough solution of 276 ± 1.0 h was calculated, in disagreement with published periods. The large scatter and variations at similar phases in the lightcurve suggest that the asteroid is tumbling. Amplitude is high, at 0.52 ± 0.08 mag, with an RMS scatter on the fit of 0.082 mag.



Acknowledgments

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

References

Aznar Macias, A., Carreno Garcerain, A., Arce Masego, E., Brines Rodriques, P., *et al.* (2016). "Twenty-one Asteroid Lightcurves at Group Observadores de Asteroides (OBAS): Late 2015 to Early 2016." *Minor Planet Bull.* **43**, 257-263.

Behrend, R. (2001, 2004, 2005, 2009, 2012, 2013). Observatoire de Geneve web site.
http://obswww.unige.ch/~behrend/page_cou.html

Binzel, R.P. (1987). "A photoelectric survey of 130 asteroids." *Icarus* **72**, 135-208.

Bohn, L., Hibbler, B., Stein, G., Ditteon, R. (2015). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2014 September." *Minor Planet Bull*. **42**, 89-90.

Brinsfield, J.W. (2008). "Asteroid Lightcurve Analysis at the Via Capote Observatory: 2nd Quarter 2008." *Minor Planet Bull*. **35**, 179-181.

Ditteon, R., West, J. (2011). "Asteroid Lightcurve Analysis at the Oakley Southern Observatory: 2011 January thru April." *Minor Planet Bull*. **38**, 214-217.

Durech, J., Hanus, J., Oszkiewsicz, D., Vanco, R. (2016). "Asteroid models from the Lowell photometric database." *Astron. Astrophys*. **587**, A48.

Florczak, M., Dotto, E., Barucci, M.A., Birlan, M., *et al.* (1997). "Rotational properties of main belt asteroids: photoelectric and CCD observations of 15 objects." *Planet. Space Sci.* **45**, 1423-1435.

Gartrelle, G. (2012). "Lightcurve Results for Eleven Asteroids." *Minor Planet Bull*. **39**, 40-46.

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.

Hanus, J., Durech, J., Oszkiewicz, D.A., Behrend, R., *et al.* (2016). "New and updated convex shape models of asteroids based on optical data from a large collaboration network." *Astron. Astrophys*. **586**, A108.

Higgins, D. (2011). "Period Determination of Asteroid Targets Observed at Hunters Hill Observatory: May 2009 - September 2010." *Minor Planet Bull*., **38**, 41-46.

Moravec, P., Letfullina, A., Ditteon, R. (2013). "Asteroid Lightcurve Analysis at the Oakley Observatories: 2012 May - June." *Minor Planet Bull*. **40**, 17-20.

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.

Sauppe, J., Torno, S., Lemke-Oliver, R., Ditteon, R. (2007). "Asteroid Lightcurve Analysis at the Oakley Observatory - March/April 2007." *Minor Planet Bull*. **34**, 119-122.

Stephens, R.D. (2002). "Photometry of 866 Fatme, 894 Erda, 1108 Demeter, and 3443 Letsungdao." *Minor Planet Bull*. **29**, 2-3.

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

Warner, B.D. (2002). "Asteroid Photometry at the Palmer Divide Observatory: Results for 573 Recha, 1329 Eliane, and 8041 Masumoto." *Minor Planet Bull*. **29**, 14-15.

Warner, B.D. (2007). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory - September-December 2006." *Minor Planet Bull*. **34,** 32-37.

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., Stephens, R.D., Harris, A.W., Pravec, P. (2009). "A Re-examination of the Lightcurves for Seven Hungaria Asteroids." *Minor Planet Bull.* **36**, 176-178.

Warner, B.D. (2010). "Upon Further Review: II. An Examination of Previous Lightcurve Analysis from the Palmer Divide Observatory." *Minor Planet Bull*. **37**, 150-151.

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

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

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

Waszczak, A., Chang, C.-K., Ofeck, E.O., Laher, F., *et al.* (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Astron. J*. **150**, A75.

ASTEROIDS OBSERVED FROM CS3: 2018 APRIL - JUNE

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

(Received: 2018 July 1)

CCD photometric observations of 8 main-belt asteroids were obtained from the Center for Solar System Studies from 2018 April to June.

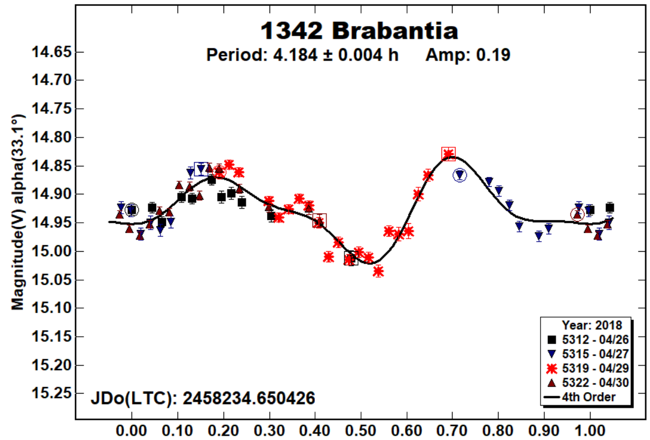
The Center for Solar System Studies "Trojan Station" (CS3, MPC U81) has two telescopes which are normally used in program asteroid family studies such as MBAs, Jovian Trojans and Hildas. During the 2nd quarter of 2018 the targets which are normally studied were either out of season, or the Moon was too close. In these cases targets of opportunity amongst the main-belt families were selected.

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

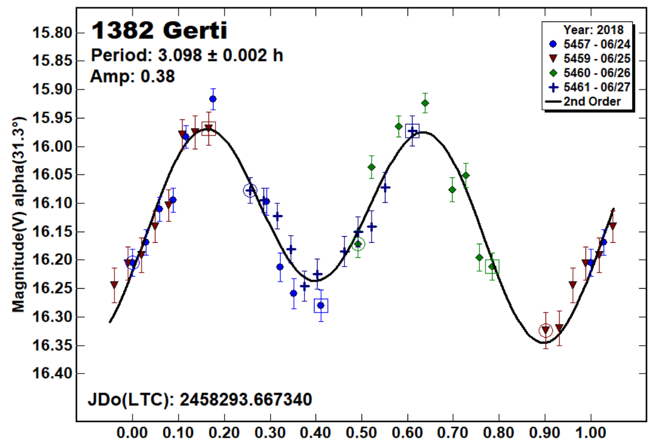
In the lightcurve plots, the "Reduced Magnitude" is Johnson V corrected to a unity distance by applying -5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using G = 0.15. The X-axis rotational phase ranges from -0.05 to 1.05. The amplitude indicated in the plots (e.g. Amp. 0.20) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

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

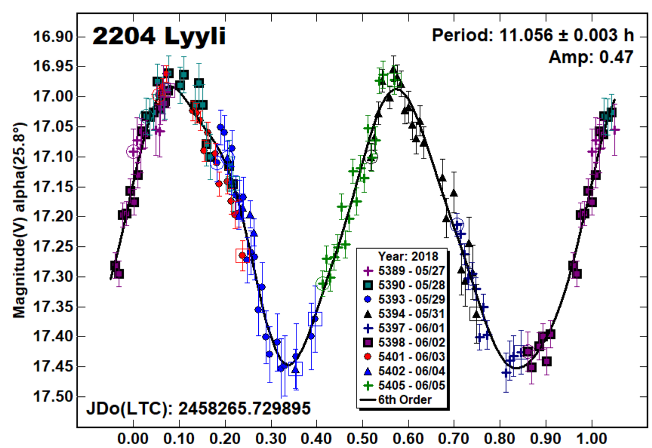
1342 Brabantia. This Phocaea family member was studied several times in the past. Behrend (2018), Franco et al. (2011, 2018) and Owings (2011) each reported periods near 4.18 h. This result is in good agreement with those results.



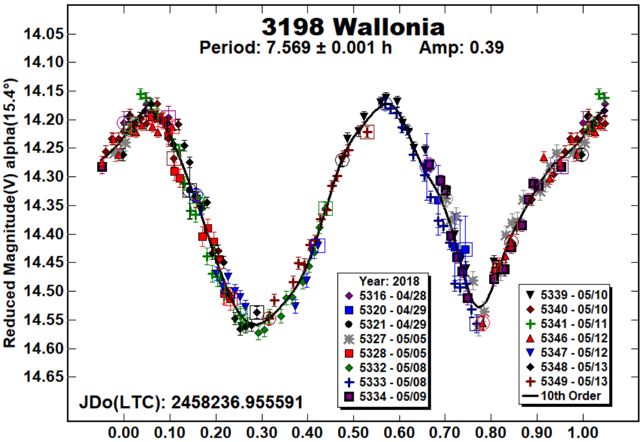
1382 Gerti. This member of the Flora family has been studied several times in the past and has a sidereal period of 3.081545 h and pole determination (Hanas et al. 2011). The result found this year is consistent with those findings.



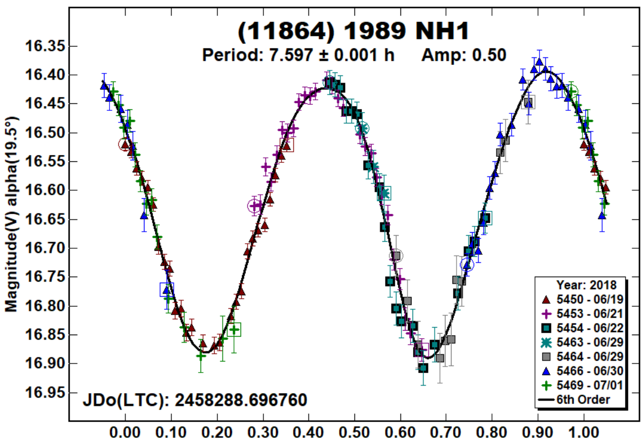
2204 Lyyli. Warner (2010, 2016) twice determine rotational periods near 11.06 h for this Mars Crosser. This year's result is in good agreement with those findings.



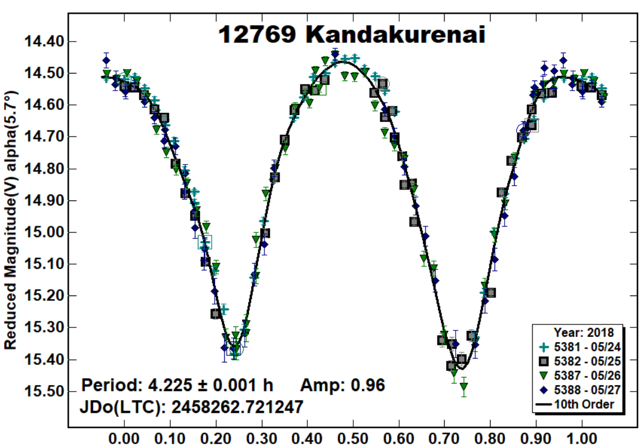
3198 Wallonia. Behrend (2018) and Warner (2008) reported periods near 7.6 h for this Mars Crosser. This year's finding is in good agreement with those results.



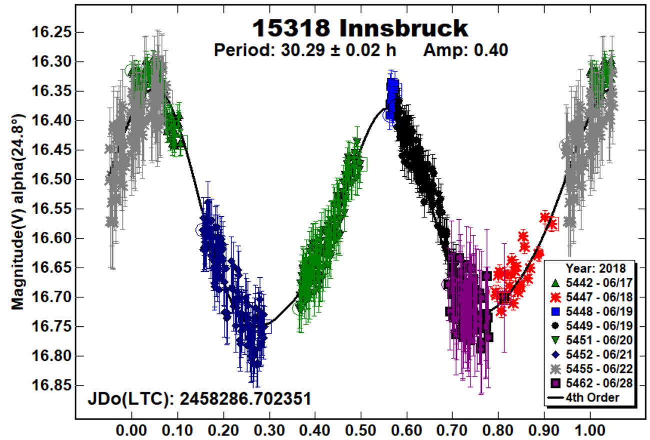
(11864) 1989 NH1. Waszczak et al. (2015) reported a period of 7.597 h using data obtained from the Palomar Transient Factory Survey. This result agrees with that finding.



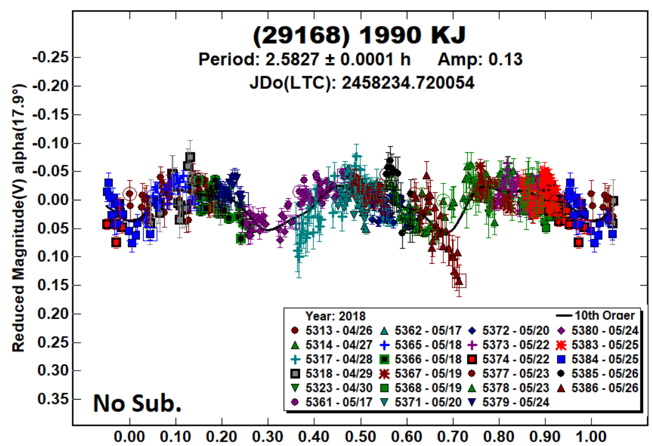
12769 Kandakurenai. Using data obtained from the Palomar Transient Factory Survey, Waszczak et al. (2015) reported a period of 4.222 h. This result is in good agreement.

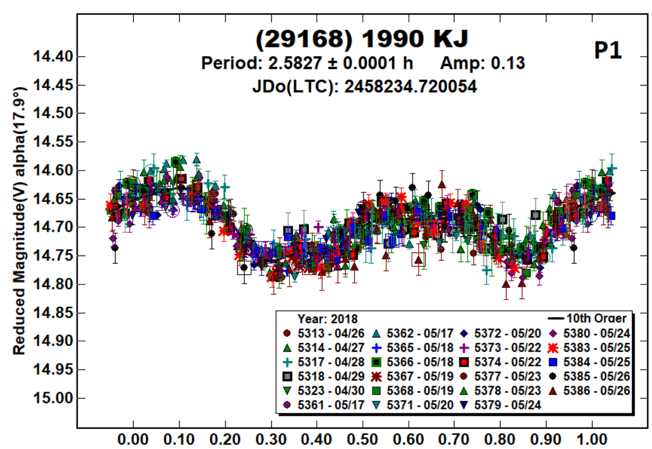


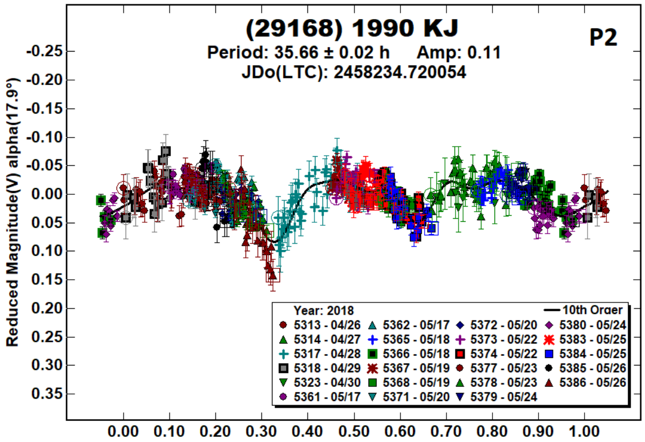
15318 Innsbruck. No entry was found in the lightcurve database (LCDB; Warner et al., 2009) for this Phocaea family member.



(29168) 1990 KJ. Pravec (2018) reported this member of the Phocaea family as a suspected binary asteroid with a primary rotation of 2.587247 h and an orbital period of 34.4 h from the Photometric Survey for Asynchronous Binary Asteroids. Observations this year spanned a month. The raw lightcurve ("No Sub." Plot) showed what appeared to be a couple of attenuation events. The dual period analysis found a primary lightcurve of P_1 = 2.5827 ± 0.0001 h, A_1 = 0.13 ± 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 seems to be *mutual events* (occultations and/or eclipses) due to a satellite ("P2" plot). The lightcurve has a period of P_2 = 35.66 ± 0.02 h, A_2 = 0.20 mag. The data for this possible satellite was sent to Petr Pravec for analysis and proved to be inconclusive, so it remains a suspected binary. A good opportunity for follow up is in 2019 November.







Acknowledgements

This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*. The purchase of a FLI-1001E CCD cameras was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

References

Behrend, R. (2018). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html*

Franco, L., Sergison, D. (2011). “Lightcurve Photometry and H-G Parameters for 1342 Brabantia.” *Minor Planet Bull.* **38**, 132-134.

Franco, L., Marchini, A., Baj, G., Scarfi, G., Casalnuovo, G.B., Luna, V., Bachini, Mauro, B.P., Maestripieri, M., Bacci, R., GBalli, 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., 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.

Hanuš, J., Durech, J., Brož, M., Warner, B.D., Pilcher, F., Stephens, R., Oey, J., Bernasconi, L., Casulli, S., Behrend, R., Polishook, D., Henych, T., Lehký, M., Yoshida, F., Ito, T. (2011). “A study of asteroid pole-latitude distribution based on an extended set of shape models derived by the lightcurve inversion method.” *Astron. Astrophys.* **530**, A134.

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.

Owens, L. (2011). “Lightcurves for 938 Cholsinde, 1342 Brabantia, 2715 Mielikki, and 3252 Johnny.” *Minor Planet Bull.* **38**, 141.

Pravec, P. (2018). Photometric Survey for Asynchronous Binary Asteroids web site.
http:// www.asu.cas.cz/~asteroid/binastphotsurvey.htm.

Warner, B.D. (2010). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2010 March - June.” *Minor Planet Bull.* **43**, 57-65.

Warner, B.D. (2008). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory: February-May 2008.” *Minor Planet Bull.* **35**, 163-166.

Warner, B.D. (2016). “Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 June-September.” *Minor Planet Bull.* **37**, 161-165.

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The Asteroid Lightcurve Database.” *Icarus* **202**, 134-146. Updated 2018 July *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.

Number	Name	mm\dd	Pts	Phase	LPAB	BPAB	Period	P.E.	Amp	A.E.	Grp
1342	Brabantia	04/26-04/30	61	33.1,33.3	147	-13	4.184	0.004	0.19	0.01	PHO
1382	Gerti	06/24-06/27	39	31.3,31.5	207	-1	3.098	0.002	0.38	0.05	FLOR
2204	Lyyli	05/27-06/05	135	25.8,25.3	171	9	11.056	0.003	0.04	0.03	MC
3198	Wallonia	04/28-05/13	204	15.5,8.8	245	10	7.569	0.001	0.39	0.02	MC
11864	1989 NH1	06/19-07/01	124	19.5,24.6	241	6	7.597	0.001	0.50	0.02	FLOR
12769	Kandakurenai	05/24-05/27	178	5.7,5.9	243	8	4.225	0.001	0.96	0.02	FLOR
15318	Innsbruck	06/17-06/28	655	24.8,27.4	228	20	30.29	0.02	0.4	0.03	PHO
29168	1990 KJ	04/26-04/30	189	17.9,17.4	225	28	2.5827	0.0001	0.13	0.03	PHO

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

NEW LIGHTCURVES OF 33 POLYHYMNIA, 49 PALES, 289 NENETTA, 504 CORA, AND 821 FANNY

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

(Received: 2018 June 30)

Synodic rotation periods and amplitudes are found for 33 Polyhymnia 18.610 ± 0.001 hours, 0.12 ± 0.01 magnitudes; 49 Pales 20.709 ± 0.001 hours, 0.19 ± 0.01 magnitudes with 4 maxima and minima per cycle; 289 Nenetta 6.916 ± 0.001 hours, 0.20 ± 0.02 magnitudes; 504 Cora 7.587 ± 0.001 hours, 0.18 ± 0.01 magnitudes; 821 Fanny, 235 ± 1 hour, amplitude increasing from 0.22 to 0.28 magnitudes. For 821 Fanny the color index V-R=0.37, H=11.763± 0.018, G=0.079±0.018.

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

33 Polyhymnia. Five previous studies all found highly consistent rotational periods for 33 Polyhymnia: Zappala et al. (1982), 18.601 hours; Pilcher (2009), 18.609 hours; Pilcher (2011), 18.608 hours; Ferrero (2012), 18.604 hours; Behrend (2012), 18.604 hours. New observations on 9 nights 2018 Apr. 10 – May 17 provide a good fit to a bimodal lightcurve (Figure 1) with period 18.610 ± 0.001 hours, amplitude 0.12 ± 0.01 magnitudes, in complete agreement with earlier results.

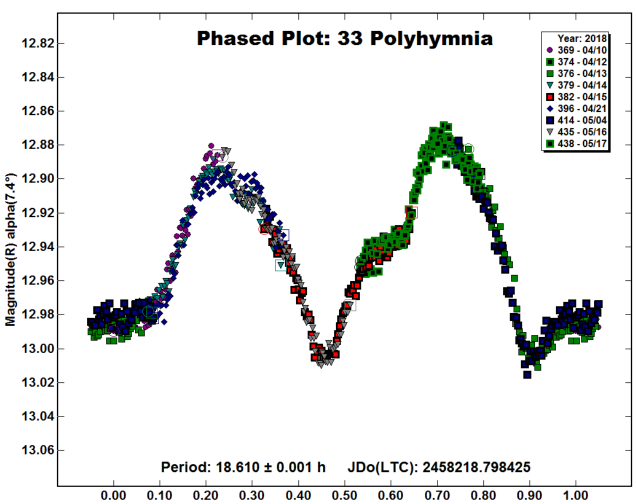


Figure 1. Phased lightcurve of 33 Polyhymnia.

49 Pales. Two early published rotation periods were by Schober (1979), 10.42 hours; and by Tedesco (1979), 10.3 hours, and for many years the period was believed to be near 10.4 hours. Behrend (2013) published a very sparse lightcurve which suggested a period <10 hours. Pilcher et al. (2016) made a much more comprehensive investigation that found a period 20.704 hours with an unsymmetric quadrimodal lightcurve. Behrend (2016) complemented this study with a period 20.7057 hours. Pilcher (2017) at the next opposition found a period 20.705 hours. The new study published here confirms the recent results. Observations on 10 nights 2018 Apr. 4 – May 11 provide a good fit to a period 20.709 ± 0.001 hours, again with an irregular quadrimodal lightcurve, and amplitude 0.19 ± 0.01 magnitudes (Figure 2). This is consistent with other recent values.

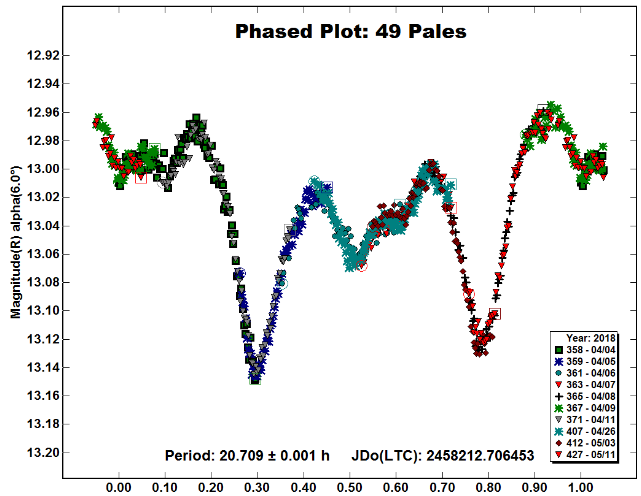


Figure 2. Phased lightcurve of 49 Pales.

289 Nenetta. Previously published period determinations are by Barucci et al. (1992), 6.902 hours; Behrend (2006), 6.9 hours; Behrend (2007), >8 hours; Behrend (2008), 6.94 hours; and by Lucas et al. (2011), 6.914 hours. New observations on 6 nights 2018 May 18 – June 18 provide a good fit to a lightcurve with period 6.916 ± 0.001 hours, amplitude 0.20 ± 0.02 magnitudes (Figure 3). This is consistent with most previous values.

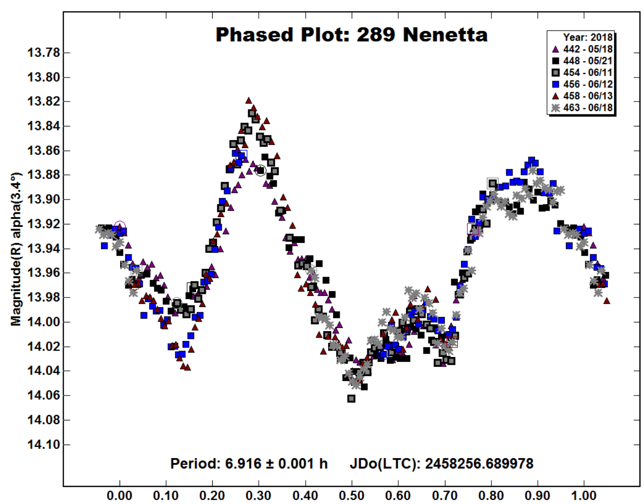


Figure 3. Phased lightcurve of 289 Nenetta.

504 Cora. Previously published period determinations are by Barucci et al. (1992), 24.06 hours; Behrend (2009), 7.591 hours; Higgins (2011), 7.588 hours; and by Waszczak et al. in the Palomar Transient Factory Survey, 7.592 hours in 2012 observations and 7.588 hours in 2013 observations. New observations on 6 nights 2018 April 16 – May 19 provide a good

fit to a lightcurve with period 7.587 ± 0.001 hours, amplitude 0.18 ± 0.01 magnitudes (Figure 4). A split halves plot of the double period 15.174 hours (Figure 5) shows that the two halves are almost identical and rules out the double period. This new result is in good agreement with most previous results.

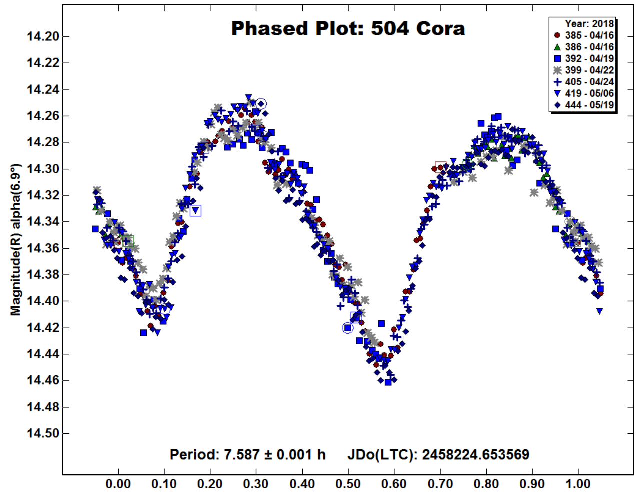


Figure 4. Phased lightcurve of 504 Cora.

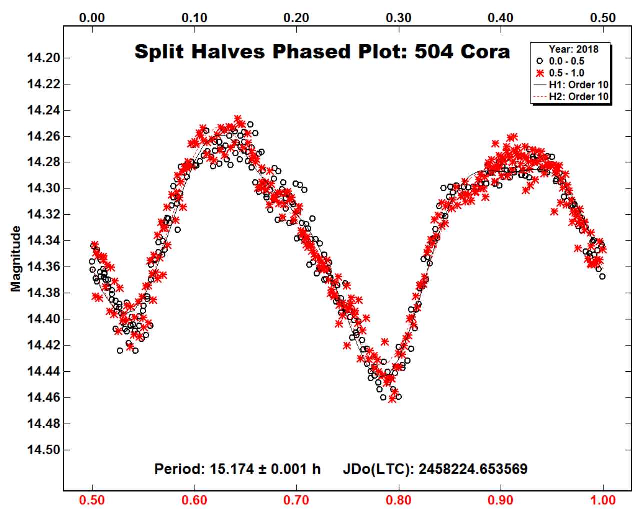


Figure 5. Split halves lightcurve of 504 Cora phased to the double period 15.174 hours.

821 Fanny. The only previously published lightcurve is for one night only and shows a period 5.44 hours, amplitude 0.01 magnitude (Behrend, 2013). New observations were obtained on 46 nights 2018 Apr. 11 – June 27. A raw lightcurve of all of these observations (Figure 6) features the usual two maxima and minima in an interval near 235 hours with amplitude near 0.22 magnitudes in April and May increasing to near 0.28 magnitudes in June at larger phase angle. Such increase in amplitude with increasing phase angle is commonly encountered. Petr Pravec (personal communication) has examined the complete data set with simultaneous dual period software and finds no evidence of tumbling behavior above an approximate 0.04 magnitude limit of consistency of the CMC15 catalog.

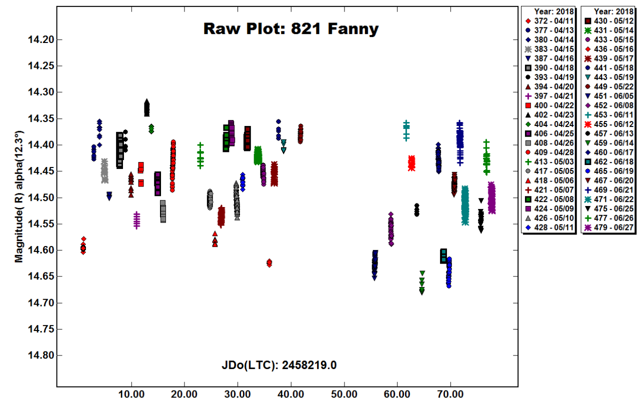


Figure 6. Raw lightcurve of 821 Fanny including all 46 sessions 2018/04/11 through 2018/06/27.

It is useful to plot separate phased lightcurves for two separate intervals. For the interval 2018 Apr. 11 – May 22, a good fit is obtained to a bimodal lightcurve (Figure 7) with synodic period 236.6 ± 0.3 hours, amplitude 0.22 ± 0.03 magnitudes. The period spectrum for this same interval is shown in Figure 8. A split halves plot for the interval Apr. 11 – May 22 (Figure 9) shows that the two sides of the 236 hour bimodal lightcurve are quite different and rules out a period near 118 hours. A split halves plot for the double period 470 hours in the same time interval (Figure 10) shows that the two sides are nearly the same and makes a period near 470 hours extremely unlikely. We may have confidence that the period is near 236 hours. For the interval 2018 June 5 – 27, a good fit is obtained to a bimodal lightcurve (Figure 11) with synodic period 230.6 ± 0.3 hours, amplitude 0.28 ± 0.03 magnitudes. The change in synodic period between these two intervals is probably due to a change in the time rate of change of phase angle bisector, but is larger than is often encountered. The night-to-night consistency of the lightcurves calibrated with CMC15 magnitudes is illustrated in raw plots of the sessions of May 9 and 10, about 6 hours each (Figure 12); and again of June 21 and 22 (Figure 13), far after opposition, where sessions were limited to less than 4 hours each as the target sank low in the sky several hours before the start of twilight.

On 2018 May 9 twenty images of exposure time 60 seconds each were obtained alternately in R and V filters and measured with the same comparison stars with their respective R and V magnitudes as derived from CMC15 catalog r', J, Ks magnitudes. The R

Number	Name	yyyy/mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
33	Polyhymnia	2018/04/10-2018/05/17	2274	7.4, 1.3, 6.1	221	-1	18.610	0.001	0.12	0.01
49	Pales	2018/04/04-2018/05/11	2376	6.0, 1.2, 5.2	214	-3	20.709	0.001	0.19	0.01
289	Nenetta	2018/05/18-2018/06/18	1403	3.4, 12.6	230	6	6.916	0.001	0.20	0.02
504	Cora	2018/04/16-2018/05/19	1817	6.9, 5.8, 9.9	216	15	7.587	0.001	0.18	0.01
821	Fanny	2018/04/11-2018/05/22	2867	12.3, 1.2, 8.8	225	2	236.6	0.3	0.22	0.03
821	Fanny	2018/06/05-2018/06/27	1401	15.2, 22.5	229	3	230.6	0.3	0.28	0.03

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

magnitude session in the raw lightcurve plot (Figure 14) of these two sessions must be adjusted downward by 0.37 magnitudes for best overlap; hence we obtain the color index V-R=0.37. The R magnitudes of sessions near mid-light on the raw lightcurve are converted to V by V-R=0.37 and used to construct an H-G plot (Figure 15) that shows H=11.763±0.018 (in the V magnitude system) and G=0.079±0.018.

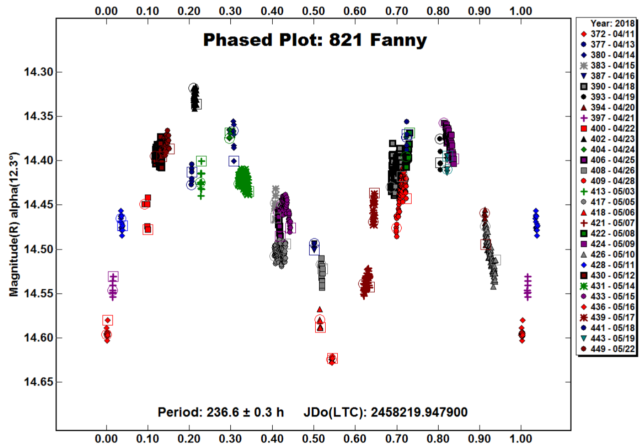


Figure 7. Phased lightcurve of 821 Fanny for the interval 2018/04/11 through 2018/05/22.

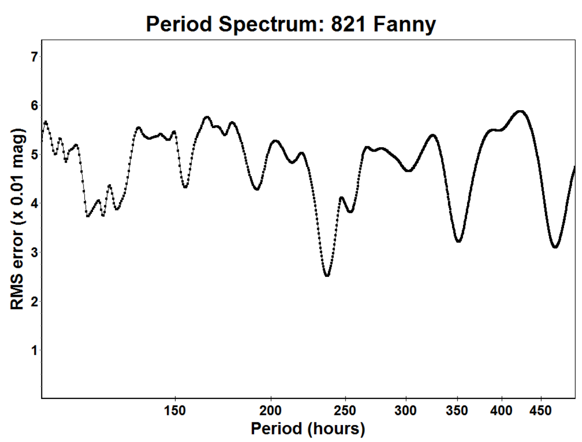


Figure 8. Period spectrum of 821 Fanny for the interval 2018/04/11 through 2018/05/22

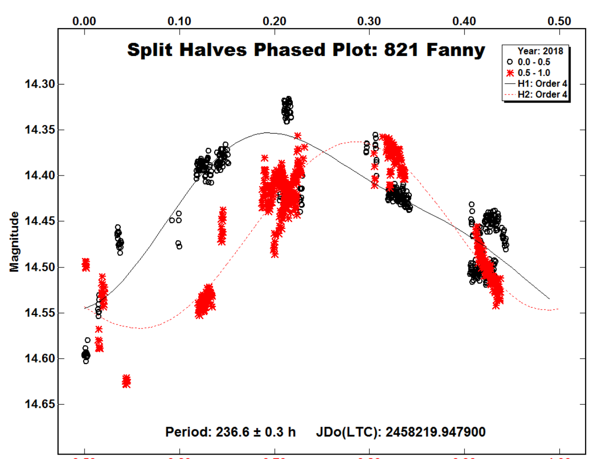


Figure 9. Split halves lightcurve for 821 Fanny for the interval 2018/04/11 through 2018/05/22.

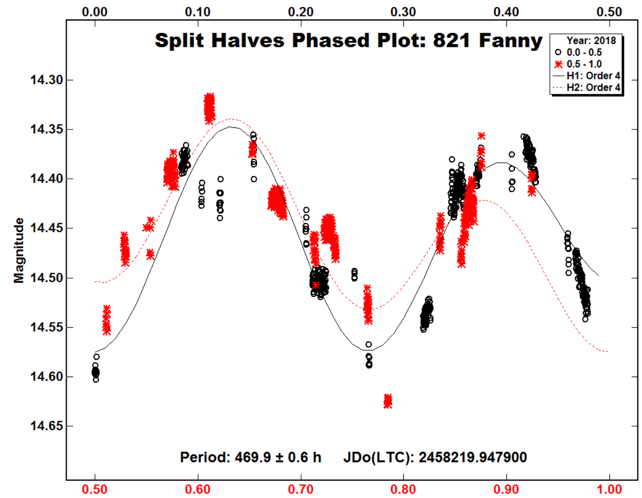


Figure 10. Split halves lightcurve for 821 Fanny for the double period 470 hours for the interval 2018/04/11 through 2018/05/22.

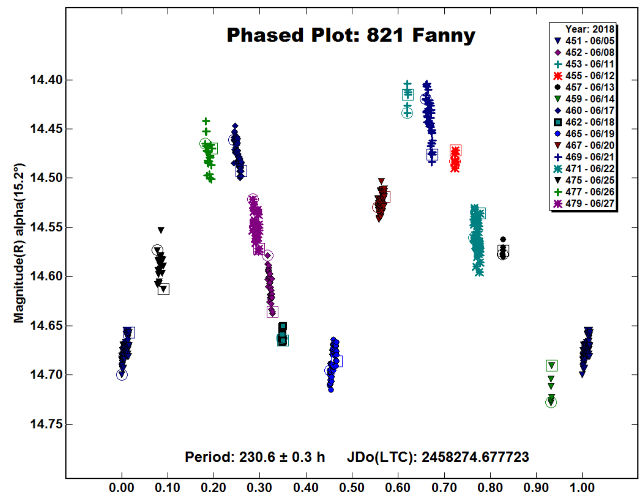


Figure 11. Phased lightcurve of 821 Fanny for the interval 2018/06/05 through 2018/06/27.

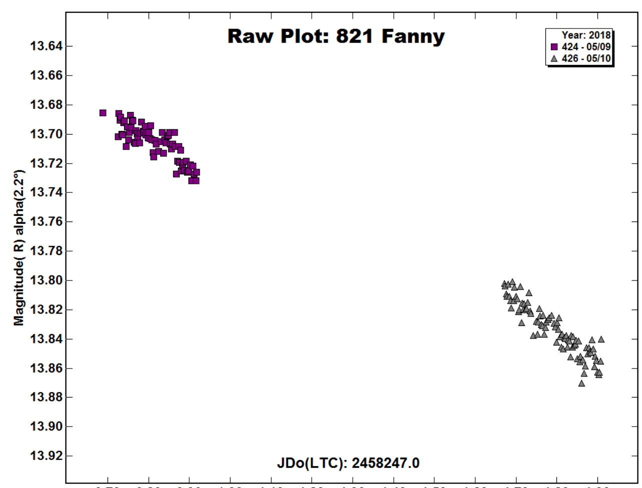


Figure 12. Raw lightcurve of 821 Fanny 2018 May 9-10.

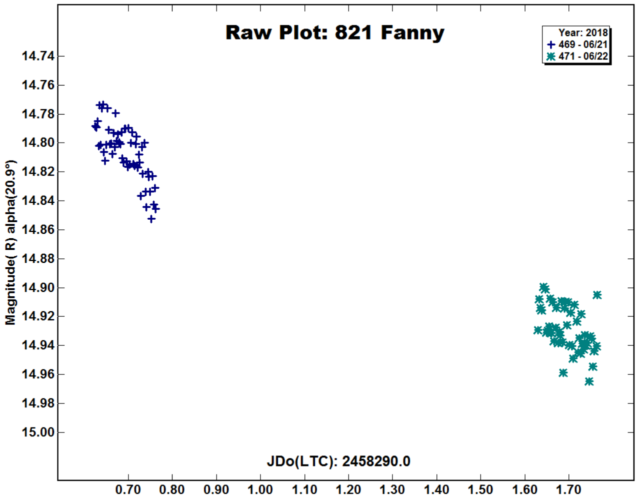


Figure 13. Raw lightcurve of 821 Fanny 2018 June 11-12.

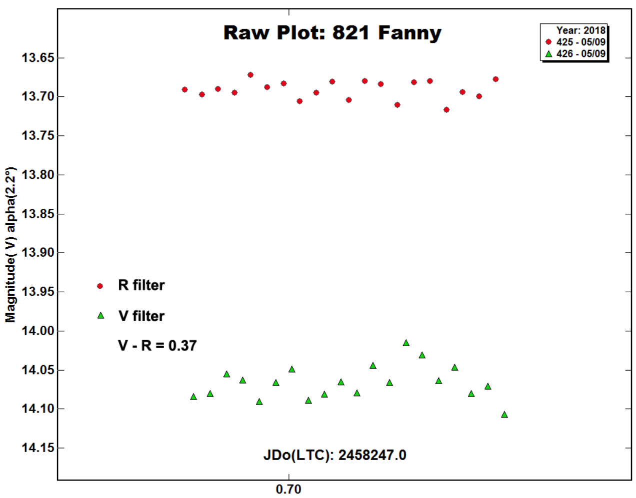


Figure 14. Raw lightcurve of R and V sessions for 821 Fanny 2018 May 9.

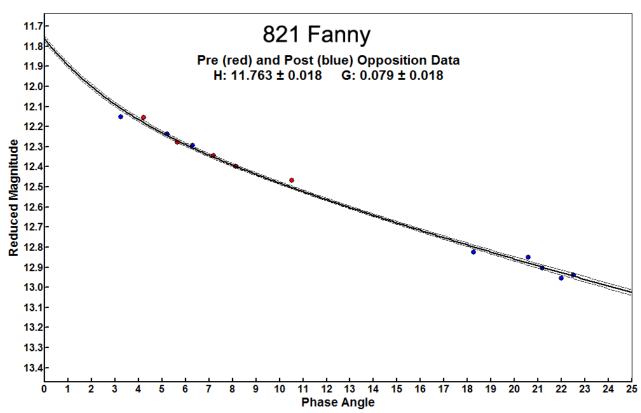


Figure 15. H-G plot for 821 Fanny in the V magnitude system.

References

Barucci, M.A., Di Martino, M., Fulchignoni, M. (1992). "Rotational properties of small asteroids – Photoelectric observations." *Astron. J.* **103**, 1679-1686.

Behrend, R. (2006, 2007, 2008, 2009, 2012, 2013, 2016). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*.

Ferrero, A. (2012). "Lightcurve photometry of six asteroids." *Minor Planet Bull.* **39**, 138-139.

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. (2011). "Period determinations of asteroid targets observed at Hungters Hill Observatory: May 2009 – September 2009." *Minor Planet Bull.* **38**, 41-46.

Lucas, M.P., Ryan, J.G., Fauerbach, M., Grasso, S. (2011). "Lightcurve analysis of five taxonomic A-class asteroids." *Minor Planet Bull.* **38**, 218-220.

Pilcher, F. (2009). "Period determinations for 33 Polyhymnia, 38 Leda, 50 Virginia, 189 Phthia, and 290 Bruna." *Minor Planet Bull.* **36**, 25-27.

Pilcher, F. (2011). "A critical re-examination of the rotation period of 33 Polyhymnia." *Minor Planet Bull.* **38**, 130-131.

Pilcher, F., Benishek, V., Klinglesmith, D.A. (2016). "Rotation Period, Color Indices, and H-G Parameters for 49 Pales." *Minor Planet Bull.* **43**, 182-183.

Pilcher, F. (2017). "Rotation Period Determinations for 49 Pales, 96 Aegle, 106 Dione, 375 Ursula, and 576 Emanuela." *Minor Planet Bull.* **44**, 249-251.

Schober, H.-J., Scaltriti, F., Zappala, V. (1979). "Photoelectric photometry and rotation periods of three large and dark asteroids – 49 Pales, 88 Thisbe, and 92 Undina." *Astron. Astrophys. Suppl. Ser.* **36**, 1-8.

Tedesco, E.F. (1979). PhD Dissertation, New Mexico State University.

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., Scaltriti, F., Lagerkvist, C.-I., Rickman, H., Harris, A.W. (1982). "Photoelectric photometry of asteroids 33 Polyhymnia and 386 Siegena." *Icarus* **52**, 196-201.

(139345) 2001 KA67: A POTENTIAL NEA VERY-WIDE BINARY ASTEROID

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: 2018 July 3)

Analysis of CCD photometric observations of the near-Earth asteroid (139345) 2001 KA67 show that it may be a very wide asynchronous binary, which features a long primary and short secondary period. The two periods that were found for 2001 KA67, $P_1 = 44.25 \pm 0.05$ h and $P_2 = 6.011 \pm 0.003$ h, are in-line with other potential members of this class.

The formation and states of binary asteroids has been analyzed by several authors (e.g., Pravec et al., 2006, 2010, 2016; Jacobson and Scheeres, 2011). In those works, even so-called "wide binaries" (Jacobson et al., 2014) featured a rapidly spinning primary and a tidally-locked satellite. However, a new class seems to have come to light: the "very wide binary asteroids" (VWBA; Warner, 2016 and references therein).

These systems feature a slowly rotating primary and, presumably, a fully asynchronous satellite with a rotation period usually similar to the primaries of "close" binary asteroids ($P < 5$ hours).

In general, the satellite is lacking just enough mass and its orbit has expanded close to but not beyond the limit where it could decouple from the primary and form an asteroid pair (e.g., Pravec et al., 2010). This leads to 1) the primary being "despun" to a long period and 2) the satellite's orbit having a very long period. Given these circumstances, the chances of seeing mutual events (eclipses and/or occultations) are very remote and so, thus far, there has been no *absolute* confirmation that any members of the VWBA class exist.

The long period can be attributed to the primary based on the relatively large amplitude. If due to the satellite, the amplitudes would be "diluted" by about a magnitude due to the primary and so require that the satellite be viewed equatorially and have an unphysically great elongation (Alan Harris, private communications).

Observations and Data Reduction

A C-14 0.35-m Schmidt-Cassegrain and FLI Microline-1001E were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures were 300 seconds. Table I gives the observing circumstances and analysis results.

Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Night-to-night calibration (generally < ±0.05 mag) was done using field stars from the CMC-15 catalog. The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

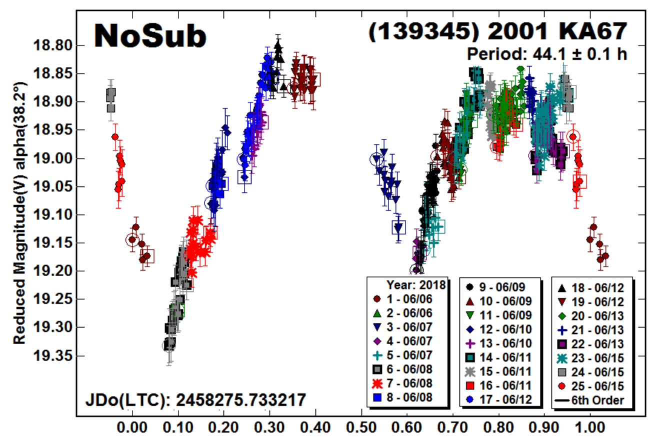
In the lightcurve plots, the "Reduced Magnitude" is Johnson V corrected to a unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses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

The amplitude indicated in the plots (e.g. Amp: 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

Data Analysis

Stephens' initial analysis of the data through June 11 indicated a single period of about 6.9 hours but with other possibilities. In his analysis, nightly zero points were adjusted by 0.4 mag or more, which is usually assumed to be systematic errors in the catalog magnitudes that are RA/Dec dependent. As it turns out, and has likely happened to many times to others, forcing the sessions to fit masked a completely different result.

Warner reviewed the data obtained through June 11, starting by resetting the nightly zero points to 0. When plotting individual nights, the data often showed a steadily increasing or decreasing trend that usually indicates a long period.



Additional data were obtained through June 15 and the nightly zero point adjustments limited to 0.05 mag or less. The initial results of the second analysis found more than one potential period, i.e., a second, shorter period superimposed on the long period lightcurve.

The "No Sub" plot shows the result of finding a single period using the full data set. The fact that the curve did not seem to repeat itself after one cycle is one indication that the asteroid might be "tumbling", i.e., in non-principal axis rotation (NPAR; Pravec et al., 2005).

The dual-period feature of *MPO Canopus* was used to look for the possibility of one or two secondary periods that would, after subtracting out, give a better fit for the long period. This led to finding two, distinct periods within the data.

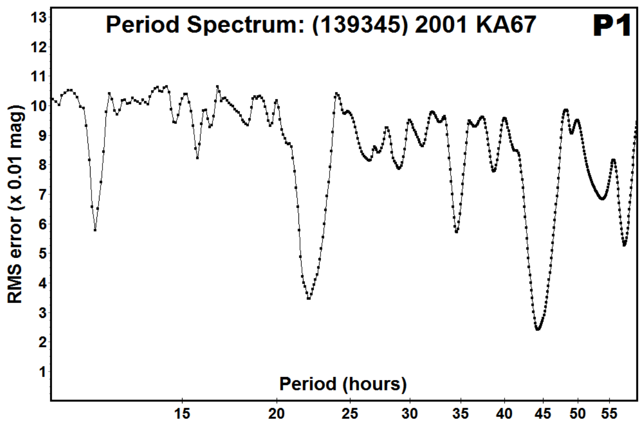
The "P1" period spectrum shows the two dominant long periods, including the adopted one near 44 hours since it produced a bimodal lightcurve with a large amplitude (Harris et al., 2014). The "P2" period spectrum showed a period near 6 hours as most likely. The two strong solutions on either side represent a one

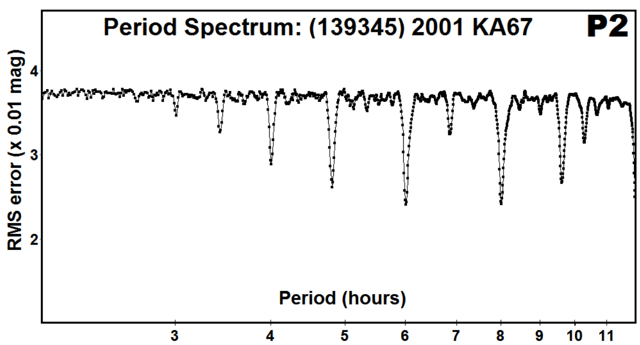
Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
139345	2001 KA67	06/06-06/15	481	38.6,24.3	271	24	44.25	0.05	0.47	0.03
							6.011	0.003	0.10	0.01

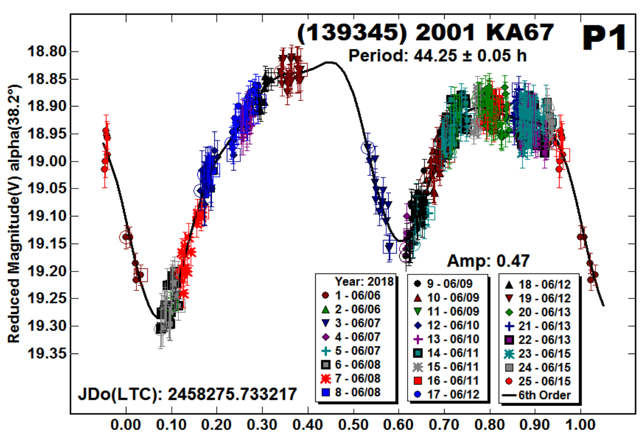
Table I. Observing circumstances and results. The first line is for the primary of the putative binary while the second line is for the presumed satellite rotation period. The orbital period was not determined. Pts is the number of data points. Phase is the solar phase angle for the first and last date. L_{PAB} and B_{PAB} are, respectively, the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

rotation per day difference. All three were used against the long period in the analysis.

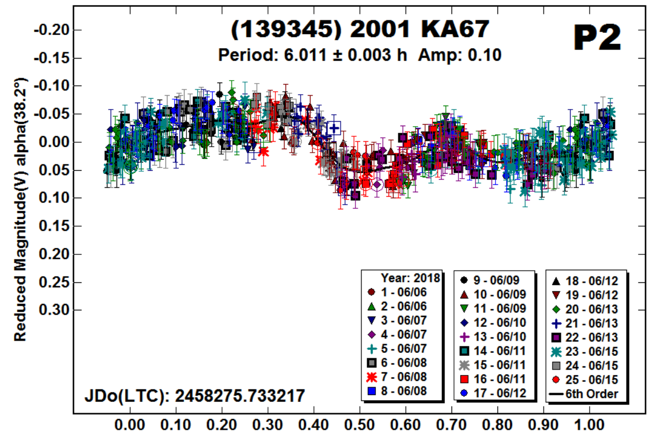
The final results are shown in the "P1" and "P2" lightcurves which give the best fits of P_1 = 44.25 ± 0.05 h and P_2 = 6.011 ± 0.003 h. Unfortunately, it was not possible to fill in the entire long period lightcurve. However, it is sufficiently well-defined to be certain of the solution.







The period for P_1 is near the short end of those found in other suspected very wide binary candidates (see Table II). It's amplitude of 0.47 mag fits well into the model for these objects, as does the amplitude of the P_2 lightcurve.



Number	Name	P1	P2	Ref
1876	Napolitania	45	2.825	MPB 43, 57-65
2026	Johnmckay	372	2.298	MPB 38, 33-36
15778	1993 NH	113	3.320	MPB 42, 60-66
19204	Joshuatree	480	21.25	MPB 43, 220-222
23615	1996 FK12	368	3.646	MPB 42, 36-42
67175	2000 BA19	275	2.716	MPB 41, 102-112
119744	2001 YN42	624	7.24	MPB 42, 79-83
218144	2002 RL66	588	2.49	MPB 37, 109-111
139345	2001 KA67	44	6.011	This work
	2014 PL51	205	5.384	MPB 42,134-136

Table II. List of suspected wide binary asterods. *P1* is the primary's period (hours). *P2* is the satellite's period, which is not tidally-locked to its orbital period. The orbital period is likely very long.

Number	Name	P1	P2	P1/P2
139345	2001 KA67	44	6.011	7.3
1876	Napolitania	45	2.825	15.9
19204	Joshuatree	480	21.25	22.6
15778	1993 NH	113	3.320	34.0
	2014 PL51	205	5.384	38.1
119744	2001 YN42	624	7.24	86.2
23615	1996 FK12	368	3.646	100.9
218144	2002 RL66	588	2.49	236.1
67175	2000 BA19	275	2.716	272.3
2026	Johnmckay	372	2.298	369.7

Table III. The ratios of the primary-to-secondary rotation periods.

What makes this candidate a bit unusual is the ratio of the primary-to-secondary periods. As shown in Table III, the ratio for 2001 KA67 is, by far, the smallest and less than half of the second lowest ratio. There does not seem to be a correlation between the ratio and primary period.

Conclusions

(139345) 2001 KA67 is a strong candidate for the small set of very wide binary asteroids discovered *so far*. We can only speculate on how many more there might be. More of a question is how many might have been overlooked by presuming that large nightly zero point shifts were systematic errors in the catalogs or measurements.

Perhaps it would be worth a second look by others who have data sets that required large zero point shifts, especially if the result was a lightcurve with a period of less than 5 hours. As shown in Table II, however, this is only a place to start since some secondary curves are much longer.

As before, we encourage more detailed observations when initial results indicate a long period. The oft-used method of obtaining only a few data points each night will not allow finding more candidates for this class. Denser lightcurve coverage may be a strain on telescope time if only one is available. It's never easy balancing priorities and program goals.

Acknowledgements

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

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.

Jacobson, S.A., Scheeres, D.J. (2011). "Dynamics of rotationally fissioned asteroids: Source of observed small asteroid systems." *Icarus* **214**, 161-178.

Jacobson, S.A., Scheeres, D.J., McHahon, J. (2014). "Formation of the Wide Asynchronous Binary Asteroid Population." *Ap. J.* **780**, A60.

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., 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., Vokrouhlicky, D., Polishook, D., Scheeres, D.J., Harris, A.W., Galad, A., Vaduvescu, O., Pozo, F., Barr, A., Longa, P., and 16 coauthors. (2010). "Formation of asteroid pairs by rotational fission," *Nature* **466**, 1085-1088.

Pravec, P., Scheirich, P., Kušnirák, P., Hornoch, K., Galád, A., Naidu, S.P., Pray, D.P., Világi, J., Gajdoš, Š., Kornoš, L., Krugly, Yu.N., Cooney, W.R., Gross, J., Terrell, D., Gaftonyuk, N., and 33 coauthors. (2016). "Binary asteroid population. 3. Secondary rotations and elongations." *Icarus* **267**, 267-295.

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

LIGHTCURVE ANALYSIS OF MAIN-BELT ASTEROIDS FROM BMO AND DRO IN 2016: I

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

Roger Groom
Darling Range Observatory
Perth, West Australia

(Received: 2018 Jun 30)

Photometric observations of selected asteroids were done from Blue Mountains Observatory (BMO) and Darling Range Observatory (DRO) in 2016. The observations were made during a favorable apparition for each asteroid as part of the Photometric Survey of Asynchronous Binary Asteroids (PSABA) program.

CCD photometric observations of several asteroids were made in 2016 from Blue Mountains Observatory by Oey and supported by Groom at Darling Range Observatory. Five telescope systems were used for the observations (Table I). Further information of the instruments used at BMO can be found at BMO (2016). Table II shows the absolute magnitude (*H*) and the instruments used for each asteroid.

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	B5	0.12	7.5	ST-8300M	5.4	3x3	3.51
BMO	B24	0.61	6.8	U42	13.5	1x1	0.70
BMO	B14E	0.35	11	U6	24	1X1	1.28

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

Number	H	Group	Comment
832	8.30	MB-O	B5, B12
910	10.50	MB-O	B5, B14
1741	11.50	MB-O	B24
2827	12.10	MB-I	B24, D12
2656	13.30	MB-F	B14
2956	12.10	MB-O	B24
3002	12.80	MB-F	B24, B14
3363	12.10	MB-O	B24
3738	12.90	MB-I	B24, B14
4022	13.10	MB-V	B14, D12
5129	13.06	MB-I	B14, B24, D12

Table II. The H values are from the MPC. The orbital groups are from the LCDB (Warner et al., 2009a). MB-I/-O = Main-belt Inner/Outer, -V = Vestoid, -F = Flora

Unless otherwise specified, all images were taken unfiltered with exposures of 300 s to maximize SNR but at the same time provide sufficient data point frequency for most main-belt asteroid rotation periods.

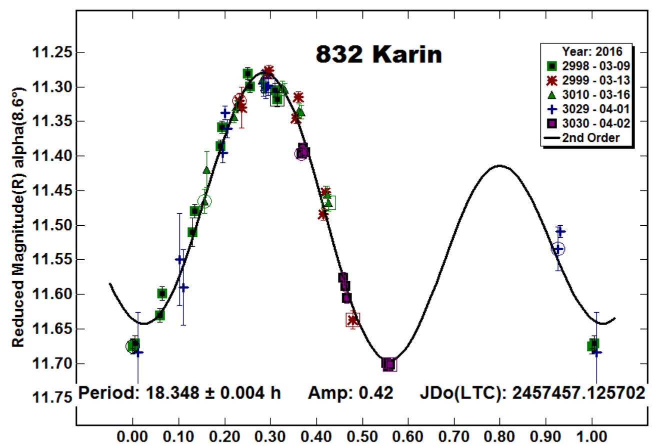
The raw data from B14 and DRO were subtracted with a library of flats, darks, and bias frames using *CCDSoft* v5 while the raw data from B24 and B14E were obtained using *The SkyX* and subsequently reduced using a library of flats, darks, and bias frames in *Maxim DL* v6. Data measurement and reduction were done using *MPO Canopus* v10, which uses the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989).

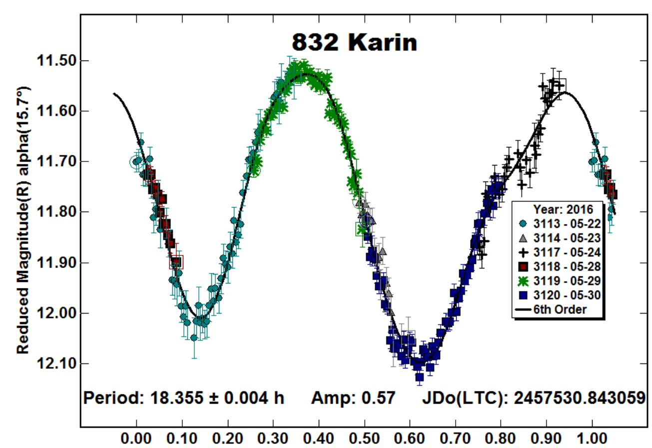
The Comp Star Selector (CSS) feature in *MPO Canopus* was used to select comparison stars. Calibration of the data was done using the *MPO Canopus* MPOSC3 catalog. The R_C magnitudes for the comparison stars were converted from 2MASS J-K values. This resulted in internal consistency of < 0.05 mag. However, due to interstellar reddening, the conversion is inconsistent and some adjustments in the nightly zero points were required during period analysis (Warner, 2007).

Most of the targets in this paper were observed to support the Photometric Survey of Asynchronous Binary Asteroids (PSABA; Pravec, 2016). Unless noted otherwise, the description of the lightcurve elements was described in Oey et al. (2015).

832 Karin was selected from CALL website (Warner, 2016) because it was reaching a favourable opposition. Recent work by Yoshida (2016) found that the period 18.346 ± 0.96 h was consistent with our refined period. This is the primary body of the Karin family, which is thought to have been formed by a collision 5.8 My ago. In this regard, it was suggested that the asteroid might have the tell-tale signs of fresh impact on its surface detectable as a color difference over its rotational cycle.

The data from 2016 March and May were plotted separately to show the change in amplitude due to the increase in phase angle.

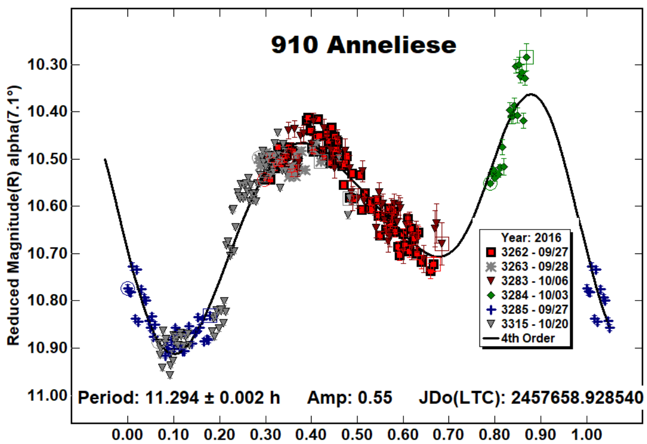




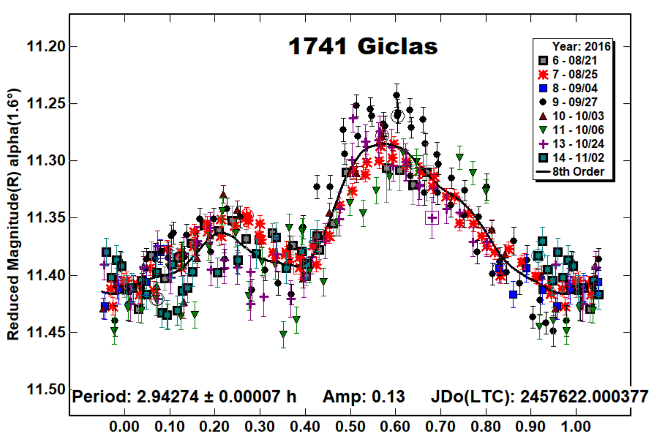
910 Anneliese was worked previously by Alvarez and Manuel (2015), who obtained a rotation period of 11.2863 ± 0.0002 h. Their data set was comprehensive, having about 3200 data points. The period reported here is based on relatively sparse data with no double coverage of the lightcurve. Even so, the result is consistent with that found by Alvarez and Manuel.

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
832	Karin	05/22-05/30	229	15,17	194	-1	18.355	0.004	0.57	0.02
832	Karin	03/09-04/02	53	8,0	192	-1	18.348	0.04	0.42	0.02
910	Anneliese	05/06-05/09	291	7,13	227	1	11.294	0.002	0.55	0.03
1741	Giclas	08/21-11/02	289	2,21	332	-4	2.94274	0.00007	0.13	0.02
2656	Evenkia	03/05-03/12	74	8,4	176	4	7.0855	0.0006	0.58	0.01
2827	Vellamo	30/02-03/07	330	13,10	189	-3	3.7392	0.0005	0.19	0.01
2956	Yeomans	11/03	61	2	44	-3	3.72	0.07	0.26	0.02
3002	Delasalle	04/26-05/04	188	12,8	231	9	6.5357	0.0004	0.35	0.02
3363	Bowen	05/17-05/18	229	4	228	3	3.016	0.003	0.19	0.03
3738	Ots	03/07-03/12	108	4,1	173	0	4.1717	0.0005	0.73	0.01
4022	Nonna	04/02-04/08	221	8,5	205	-7	2.5872	0.0004	0.08	0.01
5129	Groom	09/21-10/05	181	6,3	9	-5	3.3797	0.0003	0.23	0.02

Table III. Observing circumstances and results. 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).

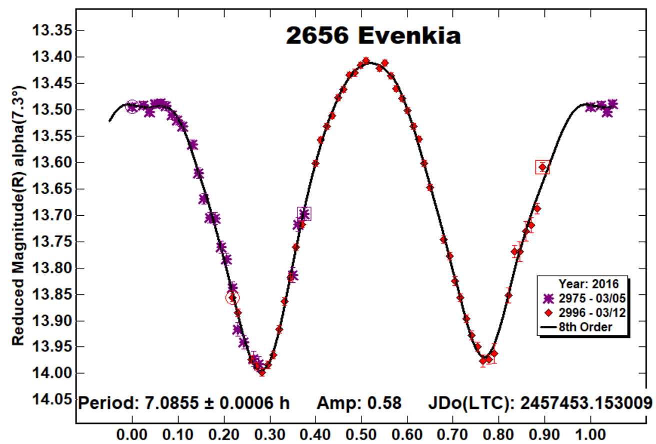


1741 Giclas is the primary of a paired asteroid within the search parameters of the PSABA project. According to Pravec et al. (2010), the primaries of binary and paired asteroids that have small secondaries (*Ds/Dp* < 0.4) have very similar, fast spin rates. Consequently, it was possible that 1741 Giclas would be a binary since its rotation period was within the range common among the primary body of binary asteroids. Our data showed no signs of a satellite.

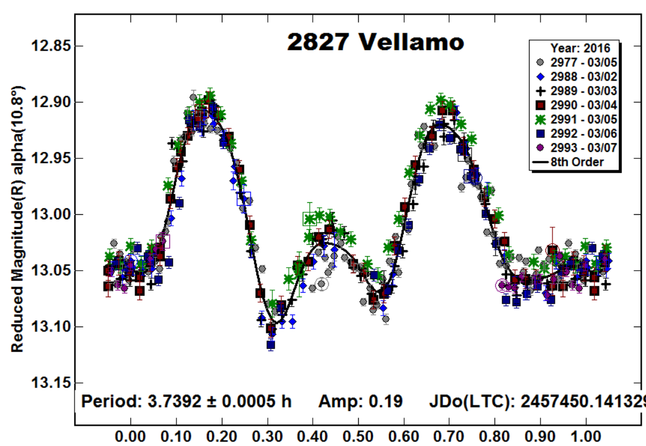


The result reported here is based on data from 2016 Aug-Nov. The changing observing geometry shift was apparent from the scatter seen in this the lightcurve. Four other sessions (June 28-29 and July 2-3) were excluded from this plot because of incorrect time stamps. Oey et al. (2015) obtained a period of 2.9426 h, which is consistent with the period found for the 2016 apparition.

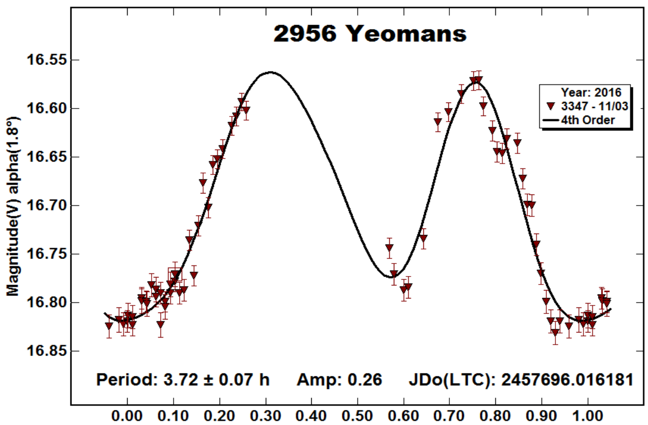
2656 Evenkia was also reported by Lang et al. (2016) during the same apparition. They found the same synodic period of 7.0870 h.



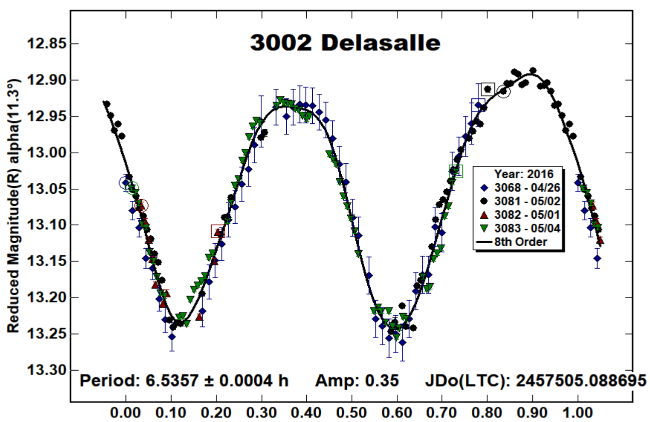
2827 Vellamo was done the through PSABA program (Pravec, 2016). The period is unique with no signs of being the asteroid being binary.



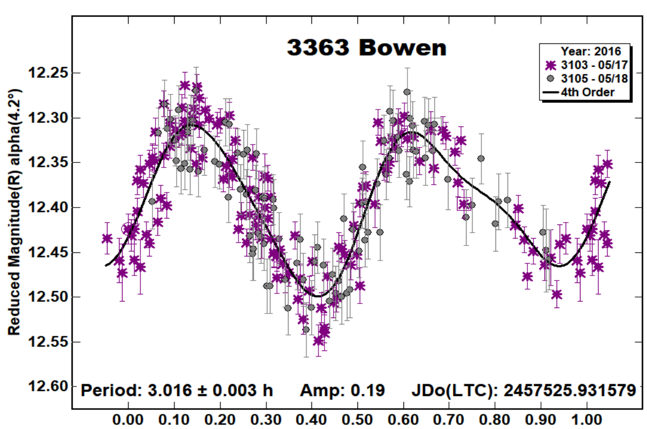
2956 Yeomans was a target of opportunity during the observations of 5112 Kusaji. Previous work done by Aznar (2015) from a single night light curve produced a U = 2 result and a period of 3.4 ± 0.1 h. His data were better than those used here in the sense that they produced a complete lightcurve.



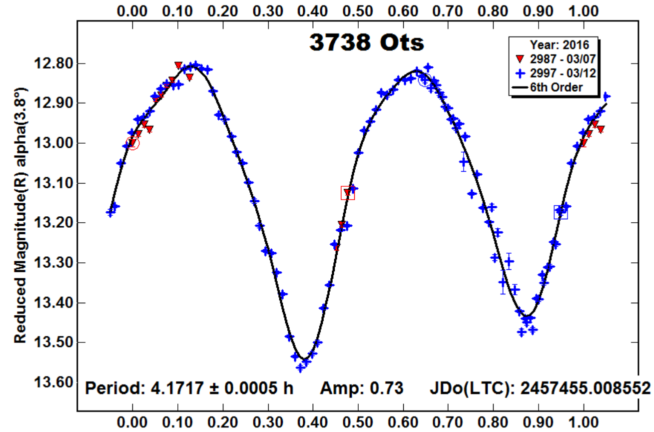
3002 Delasalle was part of the PSABA program (Pravec, 2016). The period is unique and consistent with previous work by Aznar (2016), who found a period of 6.537 ± 0.001 h.



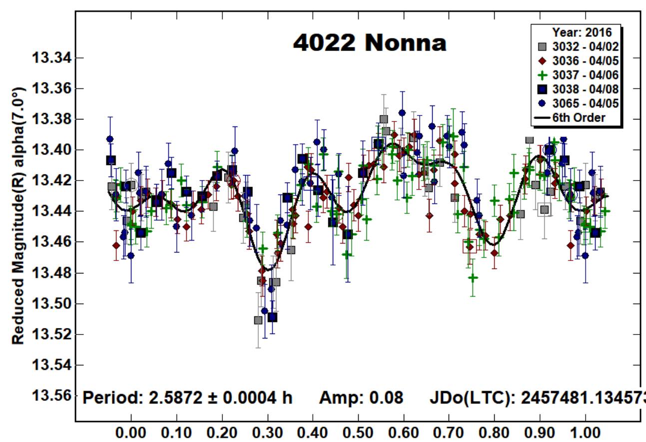
3363 Bowen was another PSABA target. The bimodal lightcurve amplitude is 0.20 mag. There was a considerable amount of scatter due to a full moon. Despite this, the resulting synodic period is consistent with that obtained from a previous apparition (Pravec, 2016), 3.0219 ± 0.0006 h



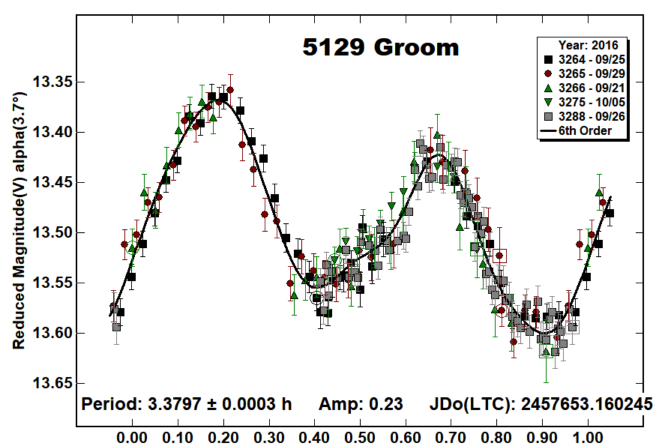
3738 Ots was part of the PSABA program. With the large amplitude of 0.73 mag and low phase angle, this asteroid can only be a prolate spheroid with a unique bimodal lightcurve (Harris et al., 2014). We found a synodic period of 4.1717 h



4022 Nonna was previously studied through the PSABA program (Pravec, 2010) and by Behrend (2013). The result reported here is consistent those previous works. It is noted here that the apparent multimodal lightcurve with the low 0.09 mag amplitude may be caused by concavities in the roughly spherical shaped asteroid.



5129 Groom was previously observed in the PSABA project (Pravec, 2016). This is the fourth apparition of this "prime suspect" observed by the PSABA team (Oey et al., 2015).



Acknowledgement

The purchase of the Apogee U42 camera was made possible by a 2015 Shoemaker NEO Grant.

References

Alvarez, E., Manuel, E. (2015). "Rotation period and H-G parameters determination for 910 Anneliese." *Minor Planet Bull.* **42**, 252-253.

Aznar, M.A. (2015). "Asteroid lightcurve analysis at Isaac Aznar Observatory Aras De Los Olmos, Valencia Spain." *Minor Planet Bull.* **42,** 4-6

Aznar, M.A. (2016). "Parameters of rotation and shapes of Main-Belt asteroids from APT observatory group: second quarter 2016". *Minor Planet Bull.* **43,** 350-353.

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

Behrend (2013). Observatoire de Geneve web site. *https://obswww.unige.ch/~behrend/r004022a.png*

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.

Lang, K., Jacobsen, J., Kristensen, L.H., Larsen, F.R. (2016). "Synodic rotation period of 2656 Evenkia." *Minor Planet Bull.* **43**, 344-346.

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., Vokrouhlický D., Polishook, D., Scheeres, D. J., Harris, A.W., Galád, A., Vaduvescu, O., Pozo, F., Barr, A., Longa, P., Vachier, F., Colas,F., Pray, D., Pollock, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A., Kušnirák, P., Henych, T., Marchis, F., Macomber, B., Jacobson, S. A., Krugly, Yu N., Sergeev A. V., Leroy, A. (2010) "Formation of asteroid pairs by rotational fission". *Nature* **466**, 1085-1088.

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

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

Warner, B.D. (2016). CALL web site. *http://minorplanet.info/call.html*

Yoshida, F., Ito, T., Dermawan, B., Nakamura, T., Takahashi, S., Ibrahimov, M.A., Malhotra, R., Ip, W.-H., Chen, W.-P., Sawabe, Y., Haji, M., Saito, R., Hirai, M. (2016). "Lightcurves of the Karin family asteroids." *Icarus* **269**, 15-22.

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2018 APRIL-JUNE

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

(Received: 2018 July 12)

Lightcurves for 39 Near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June were analyzed for rotation period and signs of satellites or tumbling. In addition, re-examination of data for 2014 UR taken in 2014 shows that the rotation period is 0.2300 h and not the 2.37 h that was originally reported.

CCD photometric observations of 39 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June. In addition, re-examination of data obtained in 2014 of the NEA (25916) 2001 CP44 revised the original period (Warner, 2014a) from 4.208 h to 4.608 h.

Table I lists the telescope/CCD camera combinations that were used. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

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

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were 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).

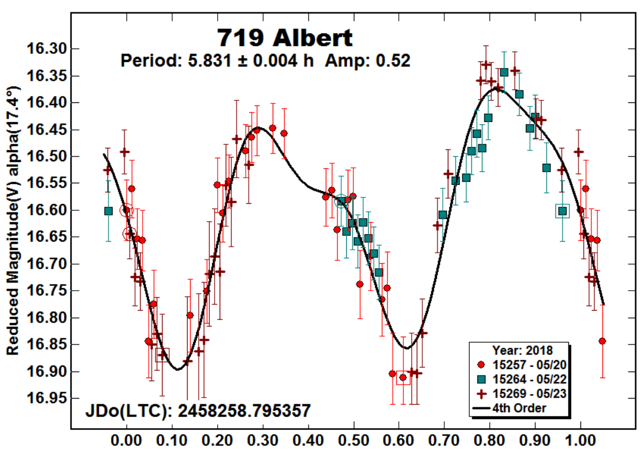
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distances by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid 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.

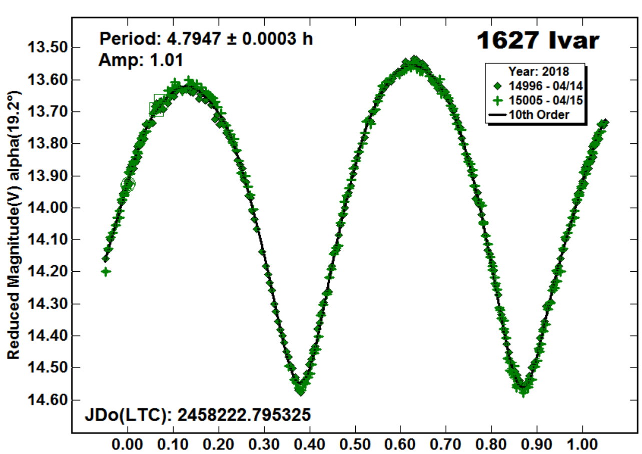
If the plot includes an amplitude, e.g., "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

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.

719 Albert. Previous results for the "lost" asteroid that was rediscovered in 2001 include Behrend (2001; 5.8007 h) and Pravec et al. (2001; 5.8011 h). Even though it was occasionally accessible with larger backyard telescopes, no are no additional lightcurve entries in the LCDB since rediscovery. The period reported here is not quite in agreement with the earlier results; that's likely due to the sparse data set over a short period.

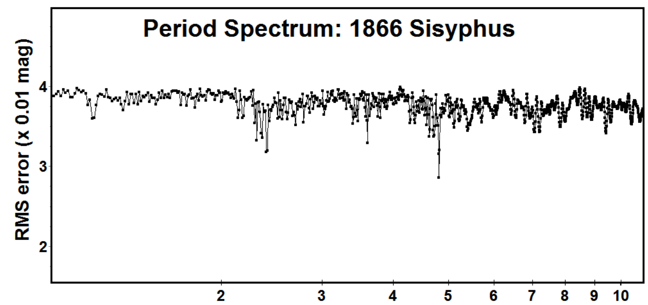


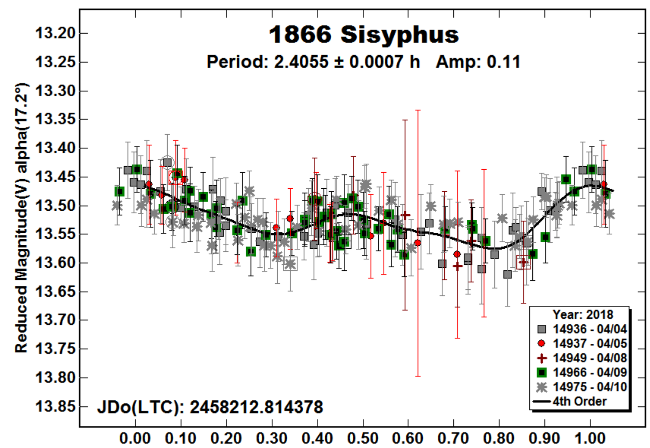
1627 Ivar. This NEA has been studied in-depth optically and by radar (see the LCDB for numerous listings). As a result, its shape and spin axis are well established. Additional observations, however, might be used to determine if the asteroid's spin rate is changing due to the YORP effect (Rubincam, 2000).

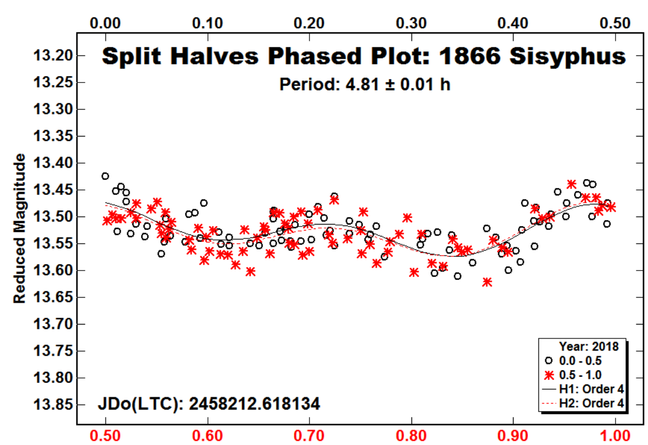


1866 Sisyphus. A rotation period of about 2.4 hours has been published before (e.g., Schober et al., 1993, 2.400 h). On two occasions, Stephens et al. (2011) and Warner (2016c), there were reports of a possible satellite with an orbital period between 25-28 hours. There were no indications of a second period or mutual events in 2018.

The period spectrum favored a period of 4.81 h, double the accepted value. This produced a quadramodal lightcurve. Using a "split halves" plot for the longer period showed that the halves were virtually identical. Either shape is possible (Harris et al., 2014); the shorter period was adopted since it was in-line with all previous results and because it was a more likely period for the primary of a binary system.

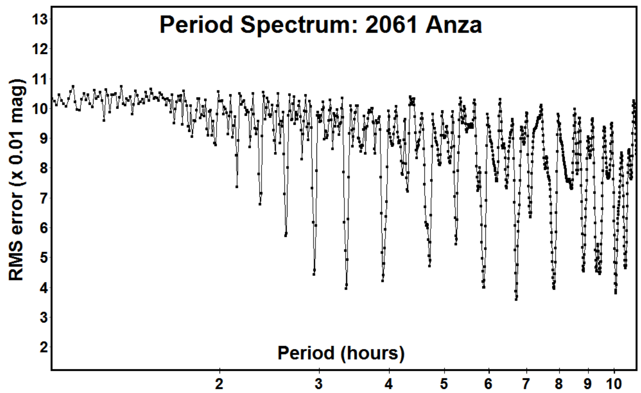


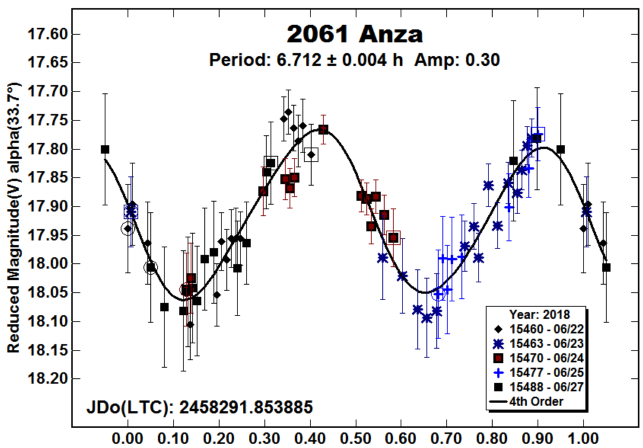




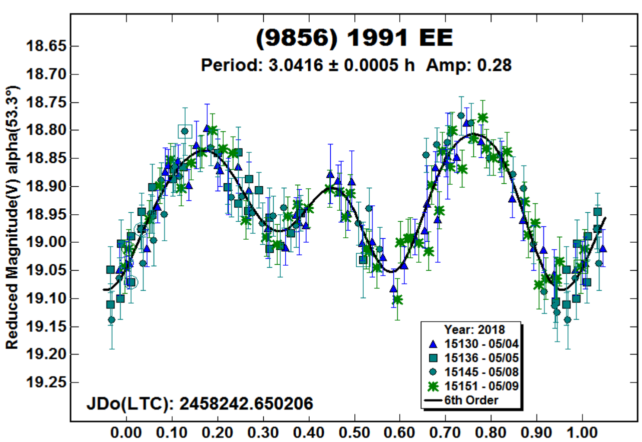
2061 Anza. Rakos (1960) reported a period of 11.50 h. Forcing the 2018 data to that period produced a quadramodal lightcurve. Given the amplitude, that shape is unlikely (Harris et al., 2014). As the period spectrum shows, the solution of 6.712 h is far from definitive.

Those observing in 2035 will see the asteroid reach V ~ 11.6 at a distance of 0.054 AU, or about 21 lunar distances. Until then, it is never brighter than V ~ 18.8.



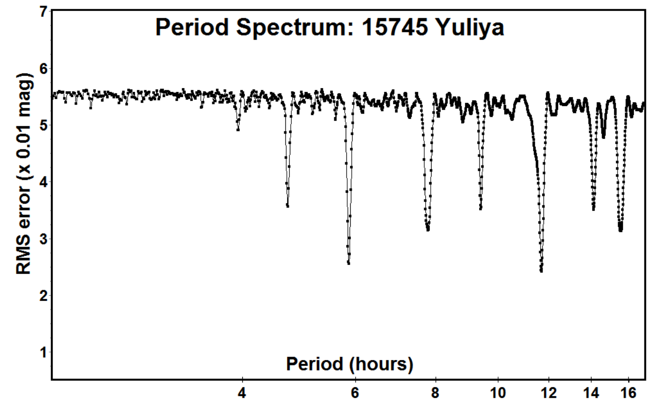


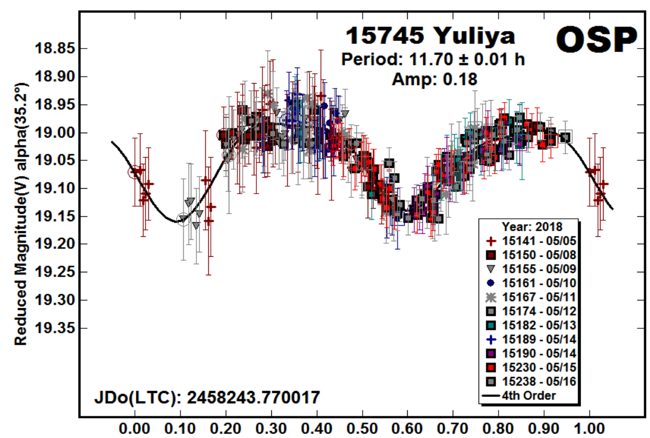
(9856) 1991 EE. Wisniewski et al. (1997) reported a period of 3.045 h for this 1-km asteroid. The results here are in good agreement. The "roller coaster" shape of the lightcurve is not unusual when observing at large phase angles, which allows shadowing effects to come into play.



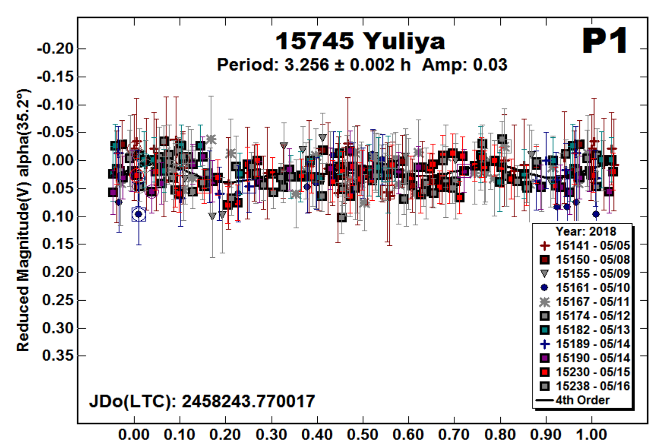
15745 Yuliya. The data from CS3-PDS in 2018 lead to several possible periods. The choice came down to 5.86 h or 11.70 h. Both were wrong. Working independently, Aznar et al. (2018) determined that the asteroid was binary with P_1 = 3.2486 h and P_{ORB} = 15.63 h. The mutual events ranged from 0.15-0.21 mag, indicating that the effective diameter of the satellite was at least 41% of the primary diameter.

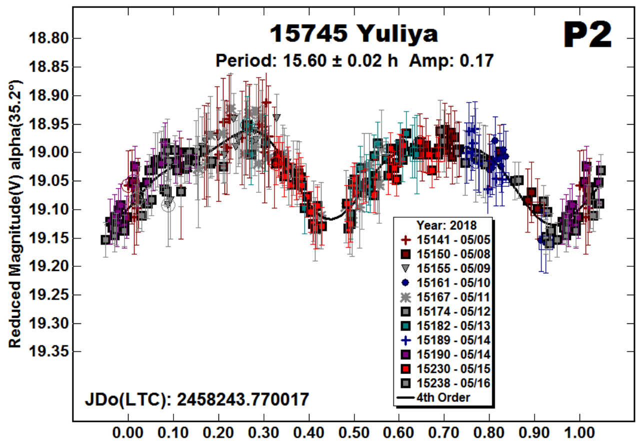
The period spectrum shows the results doing a single period search using only CS3-PDS data. The "OSP" (original single period) lightcurve shows the initially adopted period. Note that the amplitude is mid-range of the mutual events from Aznar et al. (2018).





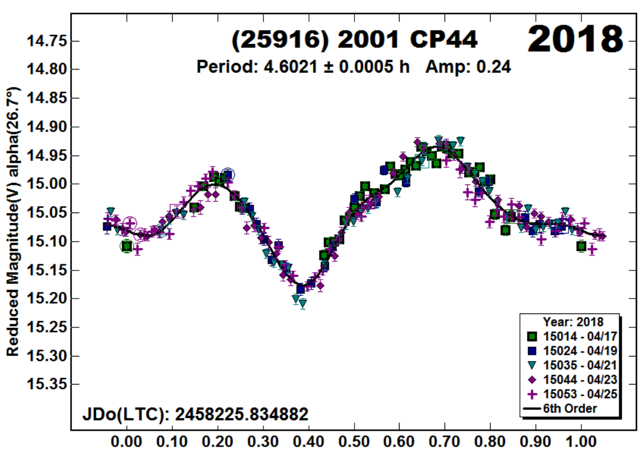
After seeing the announcement of the binary discovery, an attempt was made to force the CS3-PDS data to the results from Aznar et al. (2018). As it turns out, the analysis of the CS3-PDS data was finding the lightcurve for the satellite and its relatively deep mutual events. Furthermore, when subtracting that lightcurve from the data to find the primary's lightcurve, the period spectrum was essentially flat with dozens of very minor "wiggles". In other words, there was no indication of the primary in the CS3-PDS3 data. The "P1" plot is the result of forcing the search between 3.24-3.26 h. Even with that restriction, there were several possible solutions.

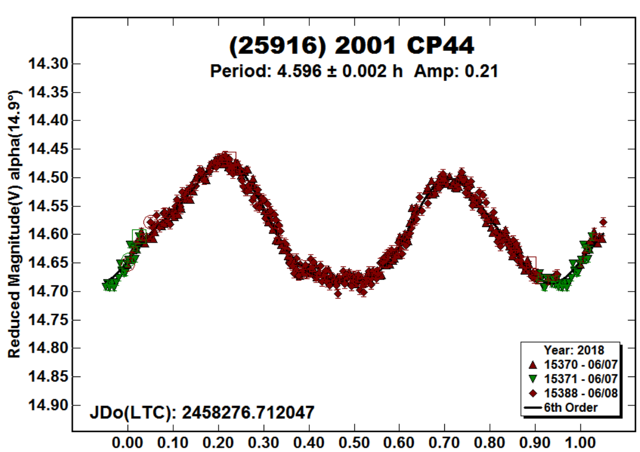


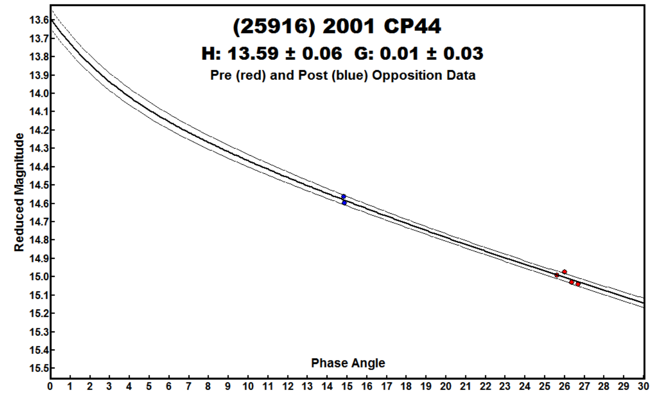


Aznar et al. (2018) reported a primary lightcurve amplitude of 0.10 mag. This should have been readily seen in the CS3-PDS data. Why it was not is unknown.

(25916) 2001 CP44. This 5.7 km NEA was observed twice: first in April and then in June. As seen in the two 2018 lightcurves, the lightcurve shape evolved considerably. When trying to merge the two to get a more precise period, a considerable zero point offset was required for one data set to get the curves to merge. Sometimes this is the result of using the default value for $G = 0.15 \pm 0.2$ and not a more accurate value. Running the data through the H-G calculator in *MPO Canopus* found $H = 13.60$, $G = 0.01 \pm 0.03$. The value for H is the same as listed in the MPCORB data file (MPC, 2018), which uses the default value for G. When using the new value for G, the zero point shift was eliminated.

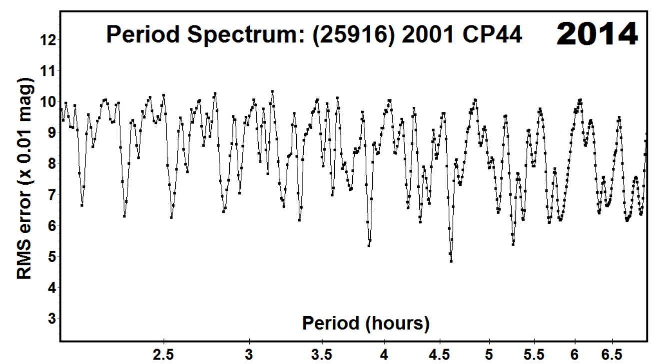


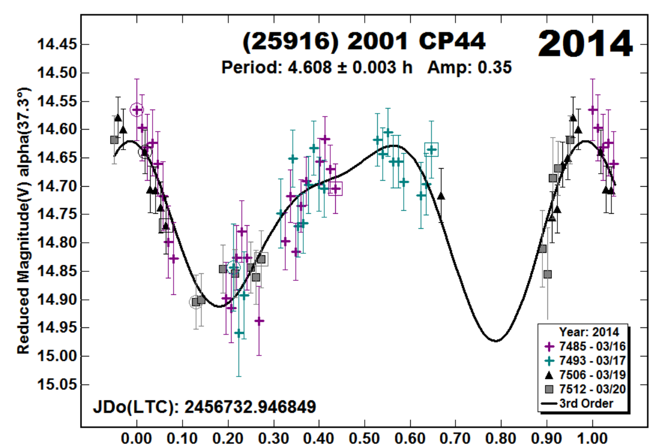




The value for H is dependent on the area of the asteroid's shape projected onto the plane of the sky. With the large changes in the lightcurve, the projected area may have changed as well, thus complicating the search for the true values of H and G. In other words, $G = 0.01$ should not be considered reliable.

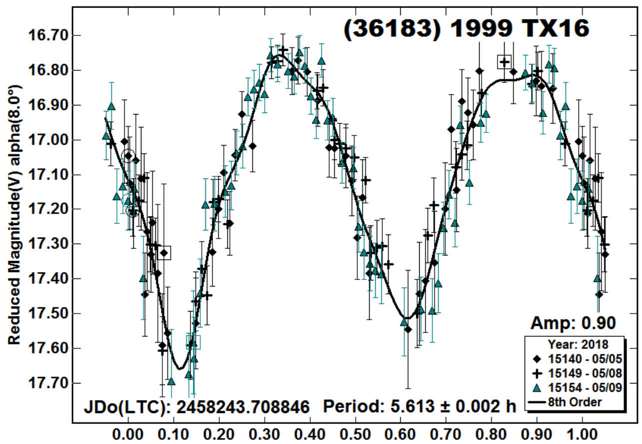
When first observed in 2014 (Warner 2014a), the period was found to be 4.208 h. Following the analysis of the 2018 data, the 2014 data were given another look. This led to a revised result of 4.608 h, which is in better agreement with the latest analysis.



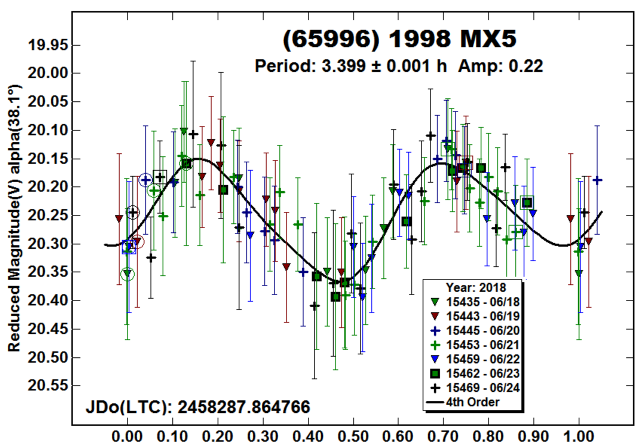


(36183) 1999 TX16. Pravec et al. (1999) observed 1999 TX16 in late 1999 when it was at phase angle $\alpha \sim 52°$. They found $P = 5.6121$ h and $A = 1.3$ mag.

The observations in 2018 were at phase angle of $\alpha \sim 7°$, but the phase angle bisector longitudes (Harris et al., 1984) were about 126° apart, so the reduced amplitude may not have been due only to the typical behavior of a lower amplitude at a lower phase angle (Zappala et al., 1990).

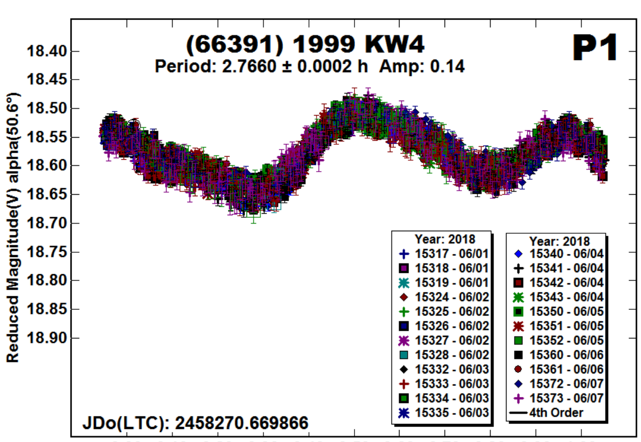


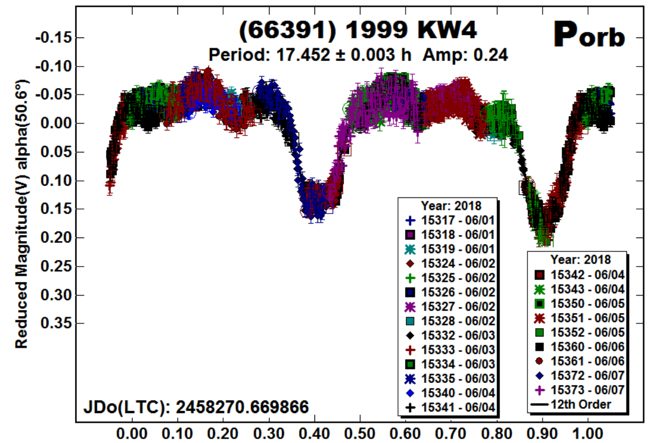
(65996) 1998 MX5. There were no previous entries of any kind the LCDB for 1998 MX5; the estimated diameter is 620 m.



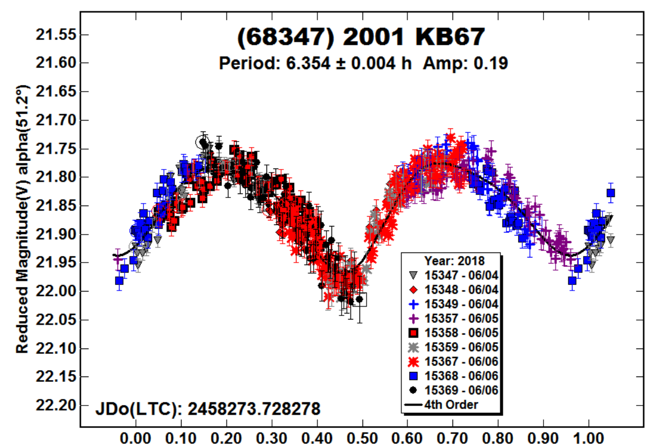
(66391) 1999 KW4. This is the famous "spinning top" asteroid thoroughly detailed with radar observations by Ostro et al. (2006). For an animation, visit *http://echo.jpl.nasa.gov/asteroids/1999KW4/kw4_20060529Afour.mov*. Note that the MOV file may not work when using default Windows video players.

The dual period search of *MPO Canopus* was used to extract the lightcurves for the primary and the mutual events of the satellite. The eclipse at 0.4 phase in "P_{ORB}" appears total. Using the attenuation of 0.15 mag gives the ratio of satellite-to-primary diameters of 0.38 ± 0.03. The radar data gave about 0.33.

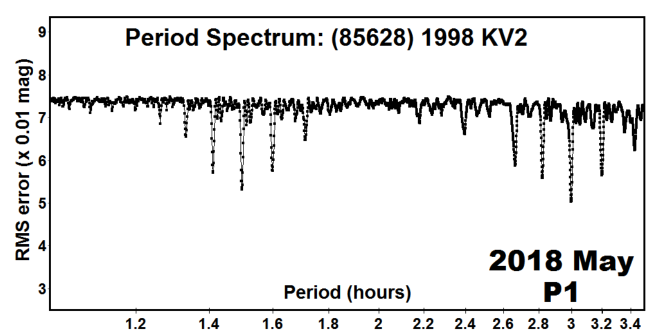




(68347) 2001 KB67. The estimated diameter is 325 m. There were no previous entries of any kind in the LCDB.



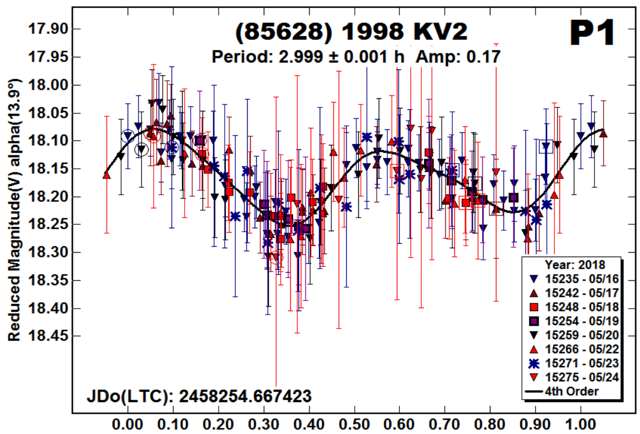
(85628) 1998 KV2. Analysis of the 2018 data found the likelihood to two periods, i.e., possible indications of a satellite. The putative primary period was ambiguous, with the more likely solution at 2.999 h, as shown in the period spectrum. The alternate, shorter period, was 2.823 h. The two differ by one-half rotation over 24 hours. Previous results by the author were all close to 2.82 h: Warner (2014b, 2.819 h; 2016a, 2.819 h; 2016c, 2.819 h).

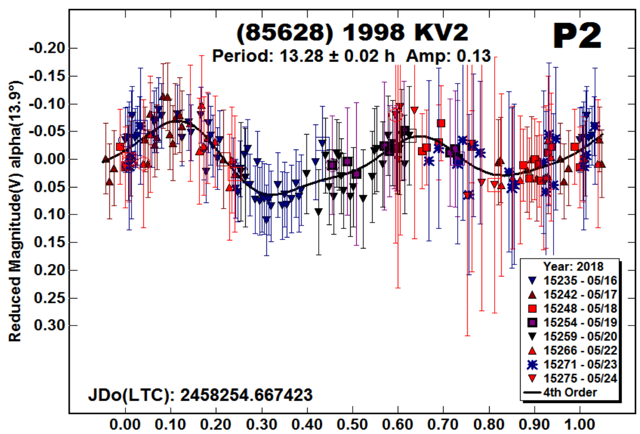


After numerous iterations of the dual period search in *MPO Canopus*, the significantly better fit was $P_1 = 2.999$ h. Regardless of which P_1 was selected, the fit was improved significantly by subtracting out $P_2 = 13.28$ h. The P_2 value varied by no more than 0.01 h when using different values of P_1.

The data from earlier apparitions were analyzed anew, but in three of the four cases, the shorter period had a lower RMS fit to 2.82 h no matter how the nightly zero points were adjusted.

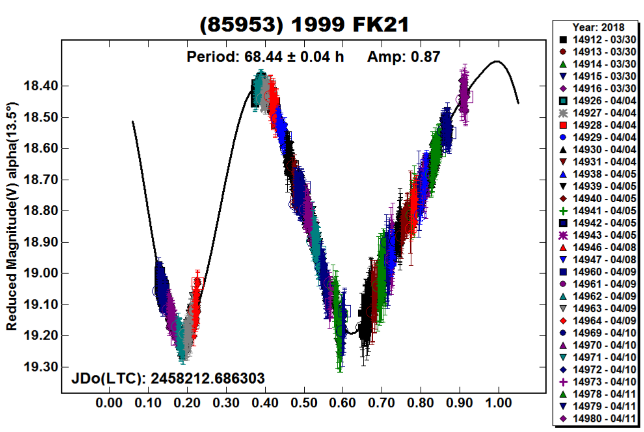
Since the two periods are nearly Earth-day commensurate and the curves are nearly symmetrical, it's very easy for one to be a *rotational alias* of the other. In other words, it's not certain how many rotations occurred over the range of observations. The 2018 observations spanned 8 days, at least 3 days longer than the earlier data sets. It's possible that the longer span almost allowed the ambiguity to resolve itself.



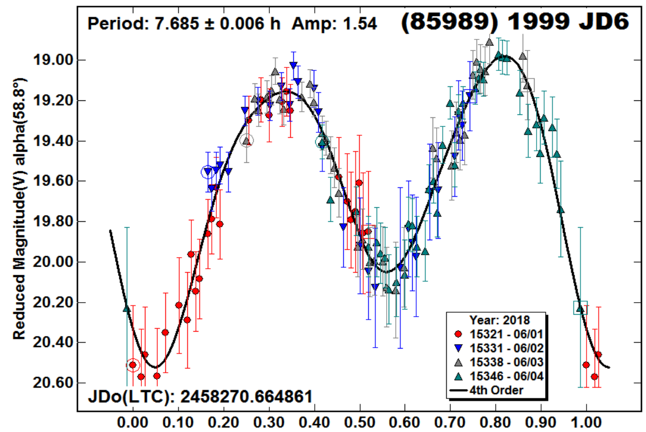


(85953) 1999 FK21. Skiff (2011) found a period of 28.1 h. Warner (2016a) found a period of 17.62 h. The 2018 data led to yet another result, P = 68.44 h. In this case, however, the data set was denser and three of the four extrema were reasonably defined.

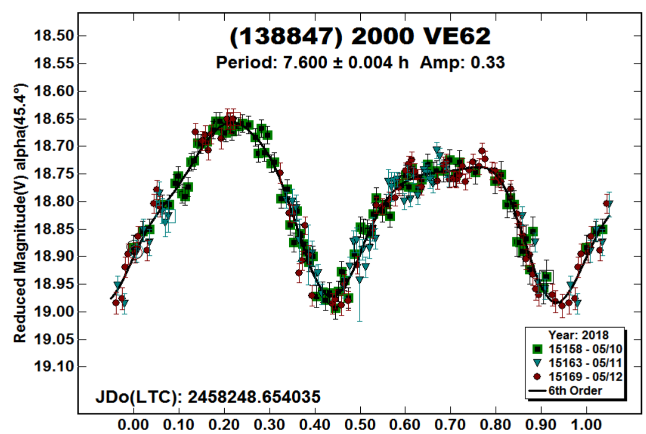
There are no obvious signs of tumbling (Pravec et al., 2005; 2014) even though the combination of diameter and period would make it likely.



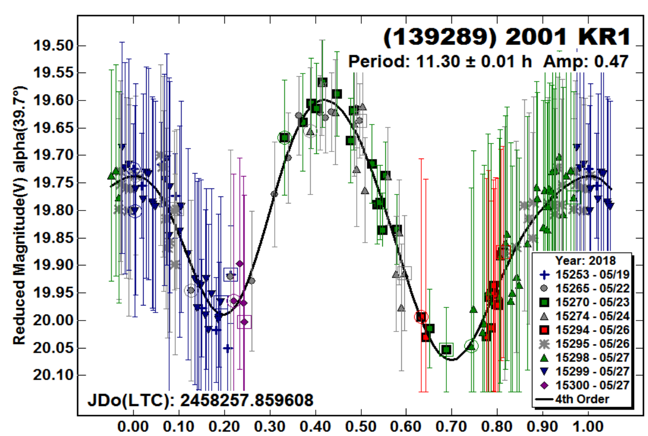
(85989) 1999 JD6. Pravec et al. (1999) reported a period of 7.666 h. This was followed with 7.6638 h by Polishook and Brosch (2008a) and 7.6611 h by Vaduvescu et al. (2017). The period reported here is in good agreement with the earlier results and those by Warner (2014b, 7.667h; 2015, 7.673 h).



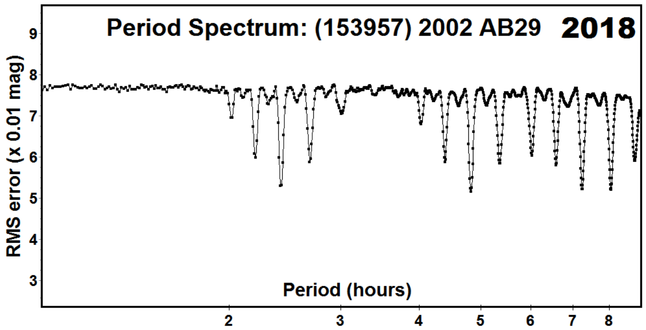
(138847) 2000 VE62. Monteiro et al. (2017) reported a period of 6.469 h. This disagrees with the results here and from Percy (2018) of 7.600 h. The two periods differ by almost one-half rotation over 24 hours, possibly indicating a *rotational alias*, i.e., a miscount of the number of rotations over the range of the observations.

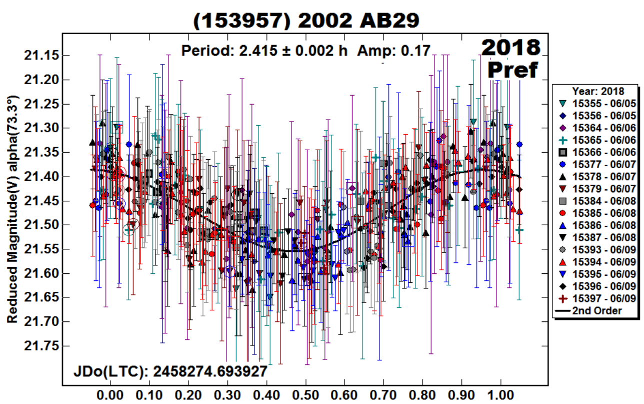


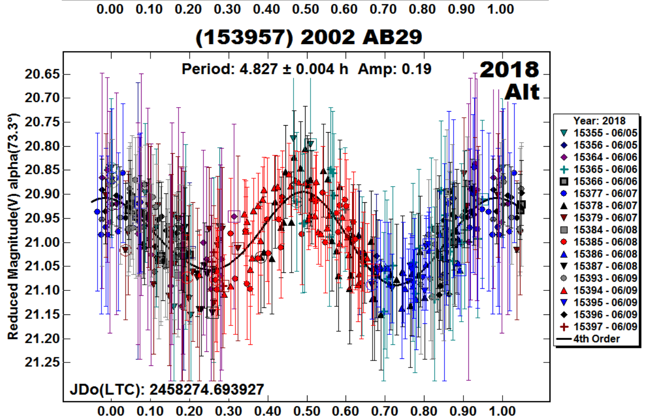
(139289) 2001 KR1. There was no previous lightcurve entry in the LCDB for this 900-m asteroid.

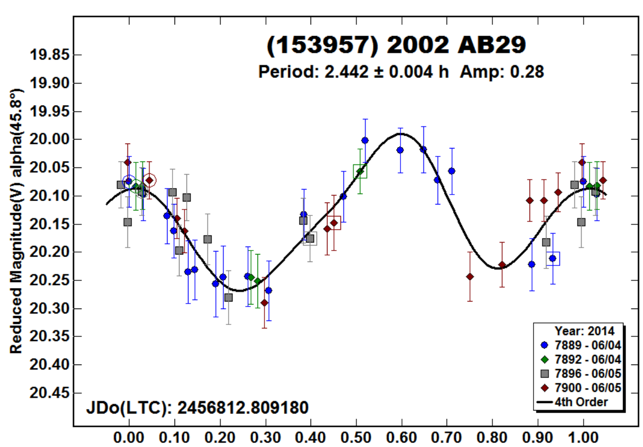


(153957) 2002 AB29. A period of 2.545 h (Warner, 2014b) was the only previous result in the LCDB. The 2018 data set was much denser but also extremely noisy. The period spectrum shows a number of possible solutions. Given the earlier result, the search was narrowed to 2-3 h. This produced a period of 2.415 ± 0.002 h, with a bimodal solution at 4.827 h.



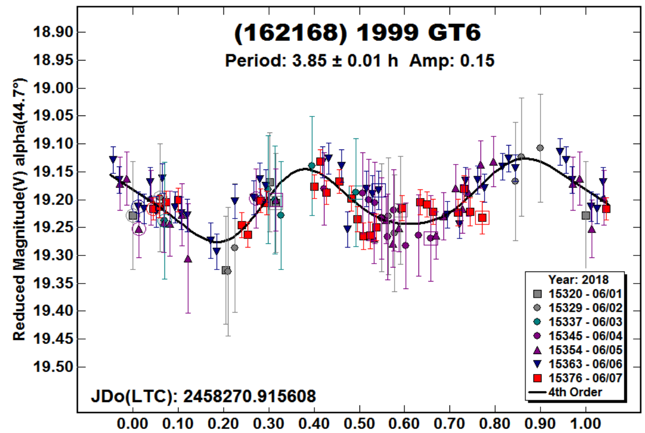


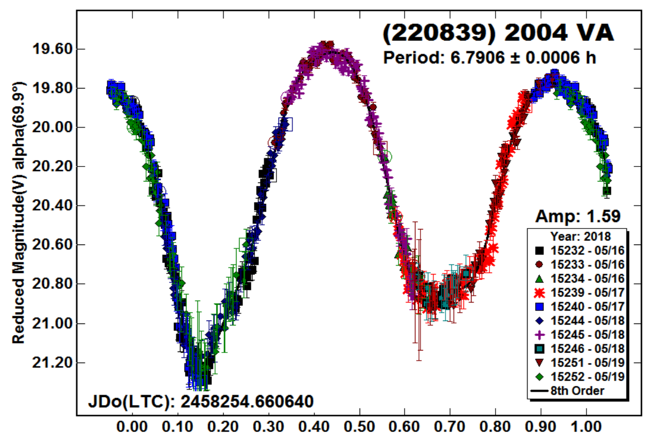




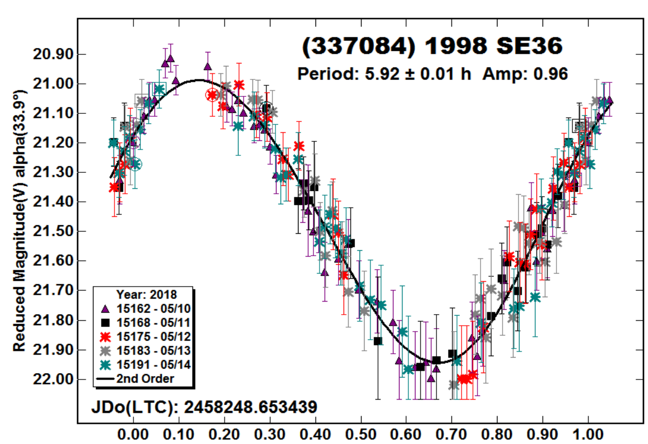
The shorter period was adopted since the 2014 data produced an unlikely quadramodal lightcurve using the longer period. In the review of the 2014 data, the period was refined to 2.442 h.

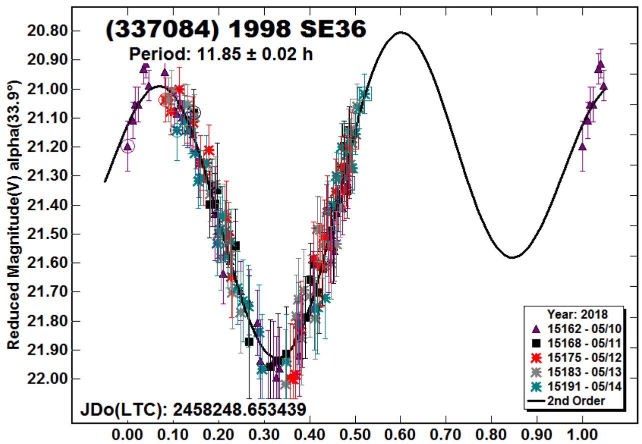
(162168) 1999 GT6, (220839) 2004 VA. These appear to be the first reported lightcurve results for these two NEAs. The estimated diameters are, respectively, 1.2 km and 1.0 km.



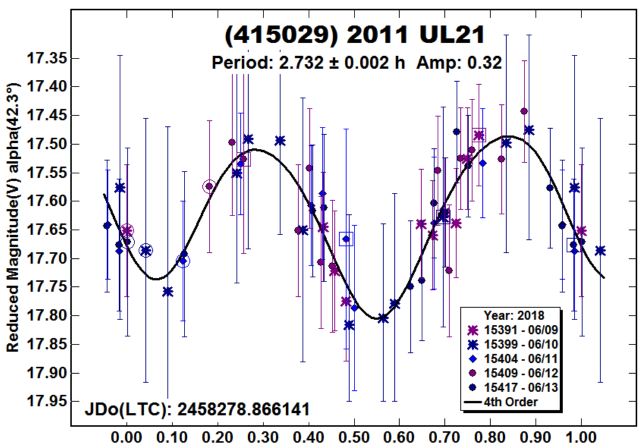


(337084) 1998 SE36. It wasn't possible to get a full lightcurve for 1998 SE36 from a single station because its period is nearly commensurate with an Earth day. The amplitude virtually requires a bimodal lightcurve (Harris et al., 2014), and so a search was made for a good fit to a monomodal lightcurve. Once found, the period was doubled to get the final result. There were no previous results in the LCDB.

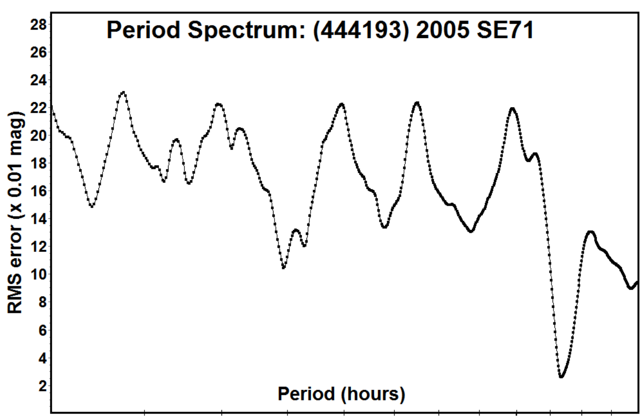


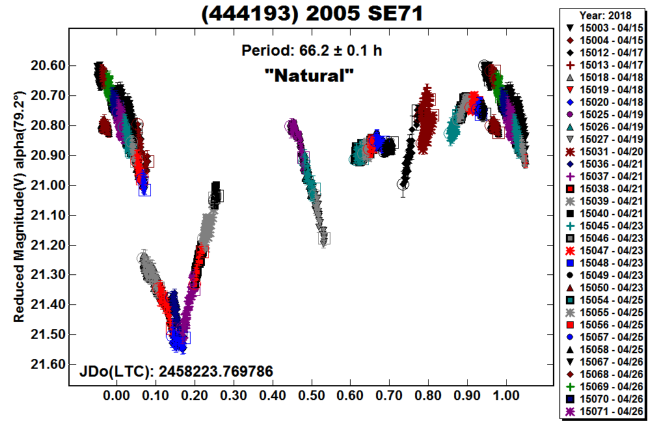


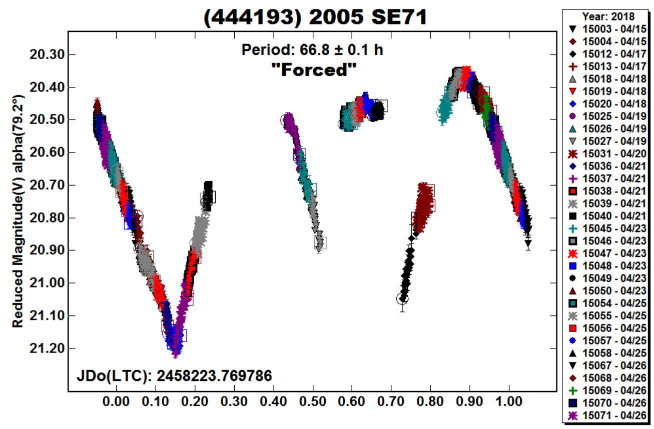
(415029) 2011 UL21. The period for this 2-km asteroid was first reported to be 1.562 h (Warner, 2018d), but that was rated "probably wrong" in the LCDB. The additional data from six months later seems to make a case for a more typical short period of 2.732 h. The large error bars reduce the reliability of the solution, however.



(444193) 2005 SE71. Because of its diameter of 700 meters and period of about 66 h, this asteroid is a very likely candidate for tumbling (Pravec et al., 2005). This appears to be the case. The "Natural" plot uses zero shifts $\Delta_0 < 0.05$ mag. This produces a lightcurve that clearly does not repeat with additional cycles: a good sign of tumbling. Even when introducing much larger than usual zero shifts to fit most data, there is still a "rouge night."



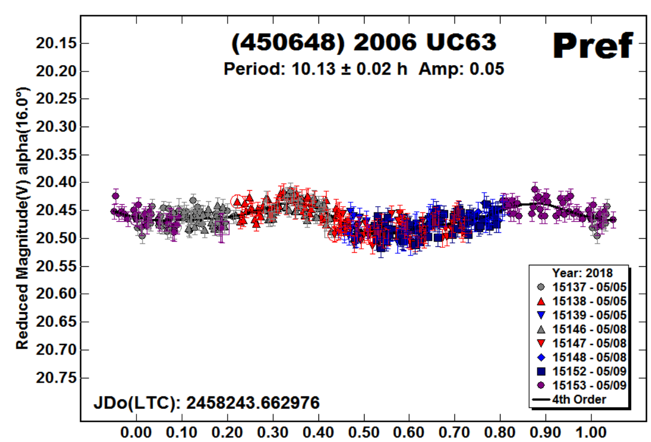


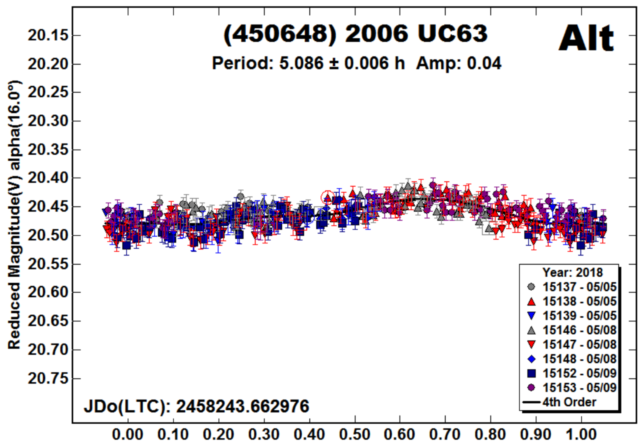


From this, it's possible that the asteroid is a low-level tumbler, meaning that there only a slight "wobble" in the primary spin axis rotation and that the two periods, rotation and precession, are close to one another.

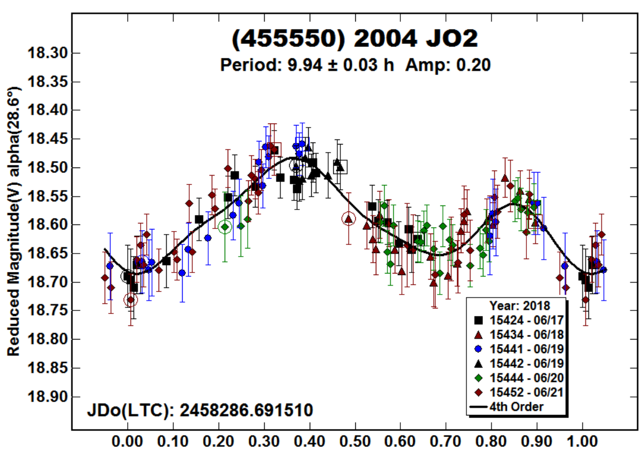
(450648) 2006 UC63 has an estimated diameter of 350 km. There were no previous lightcurve results in the LCDB.

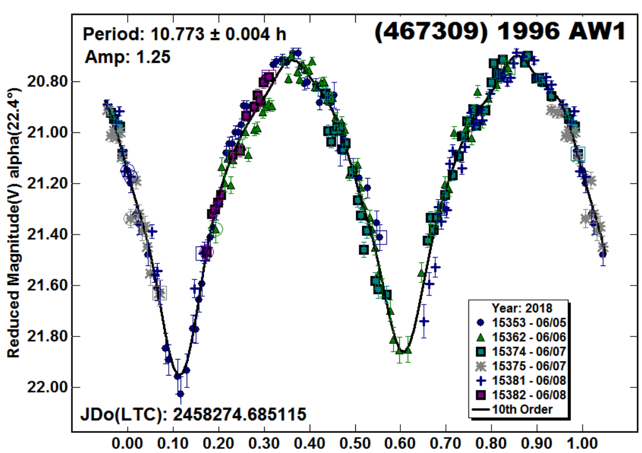
As noted in Harris et al. (2014), at relatively low phase angles a low-amplitude lightcurve cannot be assumed to be bimodal and could have 1, 2, or 3 or more extrema pairs per rotation. While two possible periods, including the preferred one of 10.13 h, are shown here, other periods, such as one about 15.3 h (trimodal) are possible. Unfortunately, the ambiguity will not be resolved any time soon. The asteroid stays at V ≥ 20 until 2041 May, when it "blazes forth" at V = 18.1.



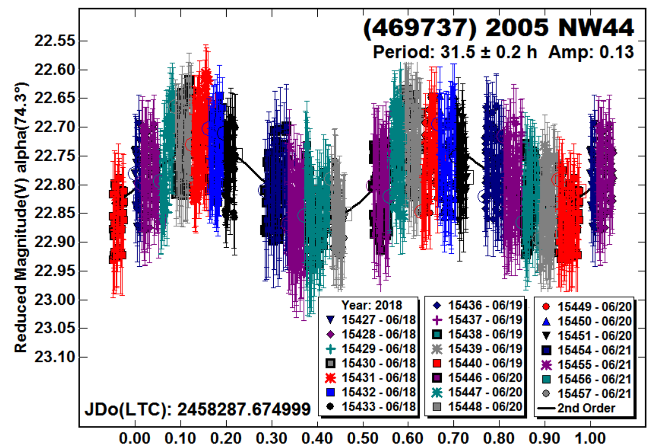


(455550) 2004 JO2, (467309) 1996 AW1. There were no previous lightcurve entries in the LCDB for the 1-km 2004 JO2. The same applies to 1996 AW1, which has an estimated diameter of 300 meters. Both solutions are considered secure, especially for 1996 AW1 because of its large amplitude lightcurve.

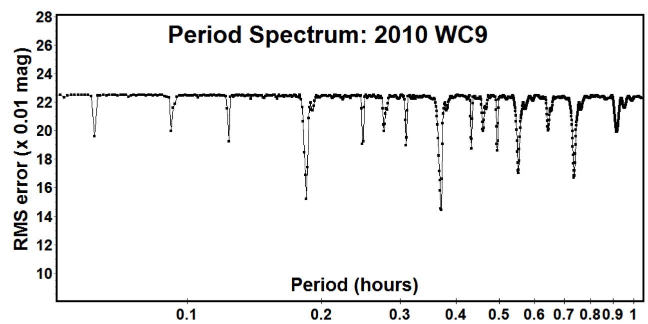


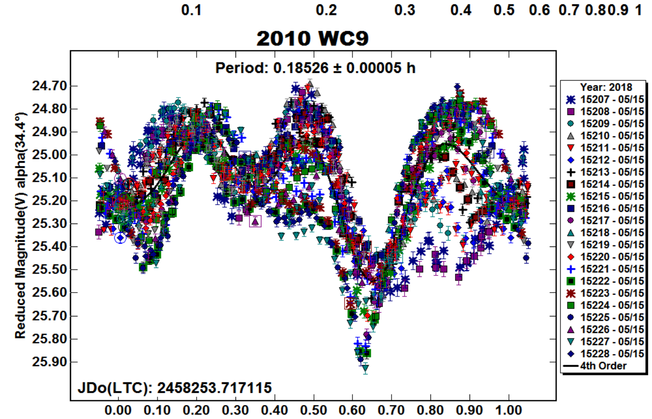


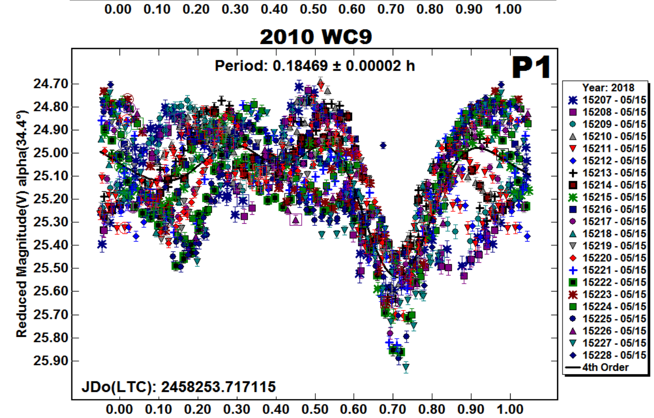
(469737) 2005 NW44. There were no previous lightcurve results in the LCDB for 2005 NW44. The estimated diameter is 250 meters. The low SNR (large error bars) is due to the asteroid's rapid sky motion. Exposures had to be limited to 30 sec to keep trailing to a minimum. The raw plots of individual nights showing a steady increase or decrease in brightness added some confidence to the solution, though it still far from certain.

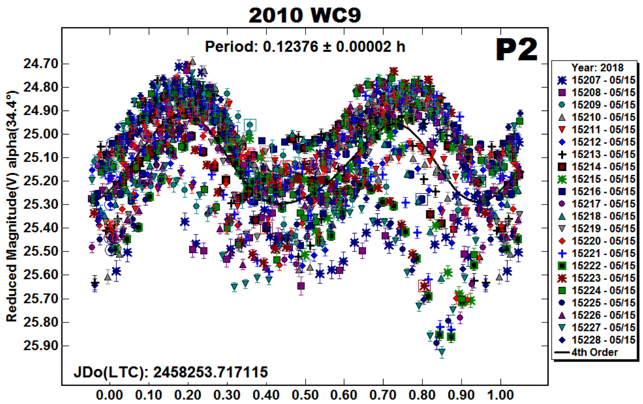


2010 WC9. This is a tumbling asteroid with nearly commensurate periods of 0.18469 h and 0.12376 h (Petr Pravec, private communications). *MPO Canopus*, which cannot analyze tumbling asteroids, was used to generate the plots at the two frequencies along with a single period lightcurve that is *almost* a good fit. The total amplitude of the lightcurve is about 1.2 mag.



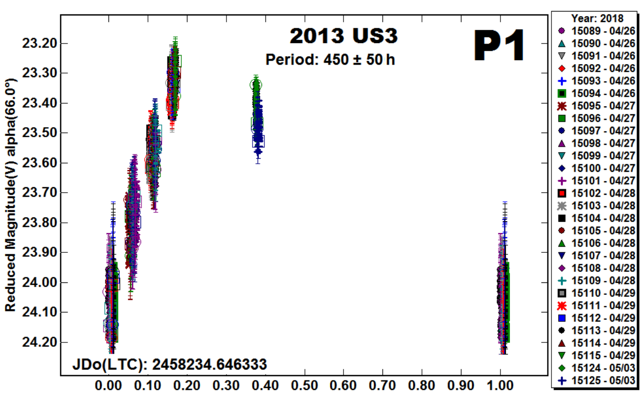


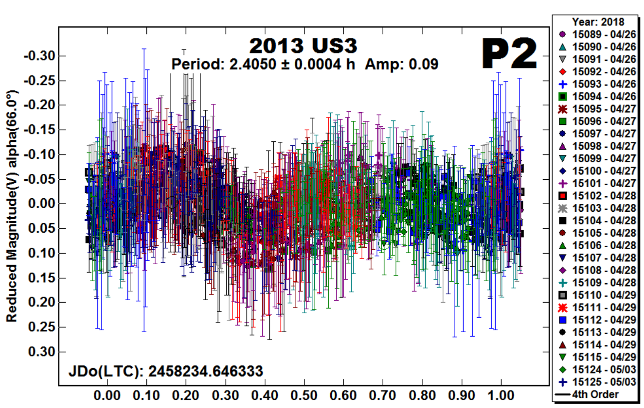




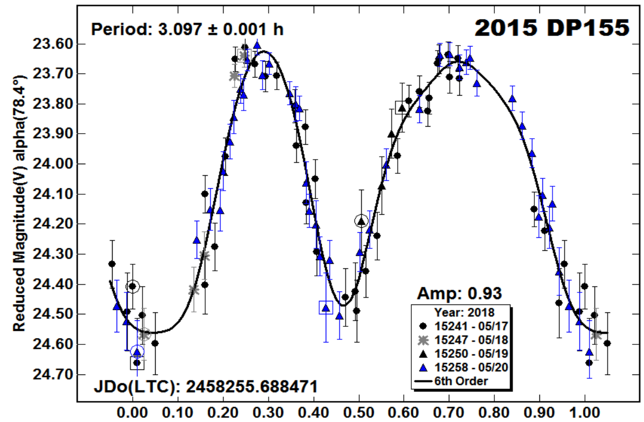
2013 US3. There may be in a subclass of asteroids called "very wide binaries" (see Warner, 2016b) where the primary has a long to very long period and the satellite has a short period, usually $P \leq 7$ h. It was not possible to follow this NEA long enough to get a complete lightcurve of the long period, but using half-period solutions gave $P_1 = 450 \pm 50$ h as a reasonable estimate. When this was subtracted from the data, despite the large error bars, a second period appeared, $P_2 = 2.4050 \pm 0.0004$ h, which is a typical period for the satellites in these systems.

To date, mutual events (occultations and/or eclipses) have not been seen, nor are they likely to be since the orbital period is very long. Therefore, 2013 US3 joins a small, but growing list of suspected candidates for the very wide binary group.

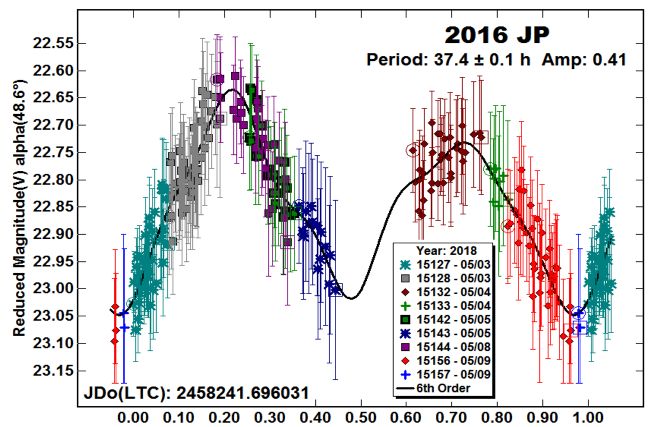




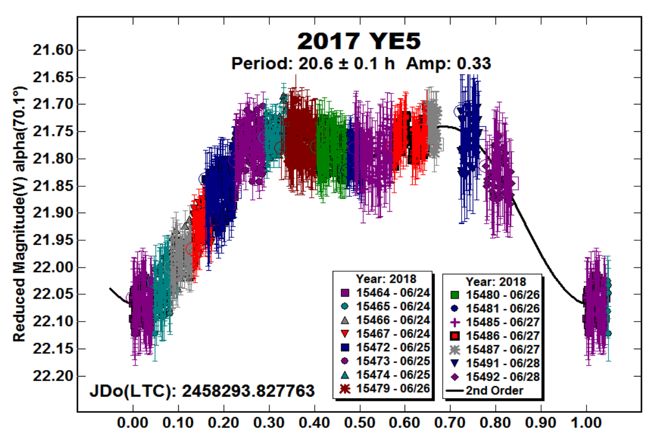
2015 DP155. Reshetnyk et al. (2018) reported $P = 3.105$ h and $A = 1.0 \pm 0.1$ mag. The CS3-PDS data were obtained about two weeks later, when the amplitude had decreased to 0.93 ± 0.05 mag. This was the brightest apparition through 2050. The best it will be is V ~ 18.9 in 2021 July at –25° declination.



2016 JP. There's a chance to confirm this first-time result in 2019 April. That will be the last time through 2050 that it is brighter than V ~ 18.3.

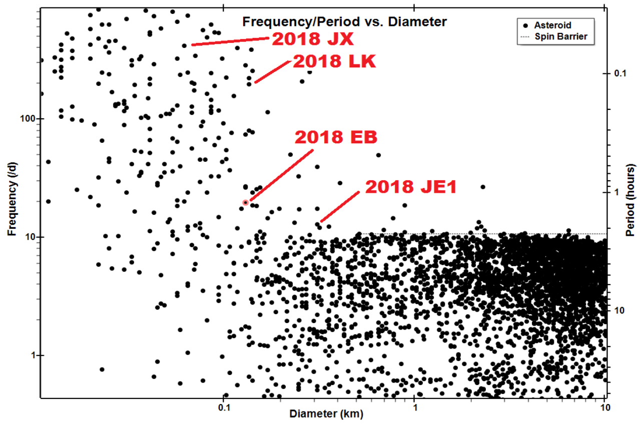


2017 YE5. Radar observations in 2018 mid-June showed this to be an "equal-mass, Hermes-like binary" (Patrick Taylor, private communications). With the large phase angle and unknown viewing geometry, just about any lightcurve could be generated. The one obtained at CS3-PDS has a large amplitude, which might be expected, but the very small secondary minimum was a challenge to explain.



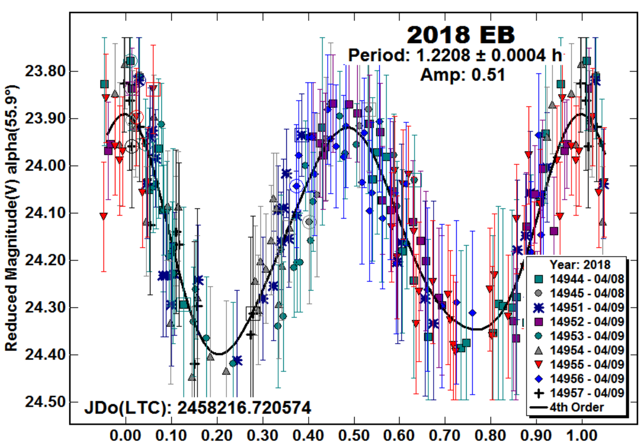
Additional radar observations in late June (JPL, 2018) at Arecibo, Goldstone, and Green Bank (West Virginia) confirmed that the asteroid is binary. The two bodies are each 900 meters in diameter and are widely separated. The orbital period was estimated to be 20-24 h, which fits with the period found using the CS3-PDS data.

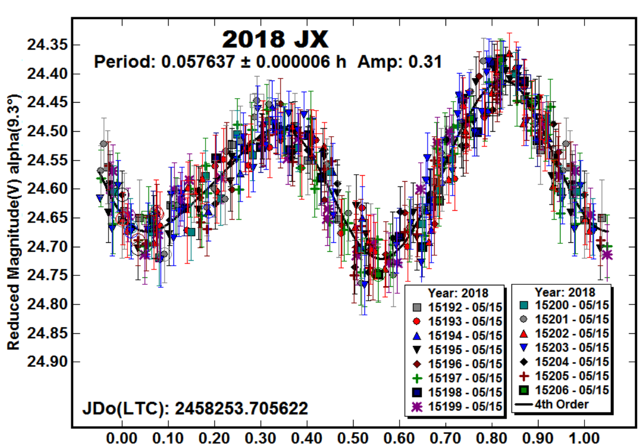
2018 EB, 2018 JX, 2018 LK. These are first-time entries into the LCDB for these three NEAs, each one having a super-fast rotation period. Their positions in the frequency-diameter plot from the LCDB show that they are in the "ascending branch" that features small, super-fast rotators.

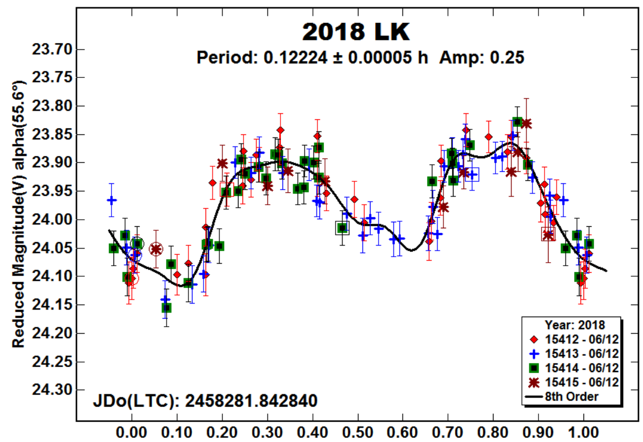


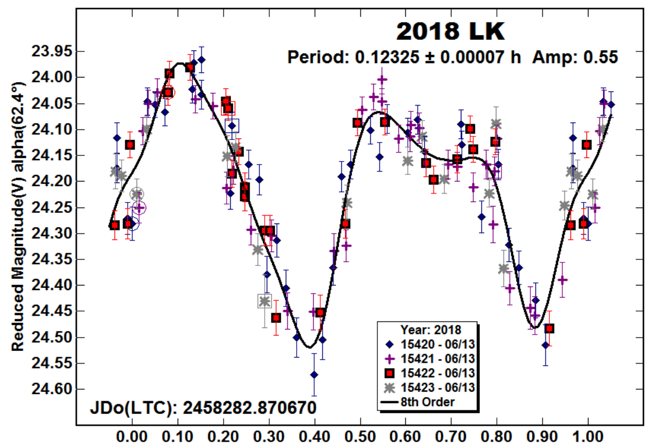
For 2018 EB, the large phase angle puts forcing a bimodal solution into question, but that is countered by the relatively large amplitude. The estimated diameter is only 130 meters, so it's not surprising for the asteroid to have a period well above the "spin barrier."

The fastest rotator of the group is 2018 JX. To avoid excessive trailing, exposures were only 6 seconds. Fortunately, the asteroid was V ~ 14.5 at the time and so the SNR was reasonable and the result was an unusually "tight" lightcurve.





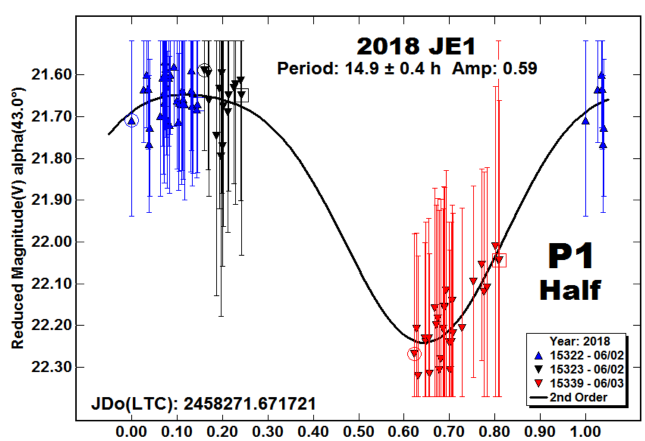


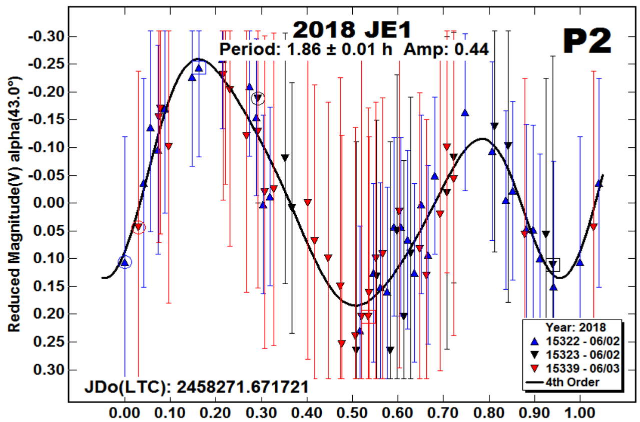


The shape of the lightcurve for 2018 LK changed so dramatically from 2018 June 12 to 13 that there was little point in merging the two nights to get a single period. The mismatch between the curves might have actually hurt the accuracy of the result.

2018 JE1. At V ~ 18.5, exposures of 240 s or more would have been preferred. However, sky motion kept them to 90 sec. The large error bars rival the amplitude of the half-period lightcurve, which was the only reasonable means to get an estimate the period.

The data from June 3 required a zero point shift of 0.81 mag to match June 2. That is far beyond what was expected and so it was assumed that there was a very long period component in the data. A short period seemed likely looking only at the June 2 data.

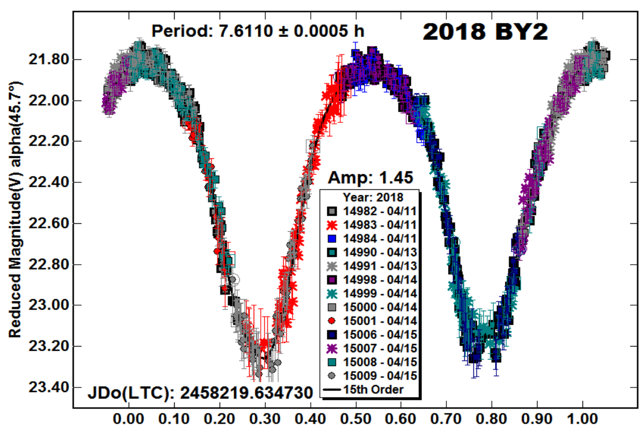




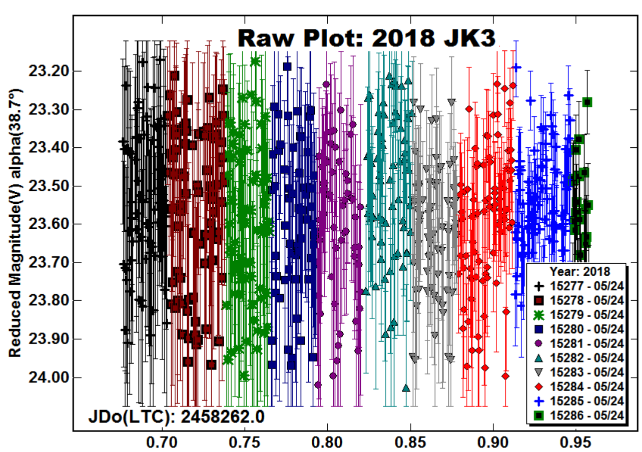
The dual period search feature in *MPO Canopus* was used to remove what appeared to be a long period, which is very probably not valid: it was a just a means to remove the large zero-point shift that could not be reasonably accounted for by other means.

Removing the supposed long period produced a secondary period, $P_2 = 1.86 \pm 0.01$ and $A_2 = 0.44$ mag, or about the same as the error bars. Its location is also seen in the frequency-diameter plot above. The diameter vs. period is reasonable, the period solution is not so much so. Next chance: 2035 May, V ~ 17.9 at +5° declination.

2018 BY2. Pravec et al. (2018) found a period of 7.6170 h. The result presented here is similar.

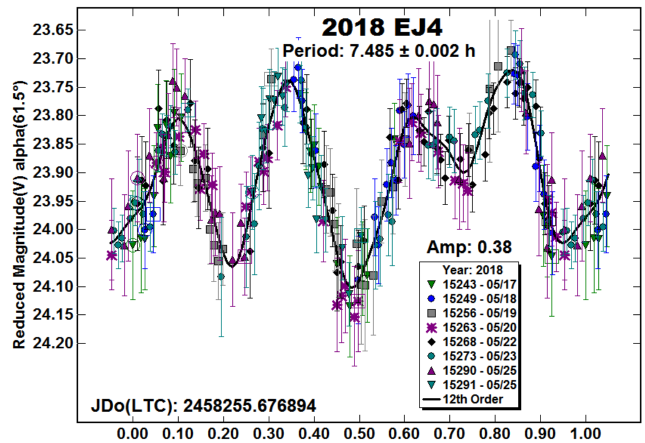


2018 JK3. A search for a very short period was fruitless. This was just an extremely noisy, "flat" data set.

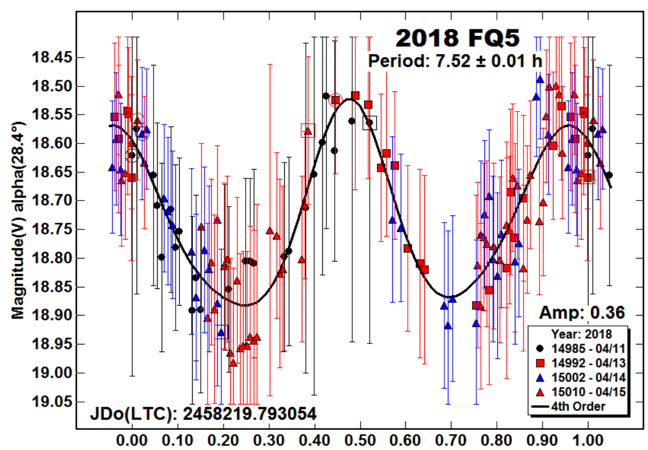


2018 EJ4. The shape of the lightcurve calls to mind a tumbling asteroid with two, nearly commensurate periods (e.g., 2010 WC9 in this paper). Radar observations (Sean Marshall, private communications) indicated the half-period of 3.742 h was more likely. When using that as a starting period for a dual period search (even though *MPO Canopus* cannot handle tumbling asteroids properly), the result was just the 7.48 h solution with a lower amplitude and considerably different shape.

The raw photometry data have been uploaded to the ALCDEF web site (alcdef.org) for others to try their hand at a solution.



2018 FQ5. There were no previous entries in the LCDB for this 500-m NEA.



Acknowledgements

Work on the asteroid lightcurve database (LCDB) is funded by National Science Foundation grant AST-1507535.

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

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, A., Vaduvescu, O., Wilson, T., Zegmott, T., Pravec, P. (2018) *CBET* **4523**.

Behrend, R. (2001) 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.

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*

JPL (2018). "Observatories Team Up to Reveal Rare Double Asteroid." Posted 2018 July 12. *https://www.jpl.nasa.gov/news/news.php?release=2018-164*

Monteiro, F., Silva, J.S., Lazzaro, D., Arcoverde, P., Medeiros, H., Souza, R., Rodriggues, T. (2017). "Lightcurve Analysis for Ten Near-Earth Asteroids." *Minor Planet Bull*. **44**, 20-22.

MPC (2018). Minor Planet Center website. *https://www.minorplanetcenter.net/iau/MPCORB.html*

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

Ostro, S.J., Margot, J.-L., Benner, L.A.M., Giorgini, J.D., Scheeres, D.J., Fahnestock, E.G., Broschart, S.B., Bellerose, J., Nolan, M.C., Magri, C., Pravec, P., Scheirich, P., Rose, R., Jurgens, R.F., De Jong, E.M., Suzuki, S. (2006). "Radar Imaging of Binary Near-Earth Asteroid (66391) 1999 KW4." *Science* **314**, 1276-1280.

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

Percy, S. (2018). Posting on CALL web site. *http://www.minorplanet.info/call.html*

Polishook, D., Brosch, N. (2008). "Photometry of Aten asteroids—More than a handful of binaries." *Icarus* **194**, 111-124.

Pravec, P., Wolf, M., Sarounova, L. (1999, 2001). *http://www.asu.cas.cz/~ppravec/neo.htm*

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.

Rakos, K.D. (1960). "Light variations of the fast moving minor planet : discovered on October 22, 1960, by H.L. Giclas." *Lowell Obs. Bul.* **5**, No. 109, 28-29.

Reshetnyk, V., Godunova, B., Sergeev, O., Simon, A. *Astronomer's Telegram* **11645**. *http://www.astronomerstelegram.org*

Schober, H.J., Erikson, A., Hahn, G., Lagerkvist, C.-I., Oja, T. (1993). "Physical Studies of Asteroids. Part XXVI. Rotation and Photoelectric Photometry of Asteroids 323, 350, 582, 1021 and 1866." *Astron. Astrophys. Suppl. Ser*. **101**, 499-505.

Skiff, B.A. (2011) Posting on CALL web site. *http://www.minorplanet.info/call.html*

Stephens, R.D., French, L.M., Warner, B.D., Wasserman, L. (2011). "The Curse of Sisyphus." *Minor Planet Bull.* **38**, 212-213.

Vaduvescu, O., Aznar Macias, A., Tudor, V., Predatu, M., Galad, A., Gajdos, S., Vilagi, 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 April. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2014a). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 January-March." *Minor Planet Bull.* **41**, 157-168.

Warner, B.D. (2014b). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 March-June." *Minor Planet Bull.* **41**, 213-224.

Warner, B.D. (2015). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 March-June." *Minor Planet Bull.* **42**, 256-266.

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

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

Warner, B.D. (2016c). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2016 April-July." *Minor Planet Bull.* **43**, 311-319.

Warner, B.D. (2018). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2017 October-December." *Minor Planet Bull.* **45**, 138-147.

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.

Wisniewski, W.Z., Michalowski, T.M., Harris, A.W., McMillan, R.S. (1997). "Photometry of 125 Asteroids." *Icarus* **126**, 395-449

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.

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
719	Albert	05/20-05/23	78	17.4,16.7	257	17	5.831	0.004	0.52	0.03
1627	Ivar	04/14-04/15	412	19.2,19.0	219	15	4.7947	0.0003	1.01	0.02
1866	Sisyphus	04/04-04/10	164	17.2,17.6	171	46	2.4055	0.0007	0.11	0.02
2061	Anza	06/22-06/25	68	33.7,33.8	306	7	6.712	0.004	0.30	0.02
9856	1991 EE	05/04-05/09	162	53.4,60.2	183	17	3.0416	0.0005	0.28	0.02
15745	Yuliya	05/05-05/16	258	35.2,35.4	241	31	5.86	0.01	0.15	0.02
25916	2001 CP44	04/17-04/25	193	26.7,25.2	238	19	4.6021	0.0005	0.24	0.02
25916	2001 CP44	06/07-06/08	447	14.9,14.8	252	12	4.596	0.002	0.21	0.01
25916	2001 CP44	[2014]03/16-03/20	67	37.3,37.9	246	14	4.608	0.003	0.35	0.04
36183	1999 TX16	05/05-05/09	147	8.0,7.3	226	10	5.613	0.002	0.90	0.04
65996	1998 MX5	06/18-06/24	90	38.1,40.0	301	7	3.399	0.001	0.22	0.02
66391	1999 KW4	06/01-06/07	1786	50.8,59.6	240	30	2.7660	0.0002	0.14	0.01
68347	2001 KB67	06/04-06/06	499	51.1,47.7	254	27	6.354	0.004	0.19	0.02
85628	1998 KV2	05/16-05/24	167	14.0,18.1	222	7	2.8234	0.0005	0.18	0.02
85953	1999 FK21	03/30-04/13	2023	13.6,68.2	175	15	68.44	0.04	0.87	0.03
85989	1999 JD6	06/01-06/04	130	58.7,57.0	204	32	7.685	0.006	1.54	0.05
138847	2000 VE62	05/10-05/12	215	45.4,47.1	206	23	7.600	0.004	0.33	0.02
139289	2001 KR1	05/19-05/27	150	39.7,45.8	260	32	11.30	0.01	0.47	0.05
153957	2002 AB29	06/05-06/09	363	73.0,59.2	266	44	2.415	0.002	0.17	0.03
162168	1999 GT6	06/01-06/07	108	44.7,47.2	286	10	3.85	0.01	0.15	0.03
220839	2004 VA	05/16-05/19	581	69.6,61.3	198	14	6.7906	0.0006	1.59	0.04
337084	1998 SE36	05/10-05/14	158	33.9,36.9	210	15	11.85	0.02	0.96	0.04
415029	2011 UL21	06/09-06/12	59	42.3,41.3	325	23	2.732	0.002	0.32	0.03
444193	2005 SE71	04/15-04/26	1826	79.2,2.3,37.8	189	30	66.8	0.1	0.8	0.1
450648	2006 UC63	05/05-05/09	369	16.2,23.5	219	10	10.13	0.02	0.05	0.01
455550	2004 JO2	06/17-06/21	137	28.6,31.1	270	29	9.94	0.03	0.20	0.02
467309	1996 AW1	06/05-06/08	240	22.5,26.3	253	15	10.773	0.004	1.25	0.04
469737	2005 NW44	06/18-06/21	1360	73.6,61.2	251	32	31.5	0.2	0.13	0.02
	2010 WC9	05/15-05/15	1325	32.7,32.7	242	15	0.18469	0.00002	0.95	0.10
	2013 US3	04/26-05/03	1244	65.2,37.0	195	12	450	50	1.2	0.1
	2015 DP155	05/17-05/19	58	78.4,78.9	212	36	3.089	0.003	1.09	0.05
	2016 JP	05/03-05/09	230	48.6,44.3	209	23	37.4	0.1	0.41	0.03
	2017 YE5	06/24-06/28	1069	70.3,42.2	303	9	20.6	0.1	0.33	0.02
	2018 EB	04/08-04/09	218	56.6,62.1	197	32	1.2208	0.0004	0.51	0.05
	2018 JX	05/15-05/15	375	6.4,6.4	233	3	0.057637	0.000006	0.31	0.03
	2018 LK	06/12-06/12	227	55.6	287	13	0.12296	0.000005	0.25	0.02
	2018 LK	06/13-06/13	113	62.4	292	11	0.12325	0.000007	0.55	0.03
	2018 JE1	06/02-06/03	75	43.1,44.5	223	10	29.8	0.5	0.59	0.05
	2018 BY2	04/11-04/15	749	45.3,35.8	181	-2	7.6110	0.0005	1.45	0.03
	2018 JK3	05/24-05/24	667	38.3,38.3	237	21	-	-	flat	-
	2018 EJ4	05/17-05/25	245	61.5,62.1	227	33	7.484	0.002	0.37	0.03
	2018 FQ5	04/11-04/15	127	28.4,25.7	219	18	7.52	0.01	0.36	0.04

Table II. Observing circumstances. [A](Period): preferred period of an ambiguous solution. [yy](Dates): data are from the year 20YY. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude.

ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2018 APRIL-JUNE

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

(Received: 2018 July 12)

Lightcurves for 24 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June.

CCD photometric observations of 24 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2018 April-June. The main focus at CS3-PDS is on near-Earth asteroids. However, a nearly full moon and most NEAs being in rich star fields during the quarter meant finding other targets to keep the telescopes working. Hungaria members were observed to provide additional data for spin axis modeling. Most of the other objects were chosen because they had no previous period reported and were bright enough to work when the moon was full or they were in more sparse areas of the sky.

Table I lists the telescope/CCD camera combinations that were used. All the cameras use the KAF-1001E blue-enhanced CCD chip and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

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

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs.

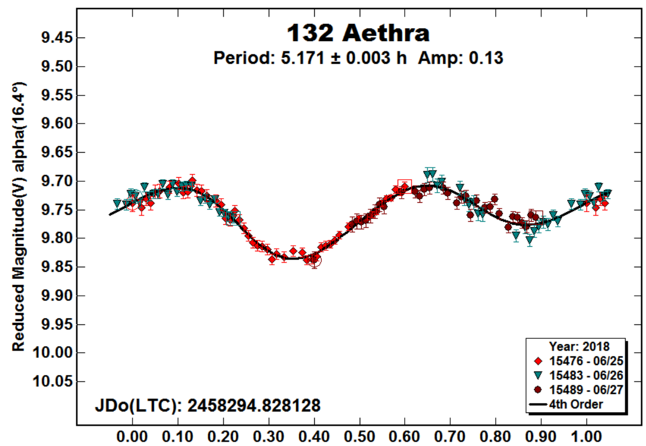
The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ±0.05 mag or better, but occasionally reach >0.1 mag. There is a systematic offset between the two catalogs and so, whenever possible, the same catalog was used for all observations of a given asteroid. Period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

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

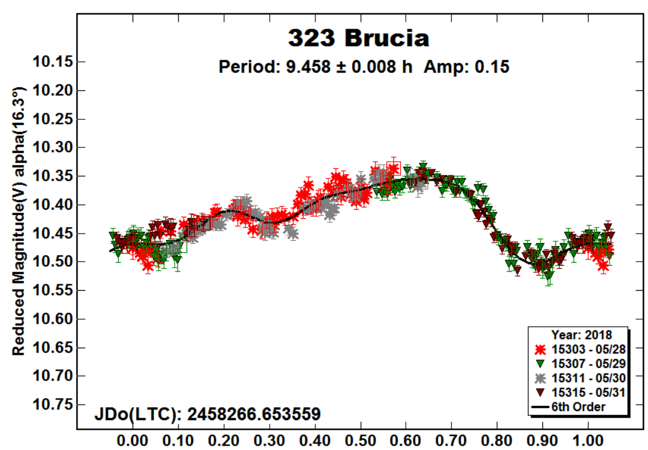
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

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

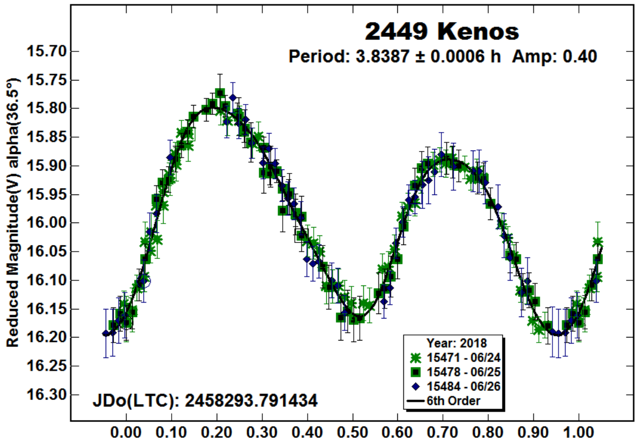
132 Aethra. Previous results include Galad (2010; 5.181 h) and Pilcher (2017; 5.1802 h). The results here are close to but not statistically the same. This could be the result of not having data for more than three consecutive nights.



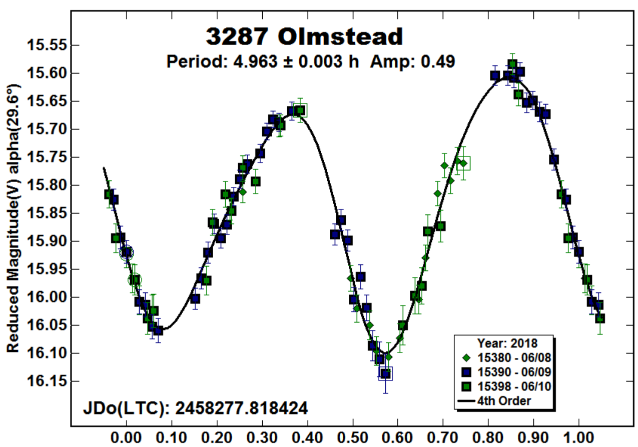
323 Brucia. The period of 9.458 h is in good agreement with Warner (2014; 9.463 h) and Behrend (2006).



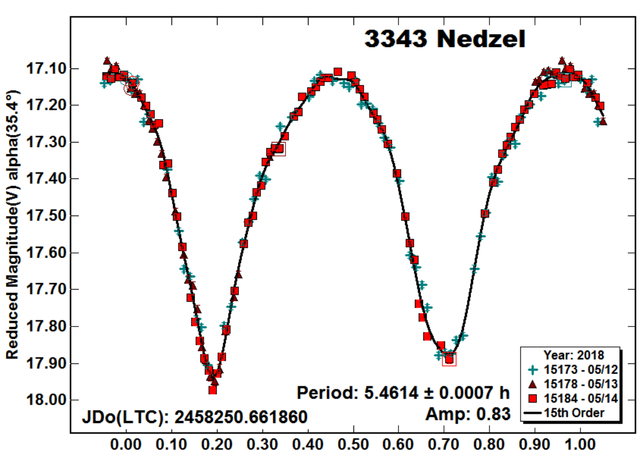
2449 Kenos. This was the fourth apparition the asteroid was observed at Palmer Divide. The earlier results include 3.8492 h (Warner, 2007), 3.846 h (Warner, 2010), and 3.8481 h (Warner, 2015b). The 2015 data indicated two periods, the second being 15.85 h. This was attributed to a non-spheroidal satellite that was tidally locked to its orbital period. No mutual events (occultations and/or eclipses) were seen at that time and so the asteroid was only a suspected binary. The 2018 data showed no indications of a secondary period. Coverage at future apparitions is suggested.



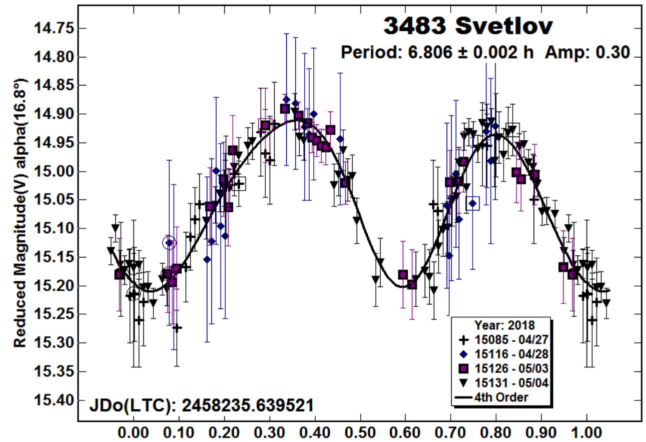
3287 Olmstead. The only previous result is from Wisniewski et al. (1997), who found a period of 4.80 h. That was based on a single night of data. The lightcurve appeared to show a full cycle but there was no overlapping data from a second cycle. Many times, even with some data from a second cycle, additional nights will change the result by a significant amount. Here, there were three consecutive nights, leading to a more secure solution.



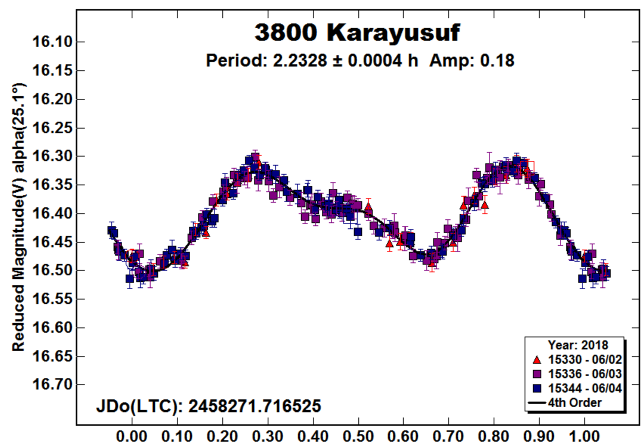
3343 Nedzel. Previous results are from Folberth (2012; 5.4620 h) and Stephens (2018; 5.467 h).



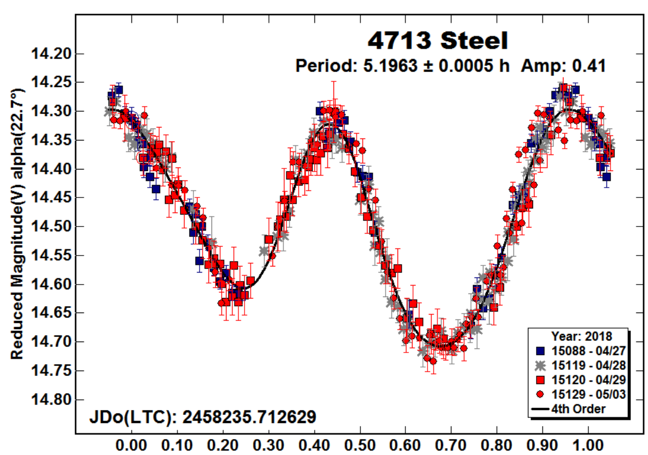
3483 Svetlov. This was the fifth time this Hungaria was observed by the author (Warner, 2010; 2012; 2015a; 2015d). The previous period results average to 6.80 ± 0.02 h.



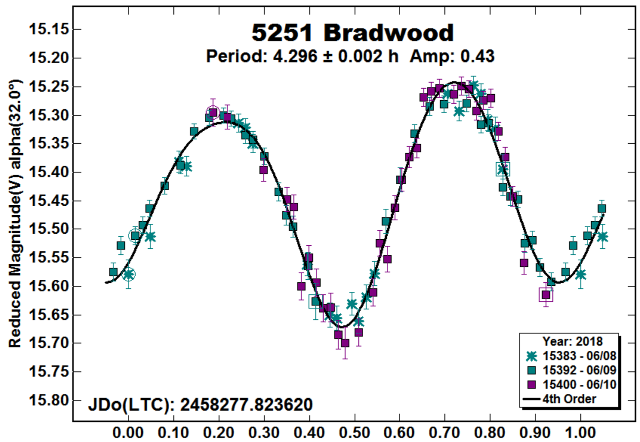
3800 Karayusuf. Three previous results are Warner (2008, 2.2319h – suspected binary; 2010, 2.232 h; 2014, 2.221 h). There were no indications of a satellite in the 2018 data.



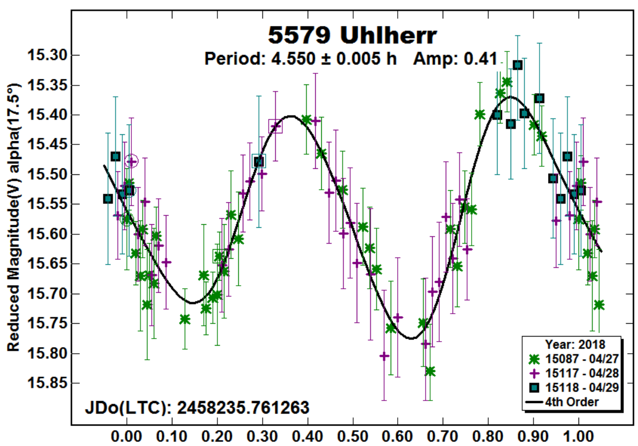
4713 Steel. Previous results from Palmer Divide observations of this Hungaria are from Warner (2010, 5.199 h; 2012c, 5.193 h; 2015a, 5.203 h).



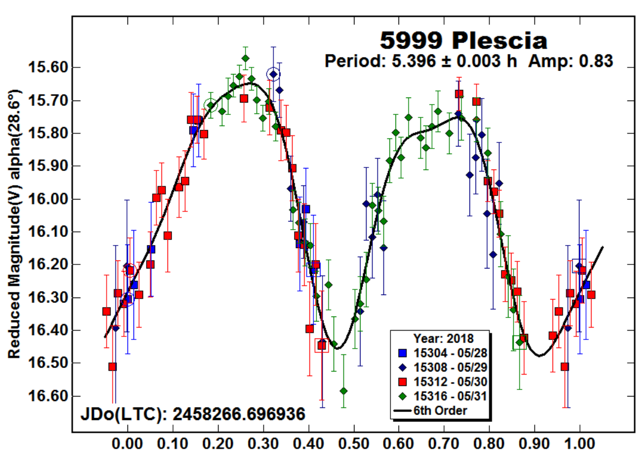
5251 Bradwood. Waszczak et al. (2015) found a period of 4.301 h using a sparse data set. Even so, their result is close to the one found here using a dense lightcurve.



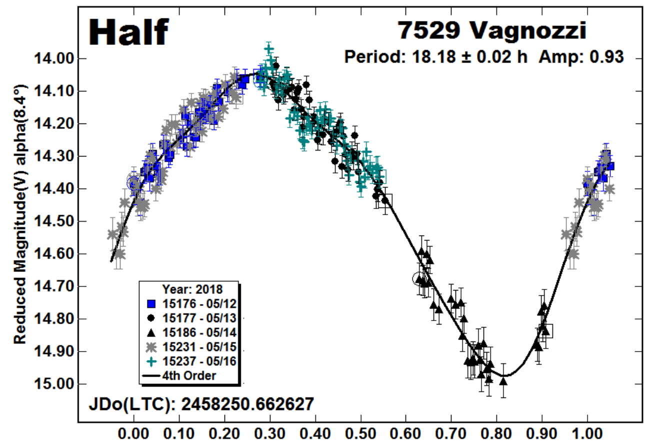
5579 Uhlherr. Being another Hungaria, Uhlherr has been observed by the author numerous times before: Warner (2009b, 4.754 h; 2012, 4.777 h; 2015c, 4.52 h), and by Stephens (2017, 4.48 h).

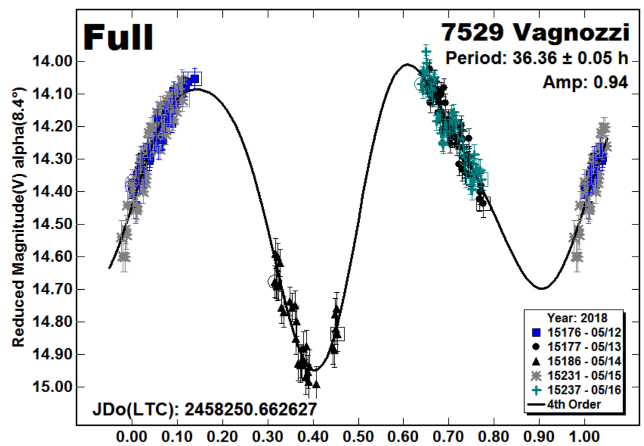


5999 Plescia. Pravec et al. (2011) found a period of 5.392 h. At about the same time, Skiff (2011) found the same result. The lightcurve from his 2010 December observations (α = 29.5°) had an amplitude of 0.95 mag. A month later (α = 25.7°) the amplitude dropped to 0.72 mag, which is expected (Zappala et al., 1990).

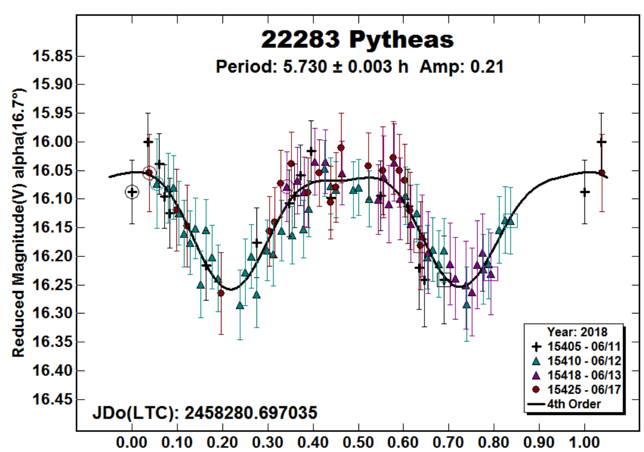


7529 Vagnozzi. There were no previous lightcurve results in the LCDB for this inner main-belt object. The period of 36.36 h is based on finding the best fit to a half period.

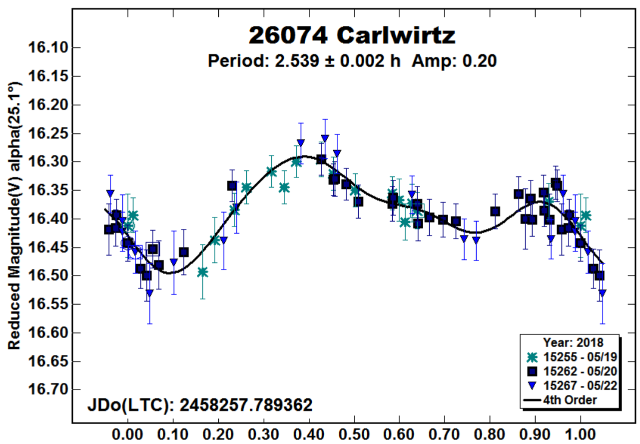




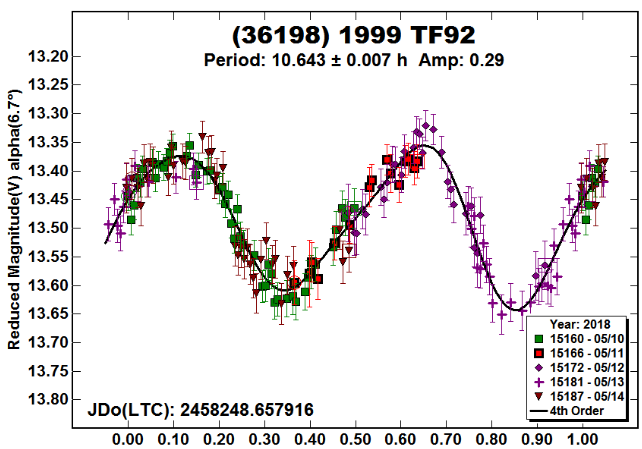
22283 Pytheas. This also appears to be a first-time lightcurve result. The solution is considered reasonably secure, although due to its symmetry and amplitude, a monomodal lightcurve with a period of 2.865 h, noticeably favored in the period spectrum, cannot be formally excluded (Harris et al., 2014).



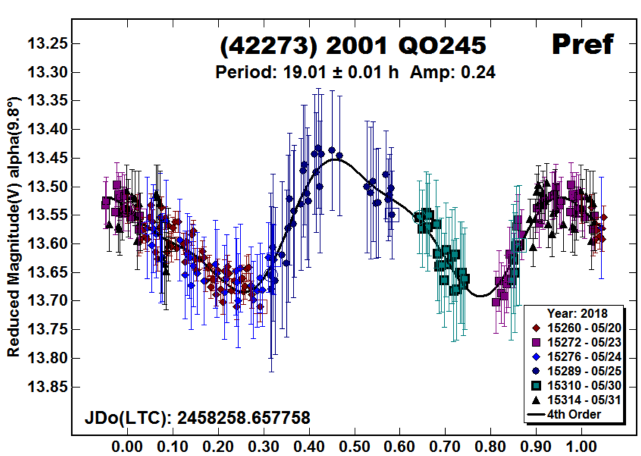
26074 Carlwirtz. This is a suspected binary (Warner, 2013). No mutual events were seen but a strong secondary period of 16.11 h was found, suggesting a tidally-locked satellite with a somewhat elongated shape. There were no indications of a satellite in the 2018 data.



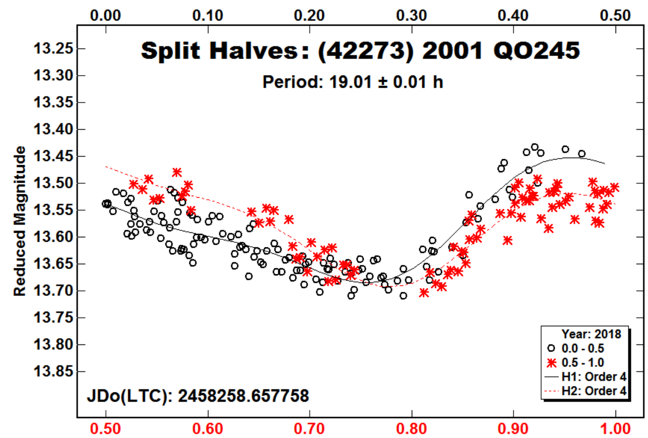
(36198) 1999 TF92. There were no lightcurve entries in the LCDB for this Eos group member. The solution is considered secure.



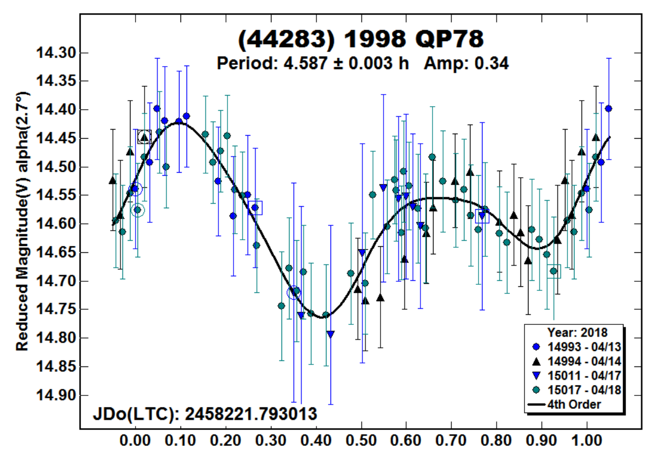
(42273) 2001 QO245. This looks to be the first reported lightcurve period for 2001 QO245, a 15-km outer main-belt asteroid. The period spectrum shows a strong preference for a solution of about 19 h. However, there was a somewhat remote possibility that the half-period was correct. A "split-halves" plot helps resolve the ambiguity at relatively low phase angles.

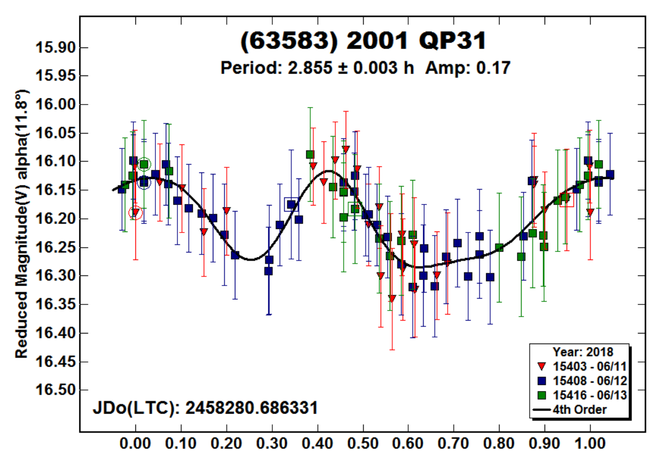


This plot splits the lightcurve for a given period into halves, superimposing the second half over the first. If the two halves are the same within the noise level, the half-period should be given consideration. In this case, however, the two halves were significantly different and so the longer period was adopted.

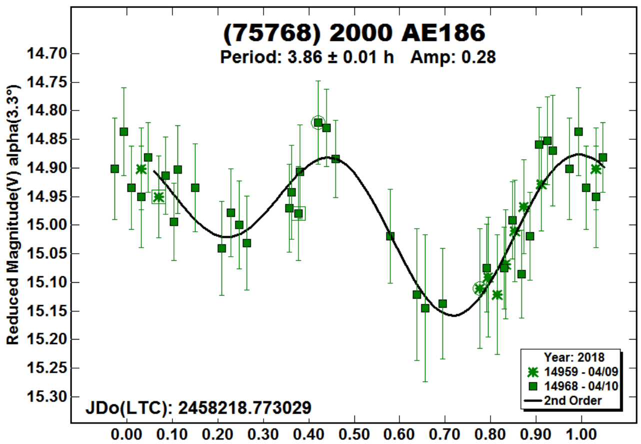


(44283) 1998 QP78, (63583) 2001 QP31. There were no previous lightcurve period entries in the LCDB for either of these asteroids. Mainzer et al. (2016) reported a diameter of D = 4.67 km and albedo $p_V \sim 0.27$ for 1998 QP78, a member of Eunomia group. For 2001 QP31, Nugent et al. (2016) found D = 2.11 km and p_V = 0.31.

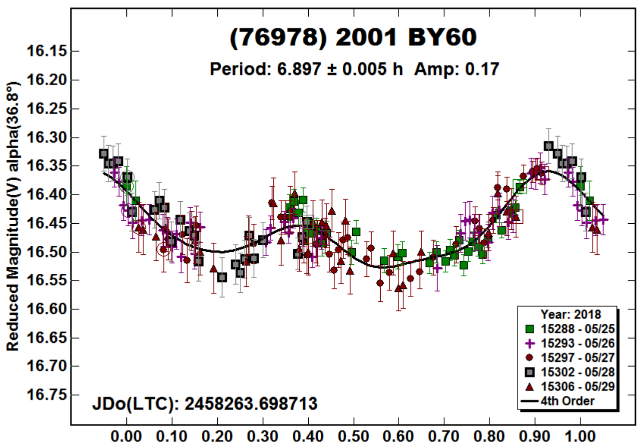


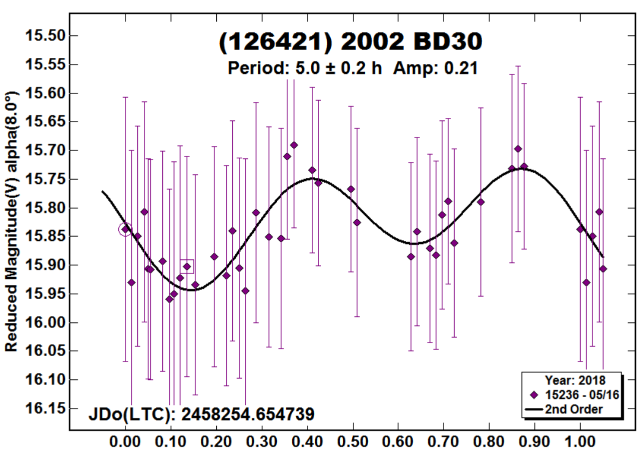


(75768) 2000 AE186 is a 3.6 km member of the Eunomia group. It was in the field of view of a planned target for a single night. There was no previous lightcurve entry in the LCDB.



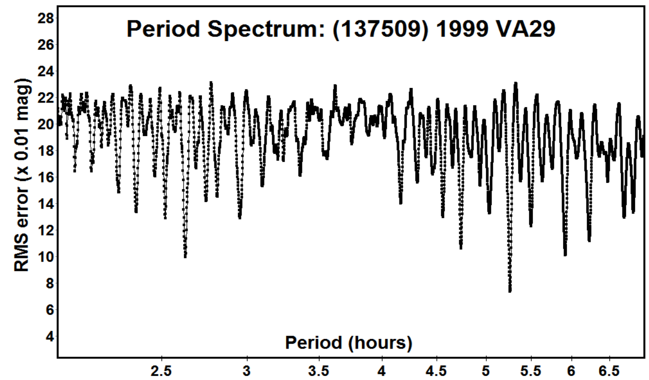
(76978) 2001 BY60, (126421) 2002 BD30. This is another pair of asteroids that didn't have LCDB lightcurve entries. The low amplitude and high phase angle for 2001 BY60 make the solution less than secure but it's probably correct. On the other hand, 2002 BD30 was in the field of view on one night, very faint, and had only a hint of a period.

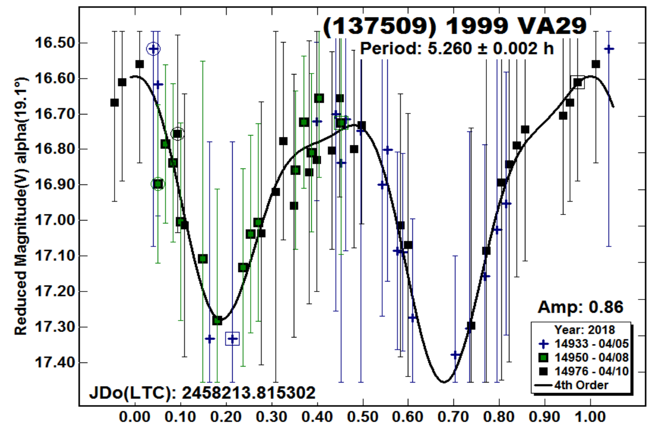




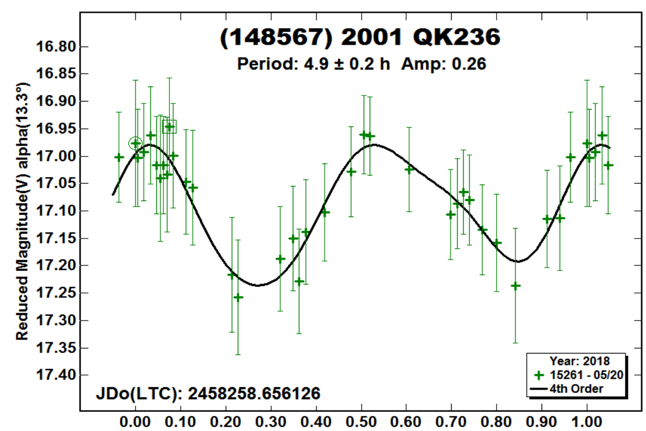
(137509) 1999 VA29. The large error bars in the data for 1999 VA29, a 1.6 km member of the Flora group, would have made finding a period nearly impossible were it not for the large amplitude of 0.86 mag and having data from more than one night. Still, the result should be viewed with some skepticism.

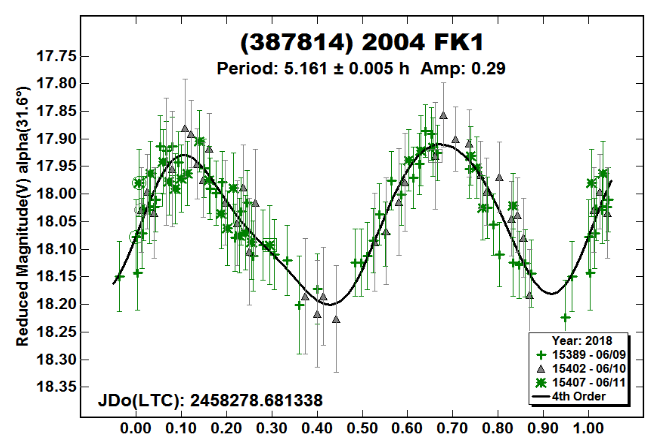
The asteroid is never brighter than V ~ 18.1. The next opportunity is 2020 Nov at +21° Declination and galactic latitude –25°.





(148567) 2001 QK236, (387814) 2004 FK1. These are two more newcomers to the LCDB.





Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Group
132	Aethra	06/25-06/27	125	16.4,16.4	352	26	5.171	0.003	0.13	0.01	MC
323	Brucia	05/28-05/31	276	16.3,16.7	201	26	9.458	0.008	0.15	0.01	MC
2449	Kenos	06/24-06/26	165	36.5,36.2	313	34	3.8387	0.0006	0.40	0.02	MC
3287	Olmstead	06/08-06/10	79	29.6,29.2	296	17	4.963	0.003	0.49	0.02	MC
3343	Nedzel	05/12-05/14	171	12.2,13.5	216	1	5.4614	0.0007	0.83	0.02	MC
3483	Svetlov	04/27-05/04	137	16.8,17.8	206	27	6.806	0.002	0.30	0.02	H
3800	Karayusuf	06/02-06/04	178	25.2,25.8	232	16	2.2328	0.0004	0.18	0.01	MC
4713	Steel	04/27-05/03	277	22.7,23.2	211	32	5.1963	0.0005	0.41	0.02	H
5251	Bradwood	06/08-06/10	89	32.1,31.9	305	20	4.296	0.002	0.43	0.02	MC
5579	Uhlherr	04/27-04/29	78	17.5,16.7	237	18	4.550	0.005	0.41	0.03	H
5999	Plescia	05/28-05/31	103	28.7,29.0	202	18	5.396	0.003	0.83	0.04	MC
7529	Vagnozzi	05/12-05/16	218	8.4,10.1	214	1	36.38	0.05	0.94	0.04	MB-I
22283	Pytheas	06/11-06/17	97	16.7,19.2	233	11	5.730	0.003	0.21	0.02	MC
26074	Carlwirtz	05/19-05/22	65	25.1,24.0	258	29	2.539	0.002	0.20	0.02	H
36198	1999 TF92	05/10-05/14	160	6.7,8.2	213	2	10.643	0.007	0.29	0.02	EOS
42273	2001 QO245	05/24-05/31	213	11.3,13.8	219	8	19.01	0.01	0.24	0.02	MB-O
44283	1998 QP78	04/13-04/18	81	2.7,3.8	202	6	4.587	0.003	0.34	0.03	EUN
63583	2001 QP31	06/11-06/12	86	11.8,12.1	247	15	2.855	0.003	0.17	0.02	MC
75768	2000 AE186	04/09-04/09	41	3.3,3.3	202	6	3.86	0.01	0.28	0.03	EUN
76978	2001 BY60	05/25-05/29	168	36.8,36.6	262	43	6.897	0.005	0.17	0.02	MC
126421	2002 BD30	05/16-05/16	37	8.0,8.0	219	9	5.0	0.2	0.21	0.03	MB-O
137509	1999 VA29	04/05-04/08	57	19.1,20.1	161	5	5.260	0.002	0.86	0.05	FLOR
148567	2001 QK236	05/20-05/20	33	13.4,13.4	221	7	4.9	0.2	0.28	0.03	MB-I
387814	2004 FK1	06/09-06/11	104	31.6,32.0	238	35	5.161	0.005	0.29	0.03	MC

Table II. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are, respectively, the average phase angle bisector longitude and latitude (see Harris *et al*., 1984). The Group column gives the orbital group to which the asteroid belongs. The definitions are those used in the LCDB (Warner et al., 2009a). EUN: Eunomia, FLOR: Flora, H: Hungaria, MB-I/O: Main-belt inner/outer, MC: Mars-crosser.

Acknowledgements

Work on the asteroid lightcurve database (LCDB) was funded by National Science Foundation grant AST-1507535. 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 based in part on data from CMC15 Data Access Service at CAB (INTA-CSIC) (*http://svo2.cab.inta-csic.es/vocats/cmc15/)*.

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.

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

Folberth, J., Casimir, S., Dou, Y., Evans, D., Foulkes, T., Haenftling, M., Kuhn, P., White, A., Ditteon, R. (2012). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2011 July-September." *Minor Planet Bull*. **39**, 51-55.

Galad, A., Kornos, L., Vilagi, J. (2010). "An Ensemble of Lightcurves from Modra." *Minor Planet Bull.* **37**, 9-15.

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*

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/*

Nugent, C.R., Mainzer, A., Baurer, J., Cutri, R.M., Kramer, E.A., Grant, T., Masiero, J., Sonnett, S., Wright, E.L. (2016). "NEOWISE Reactivation Mission Year Two: Asteroid Diameters and Albedos." *Astron. J.* **152**, A63.

Pravec, P., Wolf, M., Sarounova, L. (2011). *http://www.asu.cas.cz/~ppravec/neo.htm*

Skiff, B.A. (2011web) Posting on CALL web site. *http://www.minorplanet.info/call.html*

Stephens, R.D. (2017). "Asteroids Observed from CS3: 2016 October – December." *Minor Planet Bull*. **44**, 120-122.

Stephens, R.D. (2018). "Asteroids Observed from CS3: 2018 January – March." *Minor Planet Bull*. **45**, 299-301.

Warner, B.D. (2007). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory - December 2006 - March 2007." *Minor Planet Bull.* **34**, 72-77.

Warner, B.D. (2008). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: February-May 2008." *Minor Planet Bull.* **35**, 163-167.

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

Warner, B.D. (2009b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2008 September-December." *Minor Planet Bull.* **36**, 70-73.

Warner, B.D. (2010). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2010 March – June." *Minor Planet Bull.* **37**, 161-165.

Warner, B.D. (2012). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 December - 2012 March." *Minor Planet Bull.* **39**, 158-167.

Warner, B.D. (2013). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2013 May-June." *Minor Planet Bull.* **40**, 208-212.

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

Warner, B.D. (2015a). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 October-December." *Minor Planet Bull.* **42**, 108-114.

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

Warner, B.D. (2015c). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 December - 2015 March." *Minor Planet Bull.* **42**, 167-172.

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

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.

Wisniewski, W.Z., Michalowski, T.M., Harris, A.W., McMillan, R.S. (1997). "Photometric Observations of 125 Asteroids." *Icarus* **126**, 395-449.

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.

LIGHTCURVE AND ROTATION PERIOD DETERMINATIONS FOR SEVEN ASTEROIDS

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA
vlaben@yahoo.com

(Received: 2018 July 15)

CCD photometric observations of seven asteroids were conducted from 2018 January through June. A review of the results obtained for synodic rotation periods as well as the lightcurves established is presented here.

Photometric observations of seven asteroids were conducted at Sopot Astronomical Observatory (SAO) between 2018 January-June 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, 2018a). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq B-V \leq 0.9$) was performed using the Comparison Star Selector (CSS) utility. This helped ensure a satisfactory quality level of night-to-night zero point calibrations and correlation of the measurements within the standard magnitude framework. Depending on a case-by-case basis, primarily on the coverage quality of a certain sky zone by a particular catalog, field comparison stars were calibrated using standard magnitudes from three different catalogs: 1. Johnson V magnitudes from the AAVSO Photometric All-Sky Survey catalog (APASS; Henden *et al.,* 2009) Data Release 9; 2. Johnson V magnitudes from MPOSC3 hybrid catalog, where BVRI magnitudes were derived from J and K 2MASS catalog magnitudes by applying formulae developed by Warner (2007); 3. Cousins R magnitudes derived from the Carlsberg Meridian Catalog 15 (VizieR, 2018) Sloan r' magnitudes using the formula: $R = r' - 0.22$. All data sets pertaining to a single target were consistently calibrated using a single catalog. 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.

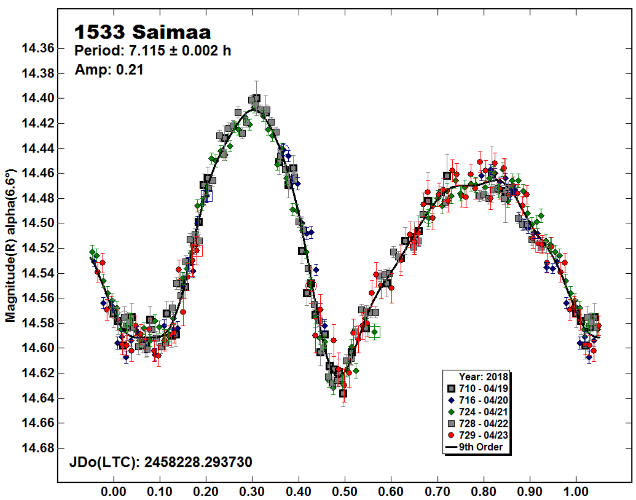
Table I gives the observing circumstances and results.

Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1533	Saimaa	04/19-04/24	314	6.5,7.9	196	9	7.115	0.002	0.21	0.01	MB-O
2764	Moeller	01/24-01/26	155	1.4,2.1	122	-1	5.954	0.005	0.26	0.02	FLOR
2811	Stremchovi	01/24-01/26	129	2.4,1.8	130	1	3.249	0.002	0.31	0.02	KOR
4221	Picasso	05/07-05/20	206	11.5,10.3	239	18	3.1114	0.0002	0.27	0.02	MB-M
5518	Mariobotta	04/19-05/09	236	9.0,17.9	202	11	108.84	0.05	0.55		FLOR
138847	2000 VE62	05/28-06/01	530	54.3,54.8	222	34	7.601	0.004	0.35	0.03	NEA
	2018 EJ4	05/20-06/01	342	62.1,58.4	231	30	3.7422	0.0006	0.30	0.03	NEA

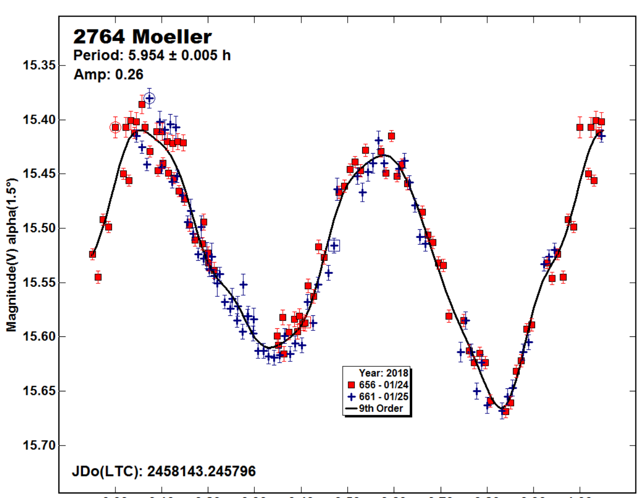
Table I. Observing circumstances and results. Pts is the number of data points. Phase is the solar phase angle given at the start and end of the date range. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude. Grp is the asteroid family/group (Warner *et al.*, 2009): FLOR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

Observations and results

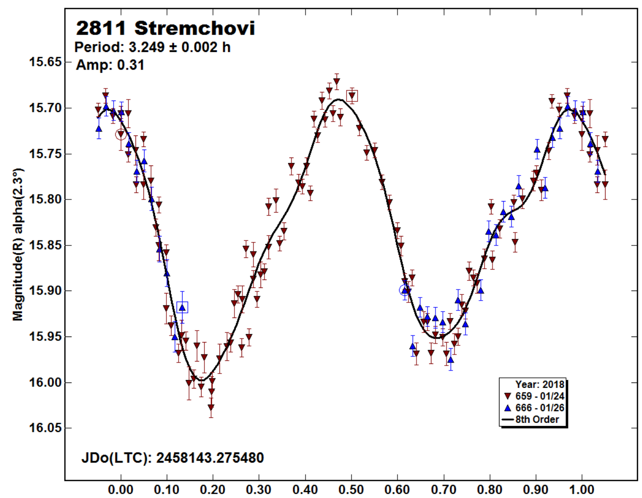
1533 Saimaa. Two previous rotation period determinations were known prior to SAO observations: by Binzel (1987; 7.08 h) and Behrend (2007; 7.1181 h). Photometric observations undertaken at SAO in 2018 April over 5 nights led to a bimodal lightcurve phased to a period of P = 7.115 ± 0.002 h.



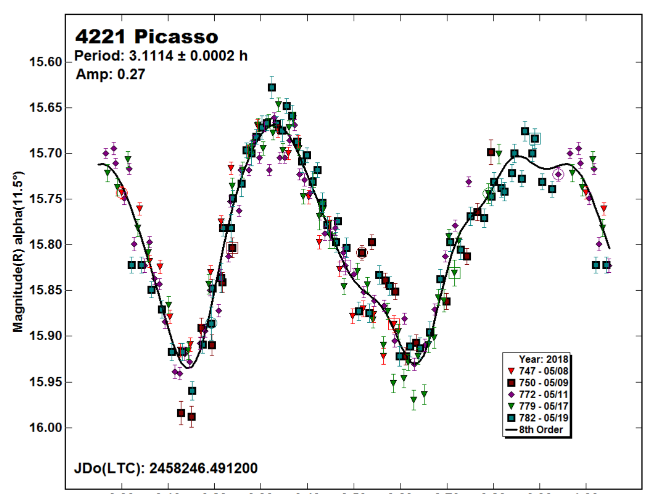
2764 Moeller. The only previous rotation period result was by Waszczak et al. (2015; 5.954 h) obtained within the Palomar Transient Factory Survey. The SAO observations of this BinAstPhot Survey target were carried out over two consecutive nights in 2018 January. The determined rotational period of 5.954 ± 0.005 h corresponds to the bimodal lightcurve with an amplitude of 0.26 mag. Pravec's analysis (Pravec, 2018) of the SAO data gave almost the same result for period (5.953 ± 0.004 h).



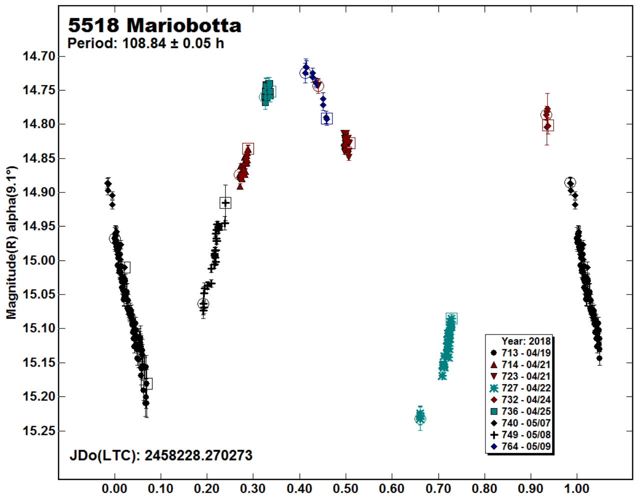
2811 Stremchovi. Previous results for synodic rotation period of this asteroid were from the Palomar Transient Factory Survey only: 3.25 h by Chang et al. (2014) and 3.248 h by Waszczak et al. (2015). Data collected over two nights at SAO led to an unambiguous bimodal result for period of P = 3.249 ± 0.002 h.



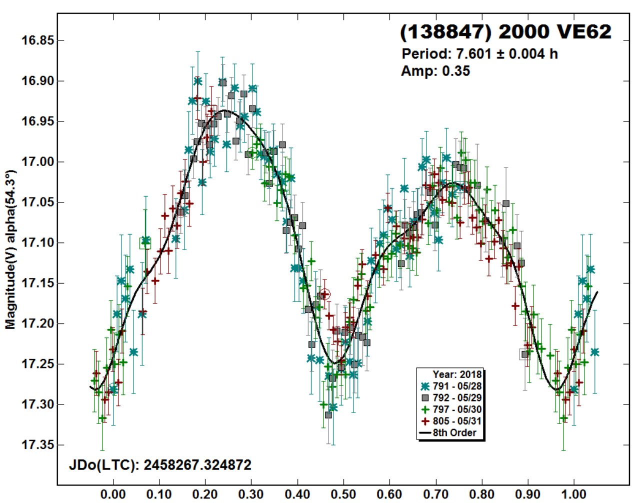
4221 Picasso. Another BinAstPhot Survey target worked at SAO over 5 nights in 2018 May. The period analysis led to a bimodal lightcurve phased to a period of P = 3.1114 ± 0.0002 h. An analysis of SAO data conducted by Pravec (2018) found exactly the same period value (3.1114 ± 0.0001 h).



5518 Mariobotta. Two previously found rotational periods by Wasczak et al. (2015; 105.538 h and 109.236 h) already indicated a slow rotator. As a BinAstPhot Survey program target it was observed at SAO from 2018 April 19 through 2018 May 9. A total of 9 individual data sets were obtained. Period analysis indicates a synodic rotation period of P = 108.84 ± 0.05 h corresponding to a fairly large amplitude (~ 0.55 mag.) bimodal lightcurve. Such a result could be adopted with a great deal of uncertainty as data coverage of the full rotational cycle is partial and quite uneven. Period analysis of the SAO data done by Pravec (2018) shows somewhat different period value of 108.60 ± 0.04 h.

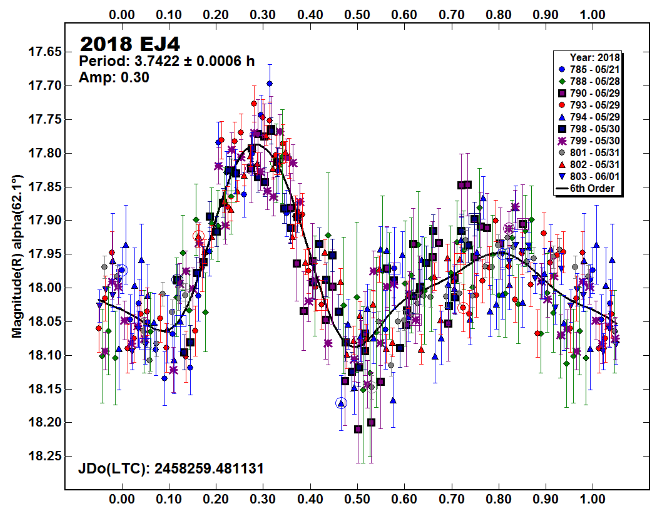


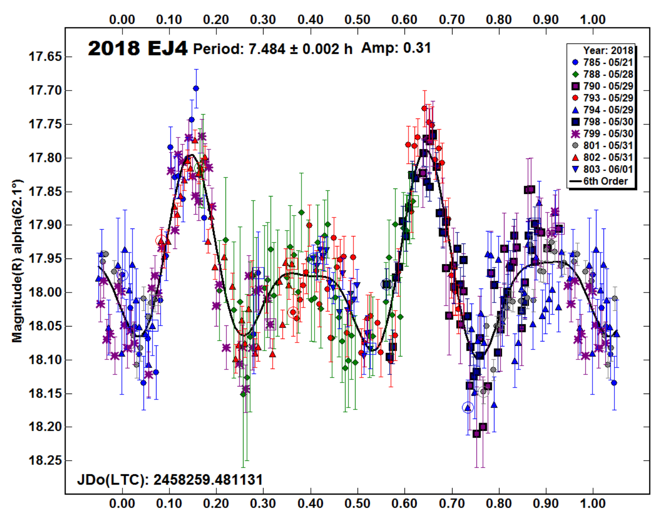
(138847) 2000 VE62. Monteiro et al. (2017) reported a value of 6.469 h for rotational period of this near-Earth asteroid. Dense photometric data were collected at SAO on four consecutive nights, from 2018 May 28 through 2018 June 1. Period analysis shows a bimodal period of 7.601 ± 0.004 h as a highly reliable result. A period of 6.55 h also quite distinctive in the period spectrum by its low RMS error and fairly close to the Monteiro et al. result by its value corresponds to the lightcurve with apparent discrepancies between the individual data sets. The period result for this asteroid recently published on the web by Warner (2018b; 7.600 h) is fully in favor of the result presented here.

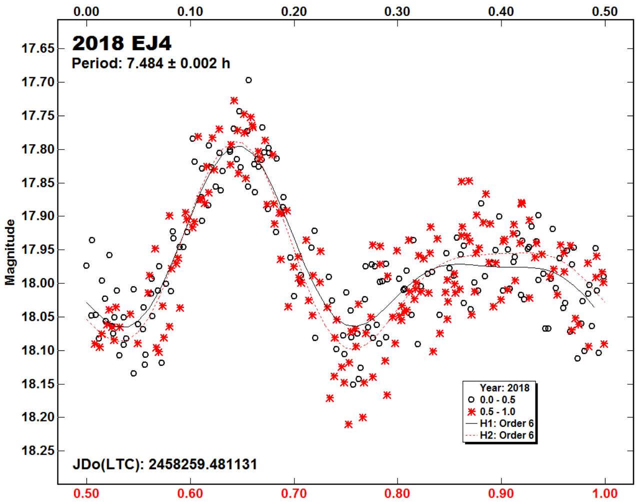


2018 EJ4. This Amor-type orbit near-Earth asteroid, also classified as a Potentially Hazardous Asteroid (PHA) was discovered by Mt. Lemmon Survey on 2018 March 13. The asteroid made a close approach to the Earth on 2018 June 10 at a distance of 0.014 AU.

To determine its rotation period photometric observations were started at SAO on 2018 May 20 and continued until 2018 June 1. A total of 10 independent data sets with 342 data points were collected during this time interval. Due to the rapid apparent motion of the asteroid and fairly small CCD field of view it was common to obtain more individual data sets over a single night. Period analysis conducted upon the combined data set yielded several harmonically related solutions for period of which the most characteristic in the period spectrum are those of about 3.742 h and 7.484 h. The lightcurve that corresponds to the longer period shows two almost identical halves, which might favor the shorter period. Nonetheless, the longer period in no case should be ruled out since somewhat higher noise level present in the data could conceal certain minor characteristic features, which could make the two halves of the longer period lightcurve different. As a formal solution a period of P = 3.7422 ± 0.0006 h is adopted in this paper.







Acknowledgements

Observational work at Sopot Astronomical Observatory is supported by a 2018 Gene Shoemaker NEO Grant from The Planetary Society.

References

Behrend, R. (2007). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Binzel, R.P. (1987). "A photoelectric survey of 130 asteroids." *Icarus* **72**, 135-208.

Chang, C.-K., Ip, W.-H., Lin, H.-W., Cheng, Y.-C., Ngeow, C.-C., Yang, T.-C., Waszczak, A., Kulkarni, S.R., Levitan, D., Sesar, B., Laher, R., Surace, J., Prince, T.A. (2014). "313 New Asteroid Rotation Periods from Palomar Transient Factory Observations." *Ap. J.* **788**, A17

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). "The AAVSO Photometric All-Sky Survey (APASS)." *https://www.aavso.org/apass*

Monteiro, F., Silva, J.S., Lazzaro, D., Arcoverde, P., Medeiros, H., Souza, R., Rodriggues, T. (2017). "Lightcurve Analysis for Ten Near-Earth Asteroids." *Minor Planet Bul.* **44**, 20-22.

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. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul.* **34**, 113-119

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2017 June 23. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2018a). MPO Canopus software, version 10.7.11.3. *http://www.bdwpublishing.com*

Warner, B.D. (2018b). Center for Solar System Studies web site. CS3 Lightcurves Page. *http://www.planetarysciences.org/PHP/CS3_Lightcurves.php*

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

LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2018 APRIL-JUNE

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

Robert D. Stephens
Center for Solar System Studies
Landers, CA

(Received: 2018 July 11)

Lightcurves for seven Hilda asteroids were obtained at the Center for Solar System Studies (CS3) from 2018 April-June: 1180 Rita, 1748 Mauderli, 1877 Marsden, (13035) 1989 UA6, (42237) 2001 EG21, and (60381) 2000 AX180. The previously reported period (Warner and Stephens, 2017) for 1180 Rita was revised following analysis of the 2018 data.

CCD photometric observations of seven Hilda asteroids were made at the Center for Solar System Studies (CS3) from 2018 April-June. This is another installment of an on-going series of papers on this group of asteroids, which is located between the outer main-belt and Jupiter Trojans in a 3:2 orbital resonance with Jupiter. The goal is to determine the spin rate statistics of the group and find pole and shape models when possible. We also we look to examine the degree of influence that the YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) effect (Rubincam, 2000) has on distant objects and to compare the spin rate distribution against the Jupiter Trojans, which can provide evidence that the Hildas are more "comet-like" than main-belt asteroids.

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

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

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

Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the APASS (Henden et al., 2009) or CMC-15 (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 so, whenever possible, the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989).

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

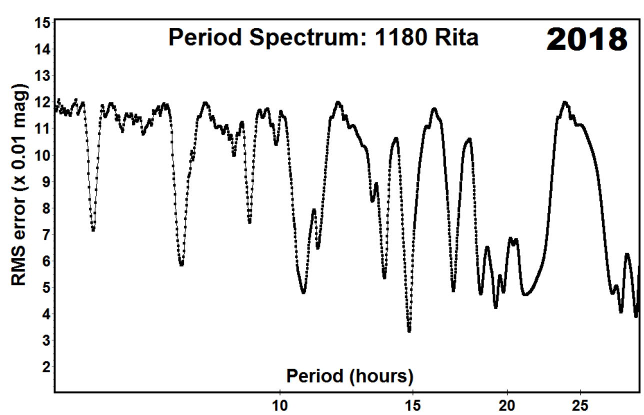
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

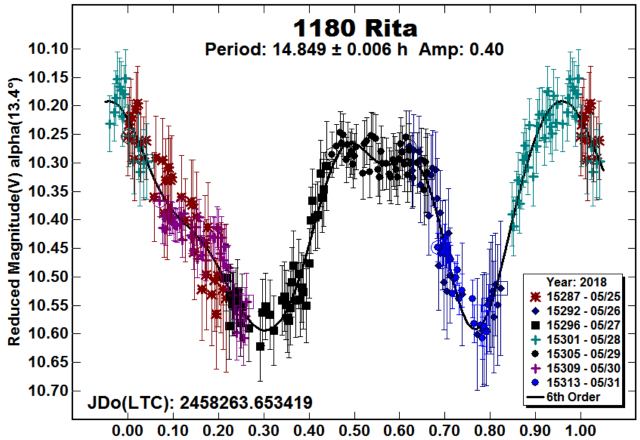
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

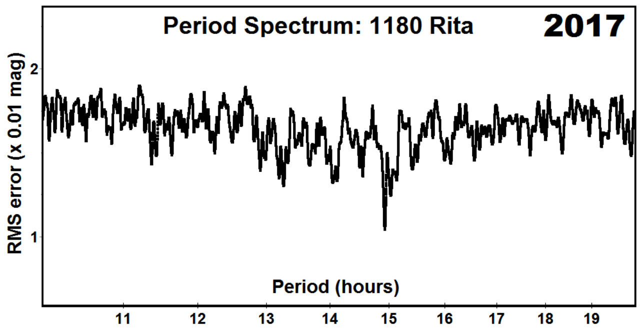
<u>1180 Rita.</u> Several different periods have been reported for this 82-km Hilda: Gonano et al. (1991; 14.72 h), Dahlgren et al. (1998; 14.902 h), and Polishook (2012; 9.605 h), among others.

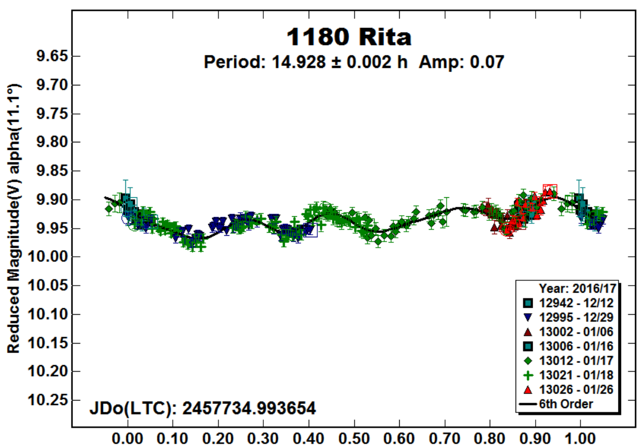
Our 2018 data led to what seems to be a convincing bimodal lightcurve with $P = 14.928 \pm 0.006$ h, $A = 0.40 \pm 0.03$ mag. This result is consistent with Dahlgren et al. (1998) but inconsistent with our results from 2017 (Warner and Stephens, 2017; 13.090 h). In his paper, Polishook (2012) phased his data to previously reported periods, all leading to improbable results.

We tried the same exercise using our data from 2018 and 2017 to force a solution between 9-10 hours. The best fit from the 2018 data was 9.130 h, but this required significant zero point shifts and some sessions being "too flat" for their position in the lightcurve. The amplitude of the 2017 data was only 0.04 mag, meaning the slightest zero point shifts could alter the solution. Even so, after many attempts, the best RMS fit, by far, was to a quadramodal lightcurve with a period of 14.849 h.





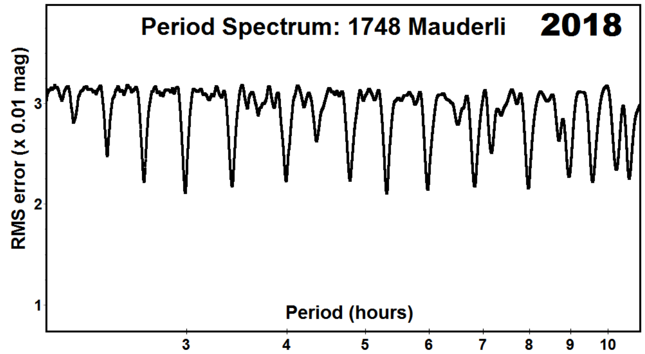


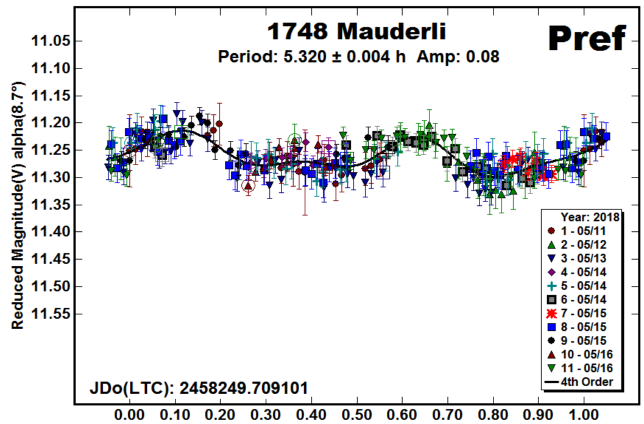


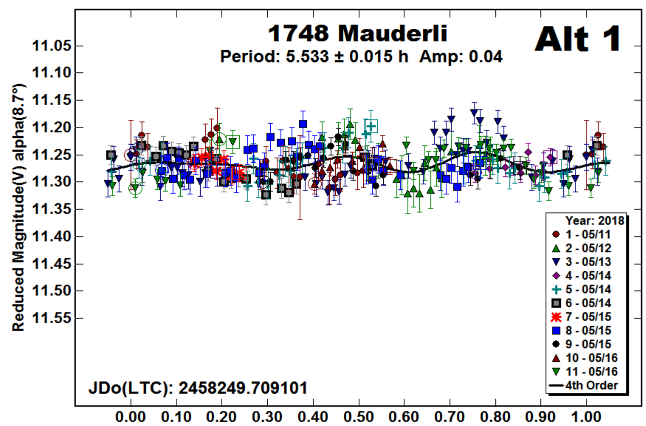
While we are confident in the 14.9-hour solution, especially given the fully-covered asymmetrical lightcurve with an amplitude of 0.4 mag (see Harris et al., 2014), we encourage additional observations at future apparitions.

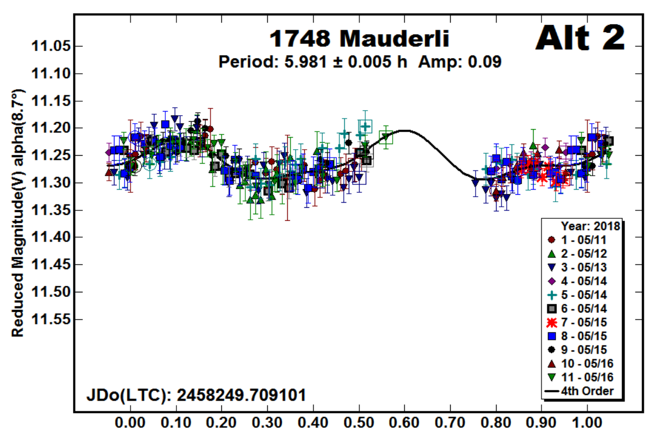
<u>1748 Mauderli</u>. The estimated size of Mauderli is 40 km. Previous results include Gonano et al. (1991; 6.00 h), Dahlgren et al. (1998; 6.00 h) and Slyusarev et al. (2012; 6.001 h). Our previous observations (Warner and Stephens, 2017; 5.552 h) differed significantly and so we observed the asteroid again in 2018 to see if the ambiguities could be resolved.

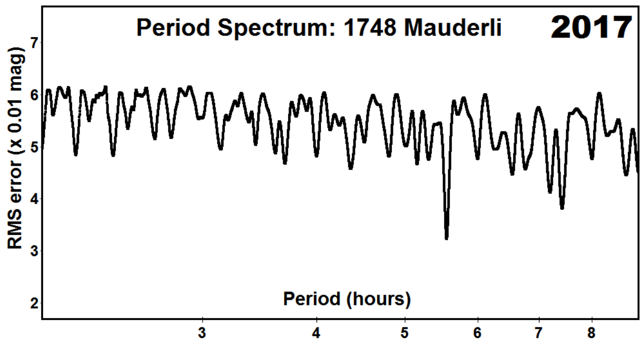
The 167 data points obtained on six consecutive nights led to a period of 5.320 h. However, as seen in the period spectrum, this was not a dominant solution and, in fact, one near 5.5 hours (our 2017 result) and 6 hours (other previous results) were also a possibility. We forced the data to fit near both of those periods. The solution at 5.981 h, in some ways, has a better fit to those parts of the curve that are filled in. However, the large gap could be the result of a "fit by exclusion", which is when the Fourier algorithm finds a local not global minimum in the RMS values. Given the uncertainty in the latest results, we double-checked those from the 2017 data. The period spectrum shows no doubt about the original period. Mauderli's period remains a mystery.

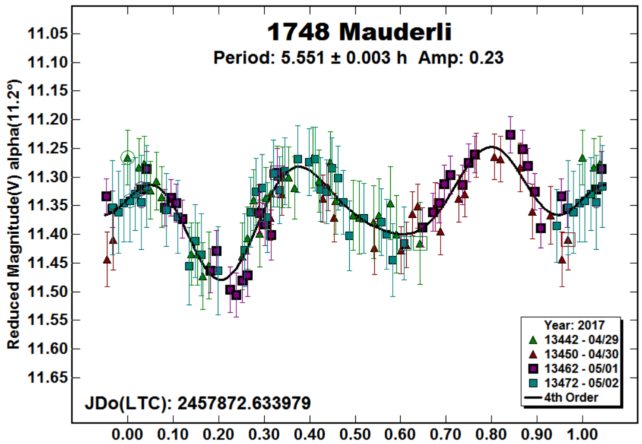




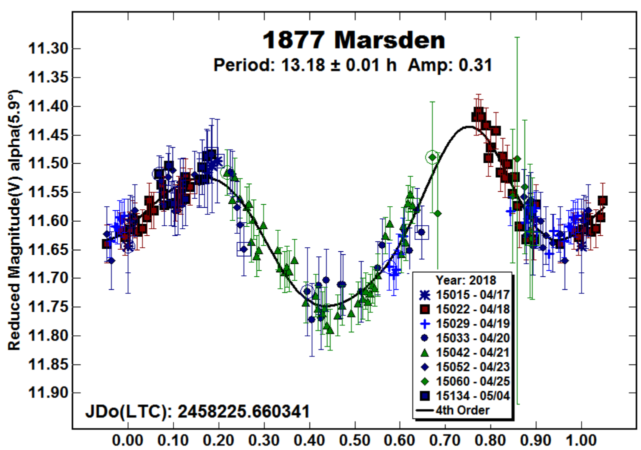




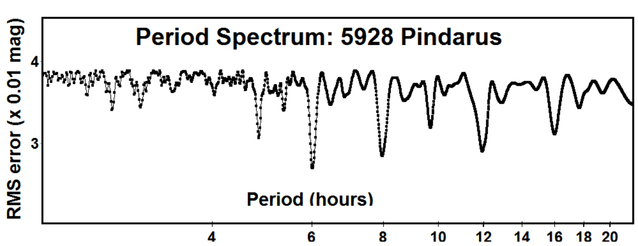


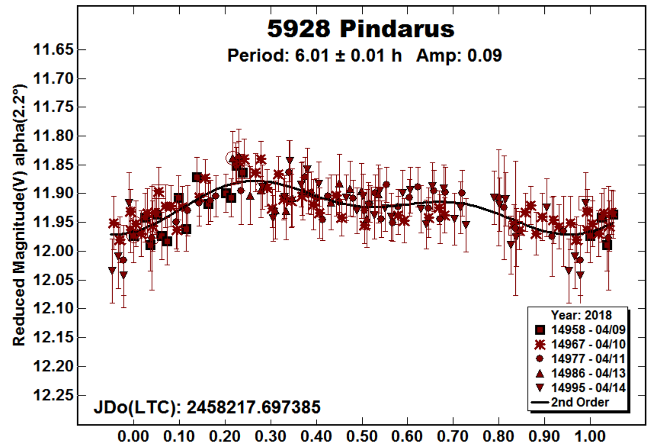


1877 Marsden. The only previous result in the LCDB was from Dahlgren et al. (1998), who found a period of 14.4 h. This was based on about 25 data points obtained from 1995 Mar 9-11 and a lightcurve with significant gaps. Our lightcurve is sufficiently covered, i.e., multiple sessions for most sections of the lightcurve, to give us high confidence in our result.



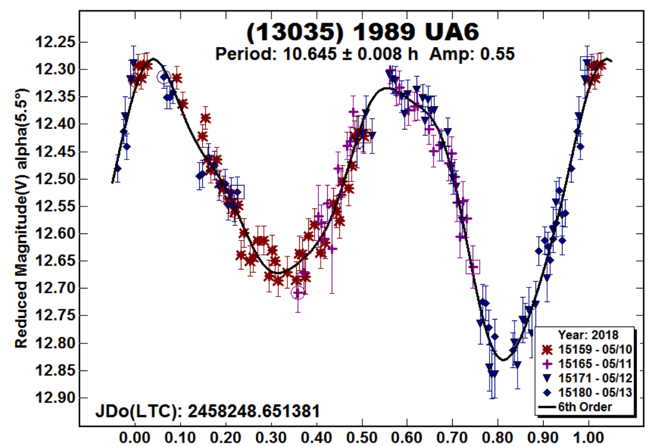
5928 Pindarus. This appears to be the first reported lightcurve. The low amplitude leaves room for doubt (see Harris et al., 2014).

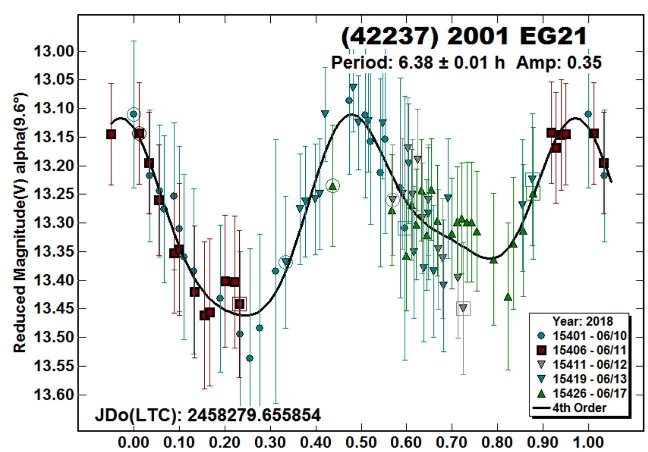




(13035) 1989 UA6, (42237) 2001 EG21, and (60381) 2000 AX180. There were no entries with periods in the LCDB for any of these Hilda asteroids. Mainzer et al. (2016) give estimated diameters of 28 km, 18 km, and 15 km for, respectively, 1989 UA6, 2001 EG21, and 2000 AX180.

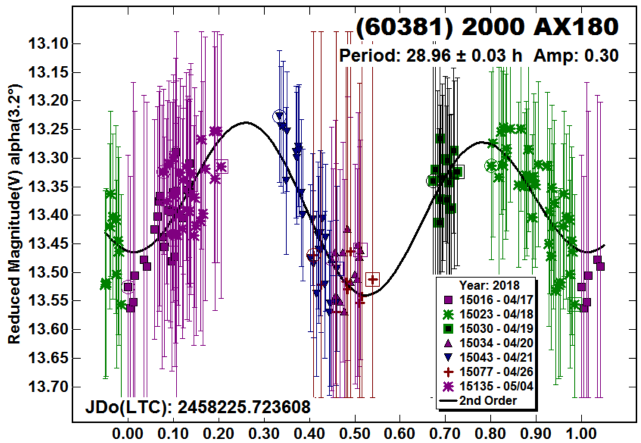
The period of 10.645 h for 1989 UA6 is considered secure given the large amplitude, asymmetrical shape, and relatively good data. The period for 2001 EG21 is less than secure because the error bars almost rival the amplitude of the lightcurve in some cases. Even so, this is better than the result for 2000 AX180 where the error bars are even larger and all four of the extrema points are not covered.





Number	Name	2018/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
1180	Rita	05/25-05/31	254	13.5,13.9	180	8	14.849	0.006	0.40	0.03
1180	Rita	[2016-17]12/12-01/26	243	11.1,3.2	139	6	14.93	0.01	0.07	0.01
1748	Mauderli	05/11-05/15	167	8.7,9.5	194	4	5.320	0.004	0.08	0.01
1748	Mauderli	[2017]04/29-05/02	125	11.2,11.4	159	2	5.551	0.003	0.23	0.02
1877	Marsden	04/17-05/04	170	6.0,9.8	186	-6	13.18	0.01	0.31	0.02
5928	Pindarus	04/09-04/14	143	2.2,2.1,2.2	202	7	6.01	0.01	0.09	0.01
13035	1989 UA6	05/10-05/14	174	5.5,6.7	213	2	10.639	0.005	0.57	0.03
42237	2001 EG21	06/10-06/17	85	9.7,11.1	225	5	6.38	0.01	0.35	0.03
60381	2000 AX180	04/17-05/04	156	3.2,6.7	201	10	28.96	0.03	0.30	0.05

Table II. Observing circumstances. 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).



Acknowledgements

Work on the asteroid lightcurve database (LCDB) by Warner was funded by National Science Foundation grant AST-1507535. 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

Dahlgren, M., Lahulla, J.F., Lagerkvist, C.-I., Lagerros, J., Mottola, S., Erikson, A., Gonano-Beurer, M., Di Martino, M. (1998). "A Study of Hilda Asteroids. V. Lightcurves of 47 Hilda Asteroids." *Icarus* **133**, 247-285.

Gonano, M., Di Martino, M., Mottola, S., Neukum, G. (1991). "Physical study of outer belt asteroids." *Adv. Space Res.* **11**, 197-200.

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/*

Polishook, D. (2012). *Minor Planet Bull.* **39**, 242-244.

Slyusarev, I.G., Shevchenko, V.G., Belskaya, I.N., Krugly, Yu.N., Chiorny, V.G. (2012). ACM 2012, #6398.

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., Stephens, R.D (2017). "Lightcurve Analysis of Hilda Asteroids at the Center for Solar System Studies: 2016 December thru 2017 April." *Minor Planet Bull.* **44**, 220-222.

2491 TVASHTRI: A NEW BINARY HUNGARIA ASTEROID

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

(Received: 2018 July 9)

CCD photometric observations were made of the Hungaria asteroid 2491 Tvashtri from 2018 Mar 29–April 27. Analysis of the data determined that the asteroid is binary with periods of P_1 = 4.0852 h and P_{ORB} = 26.712 h. The estimated ratio of effective diameters is $D_S/D_P \geq 0.24$.

The Hungaria asteroid 2491 Tvashtri has an estimated size of 4.5 km. While true Hungaria asteroids, those formed by the collision of two bodies, have a taxonomic class of E (Warner et al., 2009a), the orbital space (1.78 < *a* < 2.0 AU, *e* < 0.18, 16° < *i* < 34°) contains a large number of interlopers of both high and moderate albedo (Warner et al., 2009a; Milani et al., 2010; McEachern et al., 2010; DeMeo and Carry, 2013; Lucas et al., 2017). Tvashtri is a type X under the Tholen taxonomic system; this is a catch-all class where the spectroscopic plot is nearly flat over a large range of colors. Members of type X can include types E ($p_V \sim 0.46$), M ($p_V \sim 0.16$, and P ($p_V \sim 0.06$) (Warner et al., 2009a). Thermal observations that find the object's albedo are usually the only certain method to resolve the ambiguity.

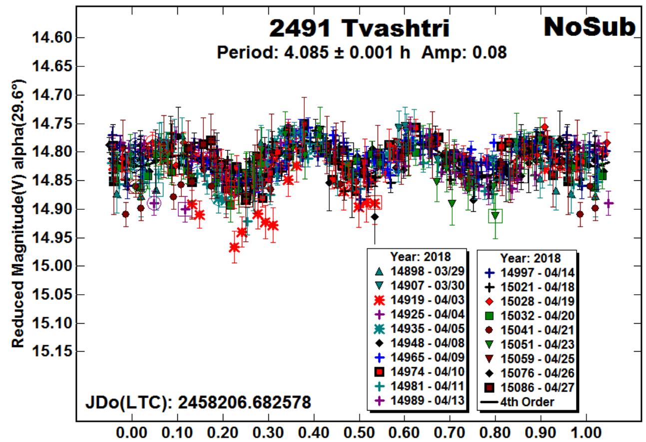
Previously published periods include Behrend (2008; 2.8 h), Stephens (2016; 4.274 h), and Waszczak et al. (2013; 5.662 h). The asteroid was also observed by the author on three previous occasions. Those will be discussed later. In all those earlier cases, there was no indication of a satellite.

The 2018 observations were made with a 0.35-m Schmidt-Cassegrain telescope and Finger Lakes ML-1001E, giving an image scale of about 1.5 arcsec/pixel. All exposures were guided, 240 sec, and unfiltered. Even a clear filter can cause a 0.1-0.3 mag loss. 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 catalog (Henden et al., 2009). The nightly zero points for the APASS catalogs are generally consistent to about ±0.05 mag or better, but occasionally reach > 0.1 mag. Period analysis was done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris *et al.,* 1989).

In the lightcurves below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying $-5*\log(r\Delta)$ 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. The X-axis is the rotational phase ranging from –0.05 to 1.05. The plots of the satellite's mutual events are differential values with the zero point being the average magnitude of the primary lightcurve.

The 2018 Observations

Analysis was done using 567 data points obtained over a period of almost one month. Fortunately, the phase angle changed very little over that time; the same applied to the phase angle bisector (PAB) longitude and latitude. This meant that was very little change in the viewing aspect during that time and, as it turned out, in the lightcurve featuring the satellite's mutual events (occultations and/or eclipses).



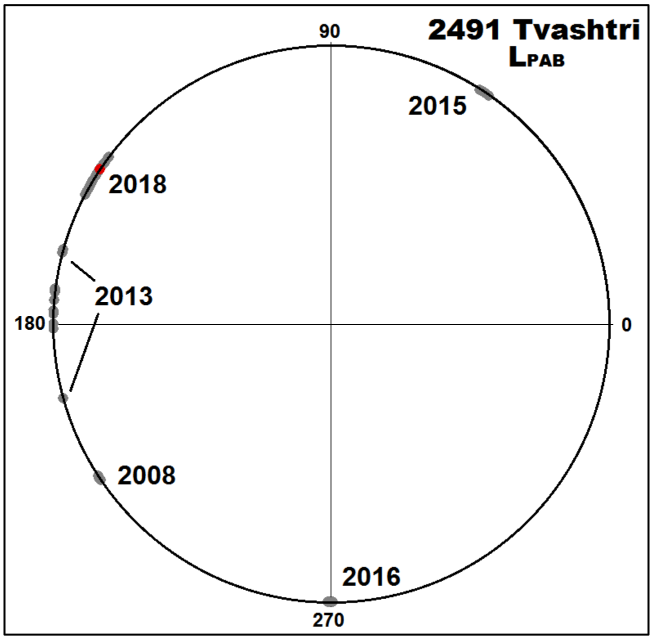
The single-period search preferred a solution of about 4.09 h. This produced a quadramodal lightcurve. This is not uncommon for low amplitude lightcurves (Harris et al. 2014). The half-period of 2.04 h produced a more typical bimodal shape with the amplitude of 0.08 ± 0.01 mag. Since the 4-hour period was similar to previous results, Warner (2008; 4.0839 h), (2013; 4.084 h), and (2015; 4.157 h), it was chosen as the more likely.

The single-period lightcurve appeared to show some deviations. The dual-period feature in *MPO Canopus*, which uses an iterative instead of simultaneous algorithm to find more than one period, was used to determine if the deviations were outlier data points or due to a second period. Given that all previous reports on the asteroid showed no signs of a satellite, the tendency was to favor spurious data.

However, it's worth noting at this point that in order to see the mutual events that confirm the existence of a satellite, the view of the asteroid must be (nearly) equatorial, assuming that the orbital plane of the satellite is close to the equatorial plane of the primary. If the pole of the primary has a very low obliquity, then the view is almost always equatorial. However, if the pole is significantly "tilted" (high obliquity) then getting an equatorial view is dependent on the viewing aspect. This is measured by the phase angle bisector longitude and, usually to a lesser degree, latitude.

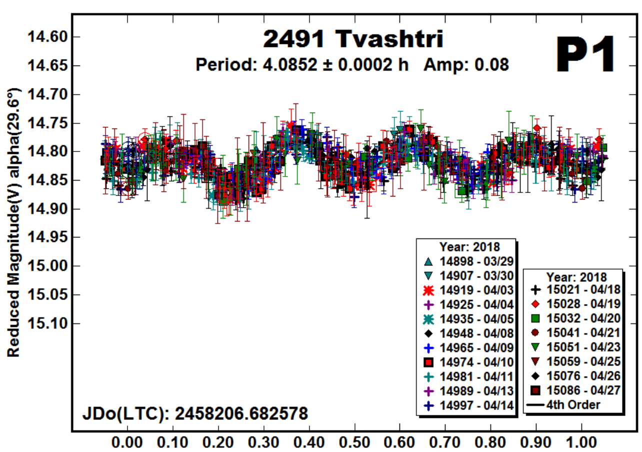
Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
2491	Tvashtri	03/29-04/27	567	29.6,33.6	148	19	4.0852	0.0002	0.08	0.01
	Orbital period						26.712	0.005	0.06-0.11	0.01

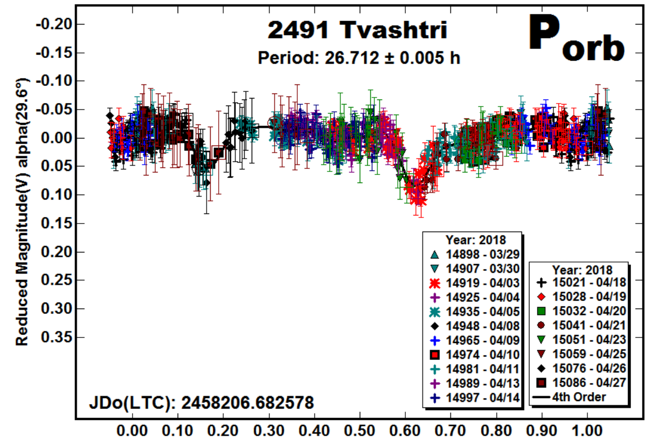
Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are, respectively, the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). The first line gives the results for the primary in the binary system. The second line gives the orbital period of the satellite and the amplitude range of mutual events.



The plot of phase angle bisector longitudes shows the values for the previous apparitions as well as in 2018. The 2013 observations (Waszczak et al., 2015) were very sparse, only a few data points a night, and so, even if conditions were right, a satellite could not have been found. The 2008 and 2015 apparitions differed by almost 180°, meaning they were essentially the same save for which of the asteroid's poles was being seen. The 2016 observations were almost 45° from the opposing longitude for 2018, making the two viewing aspects about as much different as possible. From all this, it's possible to give an approximate spin axis longitude of 145° or 325° and, less certain, |latitude| > 30°.

Using the 4-hour period as a starting point, the dual period search soon showed that the deviations were likely due to a satellite. With each night of additional data, the second period become better defined, as did the mutual events. Since the orbital period was just longer than an Earth day, getting sufficient data of the mutual events from a single longitude required a protracted campaign.





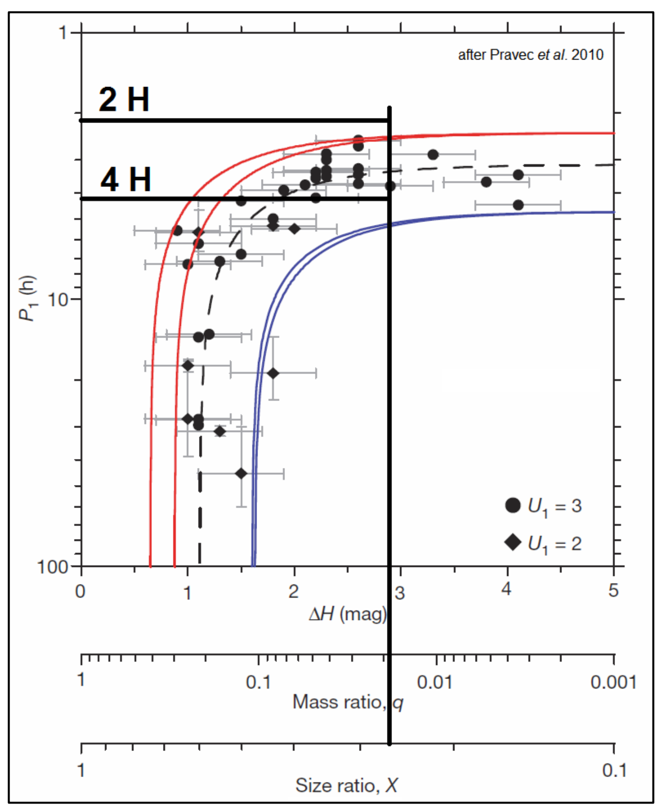
The "P_1" and "P_{ORB}" plots show the final results: P_1 = 4.0852 ± 0.0002 h, A_1 = 0.08 mag and P_{ORB} = 26.715 ± 0.005 h, A_{EVENTS} = 0.06-0.11 mag. The secondary lightcurve was flat outside of the events, indicating that the satellite is nearly spheroidal and probably tidally locked to the orbital period.

Using the lesser amplitude finds

$$\frac{Ds}{Dp} = \sqrt{(10^{0.4\Delta m} - 1.0)}$$

$$\geq 0.24 \pm 0.02$$

where D_S and D_P are, respectively, the effective diameters of the satellite and primary. The value is a minimum since no total eclipses were seen.



Positions using a 2-hour and 4-hour primary period are in shown the plot of primary period to size ratio (based on Pravec et al., 2010). The shorter period places the system outside the envelope while the 4-hour period is well within. This supports, but does not confirm, that the longer period is the more likely. “Rules are made to be broken.”

The asteroid lightcurve database (LCDB; Warner et al., 2009b) has 48 Hungaria binaries, 26 of those are confirmed binary or multiple systems. This compares to 68 confirmed near-Earth asteroids (Johnston, 2018), who lists 21 confirmed binary/multiple Hungarias. Even when using the more conservative numbers, this gives N_H/N_{NEA} of 31%.

It’s not expected that the two numbers be the same. Instead, the ratio being well above zero helped determine that it was not tidal forces during planetary encounters that formed NEA binaries (e.g., Warner and Harris, 2006; Pravec et al., 2008) but that the thermal YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack; Rubincam, 2000) effect had caused small asteroids to “spin up” (periods shortened) to where they shed mass and formed a satellite.

Acknowledgements

Work on the asteroid lightcurve database (LCDB) was funded by National Science Foundation grant AST-1507535. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

References

Behrend, R. (2008). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

DeMeo, F.E., Carry, B. (2013). “The taxonomic distribution of asteroids from multi-filter all-sky photometric surveys.” *Icarus* **226**, 723-741.

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*

Johnston, W.R. (2018). “Asteroids with Satellites” web site. *http://www.johnstonsarchive.net/astro/asteroidmoons.html*

Lucas, M.P., Emery, J.P., Pinilla-Alonso, N., Lindasav, S.S., Lorenzi, V. (2017). “Hungaria asteroid region telescopic spectral survey (HARTSS) I: Stony asteroids abundant in the Hungaria background population.” *Icarus* **291**, 268-287.

McEachern, F.M., Cuk, M., Steward, S.T. (2010). “Dynamical evolution of the Hungaria asteroids.” *Icarus* **210**, 644-654.

Milani, A., Knezevic, Z., Novakovic, B., Cellino, A. (2010). “Dynamics of the Hungaria asteroids.” *Icarus* **207**, 769-794.

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

Pravec, P., Harris, A.W., Vokrouhlický, D., Warner, B.D., Kušnirák, P., Hornoch, K., Pray, D.P., Higgins, D., Oey, J., Galád, A., Gajdoš, Š., Kornoš, L., Világi, J., Husárik, M., Krugly, Yu.N., Shevchenko, V., Chiorny, V., Gaftonyuk, N., Cooney, W.R., Gross, J., Terrell, D., Stephens, R.D., Dyvig, R., Reddy, V., Ries, J.G., Colas, F., Lecacheux, J., Durkee, R., Masi, G., Koff, R.A., Goncalves, R. (2008). “Spin rate distribution of small asteroids.” *Icarus* **197**, 497-504.

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

Stephens, R.D. (2016). “Asteroids Observed from CS3: 2016 April - June.” *Minor Planet Bull.* **43**, 336-339.

Warner, B.D., Harris, A.W. (2006). “A Comparative Study of Hungaria versus NEA Binary Populations and Spin Axis Characteristics.” *Bull. American Ast. Soc.* **38**, p. 596.

Warner, B.D., Harris, A.W., Vokrouhlicky, D., Nesvorny, D., Bottke, W.F. (2009a). “Analysis of the Hungaria asteroid population.” *Icarus* **204**, 172-182.

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

Warner, B.D. (2008). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory: February-May 2008.” *Minor Planet Bull.* **35**, 163-167.

Warner, B.D. (2013). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2013 January – March.” *Minor Planet Bull.* **40**, 137-145.

Warner, B.D. (2015). “Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 December - 2015 March.” *Minor Planet Bull.* **42**, 167-172.

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.

THREE ASTEROIDS FROM ETSCORN: 461 SASKIA, 3800 KARAYUSUF AND (42701) 1998 MD13

Daniel A. Klinglesmith III, Erin, Aaron Lovato
Etscorn Campus Observatory
New Mexico Tech
101 East Road
Socorro, NM 87801
dklinglesmith@mro.nmt.edu

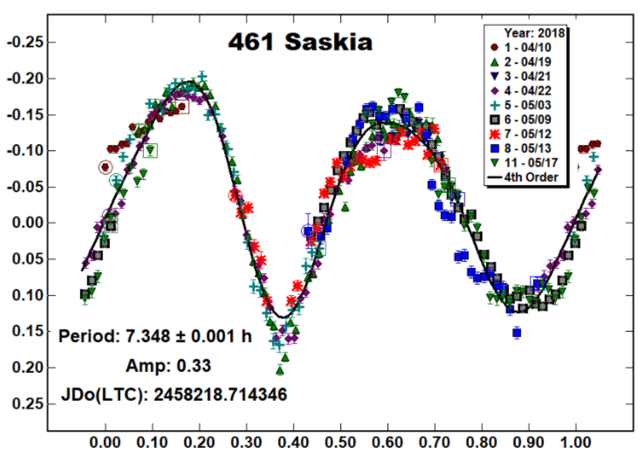
(Received: 2018 July 12)

In the second quarter of 2018 we obtained lightcurves for three asteroids. 461 Saskia, 3800 Karayusuf and (42701) 1998 MD13. 461 Saskia and 3800 Karayusuf are spin-shape candidates and (42701) 1998 MD13 is a first time observation for a lightcurve determination.

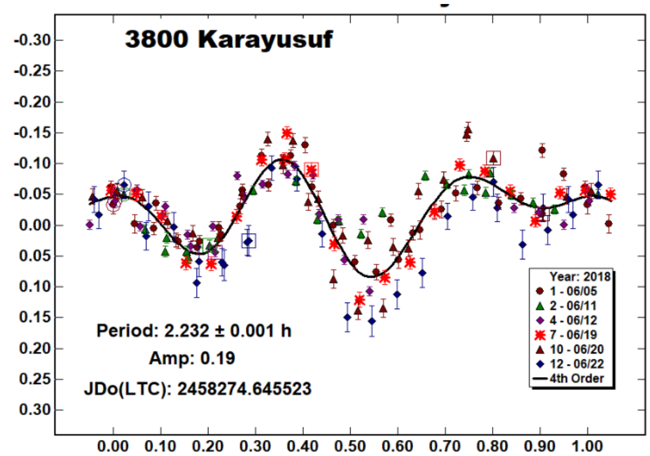
Our observations of the three asteroids reported here were obtained with two Celestron 0.35-m telescopes equipped with SBIG STL1001E CCD camera systems at the Etscorn Campus Observatory. (Klinglesmith and Franco, 2016). The images were processed and calibrated using MPO Canopus 10.7.2.0 (Warner, 2017). Exposures were between 300 and 420 seconds through clear filters depending on the brightness of the asteroids. The multi-night data sets for each asteroid were combined with the FALC algorithm (Harris et al., 1989) within MPO Canopus to provide synodic periods for each asteroid.

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

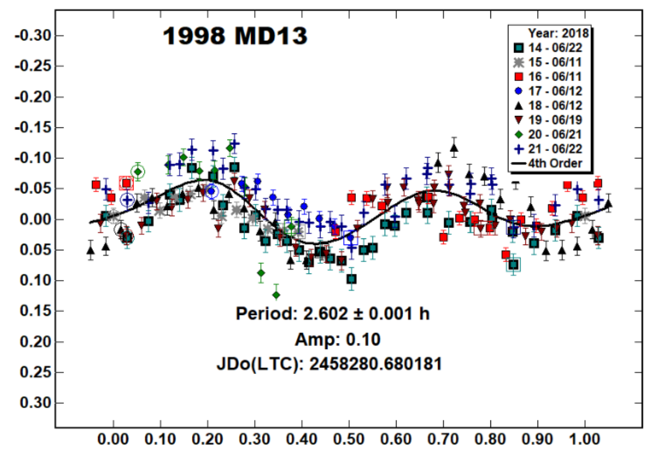
461 Saskia is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1900 Oct 22. It is also known as 1900 FP. We observed it on 9 nights between 2018 Apr 10 and May 17. We obtained a synodic period of 7.348 ± 0.001 h, with an amplitude of 0.33 mag.



3800 Karayusuf is a Mars-crossing asteroid discovered by E. F. Helin at Palomar Observatory on 1984 Jan 4. We observed it on 6 nights between 2018 Jun 05 and Jun 22. We obtained a synodic period of 2.232 ± 0.001 h, with an amplitude of 0.19 mag.



(42701) 1998 MD13 is a main-belt asteroid discovered by LINEAR at Socorro on 1998 Jun 19. We observed it on 6 nights between 2018 Jun 11 and Jun 22. We obtained a synodic period of 2.602 ± 0.001 h, with an amplitude of 0.10 mag.



Acknowledgements

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Engineering.

References

Buchhelm, R.K., (2006), "Lightcurves of 125 Liberatrux, 461Saskia, and 2781 Kleczek." *Minor Planet Bull*, **33**,63.

Behrend, R., (2001, 2007), Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.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

Klinglesmith III, D.A., Hanowell, J., Risely, E., Turk, J., et al. (2013). "Inversion Model Candidates." *Minor Planet Bull.* **40**, 190-193.

JPL (2017). Small-Body Database Browser.
http://ssd.jpl.nasa.gov/sbdb.cgi#top

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
461	Saskia	04/10-05/17	264	3.1,14.4	192	1	7.348	0.001	0.33	0.05	MB-O
3800	Karayusuf	06/05-06/22	151	26.0,32.0	234	13	2.232	0.001	0.10	0.05	MC
(42701)	1998 MD13	06/11-06/22	161	14.2-18.2	242	12	2.602	0.001	0.19	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). Grp is the asteroid family/group (Warner *et al.*, 2009).

Number	Name	References	Date	L_{pab}	B_{pab}	Phase	Period	Amp.
461	Saskia	This paper	2018 Apr 29	192	1	8.6	7.348	0.33
		Buchhelm 2006	2006 Ja 08	96	-2	5.3	7.34	0.25
		Behrend 2007	2007 Apr 20	197	1	4.8	7.348	0.36
		Klinglesmith 2017	2016 Dec 14	89	-2	3.2	7.348	0.28
		Klinglesmith 2013	2013 May 12	230	2	0.7	7.349	0.26
3800	Karayasuf	This paper	2018 Jun 18	234	13	29.0	2.232	0.10
		Warner 2008	2008 Mar 30	180	28	27.8	2.2319	0.15
		Warner 2010	2013 Mae 19	186	28	27.2	2.232	0.15
		Warner 2014	2014 Mar 16	199	26	32.1	2.231	0.19
		Skiff 2018	2018 May 10	227	22	22.3	2.225	0.15
		Warner 2018	2018 Jun 03	232	16	25.4	2.238	0.18

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

Klinglesmith III, D.A., Franco, L. (2016). "Lightcurves for 1531 Hartmut and 4145 Maximova." *Minor Planet Bull.* **43**, 121.

Klinglesmith III, D.A. (2017). "Spin-Shape Model Lightcurves", *Minor Planet Bull.* **44**, 127-129.

Skiff, B.A. (2018). Posting on CALL web site: *http://www.minorplanet.info/call.html.*

Warner, B.D. (2008). "Asteroid Lightcurve Analysis at Palmer Divide Observatory: February-May 2008." *Minor Planet Bull.* **35,** 163-167.

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. (2010). "Asteroid Lightcurve Analysis at Palmer Divide Observatory: 2010 March-June." *Minor Planet Bull.* **37**, 161-165.

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

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

Warner, B.D. (2018). *http://www.planetarysciences.org/PHP/CS3_Lightcurves.php*

LIGHTCURVES FOR 91 AEGINA, 235 CAROLINA, 1117 REGINITA, AND (505657) 2014 SR339

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

Giorgio Baj
M57 Observatory (K38), Saltrio, ITALY

Giulio Scarfi
Iota Scorpii Observatory (K78), La Spezia, ITALY

Giacomo Succi, Mauro Bachini
Santa Maria a Monte (A29), ITALY

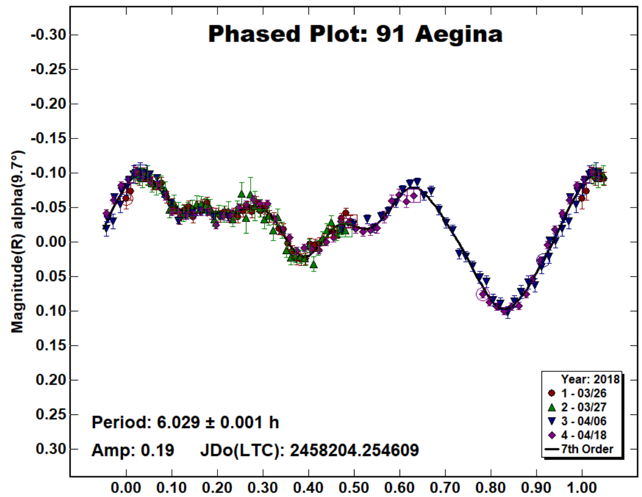
Claudio Arena
CT Observatory, Catania, ITALY

(Received: 2018 Jul 7)

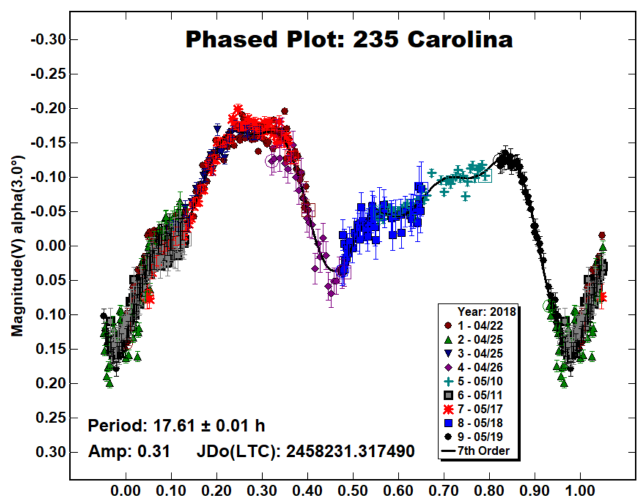
Photometric observations of three main-belt and one near-Earth asteroids were made in order to acquire lightcurves for shape/spin axis models. For 91 Aegina, the synodic rotation period is 6.029 ± 0.001 h, amplitude 0.19 mag. For 235 Carolina, the synodic rotation period is 17.61 ± 0.01 h, amplitude 0.31 mag. For 1117 Reginita, the synodic rotation period is 2.9467 ± 0.0001 h, amplitude 0.19 mag. For (505657) 2014 SR339, the synodic rotation period is 8.71 ± 0.01 h, amplitude 0.75 mag.

Collaborative observations were made inside the UAI (Italian Amateur Astronomers Union; DSTFA, 2018) of a group of asteroids listed in the Lightcurve/Photometry Opportunities and Shape/Spin Modeling Opportunities sections from recent issues of the *Minor Planet Bulletin*. The CCD observations were made in 2018 February-May using the instrumentation described in Table I. Lightcurve analysis was done at the Balzaretto Observatory with *MPO Canopus* (Warner, 2016). All the images were calibrated with dark and flat frames and converted to R magnitudes using solar colored field stars from a version of the CMC-15 catalogue (Munos, 2017) distributed with *MPO Canopus*. Table II shows the observing circumstances and results.

91 Aegina is a C-type middle main-belt asteroid discovered on 1866 November 4 by E. Stephan at Marseille. Collaborative observations of this asteroid were made over four nights. We derived a synodic period of $P = 6.029 \pm 0.001$ h with an amplitude $A = 0.19 \pm 0.01$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



235 Carolina is an S-type outer main-belt asteroid discovered on 1883 November 28 by J. Palisa at Vienna. Collaborative observations of this asteroid were made over eight nights. We derived a synodic period of $P = 17.61 \pm 0.01$ h with an amplitude $A = 0.31 \pm 0.04$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



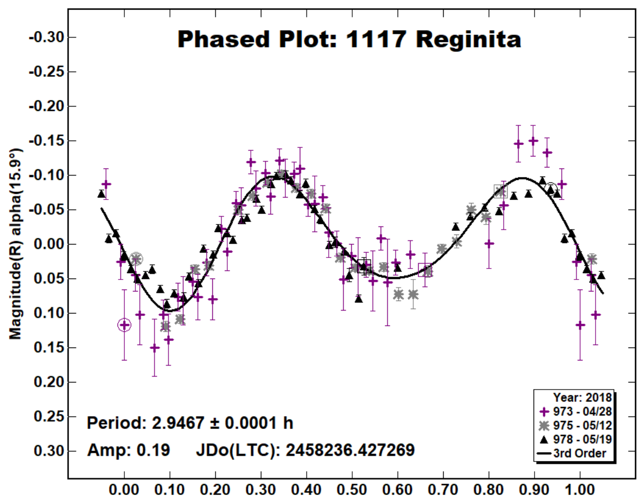
Observatory (MPC code)	Telescope	CCD	Filter	Observed Asteroids
Università Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e (bin 2x2)	Rc	91, 235, 1117
M57 (K38)	0.30-m RCT f/5.5	SBIG STT-1603	C	91, 235, (505657)
Iota Scorpii(K78)	0.40-m RCT F/8	SBIG STXL-6303e (bin 2x2)	Rc	235
Santa Maria a Monte(A29)	0.40-m NRT f/5	DTA Discovery plus Kaf 260	Rc, C	235
CT Observatory	0.20-m NRT f/5	ATIK 314L+	Rc	235

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

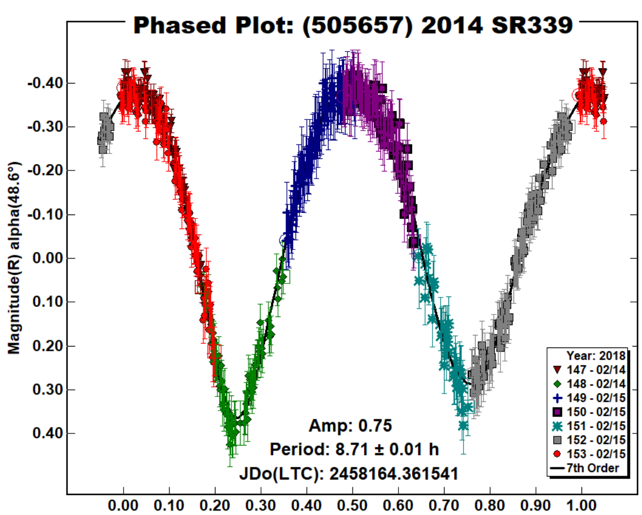
Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
91	Aegina	03/26-04/18	209	9.7,17.5	166	1	6.029	0.001	0.19	0.01
235	Carolina	04/22-05/19	624	2.9,9.9	215	5	17.61	0.01	0.31	0.04
1117	Reginita	04/28-05/19	116	15.5,5.9	243	7	2.9467	0.0001	0.19	0.03
505657	2014 SR339	02/14-02/15	541	48.5,49.3	123	16	8.71	0.01	0.75	0.03

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

1117 Reginita is a medium albedo inner main-belt asteroid discovered on 1927 May 24 by J. Comas Sola at Barcelona. Observations of this asteroid were made over three nights. We derived a synodic period of P = 2.9467 ± 0.0001 h with an amplitude A = 0.19 ± 0.03 mag. The period is consistent with the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



(505657) 2014 SR339 is a low albedo Apollo NEA discovered on 2014 September 30 by the WISE Survey. Observations of this asteroid were made over two nights. We derive a synodic period of P = 8.71 ± 0.01 h with an amplitude A = 0.75 ± 0.03 mag. The period, amplitude, and lightcurve shape are a bit different when compared to the previously published result (Warner, 2018); this is probably due to the differences in the observing geometries.



References

DSFTA (2018). 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.

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 2018 June. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2016). MPO Software, *MPO Canopus* v10.7.7.0. Bdw Publishing. *http://bdwpublishing.com*

Warner, B.D. (2018). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2018 January-April." *Minor Planet Bull.* **45**, 248-256.

LIGHTCURVE ANALYSIS OF ASTEROIDS 2040 CHALONGE, 4575 BROMAN AND 5852 NANETTE

Caroline E. Odden, Anjalie S. Kini, Jacob I. Buehler,
Eliana L. Kozol, Ora Cullen, Junping Tang
Phillips Academy Observatory (MPC I12)
180 Main Street
Andover, MA 01810 USA
ceodden@andover.edu

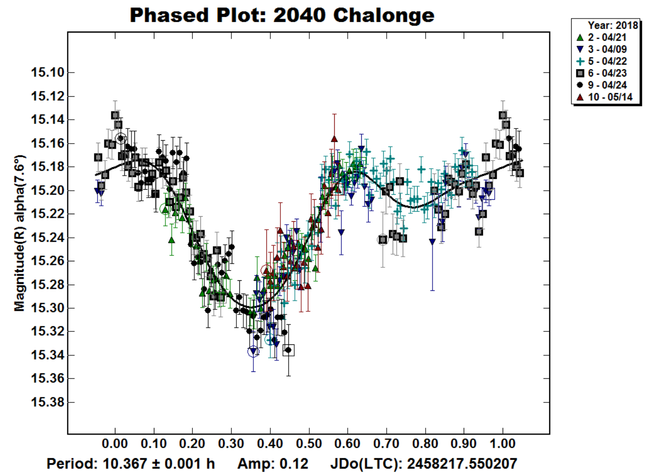
(Received: 2018 July 13)

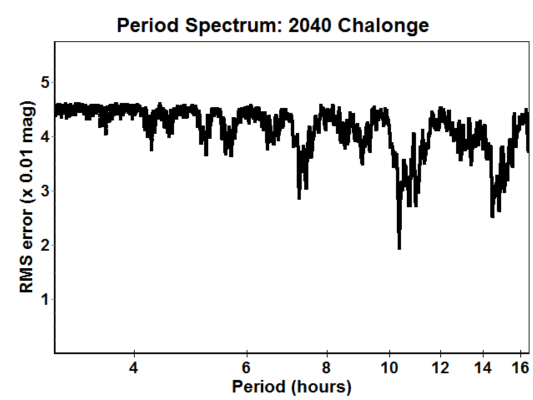
Photometric observations of asteroids 2040 Chalonge 4575 Broman, and 5852 Nanette were made at the Philips Academy Observatory from 2018 March through 2018 June. 2040 Chalonge was found to have rotational period of 10.367 ± 0.001 h with amplitude 0.12 mag, consistent with the previously reported period; 4575 Broman was found to have a rotational period of 10.774 ± 0.001 h with an amplitude of 0.59 mag; 5852 Nanette was found to have a rotational period of 5.606 ± 0.001 h with an amplitude of 0.49 mag.

CCD photometric observations of 2040 Chalonge, 4575 Broman, and 5852 Nanette were made between 2018 March and 2018 June at the Phillips Academy Observatory as part of a high school astronomy research course taught by Odden. The CALL website was used to select the targets, which were chosen for their favorable declinations, appealing names, and relatively bright magnitudes. All observations were made with a 0.40-m *f*/8 Ritchey-Chrétien telescope by DFM Engineering. Images were taken with an Andor Tech iKon DW436 camera with a 2048x2048 array of 13.5-micron pixels. The resulting image scale was 0.86 arcseconds per pixel. All images were dark- and flat-field corrected, unbinned, and guided. The images were calibrated with *AstroimageJ* software (Collins et al., 2017).

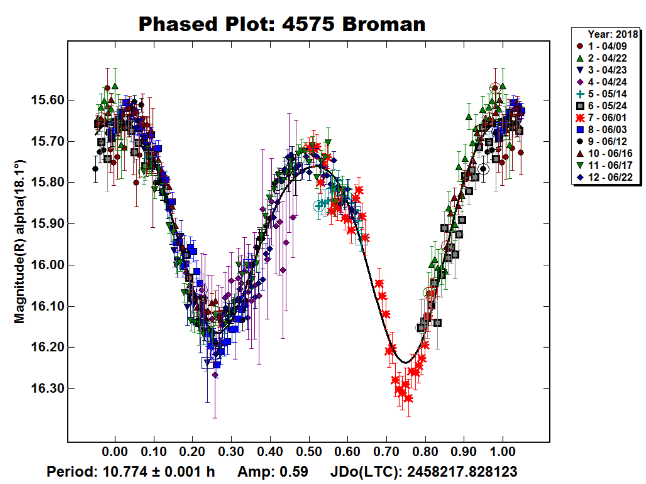
MPO Canopus was used to make photometric measurements of the asteroid as well as to generate the final lightcurve and period spectrum. Comparison stars were chosen to have near solar color using the Comp Star Selector tool in *MPO Canopus*. In addition, brighter comparison stars were favored. Data merging and period analysis were also done with *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris (Harris *et al.*, 1989). The combined data sets were analyzed by the authors.

<u>2040 Chalonge</u> was observed for six nights in 2018 April. A total of 285 data points were used, resulting in a composite lightcurve with period 10.367 ± 0.001 h and amplitude 0.12 mag. 2040 Chalonge was measured previously (Odden et al., 2016) and reported to have a rotational period of 10.383 ± 0.001 h with amplitude 0.22 mag. The results reported here are consistent with those findings. The period spectrum is included along with the composite lightcurve.



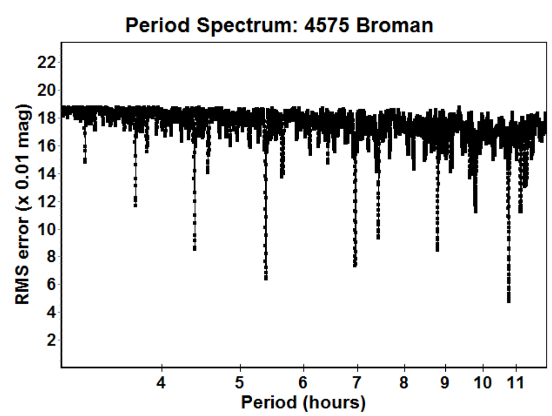


<u>4575 Broman</u> was observed for twelve nights between 2018 April and 2018 June. No previous entries were found in the asteroid lightcurve database (Warner et al., 2009). A total of 403 data points were used, resulting in a composite lightcurve with period 10.774 ± 0.001 h and amplitude 0.59 mag. Given the amplitude, a bimodal solution is expected. The period spectrum is included along with the composite lightcurve.

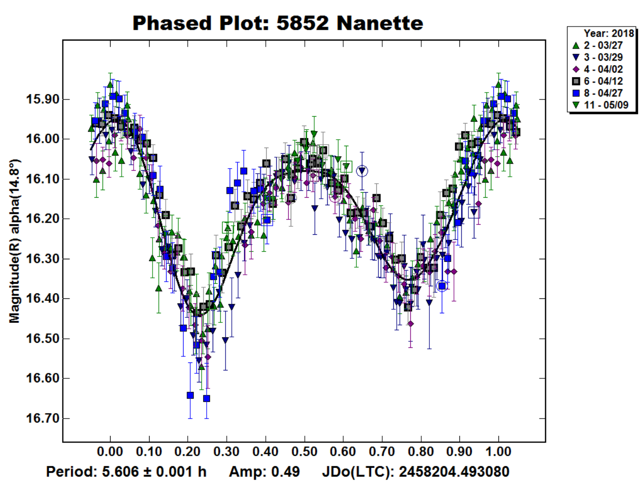


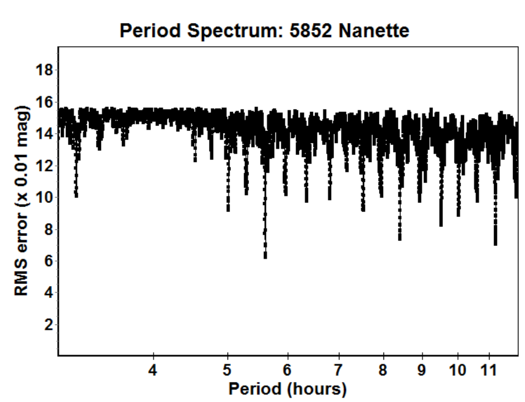
Number	Name	2016/2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	TxC
2040	Chalonge	04/09-04/24	285	3.7,8.3	194.5	7.0	10.367	0.001	0.12	0.03	C
4575	Broman	04/22-06/22	403	18.0,8.2	254.5	13.2	10.774	0.001	0.59	0.05	C
5852	Nanette	03/27-05/09	326	14.7,22.9	161.6	22.1	5.606	0.001	0.49	0.05	C

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). TxC is the taxonomic class as found in the LCDB (Warner *et al.*, 2009).



5852 Nanette was observed for six nights between 2018 March and 2018 June. No previous entries were found in the asteroid lightcurve database (Warner et al., 2009). A total of 326 data points were used, resulting in a composite lightcurve with period 5.606 ± 0.001 h and amplitude 0.49 mag. Given the amplitude, a bimodal solution is expected. The period spectrum is included along with the composite lightcurve.





Acknowledgements

Research at the Phillips Academy Observatory is supported by the Israel Family Foundation. Funding for the Andor Tech camera was generously provided by the Abbot Academy Association.

References

CALL: Potential Lightcurve Targets (with LCDB data) Query. *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*

Collins et al., 2017, *AstroImageJ*, v. 3.2.0. *http://www.astro.louisville.edu/software/astroimagej/*

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.

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

Odden, C.E., Caso, M., Dettore, C., Dial, P.J., Hoang, K., Hughes, R., Lazar, T.T., Morss, P.P., Mundra, A.R., Naiyapatana, A., Rooney, M. (2017). "Lightcurve Analysis of 1773 Rumplestilz and 2040 Chalonge." *Minor Planet Bull.* **44**, 219-220.

Warner, B.D. (2010). *The MPO Users Guide: A Companion Guide to the MPO Canopus/PhotoRed Reference Manuals.* BDW Publishing, Colorado Springs, CO.

Warner, B.D., Harris, A.W., Pravec, P. (2009). *Icarus* **202**, 134-146. Updated 2018 June 23. *http://www.MinorPlanet.info/lightcurvedatabase.html*

[Editor's Note: Congratulations to this team of high school students and a salute to their mentor Odden for guiding them.]

LIGHTCURVE FOR 3800 KARAYUSUF

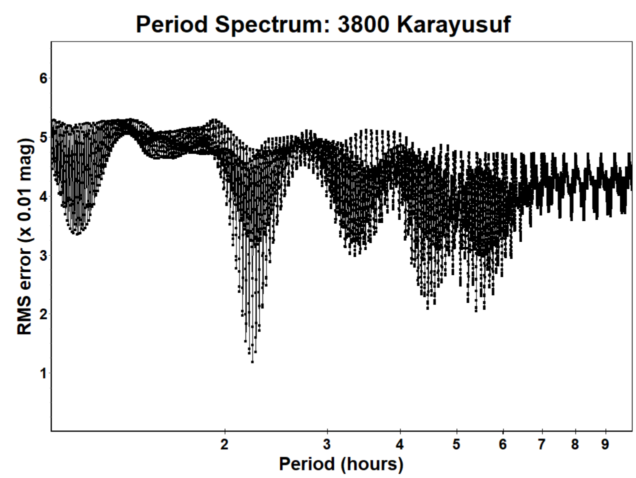
Lorenzo Franco
Balzaretto Observatory (A81), Rome, ITALY
lor_franco@libero.it

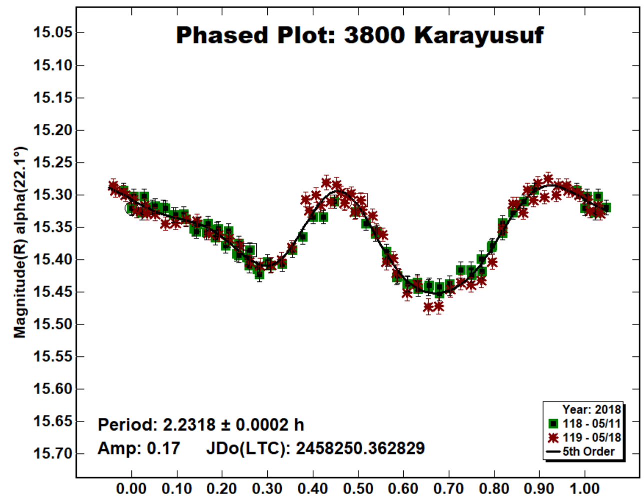
Paolo Bacci, Martina Maestripieri,
Giulio Carotta, Marco Carotta, Linda Nesti and Martina Fragai
San Marcello Pistoiese (104), Pistoia, ITALY

(Received: 2018 July 14)

Photometric observations of Mars-crosser 3800 Karayusuf were made in May 2018. Lightcurve analysis shows a synodic rotation period P = 2.2318 ± 0.0002 hours with an amplitude 0.17 magnitudes.

Photometric observations were made over two nights in 2018 May at San Marcello Pistoiese Observatory (104) using a 0.60m Newtonian Telescope (f/4) equipped with a Apogee Alta CCD camera. Lightcurve analysis was done at the Balzaretto Observatory with *MPO Canopus* (BDW Publishing, 2016). All the images were calibrated with dark and flat frames and converted to R magnitudes using solar colored field stars from CMC15 catalogue. Table I shows the observing circumstances and results. 3800 Karayusuf is an S-type Mars-crosser asteroid discovered on 1984 January 4 by Helin E. F. at Palomar. We derive a synodic period of P = 2.2318 ± 0.0002 h with an amplitude A = 0.17 ± 0.02 mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009). The lightcurve shows some attenuation events, probably due to the binary nature of this asteroid, as noted by Warner (2008, 2014).





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. (2008). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: February – May 2008." *Minor Planet Bulletin* **35**, 163-167.

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

Warner, B.D. (2016). MPO Software, MPO Canopus v10.7.7.0. Bdw Publishing. *http://minorplanetobserver.com*

Number	Name	2018 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
3800	Karayusuf	05/11-05/18	132	22.0,22.0	228	21	2.2318	0.0002	0.17	0.02

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 PHOTOMETRY OPPORTUNITIES: 2018 OCTOBER-DECEMBER

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 2018 October-December.

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 italics is a near-Earth asteroid (NEA).

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
4025	Ridley	10 01.2	15.1	-1			
2487	Juhani	10 01.8	14.6	+5			
2835	Ryoma	10 03.1	15.0	+4	18.234	0.17	2
3844	Lujiaxi	10 04.1	14.7	+0	13.33	0.34	2+
14510	1996 ES2	10 07.3	15.0	+12			
917	Lyka	10 07.4	13.1	+11	7.92	0.10-0.14	2
5321	Jagras	10 09.3	14.6	+12			
1236	Thais	10 10.3	13.6	-8	>72.	0.08	1
2056	Nancy	10 10.4	13.8	+10	>15.	0.08	1
7230	Lutz	10 11.0	14.7	+6			
2010	Chebyshev	10 12.1	14.6	+8			
2070	Humason	10 12.1	14.7	+9			
3994	Ayashi	10 12.5	14.7	+4		0.1	
1707	Chantal	10 14.1	13.8	+10	>10.	0.2	1
1053	Vigdis	10 15.6	14.9	+10			
2244	Tesla	10 17.6	14.7	-4			
3381	Mikkola	10 18.0	14.9	+16			
55567	2002 CS6	10 19.2	15.0	+12	6.646	0.48	2
6582	Flagsymphony	10 19.9	14.4	+10			
3069	Heyrovsky	10 21.8	15.0	+11	6.6	0.23	2
1390	Abastumani	10 22.9	13.9	+11	17.1	0.15	2
1033	Simona	10 23.2	14.6	+6	10.07	0.04	1+
2178	Kazakhstania	10 26.6	14.9	+15			
4467	Kaidanovskij	10 29.2	14.6	+14	>12.	0.03	1
16529	Dangoldin	10 31.4	15.0	-8			
6801	Strekov	11 01.0	14.9	+13	6.173	0.17	2
5703	Hevelius	11 01.1	15.0	+15			
2413	van de Hulst	11 01.2	15.0	+2			
7485	Changchun	11 01.9	14.9	-3			
1112	Polonia	11 04.4	13.8	+29	82.5	0.20	2
6540	Stepling	11 06.2	14.9	+11			
1385	Gelria	11 07.4	14.0	+6		0.36	
6608	Davidecrespi	11 09.3	14.9	+15	>20.	0.3	2
1839	Ragazza	11 15.9	14.6	+19			
1475	Yalta	11 17.2	14.4	+14			
37306	2001 KW46	11 18.0	14.7	+19	5.621	0.10	2
2290	Helffrich	11 18.4	14.7	-2		0.10	
1079	Mimosa	11 19.1	14.5	+21	64.6	0.07-0.13	2-
7409	1990 BS	11 19.6	14.7	+19	31.61	0.20	2
2946	Muchachos	11 21.3	15.0	+21			
3769	Arthurmiller	11 24.7	15.0	+21			
1965	van de Kamp	11 27.6	14.5	+20	>36.	0.5	1
2245	Hekatostos	11 29.9	14.3	+15	20.61	0.21	2+
3204	Lindgren	11 30.3	14.7	+19	5.614	0.15	2
2678	Aavasaksa	12 04.5	14.4	+24	>24.	0.4	1
2085	Henan	12 07.0	14.9	+18	>24.	0.25	1
1544	Vinterhansenia	12 07.9	14.0	+24	13.77	0.15-0.18	2
1826	Miller	12 10.4	14.7	+27	30.049	0.08	2
4807	Noboru	12 20.1	14.8	+24			
5522	De Rop	12 20.5	14.9	+24			
2872	Gentelec	12 23.6	15.0	+21	10.624	0.16	2
72396	2001 CU20	12 24.9	14.9	+25	8.0467	0.1	2
1553	Bauersfelda	12 30.1	14.8	+22	51.191	0.26	2

Low Phase Angle Opportunities

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

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

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

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

The International Astronomical Union (IAU) has adopted a new system, H-G_{12}, introduced by Muinonen *et al.* (2010; *Icarus* **209**, 542-555). It will be some years before H-G_{12} becomes the standard. Furthermore, it still needs refinement. That can be done mostly by having data for more asteroids, but only if at very low and moderate phase angles. We strongly encourage obtaining data every degree between 0° to 7°, the non-linear part of the curve that is due to the opposition effect. At angles 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
66	Maja	10 06.7	0.28	11.7	+06	9.7351	0.21-0.45	3
83	Beatrix	10 07.7	0.72	11.9	+04	10.16	0.18	3
766	Moguntia	10 08.0	0.63	13.9	+07	4.816	0.06-0.23	3
485	Genua	10 08.4	0.25	11.7	+05	17.59	0.12-0.16	3
160	Una	10 09.5	0.33	12.2	+07	11.033	0.10-0.18	3
569	Misa	10 16.9	0.93	12.8	+11	11.595	0.09-0.25	3
968	Petunia	10 22.1	0.09	14.0	+11	61.280	0.30-0.38	3
1390	Abastumani	10 22.9	0.06	13.9	+11	17.100	0.15	2
767	Bondia	10 30.0	0.96	13.6	+11	>60.	0.1	2
368	Haidea	11 08.4	0.15	13.7	+17	9.823	0.15-0.23	3
222	Lucia	11 09.5	0.48	13.9	+15	7.837	0.25-0.41	3
425	Cornelia	11 13.4	0.37	13.8	+17	17.505	0.19-0.21	3
508	Princetonia	11 13.6	0.72	12.8	+20	52.8	0.40	3
447	Valentine	11 17.9	0.73	12.8	+17	9.651	0.18	3
456	Abnoba	11 17.9	0.67	13.7	+17	18.281	0.2 -0.32	3
293	Brasilia	11 18.1	0.89	13.7	+17	8.17	0.20-0.30	3-
278	Paulina	11 20.9	0.25	13.5	+19	6.497	0.32-0.51	3
12	Victoria	11 22.3	0.45	10.1	+19	8.660	0.04-0.42	3
492	Gismonda	11 24.2	0.24	13.7	+21	6.488	0.10-0.14	3
1307	Cimmeria	11 28.1	0.75	14.0	+20	2.820	0.29-0.31	3
419	Aurelia	11 29.6	0.56	12.7	+20	16.784	0.07-0.18	3
153	Hilda	12 02.0	0.80	13.6	+18	5.959	0.04-0.20	2+
128	Nemesis	12 04.2	0.33	10.5	+21	77.81	0.08-0.10	3-
1303	Luthera	12 08.7	0.68	13.9	+25	5.878	0.05-0.06	3
455	Bruchsalia	12 11.3	0.44	11.8	+24	11.85	0.10-0.35	2+
847	Agnia	12 11.5	0.35	13.4	+24	14.827	0.05-0.51	3
241	Germania	12 13.2	0.44	11.6	+24	15.51	0.05-0.17	3
184	Dejopeja	12 15.4	0.48	12.7	+25	6.455	0.25-0.3	3
901	Brunsia	12 19.9	0.14	13.9	+23	3.136	0.09-0.28	3
700	Auravictrix	12 20.2	0.79	13.6	+22	6.075	0.18-0.43	3
122	Gerda	12 21.4	0.74	12.2	+21	10.685	0.10-0.26	3
90	Antiope	12 24.5	0.34	13.1	+25	16.509	0.05-0.88	3
548	Kressida	12 31.1	0.68	12.6	+22	11.940	0.44	2

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
1376	**Michelle**	**10 02.1**	**13.7**	**+1**	**5.9748**	**0.03-0.20**	**3**
2017	Wesson	10 03.6	14.5	+1	3.4158	0.38-0.60	3
1225	Ariane	10 05.7	14.3	+5	5.5068	0.30-0.36	3
766	**Moguntia**	**10 08.0**	**13.9**	**+7**	**4.8164**	**0.06-0.23**	**3**
78	Diana	10 08.3	11.8	+14	7.2991	0.02-0.30	3
256	Walpurga	10 11.0	14.2	+2	16.664	0.25-0.58	3
5080	Oja	10 11.3	14.6	+12	7.222	0.31-0.39	3
656	Beagle	10 14.4	14.6	+8	7.035	0.57-1.20	3
5985	1942 RJ	10 16.8	14.6	+22	9.7212	0.11-0.18	3
2151	**Hadwiger**	**10 18.0**	**14.1**	**+8**	**5.872**	**0.07-0.38**	**3**
3223	Forsius	10 19.4	14.4	+0	2.343	0.20-0.28	3
465	Alekto	10 21.3	15.0	+17	10.936	0.12-0.18	3
1660	Wood	10 21.9	14.3	+14	6.809	0.14-0.26	3
3447	Burckhalter	10 24.9	14.6	+33	59.8	0.10-0.39	3
1845	Helewalda	10 25.5	15.3	-2	7.2786	0.15-0.34	3-
654	Zelinda	10 29.4	11.7	+37	31.735	0.08- 0.3	3
195	Eurykleia	11 04.1	12.9	+21	16.521	0.10-0.24	3
619	Triberga	11 04.1	13.0	+3	29.311	0.30-0.45	3
2903	Zhuhai	11 04.2	14.8	+20	5.263	0.32-0.54	3
1523	Pieksamaki	11 04.5	15.1	+23	5.3202	0.28- 0.5	3
834	Burnhamia	11 04.6	14.2	+12	13.875	0.15-0.22	3
860	Ursina	11 06.5	14.1	+36	9.386	0.22-0.50	3
205	**Martha**	**11 07.7**	**12.7**	**+13**	**14.911**	**0.10-0.50**	**3**
368	Haidea	11 08.3	13.7	+17	9.823	0.15-0.23	3
4910	Kawasato	11 09.8	15.2	+10	4.662	0.10-0.22	3
4451	Grieve	11 10.9	14.6	+7	6.864	0.56-0.80	3
1830	Pogson	11 11.3	14.8	+10	2.57	0.10-0.18	3
1369	Ostanina	11 12.8	15.2	+3	8.4001	0.3 -1.11	3
545	Messalina	11 13.8	13.7	+34	7.2	0.22-0.27	3
2004	**Lexell**	**11 14.3**	**14.5**	**+22**	**5.4429**	**0.42-0.51**	**3**
755	Quintilla	11 16.0	14.8	+15	4.552	0.08-0.45	3
643	Scheherezade	11 17.2	14.3	+25	14.161	0.23-0.37	3
456	Abnoba	11 17.9	13.7	+17	18.281	0.2- 0.32	3
4497	**Taguchi**	**11 18.2**	**13.9**	**+6**	**3.563**	**0.11-0.21**	**3**
2642	Vesale	11 19.3	15.2	+4	5.566	0.12-0.39	3
1308	Halleria	11 20.5	14.8	+27	6.028	0.14-0.17	3
750	Oskar	11 21.9	14.8	+19	6.2584	0.07-0.20	3
261	Prymno	11 25.6	12.2	+17	8.002	0.13-0.20	3
101	Helena	11 25.8	11.7	+37	23.08	0.09-0.13	3
267	Tirza	11 26.9	14.2	+20	7.648	0.18- 0.4	3
8345	**Ulmerspatz**	**11 27.2**	**14.6**	**+48**	**17.13**	**0.47-1.05**	**3-**
3397	Leyla	11 30.8	15.2	+53	3.098	0.29-0.40	3
124	Alkeste	12 03.0	11.9	+18	9.906	0.08-0.30	3
939	Isberga	12 05.6	14.6	+27	2.9173	0.20-0.25	3
839	Valborg	12 08.8	14.6	+42	10.366	0.14-0.19	3
477	Italia	12 17.9	13.5	+32	19.413	0.15-0.32	3
1604	Tombaugh	12 19.0	14.7	+33	7.24	0.16-0.35	3-

```
                         Brightest           LCDB Data
 Num Name            Date    Mag  Dec    Period      Amp     U
-------------------------------------------------------------
 901 Brunsia        12 19.9 13.9 +23     3.1363  0.09-0.28 3
 453 Tea            12 22.2 13.3 +33     6.812   0.03-0.37 3
 524 Fidelio        12 27.4 12.9 +34    14.198   0.18-0.22 3
 913 Otila          12 30.4 15.0 +24     4.872   0.09-0.45 3
```

Radar-Optical Opportunities

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

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

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

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

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

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

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

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

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

About YORP Acceleration

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

It usually takes four apparitions to have sufficient data to determine if the asteroid rotation rate is changing under the influence of YORP. 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. If "Bin" is followed by "?" it 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 and "G" is for Goldstone. Note that this calculator assumes full power at Arecibo.

Asteroid	Period	Amp	App	Last	R SNR
2018 EB NEA	1.221	0.54	1	2018	**A 1540** **G 88**
(475534) 2006 TS7 NEA	-	-	-	-	**A 1210** **G 686**
2002 VE68 NEA PHA	13.50	0.9	2	2010	**A 4360** **G 248**
(65733) 1993 PC NEA	4.184	0.76 0.97	1	2013	A 172 G 10
(410088) 2007 EJ NEA	4.781	0.09 0.16	1	2015	A 236 G 55
(54660) 2000 UJ NEA	5.43	1.15	1	2009	A 116 G -
(162687) 2000 UH1 NEA	-	-	-	-	A 22 G -
(4953) 1990 MU NEA	14.218	0.68	1	1994?	A - G 22
(163899) 2003 SD220 NEA PHA NHATS	285	2.2	1	2015	**A *** **G ***
(141053) 2001 XT1 NEA	-	-	-	-	A 14 G -
(418884) 2008 WM64 NEA	-	-	-	-	A 1590 G 90

Table I. Summary of radar-optical opportunities in 2018 July-October. Data from the asteroid lightcurve database (Warner *et al.,* 2009; *Icarus* **202**, 134-146). *The SNRs for 2003 SD220 will be enormous: A: 1.76E+6, G: 96800.

The estimated SNR uses the current MPCORB absolute magnitude (H), a period of 4 hours (2 hours if $D \leq 170$ m) if it's not known, and the approximate minimum Earth distance during the current quarter. If the estimated diameter is, a period of 2 hours was used

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. This would produce a marginal signal, not enough for imaging, but might allow improving orbital parameters.

2018 EB (Oct, *H* = 21.8)

Warner (2018) found the period for this 130-meter NEA to be 1.2208 h. Even though the amplitude was 0.51 mag, the asteroid was at a large phase angle (~54°), and so there is a possibility that the period could be wrong. Rapid sky motion will require short exposures.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/04	06 10.5	+42 39	0.05	1.01	18.0	79.3	98	35	-0.32	+11
10/05	06 08.1	+33 04	0.04	1.01	17.7	77.9	100	45	-0.22	+6
10/06	06 05.9	+21 46	0.04	1.01	17.5	76.6	101	59	-0.13	+0
10/07	06 03.7	+09 21	0.04	1.01	17.4	75.6	102	75	-0.06	-6
10/08	06 01.6	-03 08	0.04	1.01	17.5	75.2	103	91	-0.02	-13
10/09	05 59.6	-14 36	0.04	1.01	17.6	75.4	102	104	+0.00	-18
10/10	05 57.6	-24 24	0.05	1.01	17.8	75.9	101	112	+0.01	-22
10/11	05 55.7	-32 26	0.05	1.01	18.1	76.5	101	117	+0.04	-25

(475534) 2006 TS7 (Oct, *H* = 21.2)

This is another strong radar target, easily within the reach of Arecibo and Goldstone. The period for the 170 meter NEA is not known. The size is just at the point where the asteroid is likely a super-fast rotator ($P < 2$ h). Keep exposures as short as practical until you have an idea of the period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/20	03 51.2	+36 38	0.10	1.08	17.9	36.6	140	92	+0.79	-14
10/21	03 54.5	+37 46	0.09	1.07	17.6	37.2	140	82	+0.86	-12
10/22	03 58.8	+39 10	0.08	1.06	17.4	38.1	139	72	+0.92	-11
10/23	04 04.4	+40 57	0.07	1.05	17.1	39.4	138	62	+0.97	-9
10/24	04 12.3	+43 17	0.06	1.04	16.8	41.4	136	53	+0.99	-6
10/25	04 24.1	+46 27	0.05	1.03	16.5	44.4	134	46	-1.00	-2
10/26	04 44.1	+50 56	0.04	1.02	16.2	49.1	129	42	-0.98	+3
10/27	05 24.0	+57 23	0.03	1.01	15.8	56.9	122	43	-0.94	+12
10/28	07 07.0	+65 20	0.02	1.00	15.7	70.5	108	50	-0.87	+26
10/29	10 53.9	+63 01	0.02	0.99	16.0	93.5	85	64	-0.79	+49

2002 VE68 (Oct-Nov, *H* = 20.5, PHA)

The better chances for photometry come at the first of November, when the moon is near new. Then again, the NEA will be nearly at the galactic plane in dense star fields. Pravec et al. (2002) and Hicks et al. (2010) found a period of 13.5 h with a large amplitude lightcurve. The estimated size is 240 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/20	09 44.0	+58 42	0.09	0.99	18.4	91.8	83	134	+0.79	+45
10/23	09 26.9	+63 12	0.07	1.00	17.9	86.3	89	108	+0.97	+41
10/26	08 51.8	+69 11	0.06	1.00	17.2	79.5	97	76	-0.98	+36
10/29	07 11.8	+76 15	0.05	1.01	16.5	70.7	106	56	-0.79	+27
11/01	02 50.4	+75 54	0.04	1.01	15.8	59.6	118	73	-0.46	+15
11/04	00 30.3	+59 32	0.04	1.02	15.2	48.2	130	114	-0.16	-3
11/07	23 46.4	+38 18	0.04	1.02	15.2	43.7	135	134	-0.01	-23
11/10	23 27.6	+20 16	0.05	1.02	15.6	48.0	130	103	+0.06	-38
11/13	23 17.9	+07 36	0.06	1.02	16.3	55.0	122	62	+0.27	-49
11/16	23 12.4	-00 54	0.07	1.02	16.9	61.2	115	22	+0.54	-55

(65733) 1993 PC (Oct-Nov, *H* = 15.4)

Warner (2014) observed this NEA twice in 2013 October, at phase angles of 12° and 34°. The better solution was 4.184 h (vs. 4.28 h). The ambiguity needs to be removed. The estimated diameter is 620 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/05	01 52.4	+23 45	0.30	1.27	17.3	19.9	154	101	-0.22	-37
10/08	01 45.6	+24 36	0.27	1.25	17.0	17.9	157	142	-0.02	-37
10/11	01 36.9	+25 29	0.25	1.23	16.7	16.3	160	159	+0.04	-36
10/14	01 26.0	+26 25	0.22	1.21	16.4	15.3	161	127	+0.25	-36
10/17	01 12.4	+27 22	0.20	1.19	16.2	15.5	161	91	+0.53	-35
10/20	00 55.5	+28 20	0.18	1.17	16.0	17.5	159	56	+0.79	-35
10/23	00 34.4	+29 14	0.16	1.14	15.8	21.6	155	30	+0.97	-34
10/26	00 08.4	+29 57	0.15	1.12	15.7	27.5	149	45	-0.98	-32
10/29	23 36.5	+30 20	0.13	1.10	15.6	35.2	140	85	-0.79	-30
11/01	22 58.3	+30 05	0.12	1.07	15.7	44.8	130	124	-0.46	-27

(410088) 2007 EJ (Oct, Dec-Jan, *H* = 18.1)

There are two chances to observe this 700-meter NEA. Southern Hemisphere observers get first try in October while Northern Hemisphere observers are favored in December. Warner (2015) found a period of 4.78 h. Vaduvescu et al. (2017) found 2.38 h, or the half-period of Warner's result. Here's another case where the ambiguity needs to be resolved.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	22 40.4	-43 12	0.29	1.20	17.4	41.0	128	110	-0.65	-59
10/04	22 33.7	-44 05	0.28	1.18	17.4	44.5	124	142	-0.32	-58
10/07	22 26.7	-44 53	0.26	1.16	17.3	48.1	121	143	-0.06	-56
10/10	22 19.3	-45 37	0.25	1.13	17.3	51.9	117	110	+0.01	-55
10/13	22 11.7	-46 17	0.24	1.11	17.2	55.8	113	75	+0.17	-53
10/16	22 03.6	-46 52	0.22	1.09	17.2	59.9	109	45	+0.43	-52
10/19	21 55.1	-47 24	0.21	1.07	17.1	64.1	105	31	+0.71	-50
10/22	21 45.8	-47 54	0.19	1.05	17.0	68.6	101	51	+0.92	-49
10/25	21 35.5	-48 21	0.18	1.03	17.0	73.3	97	84	-1.00	-47
10/28	21 23.5	-48 46	0.16	1.01	16.9	78.5	92	120	-0.87	-45
12/15	13 12.0	+21 09	0.15	0.96	17.3	94.6	77	150	+0.46	+82
12/18	13 06.2	+22 42	0.17	0.97	17.3	89.0	81	151	+0.74	+84
12/21	13 01.4	+23 57	0.18	0.99	17.3	83.9	85	117	+0.96	+86
12/24	12 57.2	+25 01	0.20	1.00	17.3	79.1	90	75	-0.98	+88
12/27	12 53.4	+25 56	0.21	1.02	17.4	74.7	93	37	-0.76	+89
12/30	12 49.8	+26 46	0.23	1.04	17.4	70.4	97	29	-0.43	+89
01/02	12 46.1	+27 32	0.24	1.05	17.5	66.3	101	59	-0.15	+89
01/05	12 42.3	+28 15	0.25	1.07	17.5	62.4	104	93	-0.01	+88
01/08	12 38.2	+28 57	0.27	1.10	17.5	58.6	108	126	+0.03	+87
01/11	12 33.8	+29 36	0.28	1.12	17.6	54.8	112	152	+0.21	+85

(54660) 2000 UJ (Oct-Nov, *H* = 18.0)

No period is reported in the asteroid lightcurve database (LCDB; Warner et al., 2009) for this 750-meter NEA. Given the estimated size, the period is almost certainly $P > 2$ h. The asteroid will always be at large phase angles from mid-October to mid-November, which could mean unusual lightcurves due to shadowing effects.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/20	07 24.2	+68 14	0.24	1.07	17.4	66.7	101	118	+0.79	+28
10/23	06 58.1	+62 45	0.20	1.07	16.9	63.8	106	93	+0.97	+25
10/26	06 33.6	+54 45	0.17	1.07	16.4	59.1	112	57	-0.98	+19
10/29	06 10.9	+43 05	0.14	1.07	15.9	52.4	121	22	-0.79	+11
11/01	05 50.2	+26 54	0.13	1.08	15.4	44.5	130	45	-0.46	+0
11/04	05 31.4	+07 36	0.12	1.08	15.2	39.3	136	93	-0.16	-14
11/07	05 14.4	-10 42	0.13	1.09	15.4	40.3	135	133	-0.01	-26
11/10	04 59.2	-24 49	0.16	1.09	15.9	44.7	129	136	+0.06	-35
11/13	04 45.7	-34 42	0.18	1.10	16.4	49.0	123	111	+0.27	-40
11/16	04 33.7	-41 27	0.22	1.11	16.8	52.1	118	86	+0.54	-43

(162687) 2000 UH1 (Nov, *H* = 19.2)

There's no period reported in the LCDB for this NEA. The estimated size is about 430 meters, so it's very likely that the period will be greater than 2 hours. Here again, the asteroid will always be at large phase angles, which could mean unusual lightcurves due to shadowing effects.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/01	05 24.1	-18 10	0.24	1.15	18.1	45.1	125	64	-0.46	-27
11/04	05 39.5	-18 49	0.22	1.12	17.9	47.4	123	94	-0.16	-24
11/07	05 58.3	-19 26	0.19	1.10	17.7	50.3	121	120	-0.01	-20
11/10	06 21.9	-19 55	0.17	1.08	17.5	54.0	118	136	+0.06	-15
11/13	06 52.0	-20 08	0.15	1.06	17.3	58.8	114	138	+0.27	-9
11/16	07 30.6	-19 51	0.13	1.04	17.1	64.9	108	129	+0.54	-1
11/19	08 19.5	-18 38	0.11	1.02	17.1	72.8	101	117	+0.81	+10
11/22	09 17.7	-16 04	0.11	1.00	17.2	82.4	92	99	+0.98	+23
11/25	10 20.0	-12 07	0.10	0.98	17.5	92.5	81	75	-0.96	+36
11/28	11 18.4	-07 31	0.11	0.96	18.0	101.5	72	46	-0.72	+49

(4953) 1990 MU (Nov, *H* = 14.1)

The summary table above shows a somewhat unusual case where the asteroid can just be observed with radar at Goldstone but not at Arecibo. This is because Arecibo's range of declinations is about –1° to +38°. The combination of distance and size when 1990 MU is within that range produces SNR < 10 at Arecibo.

The asteroid position dives into the Sun at the end of November and stays in the vicinity until 2019 July.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	04 34.2	-15 21	0.83	1.56	16.1	35.1	116	36	-0.65	-37
10/11	04 44.4	-18 16	0.68	1.47	15.6	36.1	120	138	+0.04	-36
10/21	04 53.0	-22 06	0.54	1.37	15.0	37.8	123	83	+0.86	-35
10/31	05 00.2	-27 27	0.41	1.26	14.3	41.2	123	65	-0.58	-35
11/10	05 06.4	-36 07	0.28	1.15	13.5	48.8	119	125	+0.06	-36
11/20	05 16.4	-54 57	0.16	1.04	12.7	68.4	103	76	+0.88	-35

(163899) 2003 SD220 (Nov-Dec, *H* = 17.3, PHA, NHATS)

NHATS is the acronym for *Near-Earth Object Human Space Flight Accessible Targets Study*. In other words, this asteroid is on a list of possible targets to which to send a human mission. Because of the enormous radar SNR values expected, almost 2 million for Arecibo(!), expect an abundance of news stories about the asteroid.

Part of the reason for the large SNRs is the rotation period, which has been reported to range from 175 to 285 hours (respectively, Aznar et al., 2018; Warner, 2016). This requires a good campaign involving observers over a wide range of longitudes *and* well-calibrated data. With such long period objects, often the approach is to get a limited number of data points each night. While improving telescope time efficiency, the requirements on the quality of the data go up significantly.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/01	10 35.8	+56 29	0.16	0.99	16.3	85.6	85	42	-0.46	+52
11/07	10 46.1	+56 28	0.15	1.00	16.0	83.4	88	79	-0.01	+53
11/13	10 58.2	+56 25	0.13	1.00	15.7	81.4	91	129	+0.27	+54
11/19	11 12.6	+56 21	0.11	1.00	15.4	80.0	94	124	+0.81	+56
11/25	11 30.8	+56 13	0.09	1.00	14.9	79.1	95	71	-0.96	+57
12/01	11 55.9	+55 52	0.08	1.00	14.5	79.4	96	49	-0.39	+60
12/07	12 34.7	+54 52	0.06	0.99	13.9	81.8	95	90	+0.00	+62
12/13	13 43.3	+50 57	0.04	0.98	13.3	89.8	88	122	+0.28	+64

(141053) 2001 XT1 (Dec-Jan, *H* = 18.7)

There's apparently no reported period for this 500-meter NEA. This will be a weak target at best for Arecibo but it looks to be a strong candidate for photometrists who want to find its phase (H-G) curve. During December to early January, the phase angle drops from 72° to less than 5°.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/01	10 31.7	+22 49	0.19	1.03	17.7	72.2	97	22	-0.39	+58
12/07	09 42.5	+26 03	0.20	1.09	17.4	55.4	115	111	+0.00	+48
12/13	08 56.2	+28 02	0.22	1.15	17.3	40.3	131	163	+0.28	+38
12/19	08 15.1	+28 56	0.25	1.20	17.3	27.1	146	82	+0.83	+30
12/25	07 40.5	+29 03	0.29	1.26	17.4	15.9	160	14	-0.93	+23
12/31	07 12.9	+28 41	0.33	1.31	17.4	7.0	171	103	-0.33	+17
01/06	06 51.7	+28 05	0.39	1.37	17.7	4.5	174	173	+0.00	+12
01/12	06 36.3	+27 26	0.45	1.42	18.3	9.5	166	103	+0.29	+9
01/18	06 25.7	+26 48	0.51	1.47	18.9	14.4	158	23	+0.86	+7

(418849) 2008 WM64 (Dec-Jan, *H* = 20.6)

Both Rowe (2018) and Warner (2018) found a period of 2.4 h based on observations in mid- to late-December of 2017. This makes it a potential binary candidate, so careful observations are in order.

Unfortunately, as the asteroid brightens, the moon waxes towards full. It should still be possible to get good data since the asteroid is reasonably bright and asteroid-moon elongation (sky distance) stays above 45°.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/15	06 32.0	-58 52	0.10	1.00	18.2	77.7	97	92	+0.46	-25
12/17	06 00.4	-54 03	0.08	1.00	17.6	73.1	102	83	+0.65	-29
12/19	05 24.3	-45 48	0.06	1.01	16.9	66.0	111	68	+0.83	-34
12/21	04 44.8	-31 32	0.05	1.01	16.1	55.1	123	49	+0.96	-40
12/23	04 04.3	-09 24	0.04	1.01	15.4	42.2	136	45	-1.00	-41
12/25	03 25.3	+15 24	0.05	1.02	15.5	38.4	140	72	-0.93	-33
12/27	02 49.9	+33 57	0.06	1.02	16.1	44.8	133	102	-0.76	-23
12/29	02 19.2	+45 17	0.07	1.03	16.8	51.5	125	124	-0.54	-15
12/31	01 53.5	+52 04	0.09	1.03	17.4	56.4	119	134	-0.33	-10

INDEX TO VOLUME 45

Hayes-Gehrke, M.N., Dolinka, M., Ihde, I., Liu, A., Souders, K., Umar, S., Xiong, C., Gholson, S., Brashear, D. "4767 Sutoku Lightcurve Determination" 324.

Hayes-Gehrke, M.N., Hannon, C., Lockwood, I., Lee, J., Moyer, R. III, Hidayat, A., Moore, S., Newman, M., Toujas-Bernate, O. "The Rotation Period of 3394 Banno and the Raw Lightcurve of (48697) 1996 HX14" 323.

Hayes-Gehrke, M.N., Leffle, T., Hampton, K., Chavis, J., Fong, J., Wang, Y., Hung, A. Mahoney, J., Rizal, M.H.A.S. "Photometric Observations of 1969 Alain" 1.

Hayes-Gehrke, M.N., Nakamura, C., Estes, E., Holden, K., Vo, J., Ramos, L., Tran, C., Sweeney, J., Sigler, J. "Lightcurve Analysis of Main-Belt Asteroid (9899) 1996 EH" 321.

Hayes-Gehrke, M.N., Raman, O., Ibrahim, D., Isolato, J., Strouth, K., Bacon, E., Haslup, D., Awowale, E., Valizadeh, N. "Lightcurve Analysis for 19911 Rigaux" 325.

Hayes-Gehrke, M.N., Stoeckel, B., Vishnu, S., Rhoades, D., Yang, D., Pham, A., Gingerich, A., Woo, G.Y., Brincat, S.M., Galdies, C., Grech, W. "Photometric Observations of 1856 Ruzena" 318–319.

Hergenrother, C.W. "Near-Earth Asteroid (297418) 2000 SP43: Lightcurve and Color Photometry" 237–238.

Hergenrother, C.W. "Photometry of Damocloid Asteroid 2006 BZ8" 64–65.

Hills, K. "Asteroid Lightcurve Analysis at Tacande Observatory: 4650 Mori, 6779 Perrine and 7996 Vedernikov" 128–129.

Klinglesmith, D.A., III, Erin, A.L. "Three Asteroids from Etscorn: 461 Saskia, 3800 Karayusuf and (42701) 1998 MD13" 397–398.

Klinglesmith, D.A., III, Hendrickx, S. "Asteroid Lightrcurves from Etscorn Observatory" 61–63.

Klinglesmith, D.A., III, Hendrickx, S. "Asteroid Lightcurve Observations at Etscorn Observatory" 162–165.

Lang, K., Jacobsen, J., Kristensen, L.H., Larsen, F.R. "Rotational Periods of Asteroids 184 Dejopeja, 435 Ella and 5049 Sherlock" 197–198.

Macías, A.A., Cornea, R., Suciu, O. "Photometric Analysis and Physical Parameters for Six Mars-Crossing and Ten Main-Belt Asteroids from APT Observatorygroup: 2017 April – September" 92–96.

Marchini, A., Bucalo, E., Cocchiarella, D., Nardi, B., Papini, R., Salvaggio, F. "Rotation Period Determination for 2079 Jacchia and 3394 Banno" 276–277.

Marchini, A., Papini, R., Salvaggio, F. "Period Determination for 5049 Sherlock, 16852 Nuredduna and (16943) 1998 HP42" 195–197.

Marchini, A., Papini, R., Salvaggio, F. "Period Determination for (23621) 1996 PA, (29564) 1998 ED6, and (31775) 1999 JN122" 66–67.

Mas, V., Fornas, G., Lozano, J., Rodrigo, O., Fornas, A., Carreño, A., Arce, E., Brines, P., Herrero, D. "Twenty-one Asteroid Lightcurves at Asteroids Observers (OBAS) – MPPD: Nov 2016 – May 2017" 76–82.

Mollica, M., Noschese, A., Vecchione, A. "Lightcurve Analysis and Rotation Period for (3394) Banno" 330–331.

Mollica, M., Noschese, A., Vecchione, A., D'Avino, L. "Lightcurve Analysis for Minor Planet 138925 2001AU43" 60–61.

Mollica, M., Noschese, A., Vecchione, A., D'Avino, L., Izzo, L. "Lightcurve Analysis for Minor Planet 1581 Abanderada" 4–5.

Monteiro, F., Arcoverde, P., Medeiros, H., Rondón, E., Souza, R., Rodrigues, T., Lazzaro, D. "Rotational Period Determination for 12 Near-Earth Asteroids" 221–224.

Montminy, B., McDonald, K., Durkee, R.I. "Five Lightcurves from the Shed of Science: 2017 November–2018 April" 331–333.

Noschese, A., Vecchione, A. "Lightcurve Analysis and Rotation Period for 6838 Okuda" 238–239.

Noschese, A., Vecchione, A., Ruocco, N., Izzo, L. "Lightcurve Analysis for Minor Planets 1322 Coppernicus and 9148 Boriszaitsev" 70–71.

Novak, R., Alton, K.B. "Lightcurve Analysis of 216 Kleopatra" 243.

Odden, C.E., Cohen, A.J., Davis, S., Eldracher, E.A., Fitzgerald, Z.T., Jiang, D.C., Kozol, E.L., Laurencin, V.L., Meyer-Idzik, B.D., Pennington, O., Philip, R.C., Sanchez, E.J., Warren, N.J., Klinglesmith, D.A., III, Briggs, J.W. "Lightcurve Analysis and Rotation Period Determination for Asteroids 1491 Balduinus and 2603 Taylor" 278–279.

Odden, C.E., Kini, A.S., Buehler, J.I., Kozol, E.L. Cullen, O., Tang, J. "Lightcurve Analysis of Asteroids 2040 Chalonge, 4575 Broman and 5852 Nanette" 401–402.

Oey, J., Groom, R. "Lightcurve Analysis of Main-Belt Asteroids from BMO and DRO in 2016: I" 363–366.

Owings, L.E. "Asteroid Lightcurve Analysis of Data from Dusty Files" 227–231.

Papini, R., Franco, L., Marchini, A., Cicali, C., Poggialini, A., Salvaggio, F. "Rotation Period Determination for 8994 Kashkashian, (25980) 2001 FK53 and (29128) 1985 RA1" 68–69.

Pennington, O.O., Odden, C.E. "Rotational Period Determination for Asteroid 5798 Burnett" 231–232.

Percy, S.C. "Rotation Period for 4221 Picasso" 326–328.

Percy, S.C. "Rotation Period for (138847) 2000 VE62" 313–315.

Pilcher, F. "Call for Observations" 120.

Pilcher, F. "Minor Planets at Unusually Favorable Elongations in 2018" 100–101.

Pilcher, F. "A Photometric Study of 1134 Kepler" 134–135.

Pilcher, F. "A Photometric Study of 1144 Oda" 335–336.

Pilcher, F. “General Report of Position Observations by the ALPO Minor Planets Section for the Year 2017” 280–287.

Pilcher, F. “New Lightcurves of 33 Polyhymnia, 49 Pales, 289 Nenetta, 504 Cora, and 821 Fanny” 356–359.

Pilcher, F. “Reexamining the Rotation Period of 576 Emanuela” 18–19.

Pilcher, F. “Rotation Period Determinations for 50 Virginia, 142 Polana, and 597 Bandusia” 246–247.

Pilcher, F. “Rotation Period Determinations for 59 Elpis and 295 Theresia” 181–182.

Pilcher, F. “Rotation Period Determinations for 418 Alemannia, 646 Kastalia, and 876 Scott” 55–56.

Pilcher, F. “Rotation Period Determinations for 50 Virginia, 142 Polana, and 597 Bandusia” 246–247.

Pilcher, F., Benishek, V. “Rotation Period Determination for 460 Scania” 242.

Pilcher, F., Benishek, V., Klinglesmith, D.A., III, Odden, C.E., Pennington, O.O. “763 Cupido: A Tumbling Asteroid” 111–112.

Pilcher, F., Benishek, V., Odden, C.E., Caso, M., Dettorre, C., Dial, P.J., Hoang, K., Hughes, R., Lazar, T.T., Morss, P.P., Mundra, A.R., Naiyapatana, A., Rooney, M. “The Rotation Period of 1773 Rumpelstilz Is Reexamined” 75.

Pilcher, F., Polakis, T. “A Photometric Study of 437 Rhodia” 287–289.

Polakis, T. “Lightcurve Analysis for Seven Main-Belt Asteroids” 112–115.

Polakis, T. “Lightcurve Analysis for Eleven Main-Belt Asteroids” 199–203.

Polakis, T. “Lightcurve Analysis for Eleven Main-Belt Minor Planets” 269–273.

Polakis, T. “Lightcurve Analysis for Fourteen Main-Belt Minor Planets” 347–352.

Polakis, T., Warner, B.D., Skiff, B.A. “Lightcurve Analysis for Near-Earth Asteroid (143404) 2003 BD44” 3–4.

Radford, D. “Lightcurve and Rotational Period Determination for Main Belt Asteroid (13538) 1991 ST” 2.

Rodrigo, O., Fornas, G., Arce, E., Mas, V., Carreño, A., Brines, P., Fornas, A., Herrero, D., Lozano, J., Garcia, F. “3122 Florence Lightcuve Analysis at Asteroids Observers (OBAS) – MPPD: 2017 Sep” 120–121.

Rowe, B. “Lightcurve Analysis of Ten Asteroids from RMS Observatory” 203–207.

Rowe, B. “Lightcurve Analysis of 6 Asteroids from RMS Observatory” 292–294.

Ruthroff, J.C. “Rotational Study of Asteroid 126 Velleda” 166.

Ruthroff, J.C. “Rotational Study of Mars-Crossing Asteroid 4435 Holt” 130.

Sada, P., Loera-González, P., Olguin, L., Saucedo-Morales, J.C., Ayala-Gómez, S.A., Gaza, J.R. “Results of the 2017 Mexican Asteroid Photometry Campaign – Part 1” 122–124.

Salvaggio, F., Banfi, M., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for 2578 Saint-Exupery, 4297 Eichhorn, 10132 Lummelunda and (21766) 1999 RW208” 171–173.

Salvaggio, F., Banfi, M., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for 5813 Eizaburo and (11745) 1999 NH3” 17–18.

Salvaggio, F., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for (13124) 1994 PS, (26571) 2000 EN84, and (29934) 1999 JL46” 290–291.

Schmidt, R.E. “Photometry of 3200 Phaethon” 131.

Schwab, E., Koschny, D., Micheli, M. “Rotation Period for the Potentially Hazardous Asteroid 2018 AM12” 225.

Slivan, S.M., Neugent, K.F., Melton, C., Beck, M. “Koronis Family Member (3032) Evans: Photometric Reconnaissance and Lightcurves in 2008, 2009, and 2016” 72–75.

Stephens, R.D. “Asteroids Observed from CS3”
2017 July–September 50–54.
2017 October –December 135–137.
2018 January–March 299–301.
2018 April–June” 353–355.

Stephens, R.D., Pravec, P., Kučáková, H., Kušnirák, P, Hornoch, K., Benishek, V., Macias, A.A., Warner, B.D. “2207 Antenor: A Suspected Jovian Trojan Binary” 341–342.

Stephens, R.D., Pray, D., Benishek, V., Pravec, P., Warner, B.D. “4435 Holt: A Newly Discovered Singly-asynchonous Binary” 297–299.

Stephens, R.D., Warner, B.D. “Lightcurve Analysis of L4 Trojan Asteroids at the Center for Solar System Studies: 2017 July – September” 48–50.

Stephens, R.D., Warner, B.D. “Lightcurve Analysis of L5 Trojan Asteroids at the Center For Solar System Studies”
2017 September to December 124–128.
2018 January to March 301–304.
2018 April to May” 343–347.

Stephens, R.D., Warner, B.D. “A Shape and Spin Axis Model for 607 Jenny” 168–171.

Stephens, R.D., Warner, B.D. “(139345) 2001 KA67: A Potential NEA Very-Wide Binary Asteroid” 360–362.

Tan, H., Gao, X. “Lightcurve Analysis for Near-Earth Asteroid 2012 TC4” 220–221.

Tan, H., Yeh, T., Li, B., Gao, X. “Asteroid Lightcurves from Xingming Observatory: 2017 – 2017 June” 57–59.

Tomassini, A., Scardella, M., Franceschini, F. “Rotation Period Determination of 16852 Nuredduna” 226.

Tomassini, A., Scardella, M., Franceschini, F., Pierri, F. “Rotational Period Determination of Two Mars Crossing, a Main

Belt Asteroid and a PHA: (14309) Defoy, (56116) 1999 CZ7, (5813) Eizaburo and (3122) Florence" 11–12.

Vaduvescu, O., Macías, A.A. "Lightcurve of NEA 1993 RA" 96–97.

Vecchione, A., Noschese, A., Catapano, A. "Lightcurve Analysis and Rotation Period for (140158) 2001 SX169" 183–184.

Warner, B.D. "A New and Improved *MPB* Web Site" 98–99.

Warner, B.D. "Asteroid-Deepsky Appulses in 2018" 102.

Warner, B.D. "2491 Tvashtri: A New Binary Hungaria Asteroid" 394–396.

Warner, B.D. "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station"
2017 July through October 39–45.
2017 October – December 190–195.
2018 January – April 256–259.
2018 April–June" 380–386.

Warner, B.D. "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station"
2017 July through October 19–34.
2017 October–December 138–147.
2018 January–April 248–256.
2018 April–June" 366–379.

Warner, B.D., Harris, A.W., Ďurech, J., Benner, L.A.M. "Lightcurve Photometry Opportunities"
2018 January–March 103–108.
2018 April–June 208–213.
2018 July–September 304–309.
2018 October–December" 404–408.

Warner, B.D., Pravec, P. "2018 AJ: A Tumbling Near-Earth Asteroid" 259–262.

Warner, B.D., Stephens, R.D. "Lightcurve Analysis of Hilda Asteroids at the Center for Solar System Studies"
2017 July through September" 35–39.
2018 January–February 262–265.
2018 April–June" 390–393.

Warner, B.D., Stephens, R.D., Coley, D.R. "Lightcurve Analysis of Hilda Asteroids at the Center for Solar System Studies: 2017 October–December" 147–161.

Zeigler, K., Barnhart, T., Moser, A., Duval, N., Coquat, S., Rockafellow, T., Mena, M. "CCD Photometric Observations of Asteroids 4692 Simbad, 16852 Nuredduna, (19743) 2000 AF164, (21766) 1999 RW208, (24388) 2000 AB175, and (29564) 1998 ED6" 184–186.

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.

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 (46-1) is October 15, 2018. The deadline for issue 46-2 is January 15, 2019.