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PHOTOMETRIC OBSERVATIONS OF ASTEROIDS 3829 GUNMA, 6173 JIMWESTPHAL, AND (41588) 2000 SC46

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CCD photometric observations of three main-belt asteroids conducted from the George West ISD Mobile Observatory are described. Analysis of the data found the following synodic rotation periods and lightcurve amplitudes: 3829 Gumma, P = 4.728 ± 0.004 h, A = 0.24 mag; 6173 Jimwestphal, P = 2.908 ± 0.004 h, A = 0.39 mag; and (41588) 2000 SC36, P = 5.829 ± 0.003 h, A = 0.43 mag.

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

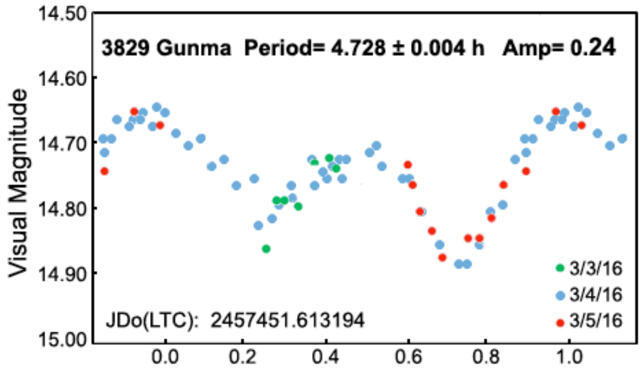
The research was conducted using a Meade 0.35-m LX600 Schmidt-Cassegrain telescope fitted with an SBIG STF-402M thermoelectrically cooled CCD Camera. The telescope is housed within a converted 8x16 foot Wells Cargo trailer with a hinged roof, which in turn sits upon concrete blocks supported by a thick concrete slab to minimize vibrations. All photometric exposures were 60 seconds and the science images were dark subtracted and flat fielded. To preserve the maximum light intensity of the objects observed, no filters were used during the observations.

The brightness of each asteroid was compared to that of a comparison star in the same CCD frame. A second star in the frame was also measured to act as a check star for assessing the precision of the observations and confirming that the comparison star was not variable. The brightness of the comparison star, check star, and asteroid were determined by measuring a 5x5 pixel sample centered on the asteroid or star. This corresponds to a 9.75 by 9.75 arcsec box centered upon the object. When possible, the same comparison star and check star were used on consecutive nights of observation. The coordinates of the asteroid were obtained from the online Lowell Asteroid Services (2016). To compensate for the effect on the asteroid's visual magnitude due to ever changing distances from the Sun and Earth, Eq. 1 was used to vertically align the photometric data points from different nights when constructing the composite lightcurve:

$$\Delta mag = -2.5 \log((E_2^2/E_1^2)\,(r_2^2/r_1^2)) \qquad (1)$$

where Δm is the magnitude correction between night 1 and 2, E_1 and E_2 are the Earth-asteroid distances on nights 1 and 2, and r_1 and r_2 are the Sun-asteroid distances on nights 1 and 2.

3829 Gunma was observed on 2016 March 3-5. Weather conditions on March 3 and 5 were not particularly favorable and so only a few hours of data were gathered on those nights. However, conditions on March 4 were excellent. A composite lightcurve with a period of 4.728 ± 0.004 hours best fits the available data. The lightcurve displays two maxima and two minima per rotation.

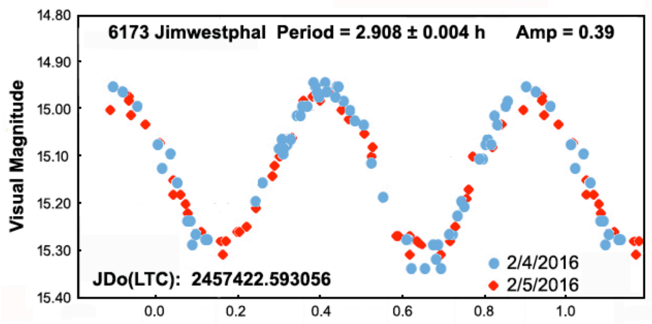


The second maximum is approximately 0.06 magnitudes fainter than the first. The second minimum is approximately 0.04 magnitudes fainter than the first. Overall, the amplitude of the lightcurve is 0.24 magnitudes. A search of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) identified no previously reported results for asteroid 3829 Gunma.

6173 Jimwestphal was discovered on 1983 January 9 by Brian Skiff at Lowell Observatory Anderson Mesa Station (JPL, 2016). It is named in honor of astronomer and engineer James Adolph Westphal (1930–2004) and is an inner main-belt asteroid with a semi-major axis of 2.562 AU and eccentricity of 0.123. It has an orbital period of 4.101 years (JPL, 2016).

The asteroid was near perihelion when it was observed on 2016 February 4 and 5. At that time, it was located 1.285 AU from Earth and 2.251 AU from the Sun.

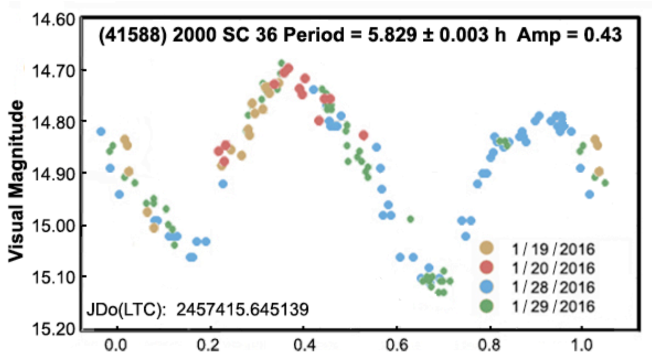
On the two nights of observation, sky conditions were excellent. It soon became apparent that this asteroid rotates very rapidly, completing three rotations during the observing session of February 4 and two on the night of February 5.



The lightcurve of 6173 Jimwestphal is very regular, with two virtually identical maxima and minima per rotational cycle and an amplitude of 0.39 magnitudes. We found a synodic rotation period of 2.908 ± 0.004 h. A search of the LCDB (Warner *et al.*, 2009) identified no previously reported results for asteroid 6173 Jimwestphal.

(41588) 2000 SC46 was discovered on 2000 September 22 from Socorro, New Mexico, by the LINEAR Survey Telescope. This asteroid has an orbital semi-major axis of 3.242 AU with a relatively high eccentricity of 0.322 (LAS, 2016). Asteroid 41588 is a Mars-crosser and has an orbital period of 3.58 years (JPL, 2016). During 2016 January, it had an unusually favorable perihelion apparition, being only 0.771 AU from Earth, just inside the orbit of Mars, on the night of 2016 January 29.

2000 SC46 was observed on the nights of 2016 January 19, 20, 28, and 29. All four nights were very clear, although a bright moon was present on the last two nights of observations.



A synodic rotation period of 5.829 ± 0.003 hours best fits our data. The amplitude was approximately 0.43 magnitudes. The lightcurve displays two maxima and two minima per rotation. The second minimum and the second maximum are approximately 0.09 magnitudes fainter than the first pair.

Blue Mountains Observatory (BMO, 2016), located in Southern Australia, reported a rotation period for 2000 SC36 of 5.8329 ± 0.0002 h, which agrees well with our results.

Acknowledgments

This research represents an effort to introduce high school level students to real astronomical research. This program has grown since its inception in 2015 December. It is the hope of author and physics instructor Zeigler that it will yield additional scientific papers on this and other areas of research in the coming months and years. Our thanks go to the McCarthy Dressman Educational Foundation and the George West Education Foundation for their continuing support.

References

BMO (2016). "Blue Mountains Observatory Research Photometry of Asteroids Taken in 2015." Web site: *http://www.bluemountainsobservatory.com.au/asteroid/2015.html*

JPL (2016). Small Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi*

Lowell Asteroid Services (accessed 2016 Feb 16). *http://asteroid.lowell.edu/asteph?asteroid=2013OM2*

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*

[Editor's Note: Ken Zeigler's name may be familiar to long-time *MPB* readers. In the 1984 to 1990 era (before the widespread application of CCD cameras), Zeigler steadily published *photoelectric* lightcurves of nearly two dozen asteroids. Most often these observations included the involvement of high school students. Zeigler's dedication to combining teaching and research continues today as evidenced by the ongoing work described here. We welcome Ken Zeigler back to the pages of the *Minor Planet Bulletin* and wish him ongoing success with his high school program mentoring students in scientific research.]

ROTATION PERIOD DETERMINATIONS FOR 1166 SAKUNTALA AND 3958 KOMENDANTOV

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Lightcurves and synodic rotation periods for 1166 Sakuntala and 3958 Komendantov are reported. 1166 Sakuntala was observed over five nights and was found to have a synodic rotation period of 6.2915 ± 0.002 hours with amplitude of 0.32 magnitudes. 3958 Komendantov was also observed over five nights and was found to have a synodic rotation period of 11.2947 ± 0.0023 hours and amplitude of 0.27 magnitudes.

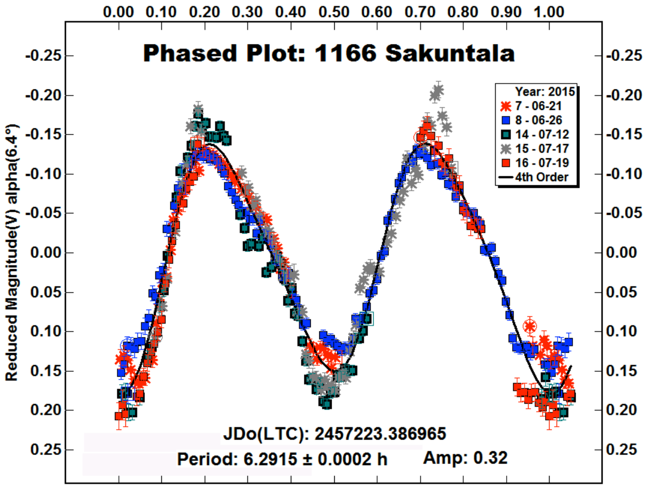
The purpose of this study was to acquire photometric observations in order to update the synodic rotation period of 1166 Sakuntala and to determine the synodic rotation period of 3958 Komendantov. Multiple nights of CCD observations were analyzed using differential photometry to determine the lightcurves for the asteroids. Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing) that incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989).

CCD photometric observations of 1166 Sakuntala and 3958 Komendantov were made at Flarestar Observatory (MPC Code: 171). All data were obtained through a 0.25-m *f*/6.3 Schmidt-Cassegrain telescope. Images were taken with a Moravian G2-1600 CCD camera that was operated at –25° C. The images had a pixel scale of 1.12 arc second per pixel and were unbinned. Light images were dark and flat field corrected prior to measurement.

The brightness of the asteroid and five comparison stars were measured on each image using aperture photometry. The difference in magnitude between the asteroid and the comparison stars was averaged for each image through ensemble photometry. The plotting of differential magnitudes versus time allowed the creation of lightcurves for each asteroid.

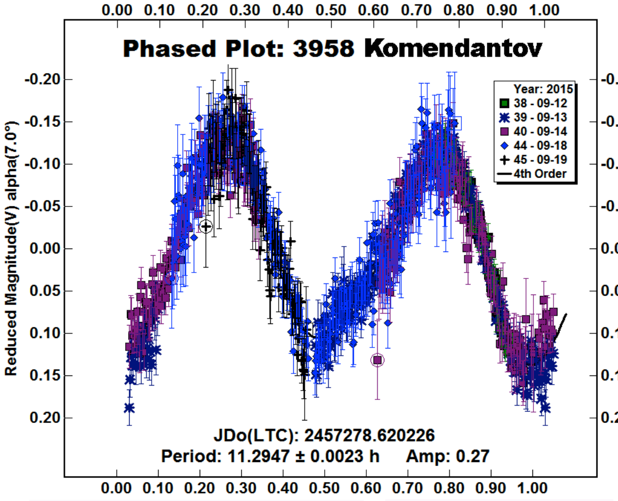
1166 Sakuntala. This asteroid was discovered at Simeis on 1930 June 27 by P. Parchomenko and independently discovered by K. Reinmuth on June 29 from Heidelberg. 1166 Sakuntala is a main-belt asteroid and has an absolute magnitude of $H = 10.3$ with an orbital semi-major axis of 2.535 AU, an inclination of 18.92°, eccentricity of 0.2088, and an orbital period of 4.04 years (JPL, 2013a).

Photometric observations of 1166 Sakuntala were acquired on 2015 June 21, 26 and July 12, 17, and 19. During that time, the phase angle ranged from 6.3° to 17.3° before opposition. All exposures were 180 seconds through a clear filter. A total of 353 images was obtained, all of which were used for the analysis. From the lightcurve, Sakuntala was found to have a synodic rotation period of 6.2915 ± 0.0002 h and lightcurve amplitude of 0.32 magnitudes. This agrees well with the period published by Malcolm (2001) who reported the period as 6.30 h.



3958 Komendantov. This main-belt asteroid was discovered by Shajn on 1953 Oct 10 from Simeis. The absolute magnitude is listed as $H = 12.3$ with a semi-major axis of 2.468 AU, inclination of 4.83°, and eccentricity of 0.2085 (JPL, 2013b). The orbital period is 3.88 years.

Photometric observations of 3958 Komendantov were obtained on 2015 September 12, 13, 14, 18, and 19. All images had exposures of 180 seconds and were taken through a clear filter. Over the five nights of observation, the phase angle ranged from 6.9° to 2.5° before opposition. The lightcurve was based on 985 photometric observations. Analysis for 3958 Komendantov yielded a synodic rotation period of 11.2947 ± 0.0023 h. The amplitude of the lightcurve is 0.27 magnitudes. A search of the Astrophysics Data System and the asteroid lightcurve database (LCDB; Warner *et al*., 2009) yielded no previously reported results.



References

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 (2013a). JPL Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=1166*

JPL (2013b). JPL Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=3958*

Malcolm, G. (2001). “Rotational Periods and Lightcurves of 1166 Sakuntala and 1568 Aisleen.” *Minor Planet Bull.* **28**, 64.

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

LIGHTCURVE ANALYSIS OF ASTEROIDS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2015 NOVEMBER AND DECEMBER

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CCD images were taken over a span of nine nights in order to collect and analyze photometric data on six asteroids: 2336 Xinjiang, 3867 Shiretoko, 4520 Dovzhenko, 4749 Ledzeppelin, 5446 Heyler, and 5709 Tamyeunleung.

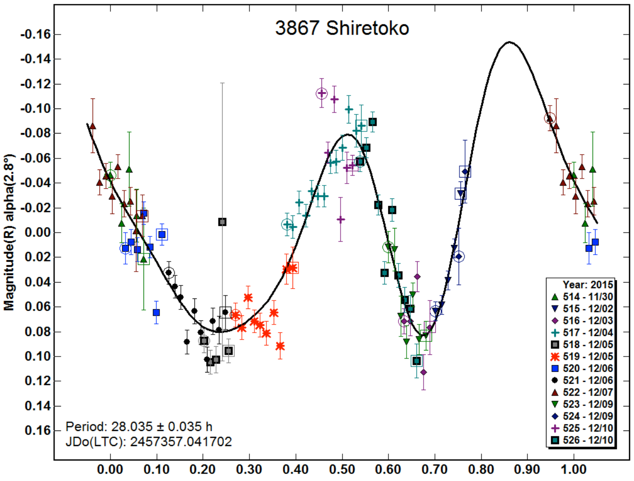
Lightcurve analysis was conducted using images of six asteroids taken at the Oakley Southern Sky Observatory in New South Wales, Australia. These images were taken on the nights of 2015 Nov 30, Dec 2-7, and Dec 9-10. We used a 0.5-m Planewave telescope with a STX-16803 camera, binned 3X3, using a luminance filter. The telescope operated at *f*/6.71 with a plate scale of 1.63 arcseconds per pixel. The six asteroids that were analyzed were 2336 Xinjiang, 3867 Shiretoko, 4520 Dovzhenko, 4749 Ledzeppelin, 5446 Heyler, and 5709 Tamyeunleung. Xinjiang, Shiretoko, and Ledzeppelin had exposure times of 180 s, Dovzhenko had an exposure time of 120 s, Heyler had an exposure time of 240 s, and Tamyeunleung had an exposure time of 150 s. The images were calibrated using *Maxim DL* software and measured in *MPO Canopus*. Lightcurves were created also using *MPO Canopus*.

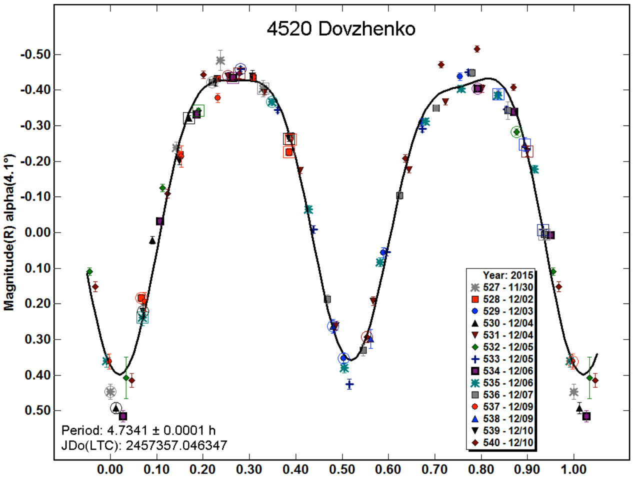
Analysis of the data determined periods for 3867 Shiretoko, 4520 Dovzhenko, 4749 Ledzeppelin, 5446 Heyler, and 5709 Tamyeunleung. We could not determine a period for 2336 Xinjiang due to the noise in the data. A summary of the periods and amplitudes of the asteroids can be found in Table I. The period for Dovzhenko lies within the uncertainties with the previously reported period of 4.7340 ± 0.0003 h (Behrend, 2016). None of the other asteroids presented here had reported results in the asteroid lightcurve database (Warner *et al.*, 2009).

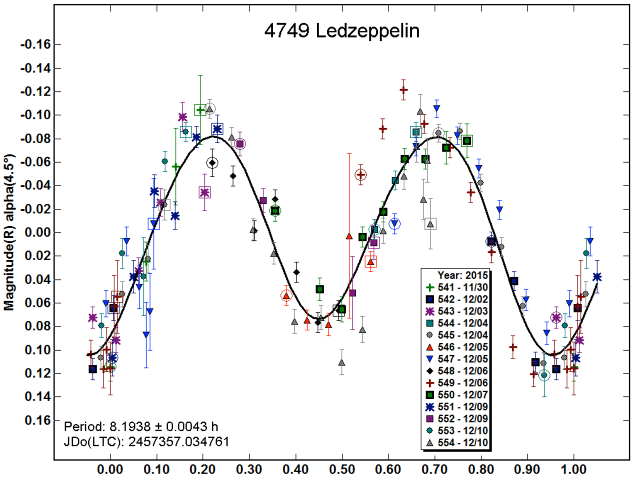
References

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database" *Icarus* **202**, 134-146. Updated 2016 Feb 20. *http://www.MinorPlanet.info/lightcurvedatabase.html*

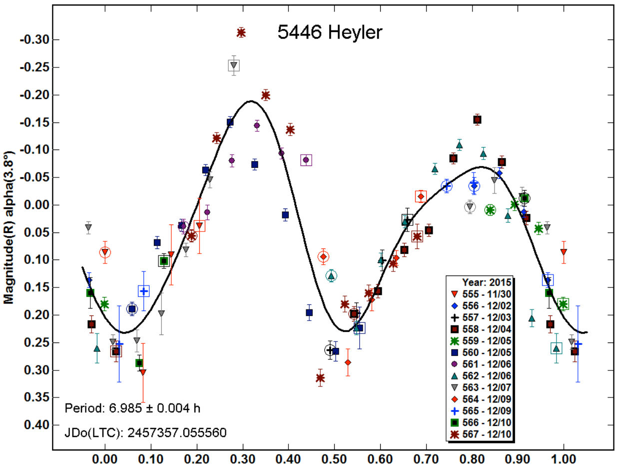


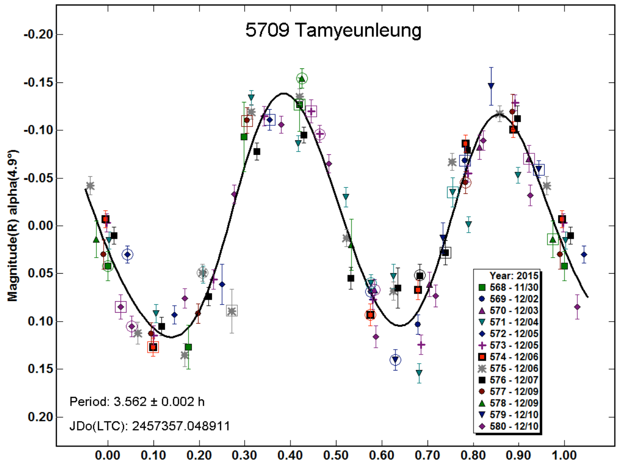




Number	Name	Dates (2015/MM/DD)	Period (h)	P.E. (h)	Amp (mag)	A.E. (mag)	Points
2336	Xinjiang	11/30, 12/2-7, 9-10	-	-	0.12	0.05	84
3867	Shiretoko	11/30, 12/2-7, 9-10	28.035	0.035	0.20	0.03	95
4520	Dovzhenko	11/30, 12/2-7, 9-10	4.7341	0.0001	0.83	0.05	90
4749	Ledzeppelin	11/30, 12/2-7, 9-10	8.1938	0.0043	0.21	0.02	109
5446	Heyler	11/30, 12/2-7, 9-10	6.985	0.004	0.47	0.08	85
5709	Tamyeunleung	11/30, 12/2-7, 9-10	3.562	0.002	0.24	0.02	88

Table I. Observing dates and results for six asteroids.





LIGHTCURVE ANALYSIS OF 2813 ZAPPALA

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Photometric observations of the main-belt asteroid 2813 Zappala were made over ten nights in 2016 Jan-Feb. Lightcurve analysis shows a bimodal solution with a synodic period of 18.231 ± 0.001 hours and an amplitude of 0.28 ± 0.03 mag. From photometric sparse data, we also derived *H* = 10.99 ± 0.05 and *G* = 0.31 ± 0.06.

The main-belt asteroid 2813 Zappala (1981 WZ) was discovered at Flagstaff (AM) on 1981 Nov 24 by Edward Bowell. It is named in honor of Vincenzo Zappala, an Italian astronomer who has provided many meaningful contributions to the studies of the small solar system bodies. A search in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) did not show any record for this asteroid.

Photometric observations were obtained on ten nights from 2016 Jan 13 to Feb 14. Observations at Balzaretto were obtained using a 0.20-m *f*/5.5 Schmidt-Cassegrain (SCT) equipped with an SBIG ST7-XME CCD camera. At Etscorn Campus (ECO, 2016), observations were obtained with two Celestron 0.35-m SCTs, one with an SBIG STL-1001E and the other with an SBIG ST-10XME CCD camera. The Astronomical Observatory of the University of Siena (DSFTA, 2016) observations were carried out with a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope and SBIG STL-6303E CCD camera (bin 2x2). All images were acquired with a clear filter and were calibrated with bias, flat, and dark frames.

Differential photometry reduction (R band) and period analysis were performed using *MPO Canopus* version 10.7.1.3 (Bdw Publishing, 2016a) and CMC-15 comparison stars of near solar-color. Some minor adjustments in the lightcurve offsets were made via the CompAdjust function to reach the minimum RMS value from the Fourier analysis (Figure 1).

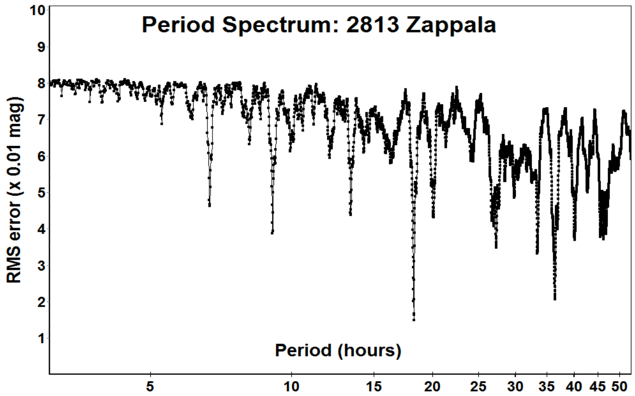

Figure 1. The period spectrum for 2813 Zappala from 5 to 50 hours.

For 2813 Zappala we find a bimodal lightcurve solution with a synodic period *P* = 18.231 ± 0.001 hours and an amplitude *A* = 0.28 ± 0.03 mag (Figure 2).

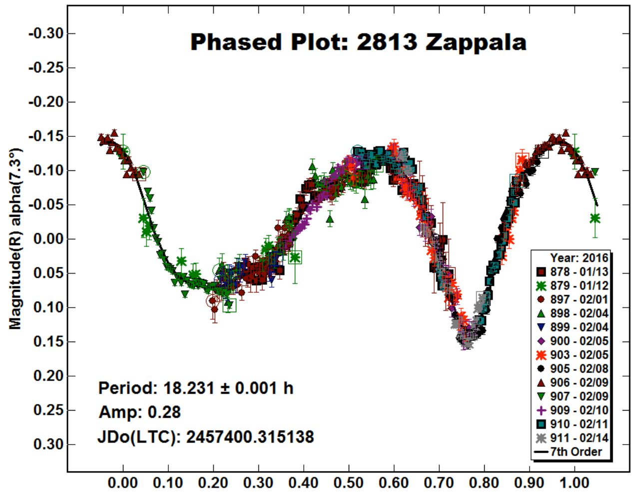

Figure 2. The phased lightcurve for 2813 Zappala.

Using photometric sparse data from USNO Flagstaff station (689) and Catalina Sky Survey (703), we derived $H = 10.99 \pm 0.05$ and $G = 0.31 \pm 0.06$ (Figure 3). Our value for H is close to that of $H = 10.9$ from the JPL Small-Body Database Browser (JPL, 2016). The sparse data were imported from Asteroids Dynamic Site (AstDys, 2016) using the AstDys Data import function implemented in *MPO LCInvert* v.11.7.2.1 (Bdw Publishing, 2016b).

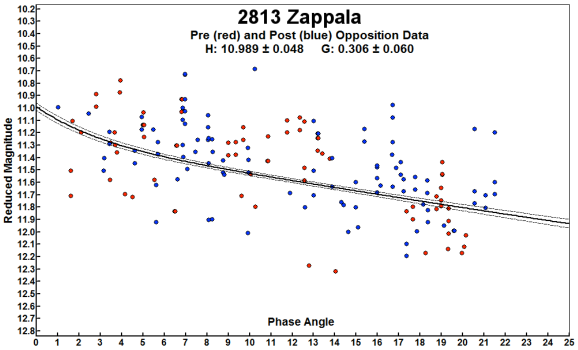

Figure 3. HG plot for 2813 Zappala based on sparse data from two wide-area surveys.

Acknowledgments

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Technology (NMIMT). Some observing sessions at the Astronomical Observatory of the University of Siena were attended by five high school students involved in an interesting vocational guidance project about astronomy: Marina Bastiani (Liceo "S. Bandini", Siena), Federico Benincasa, (Liceo "T. Sarrocchi", Siena), Giovanni La Rosa (Liceo "A. Volta", Colle Val d'Elsa), Federico Cigalotti and Michele Valenti (Liceo "G. Galilei", Siena). Author LF wants to thank Vincenzo Zappala who has always encouraged him.

References

AstDys (2016). Asteroids Dynamic Site. *http://hamilton.dm.unipi.it/astdys/index.php/*

Bdw Publishing (2016a). *MPO Canopus* software. *http:/ww.minorplanetobserver.com/MPOSoftware/ MPOCanopus.htm*

Bdw Publishing (2016b). *MPO LCInvert* software. *http://ww.minorplanetobserver.com/MPOSoftware/ MPOLCInvert.htm*

DSFTA (2016). Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente – Astronomical Observatory. *http://www.dsfta.unisi.it/en/department/science-museums/ astronomical-observatory*

ECO (2016). Etscorn Campus Observatory. *http://www.mro.nmt.edu/education-outreach/etscorn-campus-observatory/*

JPL (2016). 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 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

ROTATION PERIOD ANALYSIS FOR 2729 URUMQI

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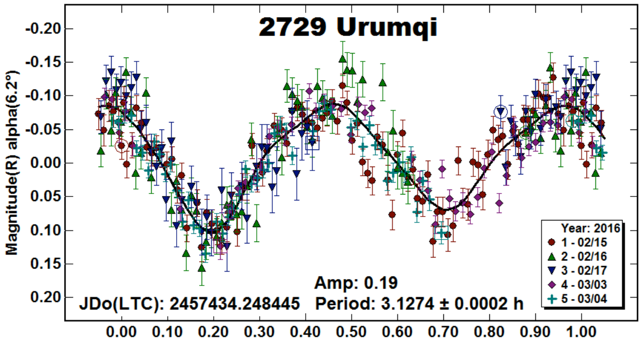
Analysis of photometric observations for the minor planet 2729 Urumqi shows a synodic rotation period of $P = 3.1274 \pm 0.0002$ h with an amplitude $A = 0.19$ mag.

Main-belt asteroid 2729 Urumqi was discovered at Nanking on 1979 Oct 18 by Purple Mountain Observatory. Its orbit has a semi-major axis of 2.891 AU, eccentricity of 0.0668, and period of 4.92 years (JPL, 2016). Previous work found a synodic rotation period $P = 3.127 \pm 0.003$ h (Slivan *et al.*, 2008).

CCD photometric observations of 2729 Urumqi were made at Lvye Observatory (IAU P34) on 2016 Feb 15-17 and at iTelescope Observatory (IAU Q62) on 2016 Mar 3 and 4. The instruments of Lvye Observatory are a Skywatcher 0.25-m *f*/4.4 Newtonian reflector, SBIG ST-402ME CCD camera at –15°C, binned 2x2, with clear filter. The system has an image scale of 3.22 arc seconds per pixel. Exposures were 120 s. The instruments of iTelescope Observatory are a Planewave 0.43-m corrected Dall-Kirkham and FLI ProLine PL4710 CCD camera at –35°C, binned 2x2, with clear filter. The image scale is 1.83 arc seconds per pixel. Exposures were 120 s. All images were dark, bias, and flat corrected using *MaxIm DL*.

Differential photometry and period analysis were done with *MPO Canopus*. A total of 295 data points was used for the analysis. The lightcurve shows a period $P = 3.1274 \pm 0.0002$ h with an amplitude $A = 0.19$ mag. The period is in agreement with the earlier work.



References

JPL (2015). Small Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi*

Slivan, S.M., Binzel, R.P., Boroumand, S.C., Pan, M.W., Simpson, C.M., Tanabe, J.T., Villastrigo, R.M., Yen, L.L., Ditteon, R.P., Pray, D.P., Stephens, R.D. (2008). "Rotation rates in the Koronis family, complete to H≈11.2." *Icarus* **195**, 226-276.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2016 Feb 20. *http://www.MinorPlanet.info/lightcurvedatabase.html*

Warner, B.D. (2013). MPO Software. *MPO Canopus* v10.4.3.17. Bdw Publishing. *http://minorplanetobserver.com/*

FINDING THE LIGHTCURVE AND ROTATION PERIOD OF MINOR PLANET 7694 KRASETIN

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The lightcurve of 7694 Krasetin was determined using images taken on twenty-one nights at the Philips Academy from 2015 September through November. Analysis of the data found a rotational period of 117.755 ± 0.017 h.

The purpose of this research was to obtain the lightcurve of 7694 Krasetin in order to determine its rotational period. The target was chosen for its magnitude and high declination. A search of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) and other sources did not reveal previously reported lightcurve results for the asteroid. Images were measured using *MPO Canopus* (Warner, 2013) using a differential photometry technique.

All observations were made with a 0.40-m *f*/8 Ritchey-Chrétien by DFM Engineering and an Andor Tech iKon DW436 CCD 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 and guided.

Comparison stars were chosen based on their brightness as well as near solar-color using the Comp Star Selector tool in *MPO Canopus*. Data merging and period analysis were also done with *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris (FALC; Harris *et al.*, 1989). The combined data sets were analyzed by Dear and Nix, students conducting an independent project in astronomy research advised by Odden at Phillips Academy.

Results

7694 Krasetin was determined to be a long rotator after several nights of imaging, resulting in rather flat raw lightcurves that were nevertheless changing in magnitude from night to night. In order to reduce the need to adjust the nightly zero points, the same comp stars were chosen for several consecutive nights when weather conditions made it possible. The resulting lightcurve consists of twenty-one sessions from nights in 2015 September through November. The period spectrum strongly favored a period of 117.755 ± 0.017 hrs. The resulting lightcurve shows an amplitude of 0.87 mag.

Acknowledgements

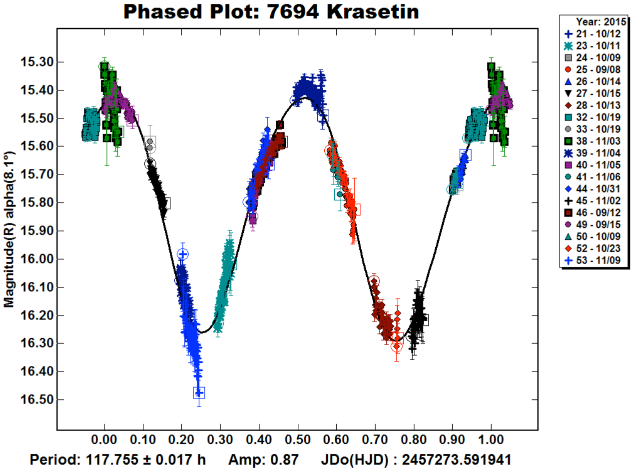
Research at the Phillips Academy Observatory is supported by the Israel Family Foundation. Funding for the Andor Tech camera was generously provided by the Abbot Academy Association.

References

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.

Warner, B.D. (2013). *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). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2016 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*



GAIA-GOSA: A COLLABORATIVE SERVICE FOR ASTEROID OBSERVERS

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We describe the Gaia-Ground-based Observational Service for Asteroids (Gaia-GOSA), which is a website aiming to facilitate asteroid observers in contributing to the Gaia mission by gathering lightcurves of selected targets. GOSA users can plan their observing runs by selecting the visible targets for a given date, collaborate with other observers and upload the frames obtained. OA UAM team will analyze the data, publish the results in the website, and create a lightcurve catalog. Once calibrated, lightcurves will be easily included in the analysis of Gaia data, which will allow us to enhance the determination of asteroids' physical properties.

There are many asteroids for which lightcurves cannot be covered during one observing run, an example being slow rotators with periods longer than 12 hours. There are also targets with periods commensurate with the Earth's day, so their lightcurves cannot be covered by observing from only one site. There are also targets of special interest, *e.g.*, binary objects where a large amount of data are needed. For all targets like those mentioned above, a coordination of observers is needed, which will also avoid unnecessary duplication of data gathering. Initiatives like CALL webpage (*www.minorplanet.info/call.html*) are already used to coordinate asteroid observations. However, our aim is to coordinate ground based observers with the space mission *Gaia*.

To derive asteroid models, we usually rely on relative photometry. However, if these observations are gathered close in time to a Gaia measurement, we can easily calibrate them to the Gaia absolute magnitude. When calibrated, the lightcurve can be easily included as an input data in the Gaia inversion algorithm (Cellino *et al.*, 2006; 2009), which will derive shapes and spin states for more than 10,000 asteroids when Gaia data become available. The Gaia mission will keep on surveying the sky for at least three more years. For this reason, it is important to encourage the observing community to collect as much asteroid data as possible during this period.

To that end, Gaia-GOSA is an ideal tool since it allows coordination among observers, it focus on interesting targets, and it can help avoid unnecessary duplication of observations for the same object at the same time. Furthermore, it is not necessary to be an advanced observer to contribute to the project. The website prepares the observing plan, providing all the necessary information to point your telescope. Users don't need to know how to analyze the data; they have only to upload their observations to the site. Astronomers from the Astronomical Observatory of the Adam Mickiewicz University (OA UAM) will process the data and give feedback to the observer. This paper briefly describes GOSA's functionalities and how you can easily exploit them to contribute to the Gaia mission.

Gaia-Ground-based Observation Service for Asteroids

General Concept. In collaboration with ESA, Gaia-DPAC and ITTI, we have created a web service available at *www.gaiagosa.eu* with the aim of facilitating collaboration between observers to gather lightcurves of selected asteroids. The subscription is free and observers with any level of experience are welcome. After registering, users can define their observing location and instrument. On that basis their observing plan is calculated.

Selected targets cover a wide range of magnitudes, from very large and bright asteroids (*e.g.* "mass perturbers") to small and faint objects close to Gaia's photometric observable limit (V ~ 20). Any observer with a 0.20-m or larger telescope should be able to contribute to the campaign.

All the data gathered by Gaia-GOSA users will be reduced and analyzed by astronomers from the Astronomical Observatory of Adam Mickiewicz University in Poznań (OA UAM). The resulting catalogue containing all the lightcurves obtained, will be used to enhance the results of the Gaia inversion algorithm. Combining both datasets will be straightforward since GOSA lightcurves are collected near a Gaia observation of the same object (Figure 1).

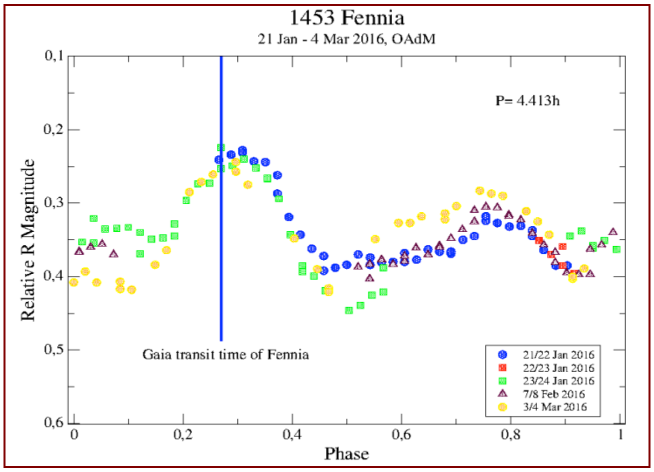

Figure 1. Example of a lightcurve with a Gaia observation (to be calibrated with Gaia data).


GOSA

This is to certify that

has become a **Regular Observer** of the Gaia-Groundbased Observational Service for Asteroids, having submitted 10 asteroid lightcurves.
The data gathered will help to enhance Gaia's solar system science.

The Gaia-GOSA partnership:

Figure 2. The official GOSA certificate for users who have contributed more than 10 valid lightcurves.

Moreover, any user contributing more than ten valid lightcurves will receive an official certificate from the GOSA partnership (European Space Agency, *Gaia* mission and OA UAM) like the one shown in Figure 2.

Observation Planner. After defining the user's observing site and instrument, the "Observation Planner" section can be used to find the asteroids to be observed. The user chooses the days for which observations are being planned and the service will show a list of targets that are visible under the conditions entered and are being observed by Gaia during the selected time. If the list includes a "Hot Target" or a "Follow-up Target" (see descriptions below), these objects are automatically selected as targets to be observed. Apart from that, the user can add additional targets to the observing plan by selecting from the list of observable objects. This section also provides a simple weather forecast for the selected observing site as well as a map with planned observations. After selecting the objects to be observed, the user can proceed to creating the observing plan.

The resulting plan contains the following information: asteroid name, Gaia transit time (UTC), asteroid's Right Ascension and Declination (or, alternatively, the altitude and azimuth), object's visibility on the start and end dates, and the expected magnitude. Moreover, it is possible to plot a star chart of the sky region, including the asteroid's path. On the basis of this information, the observer should be able to plan his observations, *i.e.*, should be able to find the object in the sky, calculate the exposure time required, and choose an adequate field of view with at least three comparison stars.

Hot Targets. We have selected about one hundred asteroids that are of special scientific interest. This includes, among others, suspected fast rotators, slow rotators, known or suspect binary asteroids, and large asteroids for which Gaia will measure gravitational perturbations during close approaches with other smaller bodies. When a GOSA user creates an observing plan, a "Hot Target" is included by default in the observation plan when the following conditions are met:

1. The object is being observed by Gaia during the chosen time
2. The object is visible from the user's observing site
3. The object fits the visibility range of the user's instrument

When all the requirements are fulfilled for a given "Hot Target," it will appear in the user's observation plan.

Follow-up Targets. For the majority of asteroids, it is necessary to combine data gathered during different observing runs in order to complete the lightcurve. For this reason, asteroids without a complete lightcurve observed by GOSA users become "Follow-up Targets." In practice this means that these objects will be included by default in any observing plan when the object is visible from the user's observing site and can be observed with the user's instrument. The full list of active "Follow-up Targets" is shown in the Home page.

Planned Observations. When a user creates an observation plan, it is shown in the "Planned Observations" table in the Home page. A table shows the details of the plan, *i.e.* asteroids planned to be observed, start and end time of the observations, asteroid's current magnitude, as well as some additional information for planning the observing run. Any user willing to support the planned observations can check if the asteroid is visible from his site by clicking on the asteroid's name. It is also possible to contact the observer for further details of the observing plan or to suggest collaboration.

Observation Processing. After gathering the data, users can submit their observations by uploading them in the "Observation Processing" section. All previously submitted observations are listed in this section, which contains information about the object observed, the observer, and date of observations. After data processing, the derived results are also shown.

Other Functionalities. Besides the planning-observing-submitting process, Gaia-GOSA also offers additional functions for registered users. In section "Gaia Status" users can check in real time what asteroid is Gaia observing (on average, an asteroid transits Gaia's focal plane every 10 seconds). This section also gives the possibility of showing the predicted Gaia observation dates for a given asteroid.

A forum is also available for registered users where they can discuss or plan coordinated campaigns, seek for collaboration, or suggest new "Hot Targets." In the "Frequently Asked Questions" (FAQ) section, new users can get a general overview of the service. We expect to extend this section by answering the more commonly asked questions submitted by GOSA observers.

(Imaginary) Example of a User's experience. John Brown has a 0.40-m telescope equipped with a CCD camera and located in Wisconsin. He wants to contribute to Solar System science, and he decides to register to the Gaia-GOSA service. The sign-up process is quick and easy; he only has to provide his location, equipment and a valid e-mail. He visits the "Observation Planner" section, where, after logging in, he types the dates on which he is planning to observe. Then, for his location and instrumentation, the service calculates the observable asteroids that are being also observed by Gaia (or those marked as "Follow-up Targets"). After selecting the objects he wants to observe, the service provides a table containing the basic information necessary to perform the observations, *i.e.*, target's position in the sky, expected magnitude, visibility time range (Figure 3).

After a successful observing run, John visits the site again to upload the data. He uses the "Observation Processing" section, where he indicates the asteroid that was observed, the observation date, and upload the CCD frames. After being analyzed, the resulting lightcurve is published on the site and John's observations count is increased.

Asteroid id (name)	Gaia transit time (UTC)	Right ascension (for max elevation)	Declination (for max elevation)	Elevation (max value)	Azimuth (for max elevation)	Object visibility start date (UTC)	Object visibility end date (UTC)	Magnitude
⚠ (611) Valeria	2016-03-13 06:54:32	+8 27 50.15	+5 21 6.36	+53 10 57.68 📈	+179 15 16.41 📈	2016-03-16 18:53	2016-03-16 23:25	13.8

Figure 3. Example of a personalized observation plan created with Gaia-GOSA.

How to Collaborate

If You are an Observer. Register at *www.gaiagosa.eu* to start planning your asteroid observations with Gaia-GOSA. Contact other GOSA observers, clear up your doubts with more experienced users, and above all, enjoy collaborating with a space mission such as Gaia. Remember that any user submitting more than ten lightcurves will be rewarded with an official certificate.

If you are a Member of an Association. Spread the word! Reprint this paper in your association's newsletter. Include *www.gaiagosa.eu* in your website's links or share it on your social networks.

Ackowledgements

We thank F. Mignard and P. Tanga (OCA, Nice) for putting at our disposal the transit predictions of Solar System objects. The web service has been developed by OA AMU in collaboration with ITTI Sp. z o.o., while the data processing is provided by OA AMU. The service has been funded under the ESA Contract No. 400011266014/NL/CBi: "Gaia-GOSA: An interactive service for asteroid follow-up observations." The Joan Oró Telescope (TJO) of the Montsec Astronomical Observatory (OAdM) is owned by the Catalan Government and operated by the Institute for Space Studies of Catalonia (IEEC).

References

Cellino, A., Delbo, M., Zappala, V., Dell'Oro, A., Tanga, P. (2006). "Rotational properties of asteroids from Gaia disk-integrated photometry: A genetic algorithm." *Adv. Space Res.* **38**, 9.

Cellino, A., Hestroffer, D., Tanga, P., Mottola, S., Dell'Oro, A. (2009). "Genetic inversion of sparse disk-integrated photometric data of asteroids: application to Hipparcos data." *Astron. Astrophys.* **506**, 935.

PHOTOMETRIC OBSERVATIONS OF NEAR-EARTH ASTEROID (348400) 2005 JF21

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The near-Earth asteroid (348400) 2005 JF21 made a close pass to Earth in 2015 August. CCD photometric observations of the asteroid were made from 2015 August through November. Analysis of the data derived the primary period. However, an attempt to constrain the orbital period of the satellite reported by radar observations had limited success.

Whenever possible, an NEA should be observed for 1-2 months before and after its closest encounter with Earth. There are a number of reasons for this. The changes in lightcurve amplitude and shape with changing phase angle and viewing aspect (phase angle bisector; see Harris *et al.*, 1984) of a near-Earth asteroid during a single apparition can provide a wealth of information about the physical characteristics of the object. There is also the opportunity to determine a precise rotational period and monitor changes in the synodic period, which can lead to determining the sense of rotation, *i.e.*, prograde or retrograde. The changing viewing geometry also presents the chance of detecting one or more satellites. Finally, having data from large and small phase angles is also important for shape modeling using convex lightcurve inversion (Kaasalainen 2001).

The difficulty working with NEAs in general is that, when they are at their brightest, they are often travelling the fastest with respect to background stars, forcing the need for many different sets of comparison stars while performing differential photometry. When the asteroid's movement is slower, it can also be too faint to observe. Some NEAs move from one hemisphere to the other, meaning that, in many cases, a single observatory can obtain data for only one leg of the apparition.

(348400) 2005 JF21 was unique in that it was observable for several months as it receded from Earth. It was observed starting in 2015 July, a month prior to closest approach, until 2015 November. The phase angle was 31° on July 19, reached a maximum of 74° in early October, and then decreased to 25° on Nov 16, the last night of observations. During the same interval, the phase angle bisector longitude (L_{PAB}) increased from 282° to 51°, reaching 0° in early September, while the latitude (B_{PAB}) decreased from 15° to –23°.

The observations by Julian Oey were taken with a 0.35-m Schmidt-Cassegrain (SCT) using an SBIG ST8XME camera. Images were unfiltered with exposures of 300 seconds to maximize SNR but, at the same time, provide sufficient data point frequency. During closest approach, when the asteroid was at its brightest and with large sky motion, observations were made with a 0.12-m refractor and SBIG ST8300M binned 2x2, which provided a much larger field-of-view. This maximized the number of data points in each session, a session being those observations using the same set of comparison stars. All images taken with this system were unfiltered. When the asteroid faded beyond the range of the smaller telescopes, supplemental data were obtained using a 0.61-m reflector and Apogee U42 camera. All images using this system were taken with a Johnson-Cousins R filter at 180 seconds integration time. Roger Groom used 0.30-m SCT and SBIG ST8XME camera unfiltered at 300 s integration time.

Obs	Telescope (m)	Camera	Pix (μm)	Bin	Scale
BMO	0.12 f/7.5	ST-8300M	5.4	2x2	2.33
BMO	0.35 f/5.9	ST-8XME	9.0	1x1	0.88
BMO	0.61 f/6.8	U42	13.5	1x1	0.70
Groom	0.30 f/7.4	ST-8XME	9.0	1x1	0.84

Table I. Equipment used for the observations of 2005 JF21. The scale is in arcsec/pixel.

All images were processed with a set of median combined bias, median combined dark frames at the same operating temperature, and median combined flat field frames taken at dusk. The images were measured by Oey using *MPO Canopus* v10. Period analysis used the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using the MPOSC3 star catalogue. Its field stars were converted to approximate Cousins R magnitudes based on 2MASS J-K colours (Warner, 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar-colour. However, the zero point was adjusted up to 0.5 mag to match adjacent sessions when it was clear that the linked sessions were not as consistent as expected. These large errors were due to inaccuracies from the conversion of one catalogue to another.

The data from the five months were split into five different lightcurve plots to demonstrate the changes in the amplitude and synodic period due the changing phase angle bisector. At low solar phase angles, the low amplitude of the lightcurve indicated a nearly spheroidal shape. The plot in the Y-axis represents reduced magnitudes that were converted 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. From the data obtained in 2015 July, we were unable to derive a reliable rotation period due to the short sessions and lack of reliable pattern in the curves (Plot '1'). However, the data from subsequent months clearly show a typical bimodal lightcurve. The combined data set of more than 2500 data points was used to find a single synodic rotation period to 2.41437 ± 0.00002 h with an average amplitude of 0.11 ± 0.04 mag ("Combined"). Plots '2' through '6' show the evolution of the lightcurve and synodic period starting in August and ending in November.

The data were sent to Petr Pravec for a complete analysis. He found that there was an indication of a satellite consistent with an orbital period of 29 h. Observations by Stephens and Warner (2016) on ten nights from 2015 June to August reported a possible binary detection with an orbital period of 14.74 h. To improve the binary search solution, their data were downloaded from the ALCDEF database (MPC, 2015) and combined with our data for reanalysis. It was found that Stephens's data were consistent with the 29-hour orbital period, but not Warner's. Meanwhile, Naidu *et al.* (2015) using radar observations found that 2005 JF21 was binary with a weak signal possibly due to a second satellite. Private communication with Naidu confirmed that the 29h period was consistent with the orbital period of the confirmed first satellite.

Despite an extended search attempt, no further improvements from the original weak detection of the mutual events were found. This could be due to the rapid change in the viewing geometry that did not favour mutual events and also the large inaccuracies associated with data linkages.

Acknowledgements

JO would like to thank Petr Pravec for all his work with binary asteroid survey. Despite not being entirely part of the survey work, he still showed tremendous interest in this NEA. Without his help, the work at BMO would not have reached its current standards. To Brian Warner for supporting JO with *MPO Canopus* software, which made it all possible. Thanks to Paul Camilleri, who tirelessly processed the massive amount of astrometric data for reporting in MPC. Work at the Blue Mountains Observatory is supported by a 2015 Shoemaker NEO Grant.

References

BMO (2015). Blue Mountains Observatory Website. *https://www.bluemountainsobservatory.com.au/asteroid/observatory.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.

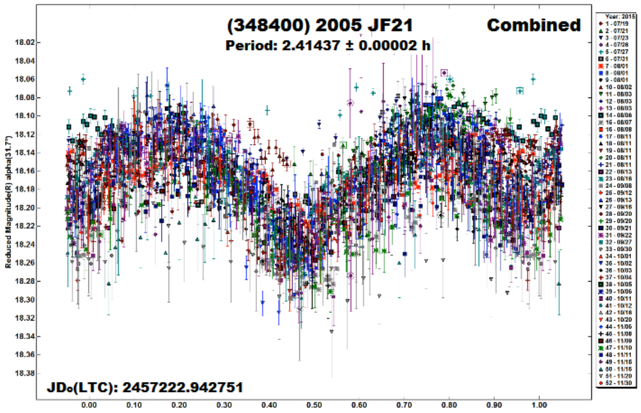
Kaasalainen, M., Torppa, J. (2001). "Optimization Methods for Asteroid Lightcurve Inversion: I. Shape Determination." *Icarus* **153**, 24-36.

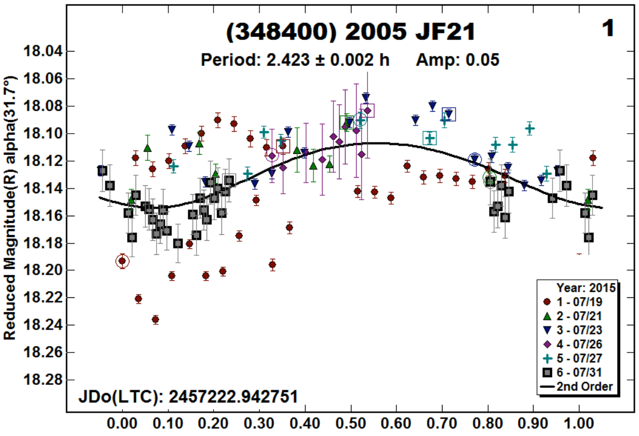
MPC (2015). Minor Planet Center. ALCDEF database. *http://minorplanetcenter.net/light_curve2/light_curve.php*

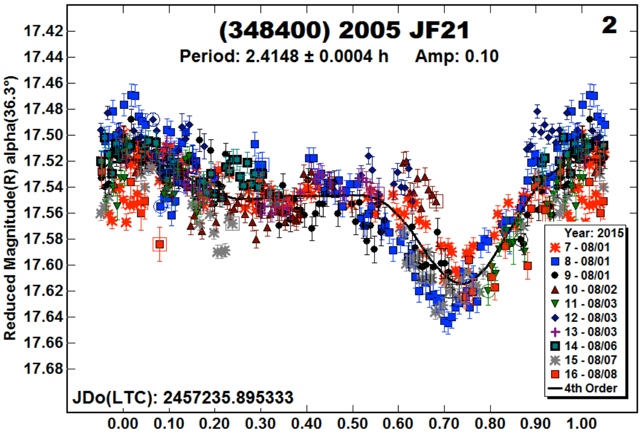
Naidu, S.P., Benner, L.A.M., Brozovic, M., Giorgini, J.D., Jao, J.S., Lee, C.G., Snedeker, L.G., Lawrence, K.J. (2015). "(348400) 2005 JF21." *CBET* **4139**, 1.

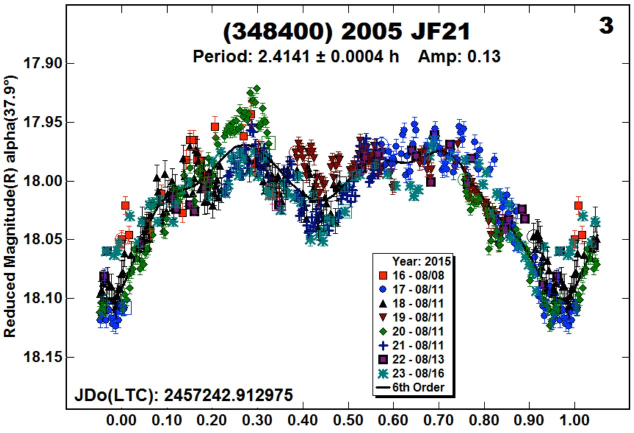
Stephens, R.D., Warner B.D. (2016). "Lightcurve Observations of (348400) 2005 JF21: an NEA Binary." *Minor Planet Bull.* **43,** 22-24.

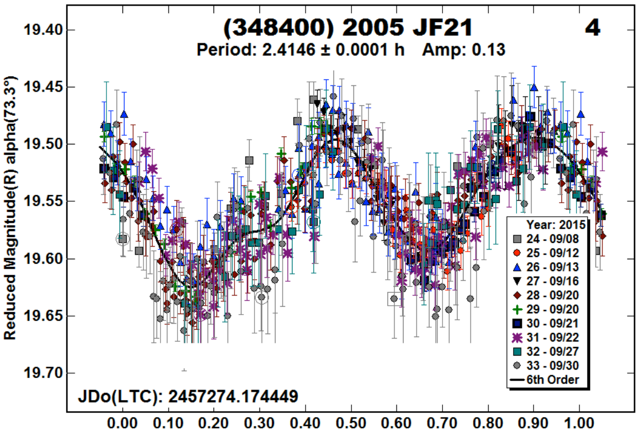
Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bull.* 34, 113-119.

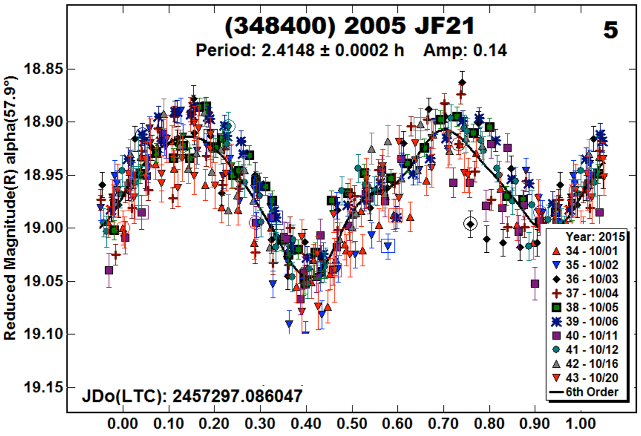


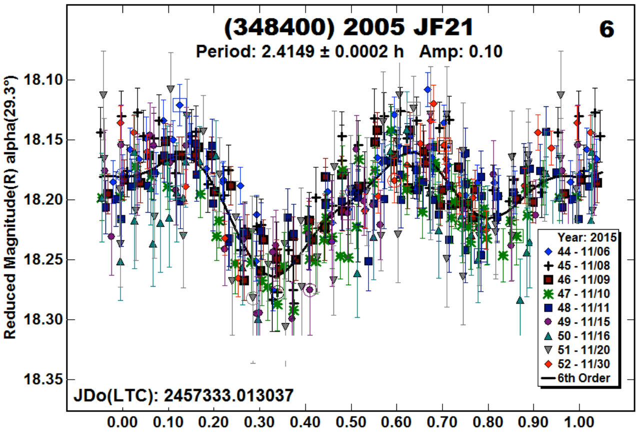












LIGHTCURVES AND ROTATIONAL PERIODS OF THREE MAIN-BELT ASTEROIDS

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Lightcurves were measured for three asteroids: 800 Kressmania, 3494 Purple Mountain, and (25891) 2000 WK9. Respectively, the rotational periods determined were 4.465 ± 0.002 hours, 2.929 ± 0.001 hours, and 4.1375 ± 0.0015 hours.

The purpose of this research was to determine the rotational periods of three main-belt asteroids: 800 Kressmania, 3494 Purple Mountain, and (25891) 2000 WK9. The method used lightcurves revealed through photometric data taken over several nights. The lightcurves were then analyzed to determine both the rotation period and a predicted shape. The asteroids studied were picked because of their apparent magnitude, declination, and opposition date. Asteroids with positive declinations were chosen when using the Northern Hemisphere telescope and negative declinations when using the Southern Hemisphere telescope. For optimum signal-to-noise ratio, the asteroid needed to have a V magnitude of 16 or brighter. Asteroids were all within a week of their opposition dates, which allowed for a maximum number of images to be taken each night.

Asteroid 800 Kressmania was discovered by M. Wolf at Heidelberg in 1915. It has an orbital eccentricity of 0.202 and a semi-major axis of 2.193 AU (JPL, 2016). Asteroid 3494 Purple Mountain was discovered in 1980 by Purple Mountain Observatory at Nanking. It has an orbital eccentricity of 0.131 and a semi-major axis of 2.349 AU (JPL, 2016). Asteroid (25891) 2000 WK9 was discovered in 2000 by C.W. Juels at Fountain Hills. This asteroid has an orbital eccentricity of 0.237 and a semi-major axis of 2.752 AU (JPL, 2016).

Method

Two separate telescopes were used for this research. Both are part of the Southeastern Association for Research in Astronomy (SARA) consortium. The telescope at SARA-North is a 0.9-m telescope, with an Apogee CCD camera located at the Kitt Peak National Observatory (KPNO) in Arizona. SARA-South has a 0.6-m telescope, also with an Apogee CCD camera, at the Cerro Tololo Inter-American Observatory (CTIO) in La Serena, Chile.

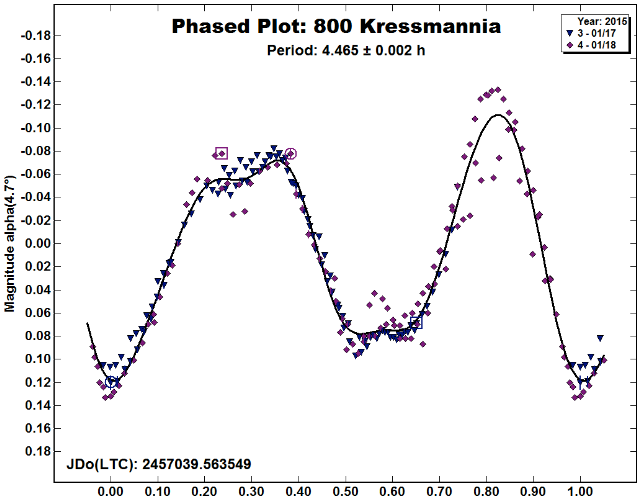
In order to reduce the images, flats, bias, and dark calibration images were taken each night. The flat-field images were taken against the twilight sky. The darks were exposed for the same time as the respective light images, three minutes for both SARA telescopes. The filter used for the SARA-North telescope was an IR-blocking and the one for SARA-South was a Luminance-5. Both filters transmit the visible portion of the spectrum but block the infrared.

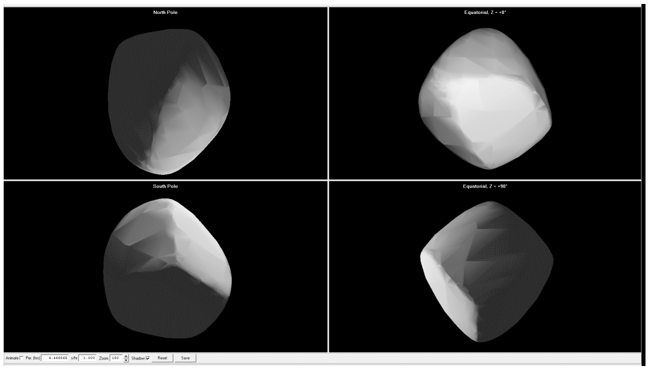
The program *MaximDL* was used to reduce and align the images. Afterward, the program *MPO Canopus* v10.2.1.0 (Warner, 2011) was used to perform differential photometry on the reduced data. For each data set, five stars were used for brightness comparison to the asteroid. Aperture photometry was used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

The processed *MPO Canopus* files were exported into *MPO LCInvert* (Warner, 2011), which is based on the original FORTRAN code by Kaasalainen *et al.* (2001a, 2001b). The reduced and light-time corrected *MPO Canopus* data files were converted into “Kaasalainen files” that have a specific format expected by the inversion algorithms. A search was done using *MPO LCInvert* for the rotational period with the lowest chi-squared value, indicating best fit. For all three asteroids, the rotational periods found were within 0.01 hours of the original lightcurve periods. This match gives credence to the accuracy of the 3-D models produced. However, limited solar phase angle variations in the data may mean the actual shapes are different than the ones found in this study. Certainly for any object observed at only one opposition, the shape model is quite speculative. Thus, these models are simply interesting visualizations of idealized convex representations for approximate shape models of each asteroid.

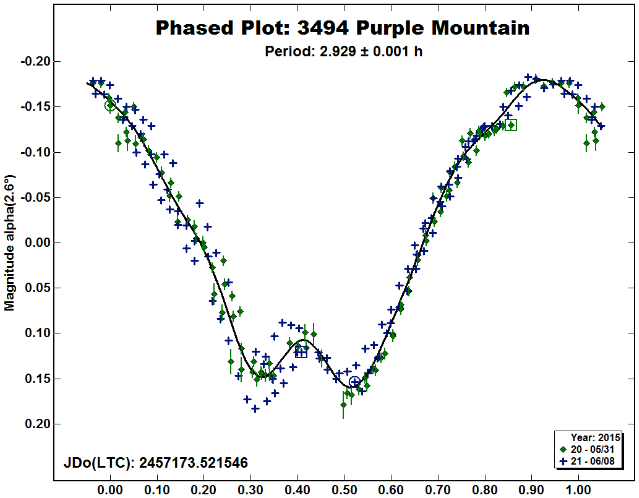
Results

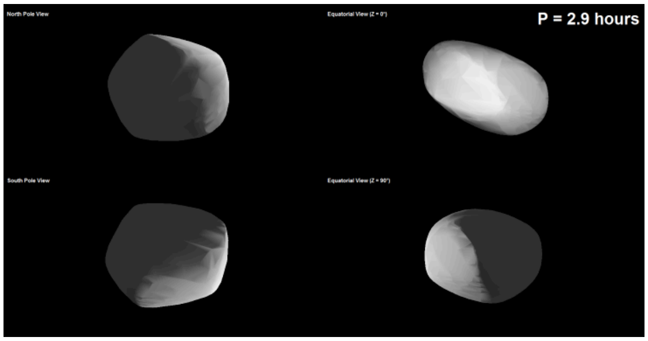
800 Kressmania. The asteroid 800 Kressmania was imaged 105 times on 2015 Jan 17 and 118 times on January 18. Both nights were done on the SARA-North telescope. Analysis of the data found a rotation period of 4.465 ± 0.002 hours with an amplitude of 0.15 magnitudes. A previous study found a nearly identical rotation period of 4.464 hours with an amplitude of 0.12 magnitudes (Kryszczynska *et al.*, 2012).

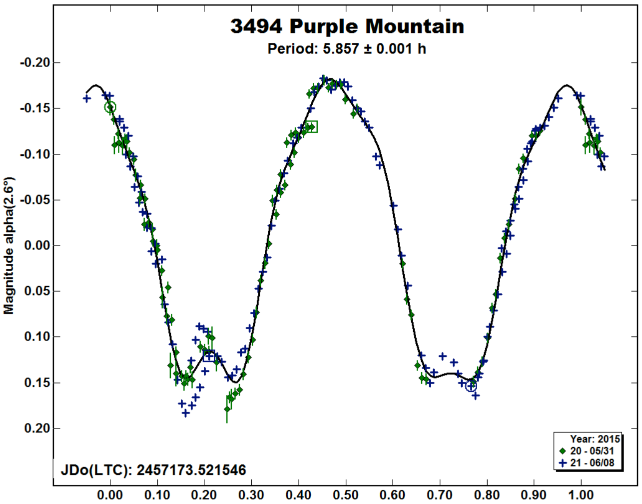


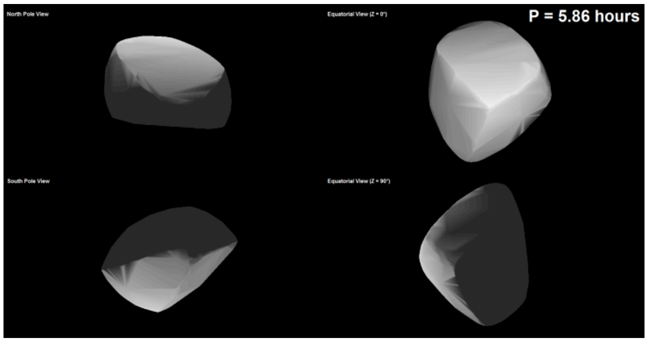


3494 Purple Mountain. The asteroid 3494 Purple Mountain was imaged 99 times on 2015 May 31 and 119 times on June 8 with the SARA-South telescope. Two lightcurves resulted from this data and produced periods of 2.929 ± 0.001 hours and 5.857 ± 0.001 hours, both with amplitudes of 0.2 magnitudes. Given that 5.857 hours is a multiple of 2.929 hours, both of these periods were carefully examined. In the lightcurve of the shorter period, the smaller maximum, at phase angle 0.4, was too distinctive a feature to likely be produced twice. In the lightcurve of the longer period, the feature is reproduced three different times. This points to there being a similar physical feature on both sides of the asteroid, which is unlikely. Thus, this study leans toward the shorter rotation period of 2.929 ± 0.001 hours, but the period of 5.857 ± 0.001 hours is possible.

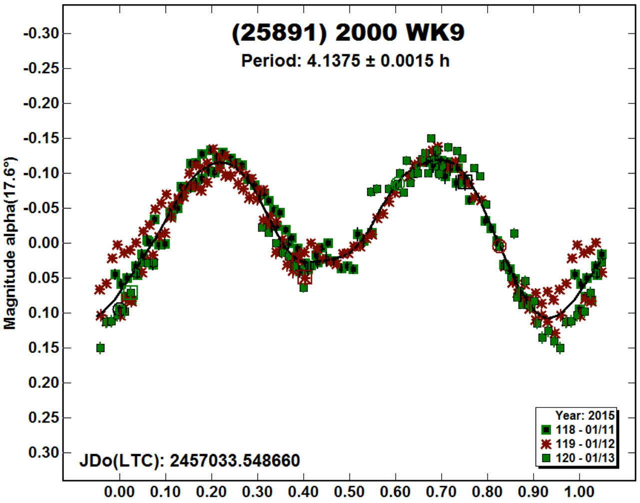


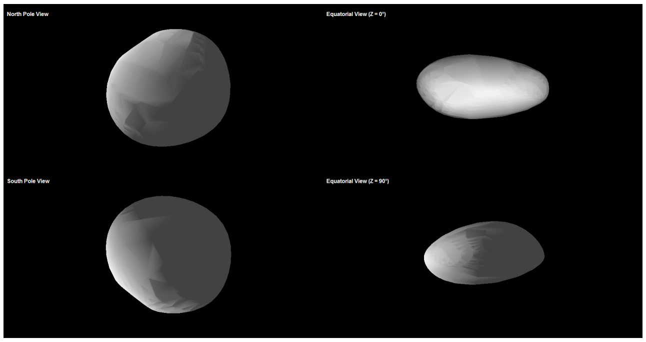






(25891) 2000 WK9. The asteroid (25891) 2000 WK9 was observed over three nights. It was imaged 90, 109, and 59 times on 2015 January 11, 12, and 13, respectively. The images were taken with SARA-South and the lightcurve produced a rotational period of 4.1375 ± 0.0015 hours with an amplitude of 0.15 magnitudes. There were no previous studies done on this asteroid.





References

JPL (2016). Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

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

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

Kryszczynska, A., Colas, F., Polinska, M., Hirsch, R., *et al*. (2012) *Astron. Astrophys.* **546**, A72.

Kryszczynska, A., Colas, F., Polinska, M., Hirsch, R., Ivanova, V., Apostolovska, G., Bilkina, B., Velichko, F.P., Kwiatkowski, T., Kankiewicz, and 20 coauthors. (2012). "Do Slivan states exist in the Flora family? I. Photometric survey of the Flora region." *Astron. Astrophys.* **546**, A72.

Warner, B.D. (2011). *MPO Canopus* software v10.2.1.0 Bdw Publishing. *http://www.minorplanetobserver.com/*

GENERAL REPORT OF POSITION OBSERVATIONS BY THE ALPO MINOR PLANETS SECTION FOR THE YEAR 2015

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Observations of positions of minor planets by members of the Minor Planets Section in calendar year 2015 are summarized.

During the year 2015 a total of 2053 positions of 291 different minor planets were reported by members of the Minor Planets Section. Of these 511 are CCD measures and the others are approximate visual positions.

The summary lists minor planets in numerical order, the observer and telescope aperture (in cm), UT dates of the observations, and the total number of observations in that period. CCD observations are indicated by C; all other obeservations are visual. The year is 2015 in each case.

Positional observations were contributed by the following observers:

Observer, Instrument	Location	Planets	Positions
Faure, Gerard and Rayon, Jean-michel 20 cm Celestron 40 cm Meade LX200	Col de l'Arzelier, France and environs	7	521 (511C)
Harvey, G. Roger 73 cm Newtonian	Concord, North Carolina, USA	198	706
Pryal, Jim 20 cm f/10 S-C	Ellensburg, WA USA	28	71
Werner, Robert 20 cm Celestron	Pasadena, CA USA	77	755

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2015)	NO. OBS.
1 Ceres	Werner, 20	Aug 5-Sep 21	17
2 Pallas	Werner, 20	Aug 9-Sep 14	13
3 Juno	Werner, 20	Jan 15-Apr 13	24
4 Vesta	Pryal, 20	Oct 6	2
	Werner, 20	Sep 7-Nov 5	14
7 Iris	Werner, 20	Feb 13-Apr 20	15
8 Flora	Werner, 20	Mar 10-Apr 17	10
9 Metis	Werner, 20	Aug 13-Nov 5	20
11 Parthenope	Werner, 20	Apr 15-Jun 20	16
13 Egeria	Werner, 20	Sep 8-Nov 5	12
14 Irene	Werner, 20	Oct 3-Nov 20	9
15 Eunomia	Pryal, 20	Oct 6	2
	Werner, 20	Sep 4-Nov 7	17
17 Thetis	Pryal, 20	Mar 10	2
	Werner, 20	Apr 10-20	7
19 Fortuna	Werner, 20	Apr 15-20	3
20 Massalia	Werner, 20	Apr 14-20	5
21 Lutetia	Werner, 20	Aug 5-Oct 21	26
22 Kalliope	Werner, 20	Sep 7-Nov 5	14

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2015)	NO. OBS.
24 Themis	Werner, 20	Jun 19-20	2
26 Proserpina	Werner, 20	Nov 5-20	6
29 Amphitrite	Pryal, 20 Werner, 20	Oct 21 Oct 2-Nov 11	2 10
32 Pomona	Werner, 20	Jul 16-Aug 17	10
38 Leda	Pryal, 20 Werner, 20	Feb 23 Feb 10-Mar 20	2 11
39 Laetitia	Werner, 20	Nov 5-20	6
43 Ariadne	Werner, 20	Nov 5-20	6
44 Nysa	Werner, 20	Apr 10-Jun 20	19
45 Eugenia	Werner, 20	Sep 7-Oct 8	10
48 Doris	Werner, 20	Jun 6-17	4
49 Pales	Pryal, 20 Werner, 20	Dec 15 Nov 5-20	2 6
51 Nemausa	Werner, 20	Jul 16-Aug 16	10
61 Danaë	Werner, 20	Sep 7-Nov 11	17
65 Cybele	Werner, 20	Aug 5-Sep 21	13
68 Leto	Werner, 20	Aug 5-Oct 12	19
69 Hesperia	Werner, 20	Feb 15-Mar 26	7
71 Niobe	Pryal, 20 Werner, 20	Feb 16-17 Feb 15-Apr 14	2 11
72 Feronia	Werner, 20	Jun 6-20	8
74 Galatea	Pryal, 20 Werner, 20	Sep 21-22 Sep 7-Nov 5	2 14
75 Eurydike	Werner, 20	Oct 3-Nov 20	11
77 Frigga	Pryal, 20 Werner, 20	Dec 15 Nov 5-20	2 6
89 Julia	Pryal, 20 Werner, 20	Feb 16-17 Feb 9-Mar 27	2 14
92 Undina	Werner, 20	Jun 15-Jul 18	11
100 Hekate	Werner, 20	Aug 5-Sep 21	15
103 Hera	Werner, 20	Nov 5-20	6
106 Dione	Werner, 20	Oct 3-Nov 20	10
109 Felicitas	Pryal, 20 Werner, 20	Sep 21-22 Sep 7-Oct 11	2 10
111 Ate	Werner, 20	Apr 10-14	4
118 Peitho	Werner, 20	Nov 5-20	6
121 Hermione	Werner, 20	Oct 12-Nov 20	8
129 Antigone	Werner, 20	Jul 14-Aug 18	14
135 Hertha	Werner, 20	Aug 5-18	9
148 Gallia	Werner, 20	Jan 14-25	8
177 Irma	Pryal, 20	Sep 12	3
179 Klytaemnestra	Werner, 20	Oct 8-12	3
182 Elsa	Werner, 20	Aug 13-16	2
192 Nausikaa	Werner, 20	Nov 5-20	6
200 Dynamene	Pryal, 20 Werner, 20	Sep 11-12 Aug 17-Sep 14	2 4
201 Penelope	Pryal, 20 Werner, 20	Sep 11-12 Aug 13-Oct 11	2 16
203 Pompeja	Pryal, 20	Oct 21	2
214 Aschera	Pryal, 20	Mar 10	2
221 Eos	Werner, 20	Aug 13-Sep 21	10
240 Vanadis	Pryal, 20 Werner, 20	Dec 15 Nov 5-20	2 6
247 Eukrate	Werner, 20	Nov 7-20	3
266 Aline	Pryal, 20	Oct 21	2
287 Nephthys	Werner, 20	Aug 9-12	4
306 Unitas	Werner, 20	Jul 14-Aug 17	11
324 Bamberga	Werner, 20	Mar 10-20	3
337 Devosa	Werner, 20	Jan 20-Feb 18	12
352 Gisela	Werner, 20	Sep 14-Oct 21	11
354 Eleonora	Werner, 20	Apr 10-Jun 20	19
356 Liguria	Pryal, 20 Werner, 20	Oct 6 Oct 2-Nov 11	2 10
362 Havnia	Pryal, 20	Oct 21	2
386 Siegena	Werner, 20	Nov 5-20	4
410 Chloris	Pryal, 20 Werner, 20	Sep 21-22 Sep 14-20	2 2
444 Gyptis	Werner, 20	Jun 9-20	6
449 Hamburga	Pryal, 20	Feb 23	2
471 Papagena	Werner, 20	Oct 2-11	10
485 Genua	Werner, 20	Jan 14-25	7
511 Davida	Werner, 20	Apr 10-20	7
514 Armida	Harvey, 73	Oct 8	3
532 Herculina	Werner, 20	Jun 17-Aug 17	17
628 Christine	Faure and Rayon, 40	Feb 20-Mar 13	4C
674 Rachele	Werner, 20	Apr 10-17	3
678 Fredegundis	Werner, 20	Nov 5-14	4
690 Wratislavia	Werner, 20	Sep 7-Oct 12	12
727 Nipponia	Pryal, 20	Feb 16-17	2
914 Palisana	Werner, 20	Jun 15-20	6
947 Monterosa	Pryal, 20	Oct 21	2
1136 Mercedes	Pryal, 20	Sep 22-23	2
1249 Rutherfordia	Harvey, 73	Dec 16	3
1429 Pemba	Harvey, 73	Nov 14	6
1487 Boda	Harvey, 73	Oct 16	3
1566 Icarus	Harvey, 73	Jun 21	6
1979 Sakharov	Harvey, 73	Oct 17	3
2037 Tripaxeptalis	Harvey, 73	Nov 14	3
2042 Sitarski	Harvey, 73	Oct 17	3
2242 Balaton	Harvey, 73	Dec 5	3
2600 Lumme	Harvey, 73	May 23	3
2601 Bologna	Harvey, 73	Jan 17 .5m f @16.1	3
2622 Bolzano	Harvey, 73	Sep 20	3
2664 Everhart	Harvey, 73	Nov 11	3
2668 Tataria	Harvey, 73	Oct 8	3
2686 Lindasusan	Harvey, 73	Dec 5	3
2700 Baikonur	Harvey, 73	Oct 18	3
2734 Hašek	Harvey, 73	Mar 24 .7m b @15.4	3
2740 Tsoj	Harvey, 73	Aug 22	3
2758 Cordelia	Harvey, 73	Dec 5	3
2929 Harris	Harvey, 73	Feb 14	3
2974 Holden	Harvey, 73	Oct 6	3

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2015)	NO. OBS.
3005 Pervictoralex	Harvey, 73	May 10	3
3050 Carrera	Harvey, 73	Jul 16 .5m f @15.7	3
3111 Misuzu	Harvey, 73	Sep 14	3
3136 Anshan	Harvey, 73	Dec 16	3
3192 A'Hearn	Harvey, 73	Feb 14	3
3249 Musashino	Harvey, 73	Nov 14	3
3357 Tolstikov	Harvey, 73	Feb 14	3
3446 Combes	Harvey, 73	Jan 25	3
3477 Kazbegi	Harvey, 73	Jul 16	3
3489 Lotte	Harvey, 73	Oct 8	3
3531 Cruikshank	Harvey, 73	Mar 24	3
3711 Ellensburg	Harvey, 73	Jan 25	3
3859 Börngen	Harvey, 73	Jan 11	3
3882 Johncox	Harvey, 73	May 24	6
3959 Irwin	Harvey, 73	Oct 8	3
3963 Pardzhanov	Harvey, 73	Dec 16	3
3987 Wujek	Harvey, 73	Nov 11	3
3995 Sakaino	Harvey, 73	Jan 11	3
4027 Mitton	Harvey, 73	May 9	3
4055 Magellan	Pryal, 20	Sep 9-11	6
4096 Kushiro	Harvey, 73	Oct 17	3
4185 Phystech	Harvey, 73	May 24	3
4186 Tamashima	Harvey, 73	Jan 17	3
4268 Grebenikov	Harvey, 73	Nov 17	3
4272 Entsuji	Harvey, 73	Oct 6	3
4273 Dunhuang	Harvey, 73	Oct 18	3
4338 Velez	Harvey, 73	May 23	3
4364 Shkodrov	Harvey, 73	Feb 14 .5m f @16.0	3
4398 Chiara	Harvey, 73	Dec 6	3
4464 Vulcano	Harvey, 73	Sep 14	3
4519 Voronezh	Harvey, 73	Oct 8	3
4567 Bečvář	Harvey, 73	Aug 22	3
4751 Alicemanning	Harvey, 73	May 23	3
4895 Embla	Harvey, 73	Nov 11	3
4963 Kanroku	Harvey, 73	Mar 24	3
5006 Teller	Harvey, 73	Dec 6	3
5037 Habing	Harvey, 73	Oct 19	3
5051 Ralph	Harvey, 73	Jul 16	3
5281 Lindstrom	Harvey, 73	Dec 6	3
5330 Senrikyu	Harvey, 73	Aug 9	6
5348 Kennoguchi	Harvey, 73	Dec 16	3
5416 Estremado	Harvey, 73	Nov 14	3
5425 Vojtěch	Harvey, 73	Nov 14	3
5455 Surkov	Harvey, 73	Sep 18	3
5478 Wartburg	Harvey, 73	Feb 20	3
5524 Lecacheux	Harvey, 73	Jan 17	3
5633 1987 UL7	Harvey, 73	May 10	3
5635 Cole	Harvey, 73	Aug 9	3

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2015)	NO. OBS.
5674 Wolf	Harvey, 73	Sep 14	3
5675 Evgenilebedev	Harvey, 73	Sep 14	3
5709 Tamyeunleung	Harvey, 73	Nov 14	3
5716 Pickard	Harvey, 73	Oct 16	3
5736 Sanford	Harvey, 73	Oct 8	3
5771 Somerville	Harvey, 73	Nov 14	3
5792 Unstrut	Harvey, 73	Sep 20	3
5818 1989 RC1	Harvey, 73	Dec 6	3
5867 1988 RE	Harvey, 73	Oct 8 .5m f @15.9	6
5890 Carlsberg	Harvey, 73	Nov 14	3
5929 Manzano	Harvey, 73	Jan 17	3
5960 Wakkanai	Harvey, 73	Nov 15	3
5981 Kresilas	Harvey, 73	Sep 14	3
6010 Lyzenga	Harvey, 73	Sep 18	3
6049 Toda	Faure and Rayon, 40	Mar 12	64C
6094 Hisako	Harvey, 73	Jul 16	3
6159 1991 YH	Harvey, 73	Dec 16	3
6339 Giliberti	Harvey, 73	Oct 18 .5m f @16.1	3
6392 Takashimizuno	Harvey, 73	Nov 15	3
6476 1987 VT	Harvey, 73	Nov 20	3
6511 Furmanov	Harvey, 73	Feb 20	3
6518 Vernon	Harvey, 73	Apr 24	3
6526 Matogawa	Harvey, 73	Sep 18 .5m f @ 15.8	3
6556 Arcimboldo	Harvey, 73	Nov 14	3
6584 Ludekpesek	Harvey, 73	May 9	3
6690 Messick	Harvey, 73	Sep 19	3
6746 Zagar	Harvey, 73	Jul 16	3
6901 Roybishop	Harvey, 73	Jan 17	3
7093 Jonleake	Harvey, 73	Aug 9	3
7097 Yatsuka	Harvey, 73	Oct 16	3
7181 1991 PH12	Harvey, 73	Jan 17	3
7188 Yoshii	Harvey, 73	Dec 5	3
7216 Ishkov	Harvey, 73	Sep 14	3
7345 Happer	Harvey, 73	Sep 18	3
7404 1988 AA5	Harvey, 73	Dec 5	3
7653 1991 UV	Harvey, 73	Oct 19	3
8079 Bernardlovell	Harvey, 73	Sep 14	3
8152 1986 VY	Harvey, 73	Nov 15	3
8261 Ceciliejulie	Faure and Rayon, 40	Feb 20-Mar 13	5C
8297 Gérardfaure	Faure and Rayon, 40	Feb 11-Mar 12	407C
8508 1991 CU1	Harvey, 73	Jan 17	3
8556 Jana	Harvey, 73	Sep 14	3
9095 1995 WT2	Harvey, 73	Sep 20	3
9216 Masuzawa	Harvey, 73	Aug 22	3
9297 Marchuk	Harvey, 73	Jul 16 1.0m f @15.3	3
9333 Hiramasa	Harvey, 73	Nov 14	3
9400 1994 TW1	Harvey, 73	Sep 9	6

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2015)	NO. OBS.
9533 Alexsejleonov	Harvey, 73	Nov 14	3
9628 Sendaiotsuna	Harvey, 73	Dec 5	3
9773 1993 MG1	Harvey, 73	Jul 16	6
9801 1997 FX3	Harvey, 73	Aug 9	3
9810 Elanfiller	Harvey, 73	Oct 8	3
9955 1991 PU11	Harvey, 73	Sep 14 .5m f @15.8	3
9970 1992 ST1	Harvey, 73	Sep 19	3
10060 Amymilne	Harvey, 73	May 10	3
10064 Hirosetamotsu	Harvey, 73	Oct 18 .5m f @15.7	3
10318 Sumaura	Harvey, 73	Sep 19	3
10459 Vladichaika	Harvey, 73	Oct 18	3
10672 Kostyukova	Harvey, 73	Aug 9	3
11268 Spassky	Harvey, 73	Nov 14	3
11503 1990 BF	Harvey, 73	Jan 17 .3m f @15.9	3
11643 1997 AM22	Harvey, 73	Dec 5	3
12207 1981 EU28	Harvey, 73	Aug 9	3
12230 1986 QN	Harvey, 73	Nov 14	3
12331 1992 UH6	Harvey, 73	Oct 6-8	4
12713 1991 FY3	Harvey, 73	Oct 17	3
12746 Yumeginga	Harvey, 73	Aug 9	3
13007 1984 AU	Harvey, 73	Dec 5	3
13165 1995 WS1	Harvey, 73	Nov 15	3
13186 1996 UM	Harvey, 73	Oct 6	3
13388 1999 AE6	Harvey, 73	Dec 5	3
13448 Edbryce	Harvey, 73	Jan 25 .5m b @ 15.3	3
13487 1981 VN	Harvey, 73	Nov 11	3
13699 Nickthomas	Harvey, 73	Oct 16 .8m f @15.9	3
13762 1998 SG130	Harvey, 73	Oct 8	3
13852 Ford	Harvey, 73	Sep 18	3
14031 Rozyo	Harvey, 73	Dec 16	3
14429 Coyne	Harvey, 73	Feb 14	3
14480 1994 PU1	Harvey, 73	Sep 20	6
14708 Slaven	Harvey, 73	Oct 6	3
14829 Povalyaeva	Harvey, 73	Jul 16	3
14938 1995 DN	Harvey, 73	Aug 22	3
15012 1998 QS92	Harvey, 73	Sep 18	3
15224 Penttilä	Harvey, 73	May 10	3
15349 1994 UX1	Harvey, 73	Oct 19	3
15362 1996 ED	Harvey, 73	Dec 5	3
16446 1989 MH	Harvey, 73	May 23	6
16556 1991 VQ1	Harvey, 73	Sep 19	3
16592 1992 TM1	Harvey, 73	Jan 11	3
17296 3541 P-L	Harvey, 73	Oct 16	3
18103 2000 MC5	Harvey, 73	Nov 15	3
18389 1992 JU2	Harvey, 73	Aug 22	3
19155 Lifeson	Harvey, 73	Oct 19	3
19734 1999 XE175	Harvey, 73	Oct 18	3
20762 2000 EE36	Harvey, 73	Dec 6	3
20188 Cheliabinsk	Faure, 40	Aug 17	4
21690 1999 RA39	Harvey, 73	Feb 14 .5m f @15.8	3
23482 1991 LV	Harvey, 73	Nov 14	3
24417 2000 BK5	Harvey, 73	Dec 5	3
25281 1998 WP	Harvey, 73	Oct 6	3
25282 1998 WR	Harvey, 73	Oct 18 .5m f @15.8	3
26097 1998 VJ1	Harvey, 73	Sep 14 .5m B @14.7	3
26125 1992 RG	Harvey, 73	Nov 20	3
26573 2000 EG87	Harvey, 73	Sep 20	3
27351 2000 DO71	Harvey, 73	Sep 19	3
28321 Arnabdey	Harvey, 73	Nov 20	3
30773 Schelde	Harvey, 73	Sep 14	3
31450 1999 CU9	Harvey, 73	Aug 22	3
33342 1998 WT24	Pryal, 20	Dec 10-11	9
36619 2000 QE151	Harvey, 73	Jan 17 .5m f @15.9	3
41588 2000 SC46	Harvey, 73	Dec 19	6
51690 2001 KS13	Faure and Rayon, 40	Mar 12	31C
80019 1999 HL2	Harvey, 73	Oct 16	3
85989 1999 JD6	Harvey, 73	Jul 10	6
85990 1999 JV6	Harvey, 73	Jan 22	6
86666 2000 FL10	Harvey, 73	Sep 18-19	12
88263 2001 KQ1	Harvey, 73	Nov 15	6
90416 2003 YK118	Harvey, 73	Feb 11	6
130988 2000 WT141	Harvey, 73	Oct 18	3
141527 2002 FG7	Harvey, 73	Mar 18-24	12
154661 2004 FL32	Harvey, 73	Dec 16	6
163696 2003 EB50	Harvey, 73	Dec 4-5	12
163899 2003 SD220	Harvey, 73	Dec 20 .7m f @15.7	6
206378 2003 RB	Harvey, 73	Aug 9	6
303142 2004 DU24	Harvey, 73	Oct 18	3
337866 2001 WL	Harvey, 73	Dec 16	6
357439 2004 BL86	Harvey, 73 Pryal, 20 Werner, 20	Jan 28 Jan 28 Jan 28	6 5 4
413577 2005 UL5	Harvey, 73	Nov 15	6
436724 2011 UW158	Harvey, 73	Jul 18	6
2006 UY64	Harvey, 73	Oct 23	6
2014 UF206	Harvey, 73	Jan 15	6
2014 YM9	Harvey, 73	Feb 8	6
2015 FW117	Harvey, 73	Mar 31	6
2015 FS332	Harvey, 73	Oct 6	6
2015 KA122	Harvey, 73	Jun 5	6
2015 TB145	Faure, 20 Harvey, 73 Werner, 20	Oct 30 Oct 31 Oct 31	6 6 10

PHOTOMETRIC OBSERVATIONS OF MARTIAN TROJAN ASTEROIDS

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We present R filter photometry of the Martian Trojan asteroids (101429) 1998 VF31 and (385250) 2001 DH47, carried out with the 2-m RCC and 1.3-m SMARTS telescopes during 11 nights in 2015 November and 2016 January. A periodogram analysis of the lightcurves suggests a rotation period of *P* = 7.70h with a low amplitude (*A* ≲ 0.1mag) for 1998 VF31 and *P* = 3.97h with amplitude *A* ≅ 0.6mag for 2001 DH47.

The asteroids (101429) 1998 VF31 (VF31 hereafter) and (385250) 2001 DH47 (DH47 hereafter) are two members of a group of small Trojan asteroids that orbit near Mars's L_5 Lagrangian point, on average trailing 60° behind the planet. Their orbits are highly stable, suggesting they may be primordial leftovers from terrestrial planet formation (Scholl *et al.*, 2005). To date, rotational state information exists only for one Martian Trojan, 5261 Eureka (Koehn *et al*., 2014). The authors' analysis suggests a binary system with an orbital period of 16.93h for the secondary and a low-amplitude (*A* = 0.064mag) rotational lightcurve for the primary with a period of 2.69h. Interestingly, Eureka is associated with a small family of Mars Trojans (Christou, 2013; de la Fuente Marcos and de la Fuente Marcos, 2013). Based on the orbital distribution of family members, it has been suggested that these are the products of rotational spin-up and fission due to the YORP effect or, alternatively, collisional fragmentation of one or more parent bodies (Christou, 2013; Ćuk *et al*., 2015). It is therefore of interest to establish the rotational states of Martian Trojans.

Object	UT Date	Obs. Duration	Telescope
VF31	2015 Nov 04	04:30 - 08:05	1.3m SMARTS
VF31	2015 Nov 05	04:55 - 08:05	1.3m SMARTS
VF31	2015 Nov 06	22:52 - 02:10	2mRCC Rozhen
VF31	2015 Nov 06	04:22 - 06:27	1.3m SMARTS
VF31	2015 Nov 09	04:20 - 08:28	1.3m SMARTS
VF31	2015 Nov 11	23:59 - 02:14	2mRCC Rozhen
VF31	2015 Nov 18	03:56 - 07:25	1.3m SMARTS
VF31	2015 Nov 19	03:01 - 06:25	1.3m SMARTS
VF31	2015 Nov 20	03:03 - 06:42	1.3m SMARTS
VF31	2015 Nov 21	03:03 - 07:06	1.3m SMARTS
VF31	2015 Nov 22	04:37 - 06:56	1.3m SMARTS
DH47	2016 Jan 08	22:36 - 02:39	2mRCC Rozhen

Table 1. Observation circumstances. From left to right, the columns give the object abbreviation, the date, the UT at the start and end of the observations and the telescope used.

As part of an ongoing programme to obtain this information, we observed VF31 during 10 nights at the 2-m Ritchey-Chretien-Coude (RCC) telescope at National Astronomical Observatory (NAO; Rozhen, Bulgaria) equipped with a 2-channel focal reducer (FoReRo2) and at the 1.3-m Small and Moderate Aperture Research Telescope System (SMARTS; Cerro Tololo, Chile). DH47 was observed during a single night at the 2-m RCC and FoReRo2. The standard R filter was used for all observations.

Standard data reduction with bias and flat fields was performed. Aperture photometry was carried out with an aperture radius of 2xFWHM to achieve the highest possible S/N.

Lightcurve Analysis

For period determination, we used the Lomb-Scargle (L-S) algorithm (Scargle, 1982) as implemented in the NASA Exoplanet Archive website. Rotation period estimates presented here are twice the periods corresponding to the location of peak power in the period spectra (periodograms). Before the analysis, we compute the average R magnitude of the target for each night and use these averages to shift the measurements for all nights to the same zero datum. The periodogram for VF31 (top panel of Figure 1) shows that the six highest peaks lie in the interval *P* = 5-12h. The highest corresponds to a rotation period of *P* = 7.70h, which we adopt as our nominal solution. Based on the location of the 2nd and 3rd highest peaks – longward and shortward of the nominal solution respectively – we conclude that the true rotation period lies in the range 5.19-9.15h.

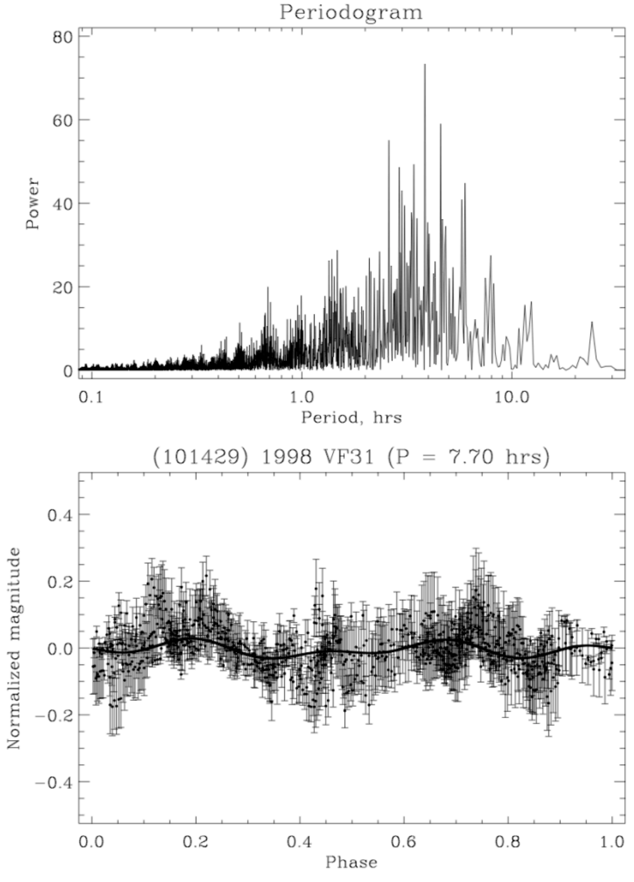

Figure 1. Power spectrum and lightcurve of the asteroid (101429) 1998 VF31.

Fixing the period at that value and letting all other parameters vary results in the best-fit lightcurve shown in the bottom panel of Figure 1. The relatively low amplitude of the lightcurve, 0.07 mag, is similar to that of 5261 Eureka and suggests either that the asteroid shape is axially (or spherically) symmetric or that the asteroid presented a pole-on aspect during the observations.

The periodogram for DH47 (Figure 2, top panel) indicates a most likely rotation period of *P* = 3.97 h. Adopting this as our nominal solution for the asteroid, we obtain the lightcurve shown in the bottom panel, which has an amplitude of 0.58 mag and achieves a goodness-of-fit of $\chi^2 = 1.3$. Adopting the period corresponding to the second highest peak in the periodogram, *P* = 2.2 h, results in a poorer fit with $\chi^2 \cong 7$. Assuming that the periodogram power for the true period must be higher than the peak power for this (incorrect) value, we conclude that the rotational period lies in the range 3.2-4.8 h.

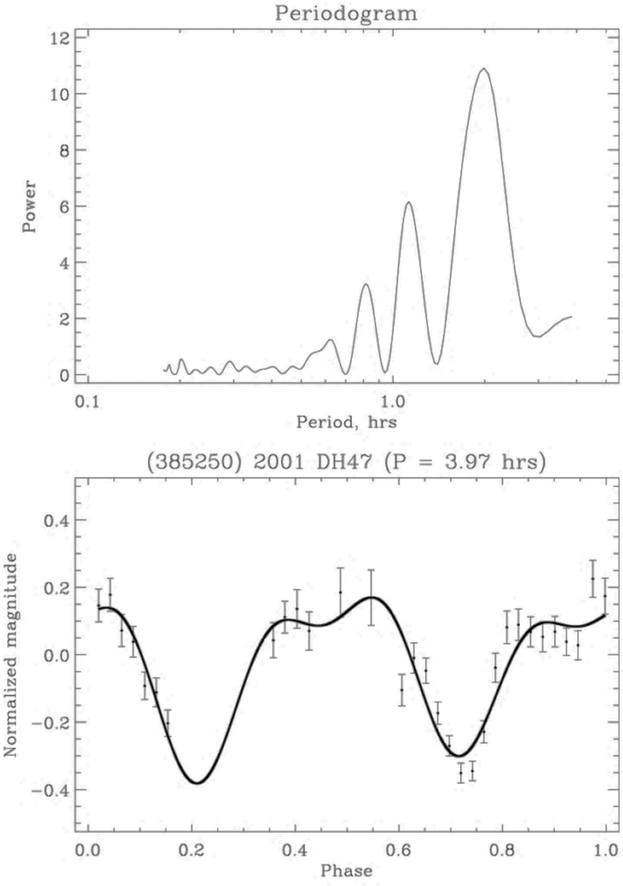

Figure 2. Power spectrum and lightcurve of the asteroid (385250) 2001 DH47.

We assign to both period determinations a quality code U = 2 (Warner *et al*., 2009) since it is unlikely that our nominal estimates are off by a factor of 2 or more.

Acknowledgments

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This research is based in part on observations and data collected at the 2-m RCC telescope at Rozhen National Astronomical Observatory and at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory (Project ID: CHILE-15B-FT01, PI: AAC), which is operated by the Association of Universities for Research in Astronomy (AURA) under a cooperative agreement with the National Science Foundation. This research has also made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program. Astronomical research at the Armagh Observatory is funded by the Northern Ireland Department of Culture, Arts and Leisure.

References

Christou, A.A. (2013). “Orbital clustering of Martian Trojans: An asteroid family in the inner solar system?” *Icarus* **224**, 144-153.

Ćuk, M., Christou, A.A., Hamilton, D.P. (2015). “The Yarkovsky-driven spreading of the Eureka family of Mars Trojans.” *Icarus* **252**, 339-346.

de la Fuente Marcos, C., de la Fuente Marcos, R. (2013). “Three new stable L5 Martian Trojans.” *MNRAS* **432**, 31-35.

Koehn B.W., Bowell, E.G., Skiff, B.A., Sanborn, J., McLelland, K.P., Pravec, P., Warner, B.D. (2014). “Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) – 2009 January through 2009 June.” *Minor Planet Bulletin* **41**, 286-300.

NASA Exoplanet Archive.
http://exoplanetarchive.ipac.caltech.edu/cgi-bin/Pgram/nph-pgram

Scargle, J.D. (1982). “Studies in Astronomical Time Series Analysis II: Statistical Aspects of Spectral Analysis of Unevenly Spaced Data.” *Ap. J.* **26**, 835-853.

Scholl, H., Marzari, F., Tricarico, P. (2013). “Dynamics of Mars Trojans.” *Icarus* **175**, 397-408.

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*

CCD LIGHTCURVE FOR THE MAIN-BELT ASTEROID 240 VANADIS

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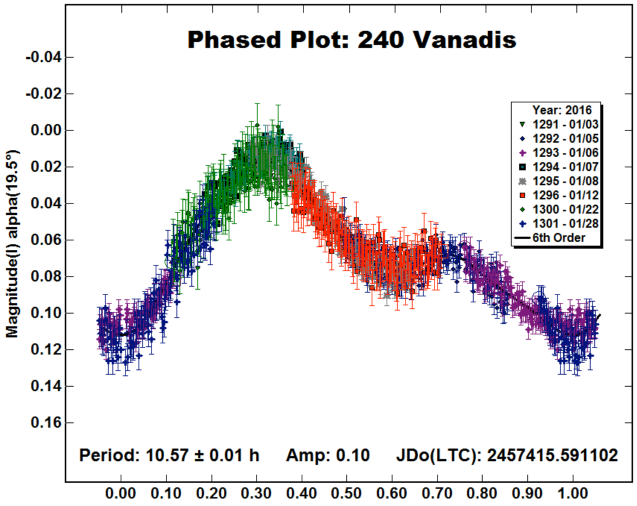
Fourier analysis of a new CCD-derived lightcurve produced a synodic period solution for 240 Vanadis of 10.57 ± 0.01 h.

Observations of the main-belt asteroid 240 Vanadis were made in 2016 January at the UnderOak Observatory (UO). The instrument used was a 0.28-m Schmidt-Cassegrain (SCT) equipped with an

SBIG ST-8XME thermoelectrically-cooled CCD camera. Image calibration and registration procedures employed at UO have been published elsewhere (Alton, 2013). Data reduction with *MPO Canopus* (Warner, 2015) used at least four non-varying comparison stars in the same field-of-view (FOV) to generate lightcurves by differential aperture photometry. Data were light-time corrected but not reduced to standard magnitudes. Fourier analysis (Harris *et al.*, 1989) yielded a period solution from the folded dataset which was independently verified with *Peranso* (Vannmunster 2006) using ANOVA (Schwarzenberg-Czerny, 1996). Phased lightcurve data are available via email to the author upon request.

This somewhat dark (p_v = 0.0411) taxonomic type-C main-belt asteroid with an estimated diameter of D = 91 km (Mainzer *et al.*, 2011) was discovered in 1884 by A. Borrelly. The only published photometric study that produced a lightcurve and determined a synodic period was by Denchev (2000; 10.64 ±0.08 h). At UO, a total of 1055 images (I_C bandpass for 75 s) were taken over eight nights from 2016 Jan 3-28. Fourier analysis of these lightcurve data produced a best folded fit at 10.57 ± 0.01 h. The period solution (10.64 h) reported from the 1999 apparition (Denchev, 2000) did not provide a good fit to the 2016 data. The maximum peak-to-peak amplitude of 0.1 mag observed in 2016 is smaller than the 0.34 mag from Denchev (2000) and reported in the Asteroid Lightcurve Database (Warner *et al.*, 2009).



Acknowledgements

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

References

Alton, K.B. (2013). "Simultaneous CCD Photometry of Two Eclipsing Binary Stars in Pegasus – Part 1: KW Pegasi." *JAAVSO* **41,** 97-113.

Denchev, P. (2000). "Photometry of 11 asteroids during their 1998 and 1999 apparitions." *Plan. Space Sci.* **48**, 987-992.

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.

Mainzer, A., Grav, T., Bauer, J., Masiero, J., McMillan, R.S., Cutri, R.M., Walker, R., Wright, E., Eisenhardt, P., Tholen, D.J., Spahr, T., Jedicke, R., Denneau, L., DeBaun, E., Elsbury, D., Gautier, T., Gomillion, S., Hand, E., Mo, W., Watkins, J., Wilkins, A., Bryngelson, G.L., Del Pino Molia, A., Desai, S., Gómez Camus, M., Hidalgo, S.L., Konstantopoulos, I., Larsen, J.A., Maleszewski, C., Malkan, M.A., Mauduit, J.-C., Mullan, B.L., Olszewski, E.W., Pforr, J., Saro, A., Scotti, J.V., Wasserman, L.H. (2011). "NEOWISE observations of near-Earth objects: Preliminary results." *Ap. J.* **743**, A156.

Schwarzenberg-Czerny, A. (1996). "Fast and Statistically Optimal Period Search in Uneven Sampled Observations." *Ap. J.* **460**, L107.

Vannmunster, T. (2006). *Peranso* v2.5. Period Analysis Software. CBA Belgium Observatory.

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. (2015). MPO Software, *MPO Canopus* v10.7.1.3. Bdw Publishing, Eaton, CO.

FINDING THE LIGHTCURVES AND ROTATION PERIODS OF 2925 BEATTY, 3012 MINSK, AND 9060 TOYOKAWA

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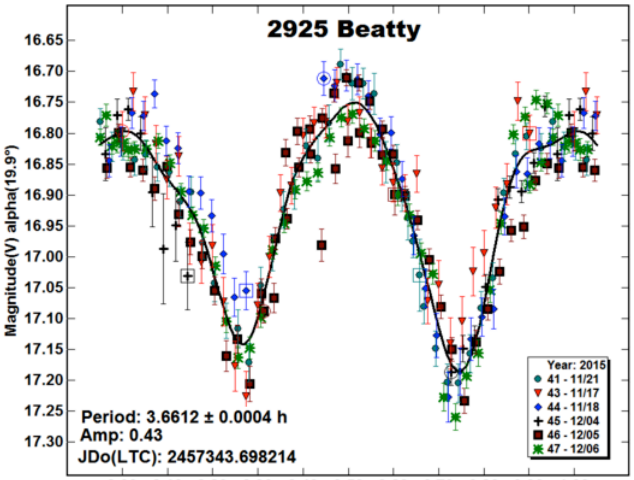
Lightcurves of three asteroids were made from 2015 December to 2016 January. We report the results of our lightcurve analysis for 2925 Beatty, 3012 Minsk, and 9060 Toyokawa.

CCD photometric observations were made from the Phillips Academy of three asteroids from 2015 December and 2016 January. The targets were chosen for their relatively bright magnitudes and high declinations. All observations were made with a 0.40-m *f*/8 Ritchey-Chrétien by DFM Engineering and Andor Tech iKon DW436 CCD 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 and guided.

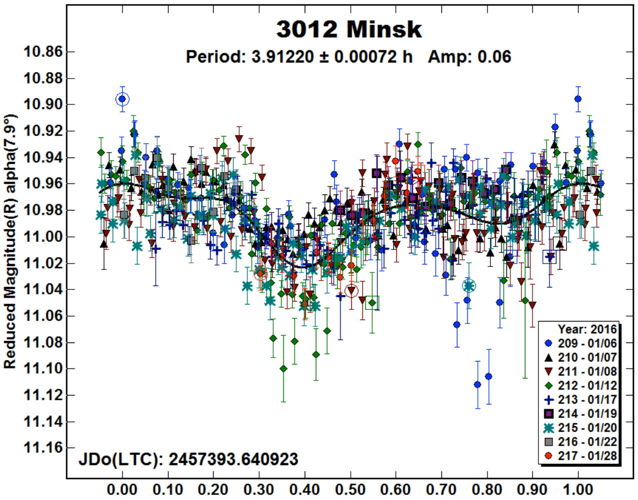
MPO Canopus (Warner, 2013) was used to make photometric measurements of the images using differential photometry as well as to generate the final lightcurves. Comparison stars were chosen to have near solar-color using the Comp Star Selector tool in *MPO Canopus*. In addition, brighter comparison stars were favored. Data merging and period analysis were also done with *MPO Canopus* using an implementation of a Fourier analysis algorithm by Harris (FALC; Harris *et al.*, 1989). The combined data set was analyzed by students in an astronomy research class taught by Caroline Odden.

2925 Beatty. The lightcurve of 2925 Beatty was determined using six nights of data from 2015 November and December. Given the amplitude of the light curve, a bimodal solution was expected (see Harris *et al.*, 2014).

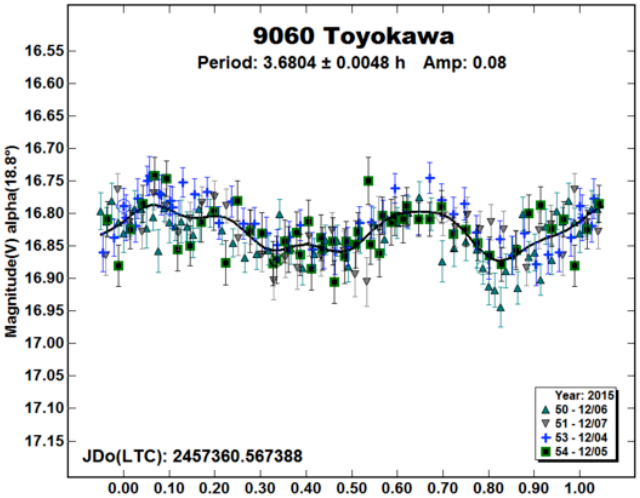


The period spectrum favored a period of 3.661 ± 0.0004 hours. The amplitude was 0.43 mag. A search of the asteroid lightcurve database (LCDB; Warner *et al*., 2009) and other sources revealed that a previous study (Waszczak *et al.*, 2015) determined Beatty's rotational period to be 3.6583 hours, which is consistent with our findings. The lightcurve for 2925 Beatty was compiled by Lior Hirschfeld.

3012 Minsk. The lightcurve of 3012 Minsk was determined using nine nights of data from 2016 January. A search of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) and other sources revealed no previous entries. The resulting lightcurve was found to have an amplitude of 0.06 mag and a period of 3.91220 ± 0.00072 hours. Given the small amplitude of this lightcurve, it is likely that 3012 Minsk is nearly spherical in shape or was oriented pole-on at the time of the observations. Because the image sets were taken several days apart with nearly no magnitude change, the possibility of an extremely long period can be ruled out. The lightcurve for 3012 Minsk was compiled by Aidan Driscoll.



9060 Toyokawa. The lightcurve of 9060 Toyokawa was determined using four nights of data from 2015 December, from which its rotation period was found to be 3.6804 ± 0.00048 h and its amplitude to be 0.08 mag. A search of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) found no previous studies on 9060 Toyokawa's rotational period.



Given the small amplitude of this lightcurve, it is likely that 9060 Toyokawa is nearly spherical in shape or was oriented pole-on at the time of the observations. Because the image sets were taken several days apart with nearly no magnitude change, the possibility of an extremely long period can be ruled out. The lightcurve for 9060 Toyokawa was compiled by Lior Hirschfeld.

Acknowledgments

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References

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., 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.

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. (2013). *The MPO Users Guide: A Companion Guide to the MPO Canopus/PhotoRed Reference Manuals*. BDW Publishing, Colorado Springs, CO.

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.

19204 JOSHUATREE – NOT SO FAST

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CCD photometric observations in 2016 February and March and a reevaluation of observations made in 2013 June of 19204 Joshuatree show it to be a possible binary. It is another candidate for the special case of very wide binaries. The primary lightcurve has a period of 480 ± 5 h and an amplitude 0.25 ± 0.02 mag. and the secondary lightcurve has a period of 21.25 ± 0.05 h.

19204 Joshuatree was discovered by Jean E. Mueller in 1992 as part of the POSS II survey at Palomar Observatory. She recently named the asteroid after Joshua Tree National Park, near where she now lives. She contacted us in hopes of obtaining a rotational period to augment a presentation to park officials featuring the naming of the asteroid. Since we doubt the Superintendent of Joshua Tree National Park or the Yucca Valley City Council are regular readers of the *Minor Planet Bulletin*, we feel safe in announcing the results here.

We informed Mueller that a previous lightcurve had been obtained by the authors in 2006 and 2013 (Stephens, 2006; Warner, 2013). The most definitive result was a 19.55 h period obtained by Warner from observations in 2013 June obtained at the Center for Solar System Studies (CS3, MPC U81), also near Joshua Tree National Park. However, this lightcurve had a low amplitude, a single extrema, and did not have dense coverage over the range of the lightcurve due to the short summer nights in the Northern Hemisphere. With an amplitude of only 0.08 mag., it is possible that the lightcurve could have only a single extrema, or three or more extrema (Harris *et al*, 2014). Because of this, the 2013 result had a U = 2 rating in the asteroid lightcurve database (LCDB; Warner *et al*., 2009), meaning that the period may be wrong by 30 percent or more. To assist Mueller in her presentation and remove the ambiguity, we agreed to reobserve Joshuatree in 2016.

Observations

The observations were made by Stephens using a 0.35-m Schmidt-Cassegrain telescope with Finger Lakes MicroLine ML-1001E CCD camera. The 300-second exposures were unguided and made without a filter. Table I gives the observation circumstances over a span of over a month.

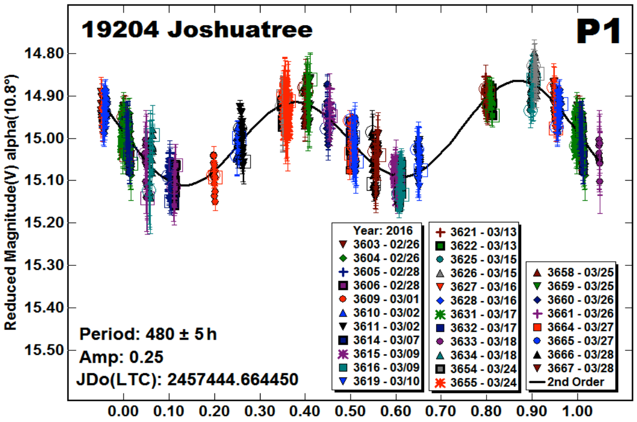
The raw images were flat-field and dark subtracted before being measured in *MPO Canopus*. Night-to-night linkage was aided by the Comp Star Selector utility which helps find near-solar color comparison stars, thus reducing color difference issues. Stars were chosen from the MPOSC catalog, which is based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

2016 mmm/dd	Phase	L_{PAB}	B_{PAB}
Feb 26	10.83	142.7	15.2
Feb 28	11.64	142.7	15.4
Mar 01	12.45	142.7	15.6
Mar 02	12.87	142.7	15.7
Mar 07	14.93	142.7	16.3
Mar 09	15.74	142.7	16.5
Mar 10	16.13	142.7	16.5
Mar 13	17.30	142.8	16.8
Mar 15	18.06	142.9	17.0
Mar 16	18.43	143.0	17.1
Mar 17	18.79	143.0	17.2
Mar 18	19.14	143.1	17.3
Mar 24	21.14	143.5	17.7
Mar 25	21.45	143.6	17.8
Mar 26	21.75	143.7	17.9
Mar 27	22.05	143.8	17.9
Mar 28	22.34	143.9	18.0

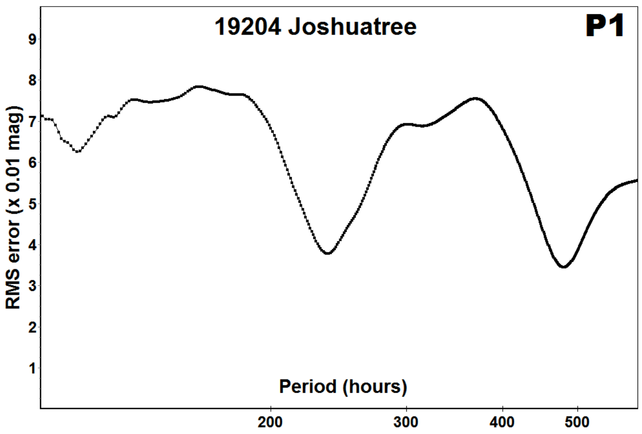
Table I. Observing circumstances for 19204 Joshuatree during the 2016 observing apparition. The last two columns are the phase angle bisector longitude and latitude (see Harris et al., 1984). The values were computed for 8 h UT, or about the middle of each observing run.

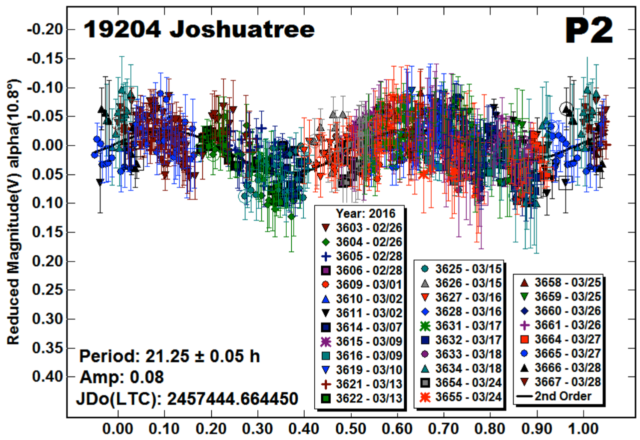
Period Analysis

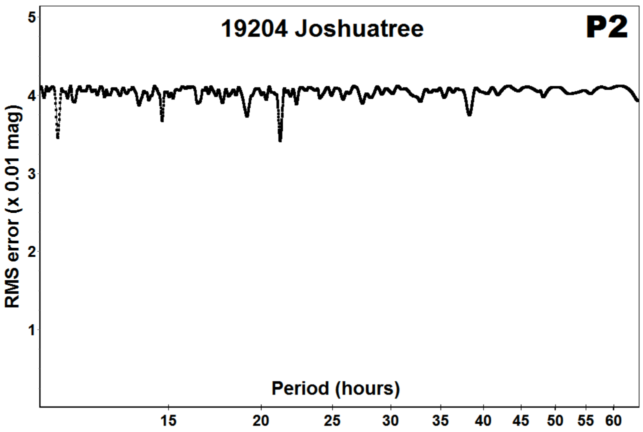
Period analysis was done using *MPO Canopus*, which employs the FALC Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989). *MPO Canopus* can do a dual-period search process. The program first finds an initial value for the dominant (usually shorter) period. The Fourier model lightcurve is subtracted from the data set in the succeeding search for a second period. The Fourier curve for that second period is then subtracted from the data set in a new search for the dominant period. The iterative process continues until both periods stabilize and it produces reasonable lightcurves.



The dual period analysis found a primary lightcurve of P_1 = 480 ± 5 h, A_1 = 0.25 ± 0.02 mag ("P1" plot). Assuming an equatorial view of the asteroid, this leads to an a/b ratio of the asteroid's silhouette of 1.26:1. As expected, subtracting this lightcurve from the data set and doing a period search found a solution that showed no *mutual events* (occultations and/or eclipses) due to a satellite ("P2" plot). The lightcurve has a period of P_2 = 21.25 ± 0.05 h, A_2 = 0.08 mag. The lightcurve was essentially flat, which likely indicates a nearly spheroidal shape for the satellite.

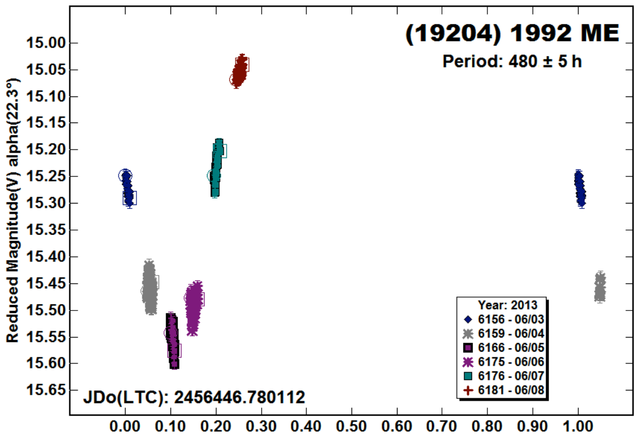


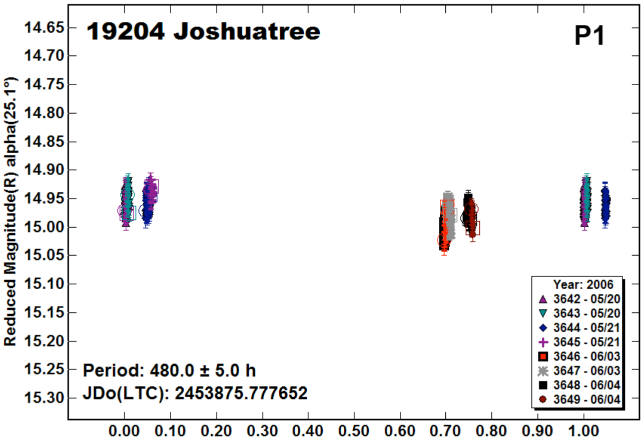


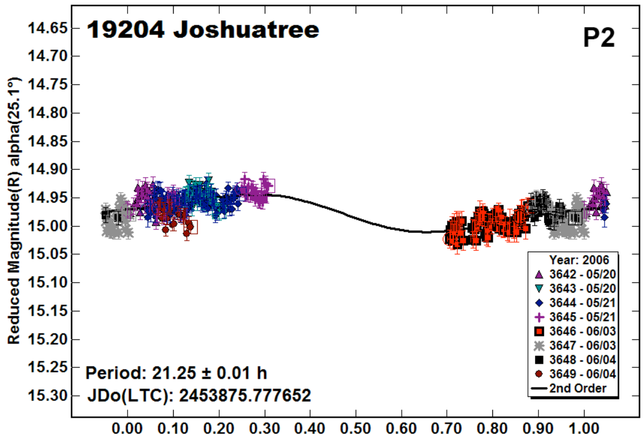


With the finding of a long period component of the lightcurve, Warner reevaluated the 2013 data. By removing all nightly zero point adjustments, Warner was able to show a large amplitude in the dataset over the five night span, consistent with a 480 h primary period. The phase angle bisector longitude for the 2013 observations was 263°, significantly different from the 2016 observations. There were insufficient data to solve for a secondary period.

Stephens' 2006 observations were made before the creation of the MPOSC catalog, so he remeasured the original images which were still available a decade later. The phase angle bisector longitude during the 2006 observations was 253°, similar to those from the 2013 observations. However, the observations occurred on four nights with a two week gap in between; sufficient to mask any large changes in amplitude. Plotting for the possible secondary period of 21.25 h is consistent a single modal lightcurve with coverage of about 60% of the lightcurve







Analysis

19204 Joshuatree is another possible candidate for a special case of very wide binaries (see Jacobson *et al.*, 2014). This is where the primary period is long with a large amplitude and the secondary period is short with a low amplitude. For wide binaries, the chance of observing a *mutual event* (eclipse or occultation) would be very rare because of the long primary period. Table II gives a list of suspected wide binary asteroids. Because of the lack of mutual events, confirmation of the nature of these asteroids will require long observing runs at future oppositions.

Number	Name	P1	P2	Ref
1876	Napolitania	45	2.825	MPB 43, 57-65
8026	Johnmckay	372	2.2981	MPB 38, 33-36
15778	1993 NH	113	3.320	MPB 42, 60-66
19204	Joshuatree	480	21.25	This work
23615	1996 FK12	368	3.6456	MPB 42, 182-186
67175	2000 BA19	275	2.7157	MPB 42, 36-42
119744	2001 YN42	624	7.24	MPB 41, 102-112
190208	2006 AQ	182	2.621	MPB 42, 79-83
218144	2002 RL66	588	2.49	MPB 37, 109-111
	2014 PL51	205	5.384	MPB 42,134-136

Table II. List of suspected wide binary asteroids. P1 is the primary's period (hours). P2 is the satellite's, which is not tidally-locked to its orbital period. All references are Warner (*et al.*).

The long period (P1) might suggest tumbling. This was rejected because of the short period and its amplitude. The two periods for a true tumbler should be within a factor of two of one another when one of the amplitudes is so large. Additional insights into this reasoning were provided by Alan Harris (private communications).

> "A large amplitude indicates a very irregular (elongate) object, so the two tumble frequencies should be not far apart since the 'precession' frequency is essentially the moment of inertia differences (elongation or flattening of the object) times the 'rotation' frequency. For a very regularly shaped body (hence very low lightcurve amplitude), the precession frequency can be much longer than the rotation frequency, for example, for the Earth, the 'Chandler wobble' period is around 300 days. The bottom line, though, is that the long period of this one is unlikely (impossibly, in fact) due to tumbling of a single body."

Conclusion

There are a couple of lessons to be learned. The first is when using a star catalog of standard or secondary standard stars is to trust the data and follow through when needed. A second point concerns the wide spread practice of only getting a few data points each night when a long period asteroid is found. While understandable when telescope observing time is limited to a few days, one has to wonder how many binary or otherwise unusual asteroids went undiscovered because it was assumed that a long period asteroid will not have a satellite. In these ten cases, the satellites would not have been discovered without truly dense lightcurve data.

Acknowledgements

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

Jacobson, S.A., Scheeres, D.J., McMahon, J. (2014). "Formation of the Wide Asynchronous Binary Asteroid Population." *Ap. J.* **780**:60.

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

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

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

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*

ROTATION PERIOD DETERMINATIONS FOR 123 BRUNHILD, 314 ROSALIA, 346 HERMENTARIA, 633 ZELIMA, AND 730 ATHANASIA

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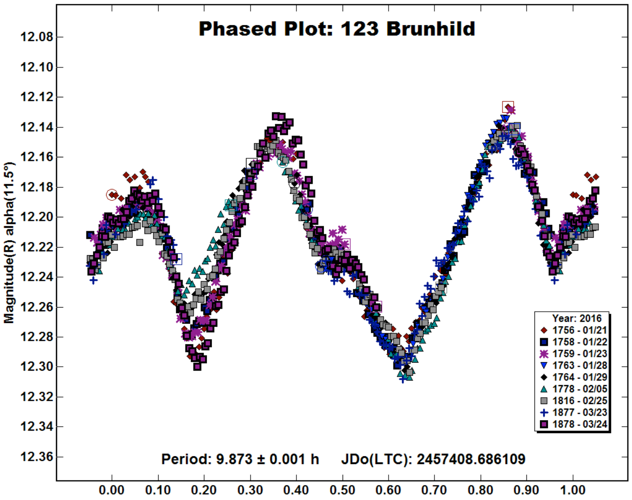
(Received: 4 April)

Synodic rotation periods and amplitudes are found for 123 Brunhild 9.873 ± 0.001 hours, 0.14 ± 0.01 magnitudes; 314 Rosalia 20.465 ± 0.001 hours, 0.15 ± 0.01 magnitudes; 346 Hermentaria 28.523 ± 0.001 hours, 0.14 ± 0.01 magnitudes; 633 Zelima 11.730 ± 0.001 hours, 0.40 ± 0.02 magnitudes; 730 Athanasia 5.7348 ± 0.0001 hours, 0.63 ± 0.04 magnitudes.

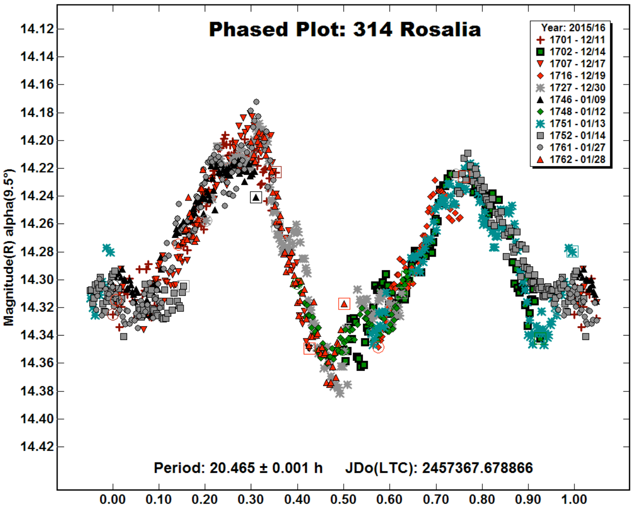
Observations to produce the asteroid lightcurve period determinations reported here have been made at the Organ Mesa Observatory with a 35.4 cm Meade LX200 GPS S-C and SBIG STL 1001-E CCD. Photometric measurement and lightcurve construction are with *MPO Canopus* software. Sixty second exposure times were used for 123 Brunhild, 314 Rosalia, 346 Hermentaria, and 633 Zelima, and 120 seconds for 16th magnitude 730 Athanasia, unguided, clear filter. 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 maximum time difference 5 minutes.

123 Brunhild. Previous rotation period determinations have been made by Barucci and di Martino (1984), 10.04 hours; and Behrend

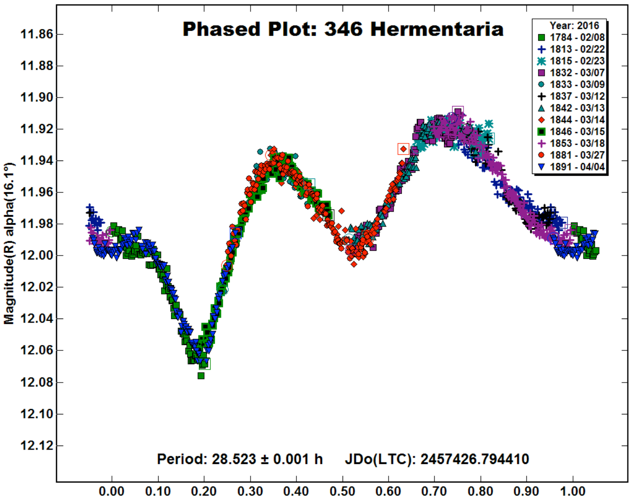
(2010), 9.8 hours. A much denser data set was obtained on 9 nights from 2016 Jan. 21 at phase angle 11.5 degrees to a minimum phase angle of 4.8 degrees to Mar. 24 at phase angle 15.5 degrees. These data provide a good fit to an unsymmetric lightcurve with three unequal maxima and minima phased to 9.873 ± 0.001 hours, amplitude 0.14 ± 0.001 magnitudes, consistent with, and improving upon, the earlier results. The composite lightcurve shows some changes of shape that correlate with changing phase angle.



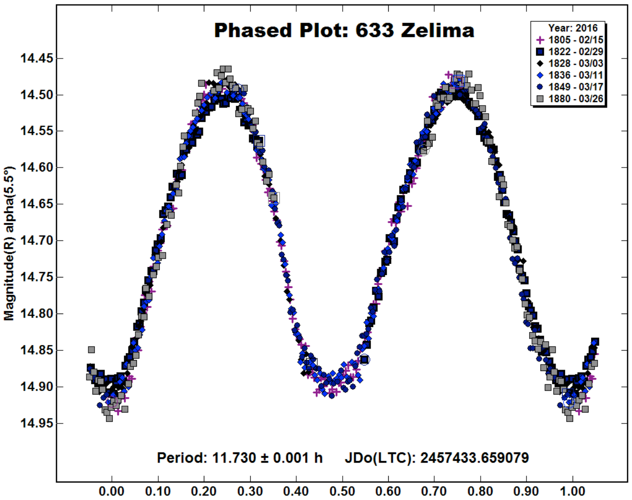
314 Rosalia. Previous rotation period determinations have been made by Warner (2006), 20.43 hours; and by Hawkins and Ditteon (2008), 20.369 hours. New data on 11 nights 2015 Dec. 11 – 2016 Jan. 28 provide a good fit to a lightcurve phased to 20.465 ± 0.001 hours, amplitude 0.15 ± 0.01 magnitudes. These results are all consistent with each other and the rotation period of 314 Rosalia should now be considered secure.



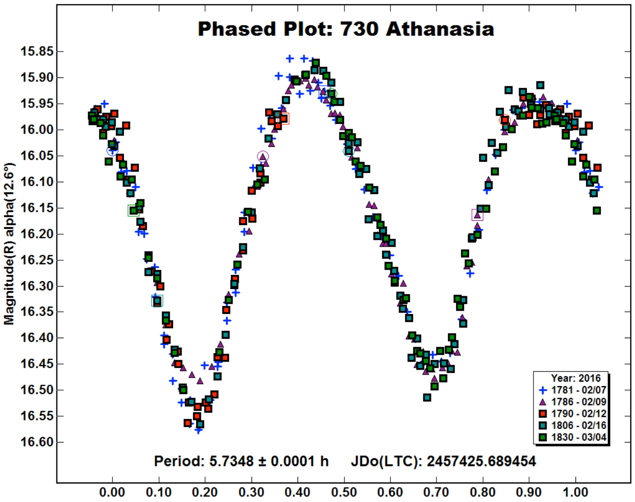
346 Hermentaria. Previous rotation period determinations have been made by Harris and Young (1989), 28.33 hours; Wang and Shi (2002), 19.408 hours; Bembrick et al. (2004), 28.43 hours; and Robinson (2011), 9.7 hours. New observations on 12 nights 2016 Feb. 8 – Apr. 4 provide a good fit to an unsymmetric bimodal lightcurve with period 28.523 ± 0.001 hours, amplitude 0.14 ± 0.01 magnitudes. This is consistent with Harris and Young (1989) and Bembrick (2004), and rules out the determinations of Wang and Shi (2002) and Robinson (2011).



633 Zelima. Previous rotation period determinations have been made by Lagerkvist (1978), 10. hours; Behrend (2005), 11.768 hours; Behrend (2006), 11.77 hours; Warner (2006), 11.724 hours; and Behrend (2014), >8. hours. New observations on 6 nights 2016 Feb. 15 – Mar. 26 provide a good fit to a bimodal lightcurve with period 11.730 ± 0.001 hours, amplitude 0.40 ± 0.02 magnitudes. All of these determinations except Lagerkvist (1978) are consistent.



730 Athanasia. The only previously published rotation period is by Pilcher (2013), who preferred a period of 5.7345 hours with a slightly asymmetric bimodal lightcurve of amplitude 0.14 magnitudes but could not rule out a period 3/2 as great, 8.6016 hours, with a trimodal lightcurve. New observations on five nights 2016 Feb. 7 – Mar. 4 provide a good fit to a bimodal lightcurve with period 5.7348 ± 0.0001 hours, amplitude 0.63 ± 0.04 magnitudes. The period agrees closely with the earlier determination of 5.7345 hours but the amplitude is much larger, indicating the year 2016 observations were at aspect much closer to equatorial.



References

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

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

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

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

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

Behrend, R. (2014). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html.*

Bembrick, C. S., Pereghy, B., Ainsworth, A., Bolt, G. (2004), "346 Hermentaria – Another Slow Rotator?" *Minor Planet Bull.* **31,** 52-53.

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

Hawkins, S., Ditteon, R. (2008). "Asteroid Lightcurve Analysis at the Oakley Observatory – May 2007." *Minor Planet Bull.* **35**, 1-4.

Lagerkvist, C.-I. (1978). "Photographic photometry of 110 main-belt asteroids." *Astron. Astrophys. Suppl. Ser.* **31**, 361-381.

Pilcher, F. (2013). "Rotation Period Determination for 730. Athanasia," *Minor Planet Bull.* **40**, 194-195.

Robinson, L. (2011). *http://btboar.tripod.com/lightcurves/.*

Wang, X.-B., and Shi, Y. (2002). "CCD Photometry of Asteroids 38, 174, 276, and 346." *Earth, Moon, and Planets* **91**, 181-186.

Warner, B.D. (2006). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory – March-June 2006. *Minor Planet Bull.* **33**, 85-88.

SHAPE AND SPIN AXIS MODEL FOR 53 KALYPSO

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We present shape and spin axis model for main-belt asteroid 53 Kalypso. The model was achieved with the lightcurve inversion process, using combined dense photometric data acquired from six apparitions between 1979-2012 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 9.035058 ± 0.000008 hours and two mirrored pole solutions at (λ = 168°, β = 12°) and (λ = 349°, β = 8°), with an error of ± 5 degrees.

The main-belt asteroid 53 Kalypso has been observed for six apparitions from 1979 to 2012 over a wide range of phase angles and phase angle bisectors. Dense photometric data were mainly downloaded from the Asteroid Photometric Catalogue (APC, 2001) by Lagerkvist et al. (2001) and from the Asteroid Light Curve Database (ALCDEF, 2016). The observational circumstances over six apparitions are reported in Table I.

Year	#LCs	Data Points	PA°	PABL°	PABB°	Ref.
1979	1	10	6	23	-6	(1)
1981	3	157	3/8	191	5	(2)(3)
2006	8	204	8/22	126/131	-2/0	(4)
2009	7	1625	18/4	73/76	-6.8	(5)
2011	14	2734	13/18	223/226	6	(6)
2012	7	800	7/11	297/296	3/2	(7)

Table I. Observational circumstances for 53 Kalypso over six apparitions, a total of 40 lightcurves were used for lightcurve inversion analysis. PA, PABL and PABB are, respectively, the phase angle, phase angle bisector longitude and latitude. References: (1) Harris *et al.* (1989); (2) Debehogne *et al.* (1982); (3) Surdej *et al.* (1981); (4) Pray *et al.* (2006); (5) Pilcher (2010); (6) Pilcher (2011); (7) Audejean web.

In order to improve the solution we have also used sparse data from USNO Flagstaff Station, as has been shown by Kaasalainen (2004), Ďurech et al. (2009). Sparse data were taken from the Asteroids Dynamic Site (AstDyS-2, 2016) for a total of 237 photometric data points. Figure 1 shows the phase angle bisector (PAB) longitude and latitude distribution for dense and sparse data used for the lightcurve inversion model. Figure 2 shows the distribution of the sparse photometric data points from (689) USNO Flagstaff station.

Lightcurve inversion was performed using *MPO LCInvert* v.11.7.2.1. Software (Bdw Publishing, 2012), which implements algorithms and code provided by Mikko Kaasalainen and Josef Ďurech.

All data from forty dense lightcurves and one sparse dataset were imported in *LCInvert* for analysis, assigning them a different weighting factor, from 1.0 for best dense data to 0.3 for sparse data.

The period search was started around the average of the synodic periods previously published in literature. The search process found a well-defined sidereal period with lowest chi-square value (Figure 3).

The pole search was started using the "medium" search option (312 fixed pole position with 15° longitude-latitude steps) and the previously found sidereal period set to "float". The "dark facet" weighting factor was set to 0.7 to keep the dark facet area below 1% of total area and the number of iterations of processing was set to 75. In this step we found two rough solutions with lower chi-square values differing by 180° in longitude. See Figure 4 for log(chi-square) values distribution, where the darker blue indicates the better solutions, while orange-red the worst ones.

The pole search process was then refined with "fine" option (49 fixed pole steps with 10° longitude-latitude pairs) and previous period/longitude/latitude set to "float". Figure 5 shows the distribution of the better solutions with chi-square values below 5% than the others. These solutions are clustered within 5 degrees in longitude-latitude pairs and the two mirrored best solutions (lower chi-square) are reported in Table II. Typical errors in the pole solution are ± 5 degrees and the uncertainty in sidereal period has been evaluated as a rotational error of 10° over the total time-span of the dense observations.

λ°	β°	Sidereal Period (h)	ChiSq	RMS
168	12	9.035058 ± 0.000008	1.6513	0.0169
349	8		1.6612	0.0170

Table II. The two best spin axis solutions for 54 Kalypso. The sidereal period was the average of the two solutions found in the pole search process.

Figure 6 shows the shape model (first solution) while Figure 7 shows the fit between the model (black line) and observed lightcurves (red points).

The model and the data will be stored in Database of Asteroid Models from Inversion Techniques (DAMIT, 2016).

References

ALCDEF (2016). *http://www.minorplanetcenter.net/light_curve2/light_curve.php*

APC (2001). Asteroid Photometric Catalogue, *http://asteroid.astro.helsinki.fi/apc*

AstDyS-2 (2016), Asteroids - Dynamic Site, *http://hamilton.dm.unipi.it/astdys/index.php?pc=0*

Bdw Publishing (2012). *http://www.minorplanetobserver.com/MPOSoftware/MPOLCInvert.ht*m

DAMIT (2016). Database of Asteroid Models from Inversion Techniques, *http://astro.troja.mff.cuni.cz/projects/asteroids3D/web.php*

Debehogne, H., de Sanctis, G., Zappala, V. (1982). "Photoelectric photometry of three dark asteroids". *Astronomy and Astrophysics* **108**, 197-200.

Ďurech, J., Kaasalainen, M., Warner, B.D., Fauerbach, M., Marks, S.A., Fauvaud, S., Fauvaud, M., Vugnon, J.-M., Pilcher, F., Bernasconi, L., Behrend, R. (2009). "Asteroid models from combined sparse and dense photometric data". *Astronomy and Astrophysics* **493**, 291-297.

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

Kaasalainen, M., (2004). "Physical models of large number of asteroids from calibrated photometry sparse in time". *Astronomy and Astrophysics* **422**, L39-L42.

Lagerkvist C.-I., Piironen J., Erikson A., eds. (2001). Asteroid Photometric Catalogue, 5th edition. Astronomical Observatory, Uppsala University, Sweden. 201 pp.

Pilcher, F. (2010). "Rotation Period Determination for 53 Kalypso". *Minor Planet Bull.* **37**, 75-76

Pilcher, F. (2011). "53 Kalypso, a Difficult Asteroid". *Minor Planet Bull.* **38**, 206-208

Pray, D.P., Galad, A., Gajdos, S., Vilagi, J., Cooney, W., Gross, J., Terrel, D., Higgins, D., Husarik, M., Kusnirak, P. (2006). "Lightcurve analysis of asteroids 53, 698, 1016, 1523, 1950, 4608, 5080 6170, 7760, 8213, 11271, 14257, 15350 and 17509". *Minor Planet Bull.* **33**, 92-95

Surdej, J., Surdej, A., Louis, B. (1983). "UBV photometry of the minor planets 86 Semele, 521 Brixia, 53 Kalypso and 113 Amalthea". *Astronomy and Astrophysics Supplement* **52**, 203-211.

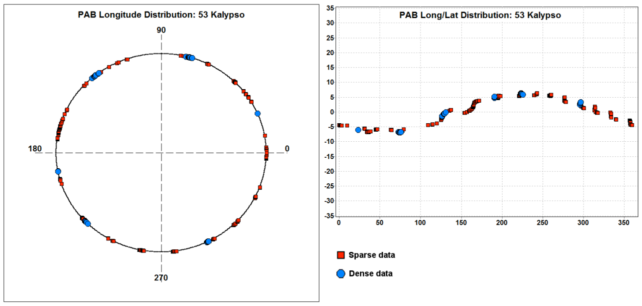

Figure 1. PAB longitude and latitude distribution of the data used for lightcurve inversion model.

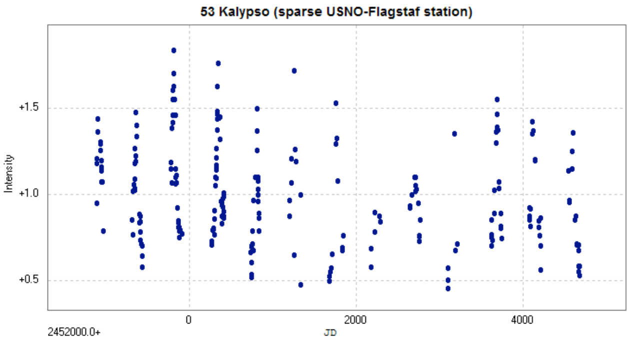

Figure 2. Sparse photometric data points from (689) USNO Flagstaff station.

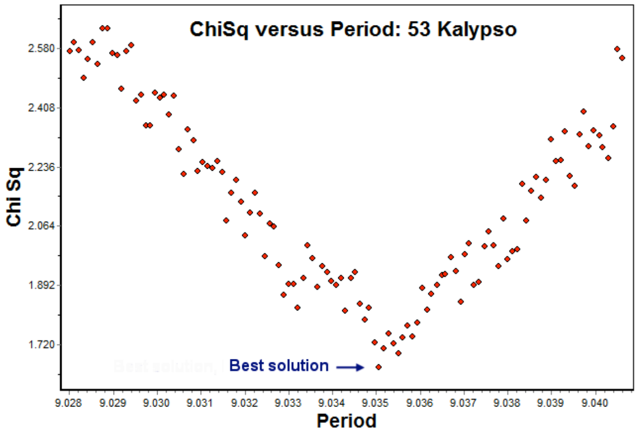

Figure 3. The period search for 53 Kalypso shows a well-defined lowest chi-square minimum.

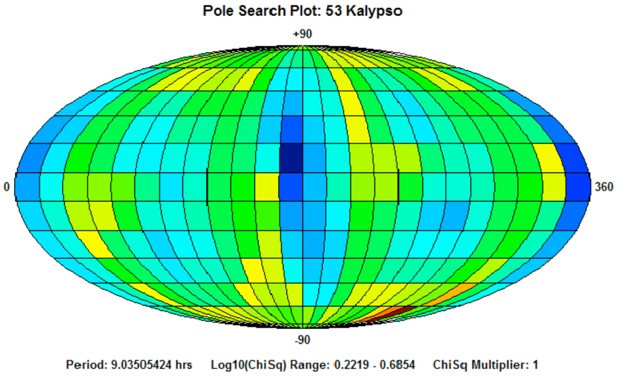

Figure 4. The pole search plot. Darker blue indicates the better solutions, while orange-red the worst ones.

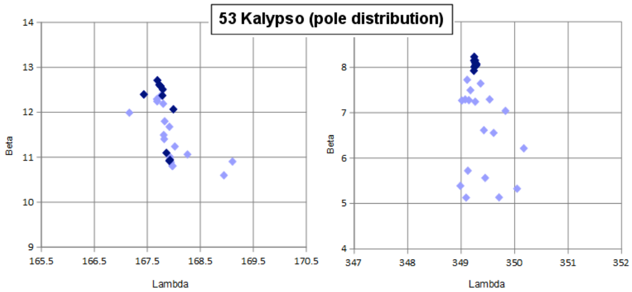

Figure 5. The distribution of the two clustered solutions obtained with "fine" option and chi-square values below 5% than the others. The lowest chi-square solutions are in dark blue.

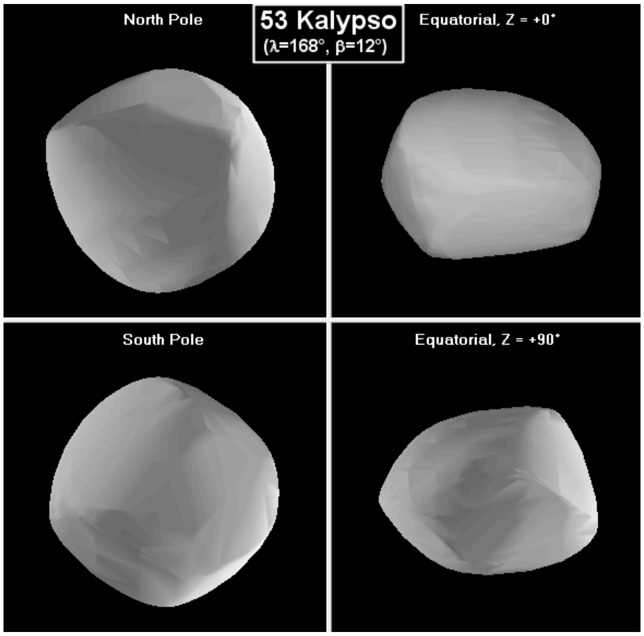

Figure 6. The shape model for 53 Kalypso (λ = 168°, β = 12°).

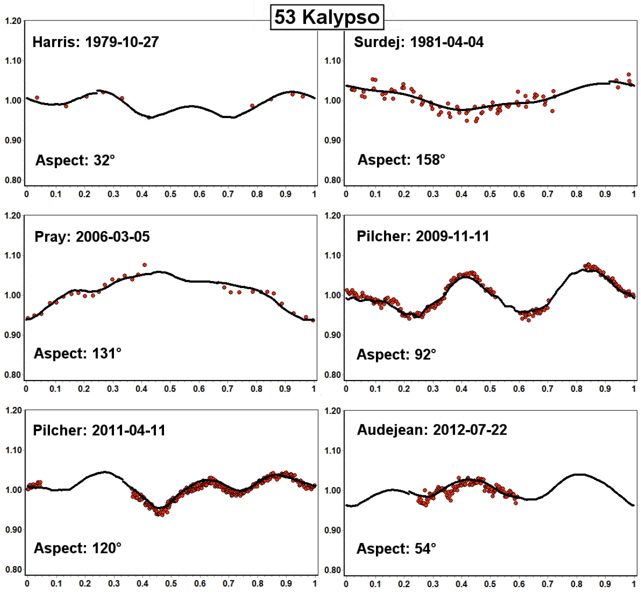

Figure 7. Model fit (black line) versus observed lightcurves (red points). Note the wide variety of lightcurve shapes.

ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2015 DECEMBER – 2016 APRIL

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Lightcurves for 16 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2015 December into 2016 April.

CCD photometric observations of 16 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2015 December into 2016 April. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

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

Measurements were made using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. 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 catalog (Henden et al., 2009). When there were insufficient stars, the MPOSC3 catalog was used. This catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag. There is a systematic offset between the two catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

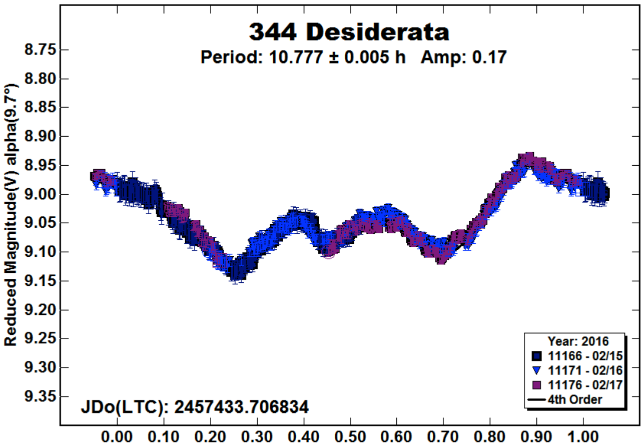
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances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

If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*. The value is meant only to be a quick guide.

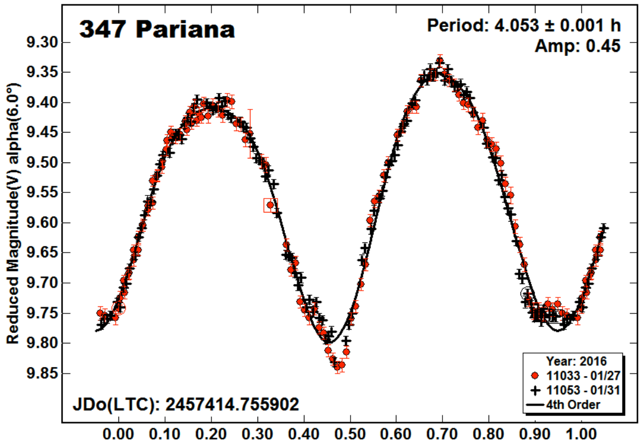
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

The period shown in the lightcurve (7.0 ± 0.82 h) is just one of many that fit the data. Assuming a bimodal lightcurve, the best solution is an indefinite one of $P \geq 12$ h and $A \geq 0.2$ mag.

<u>344 Desiderata</u>. This is an inner main-belt asteroid. Behrend (2004, 2005, 2012) found a period near 10.75 hours. The results from the CS3-PDS observations are in good agreement.

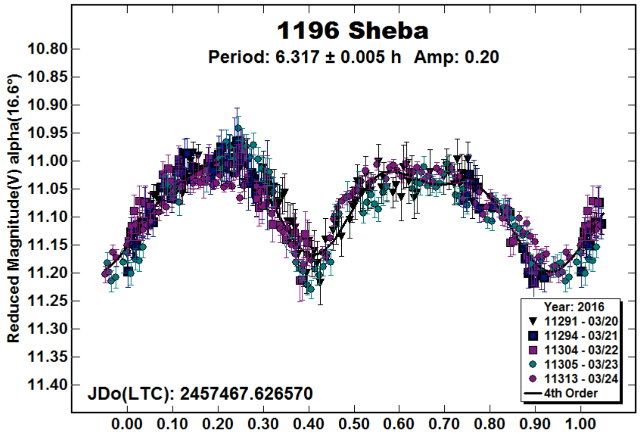


<u>347 Pariana</u>. The period for this M-type (Tholen, 1984) Eunomia member has been reported several times in the page, e.g., Majcen and Wetterer (1999; 4.0529 h) and Behrend (2012, 4.0524 h). The PDS period of 4.053 ± 0.001 h is consistent with the previous results.

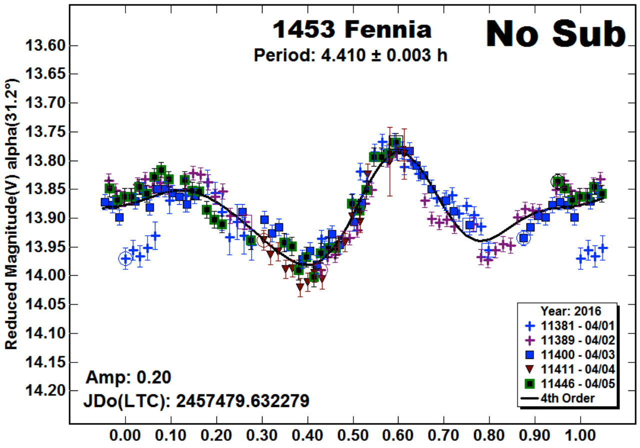


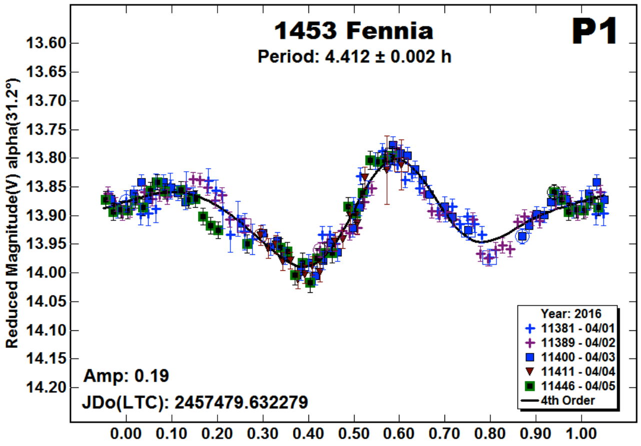
<u>1196 Sheba</u>. Binzel (1987) reported a period of 7.08 h for this middle main-belt asteroid. Stephens (2004) found a period of 6.32

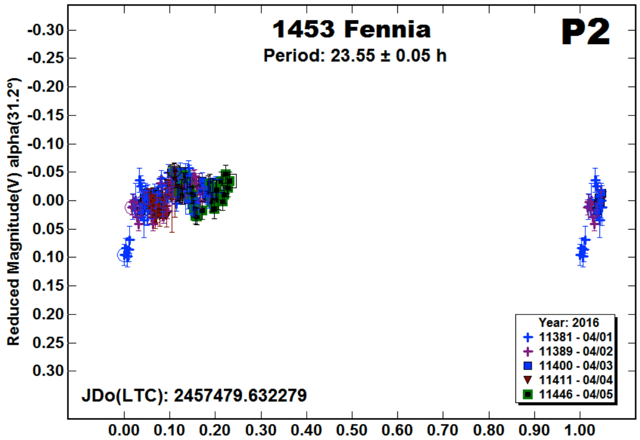
hours based on an extended data set obtained over three nights in 2004 April. The PDS data set contained 395 data points obtained over five consecutive nights in 2016 March. Analysis of the PDS data found a period of 6.317 ± 0.005 h and amplitude of 0.20 mag. The period verifies the one found by Stephens.



1453 Fennia. This is a known Hungaria binary (Warner *et al.*, 2007) that was further confirmed in 2008 (Warner *et al*., 2008b) and 2011 (Higgins *et al.*, 2011). The primary's rotation period is 4.4121 h and the satellite's orbital period is almost exactly 23 hours. The latter makes it essentially impossible for a single station to cover the secondary lightcurve and look for mutual events.

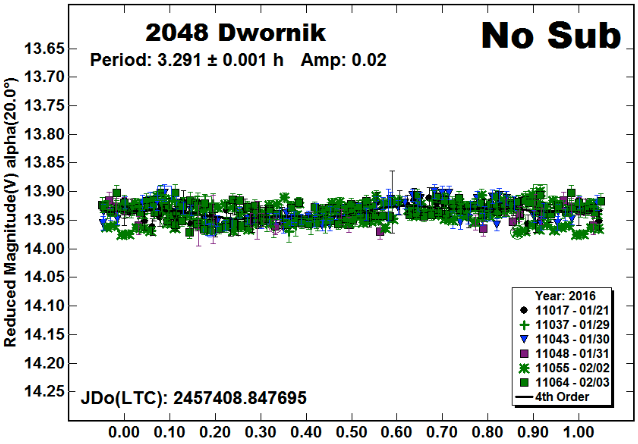


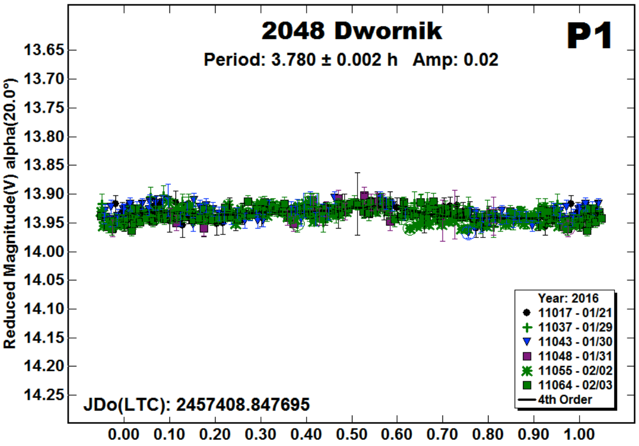


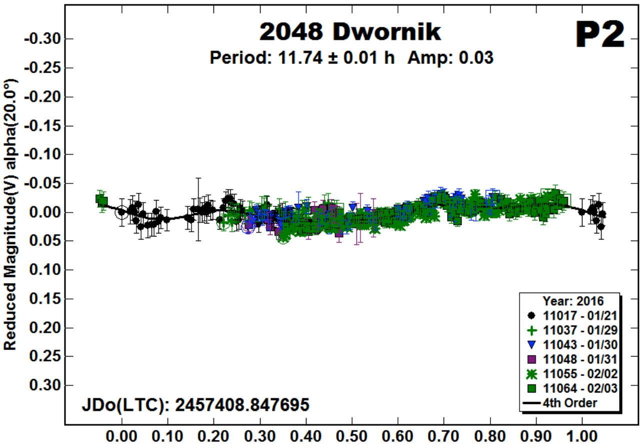


The "No Sub" plot shows the lightcurve using a single-period search. When looking for the primary period, the secondary period was forced to between 23-24 hours, with the resulting Fourier curve subtracted to find the primary period. Forcing the range was required because the lack of coverage led to a number of solutions for the secondary period. Even though incorrect by about 0.5 hours, subtracting the secondary period led to a primary period of 4.412 h, which agrees with earlier results.

2048 Dwornik. This Hungaria asteroid was observed by the author at four previous apparitions (Warner 2008d, 2011, 2013c, 2014a) with the last three leading to periods of about 3.7 hours. The period of 8.65 h Warner (2008d) was eventually ruled out by the subsequent results.



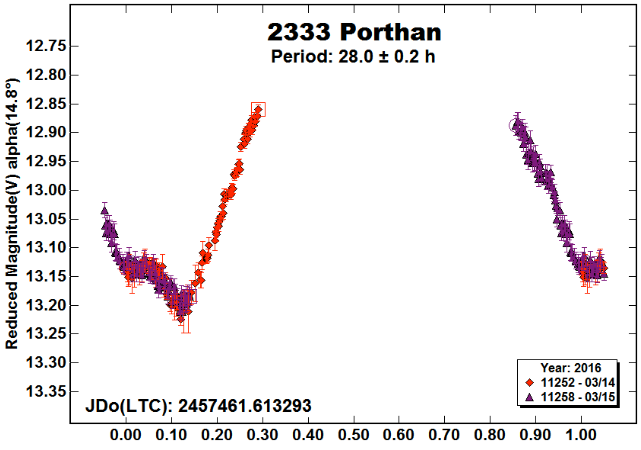




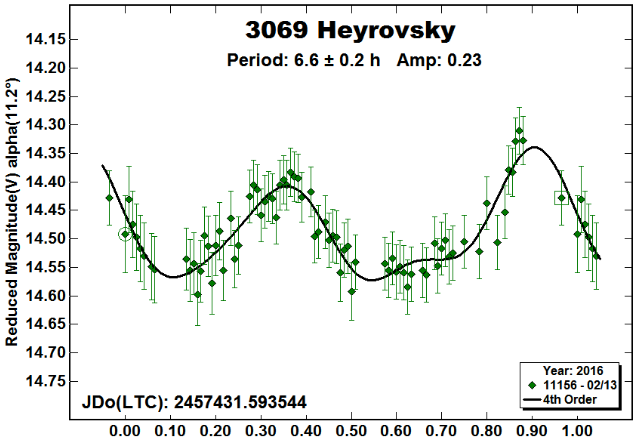
Analysis of the 2016 data seemed to indicate two low-amplitude periods ("No Sub"). A dual period search in *MPO Canopus* found a primary period ("P1") of 3.780 h, in good agreement with previous results. The secondary period ("P2") is close to, but not exactly, an integer multiple of P1 and so may be an artifact of the Fourier analysis.

The data from the previous apparitions were re-examined for dual periods. Surprisingly, the 2008 data showed the best indication, with P_1 = 3.709 ± 0.002 and P_2 = 11.80 ± 0.02 h, both with amplitudes of $A < 0.05$ mag. There were no indications in the 2011 data set, which had a primary amplitude of 0.16 mag. The larger amplitude would indicate a more equatorial view. A presumptive satellite's orbit would be near the equatorial plane of the asteroid and so mutual event would seem more likely. Absence of proof is not proof of absence, however. This asteroid warrants close examination at future apparitions.

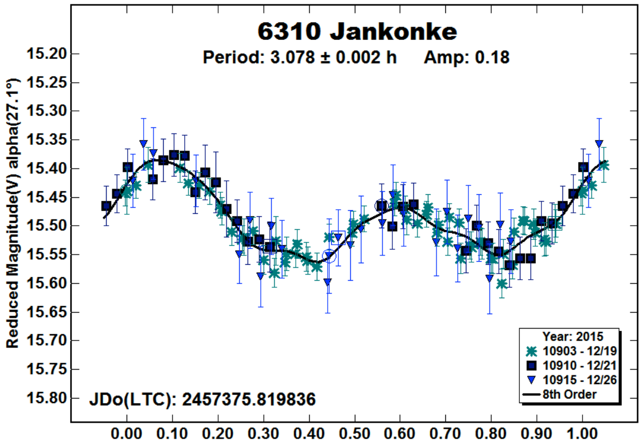
2333 Porthan. Waszczak (2015) and Behrned (2003) both reported periods of about 28 hours for this member of the Eunomia group. Due to equipment problems, only two nights of data were obtained. In the lightcurve presented here, the data have been forced to a period near the earlier results. The slopes of the ascending and descending branch are consistent with the adopted period. In addition, a search for the half-period monomodal solution found a reasonably good fit at 14.2 h.



3069 Heyrovsky. This appears to be the first reported period for this inner main-belt asteroid, which was in the field of a planned target for only one night. However the data nearly cover the full period and so the solution is considered reasonably secure. The WISE survey (Mainzer *et al.*, 2011) reported a diameter of 4.7 km and a relatively high albedo for an inner main-belt asteroid of p_V = 0.3497. This was based on H = 13.4. Using the algorithm from Harris and Harris (1997) to correct albedo based on a new value of H for thermal observation and the current value of H = 13.6, the albedo is reduced to 0.2977. This puts the value just more than one sigma over the average value for S-type asteroid found by Warner *et al.* (2009)

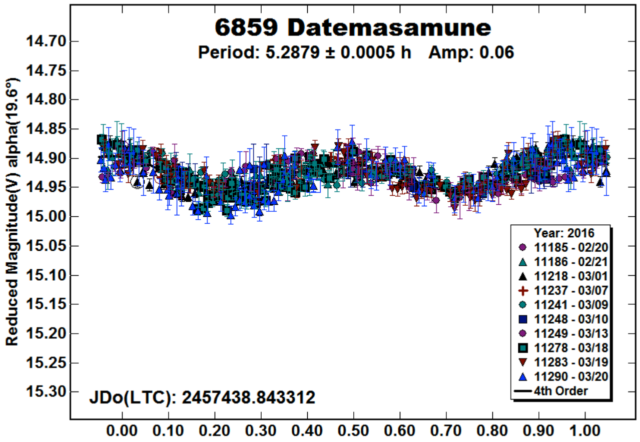


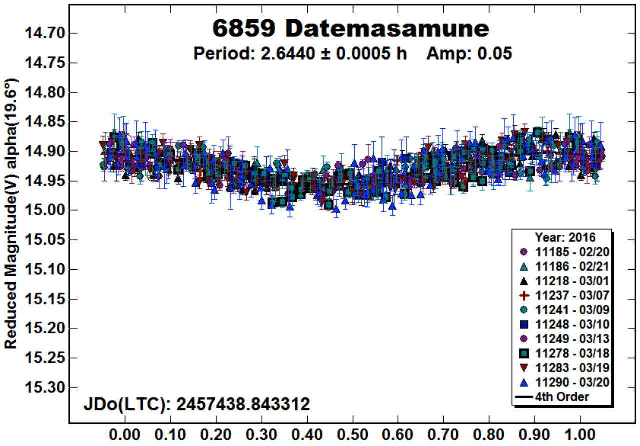
6310 Jankonke. The 2015-16 apparition was the fifth one at which the author observed this Hungaria asteroid. The periods that were found varied slightly, but significantly: Warner (2005, 3.042 h; 2008c, 3.080 h; 2011, 3.0433 h; 2013b, 3.076 h). These variations are most likely attributed to differences of quality in the data sets and the natural change in synodic period as an asteroid approaches and then moves away from opposition.



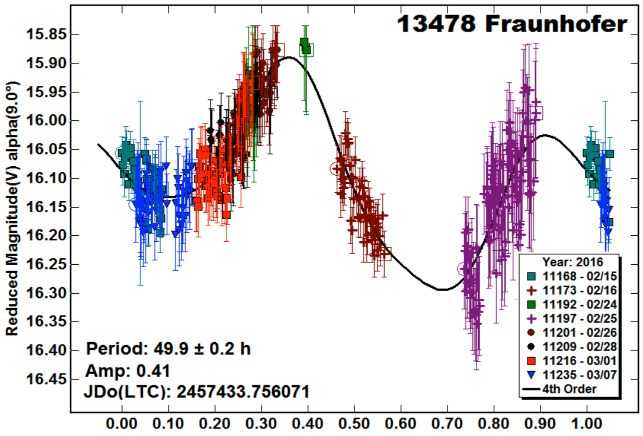
6859 Datemasamune. When it comes to finding a period, this Hungaria asteroid has proved to be very difficult over the years: Warner (2006, 12.95 h; 2010a, 22.1 h; 2011, 86.1 h). The mystery may be (almost) finally solved. Analysis of the PDS data obtained in 2016 February and March found one of two possible periods depending on whether a monomodal or bimodal lightcurve is adopted.

As covered by Harris *et al.* (2014), low-amplitude lightcurves at low phase angles can be almost any modality and so a bimodal solution cannot be guaranteed. Despite that, the longer, bimodal solution of 5.2879 h is adopted for this paper with the acknowledgement that the shorter period cannot be discarded out-of-hand.



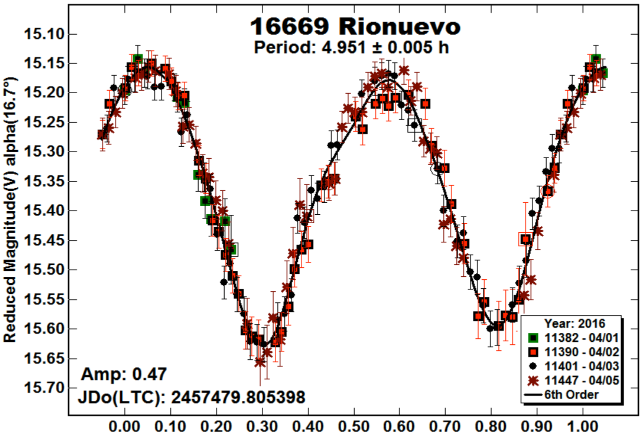


13478 Fraunhofer. There were no previous entries in the asteroid lightcurve database (LCDB) for this Hungaria asteroid. The solution should be considered tentative, although a monomodal half-period solution does support the period given here.

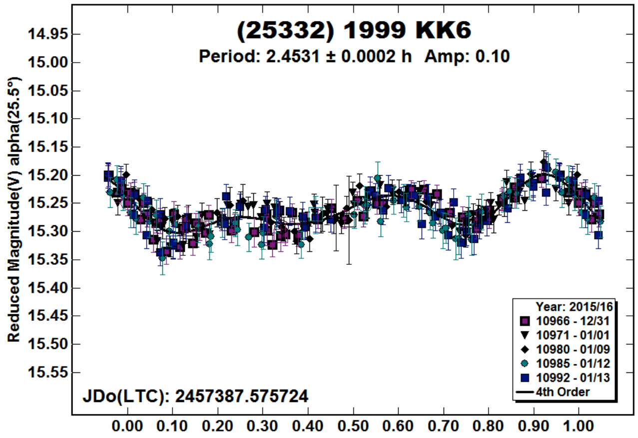


16669 Rionuevo. The period of 4.951 h found from the 2016 PDS data is essentially the same as reported in previous works: Warner (2010b, 4.951 h; 2013c, 4.953).

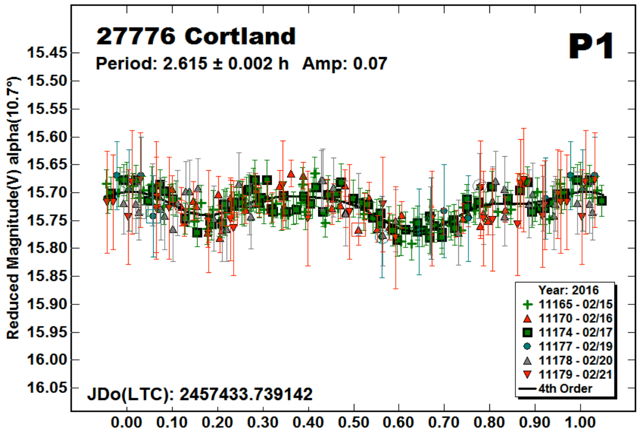
A preliminary pole position (ecliptic coordinates) of λ = 338°, β = +12°, $P_{sidereal}$ = 4.952415 (Warner *et al.*, 2014b) was found based on the dense lightcurve data from the two previous apparitions and sparse data from NEO surveys. The solution was rated Q = 3 on a scale of 1 to 5, meaning that the sense of rotation (prograde vs. retrograde) was reasonably determined but the ecliptic coordinates were very uncertain. The modeling will be done anew, adding the new data set.

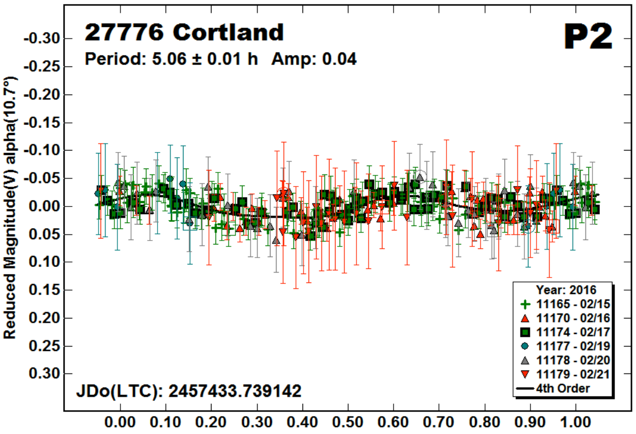


(25332) 1999 KK6. Two of the previous results by the author are both near 2.453 h (Warner 2008a, 2013a), matching the period found from the 2016 data. Warner (2013a) reported that there were small indications of a satellite with an orbital period of about 29 or 16 hours. There were no indications a satellite in 2016.



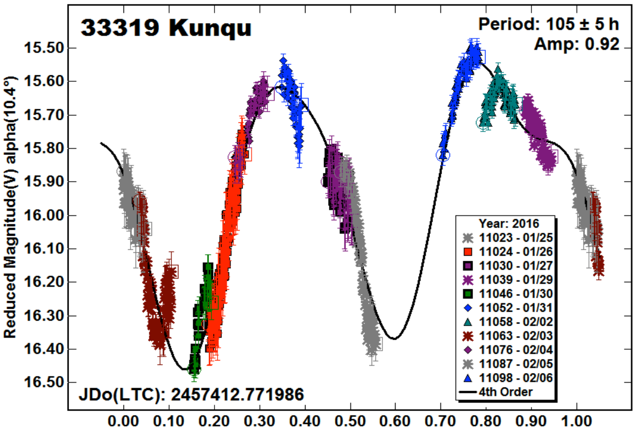
27776 Cortland. The author observed this Hungaria in 2009 and 2012 (2013b) where periods of about 2.610 h were found.



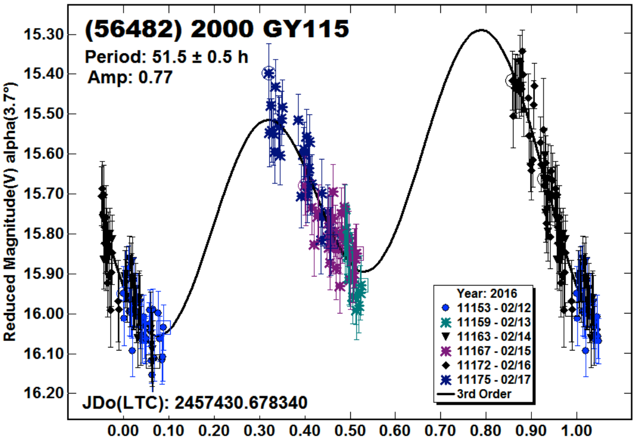


Unlike at earlier apparitions, the 2016 PDS data showed indications of two periods, the first (“P1”) matching those found earlier. The secondary period (“P2”), if substantiated, might indicate the rotation of a satellite that is not tidally-locked to its orbital period. In this case, the separation between the two bodies would be substantial in terms of the primary diameter (see, *e.g.*, Jacobson *et al.*, 2014; Pravec *et al.*, 2014, 2016).

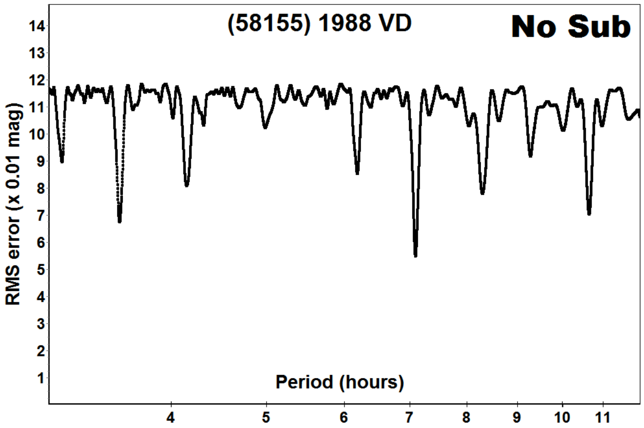
33319 Kunqu. This appears to be the first reported period for this Hungaria member. There are signs of tumbling (see Pravec *et al.*, 2005, 2014) since the lightcurve did not repeat itself and some sessions seem “out of place” or have the wrong slope.

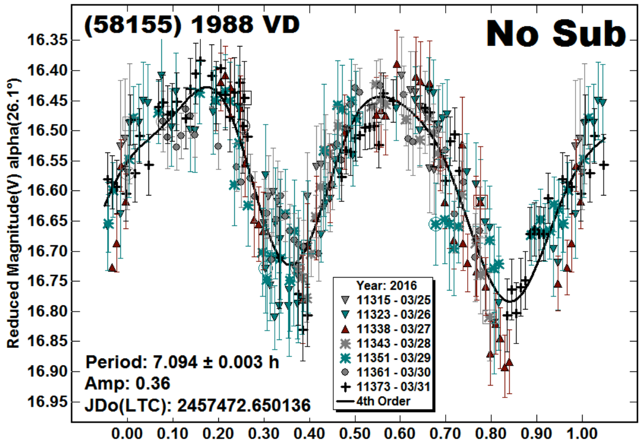


(56482) 2000 GY115. There were no prior entries in the LCDB for 2000 GY115, an inner main-belt asteroid.

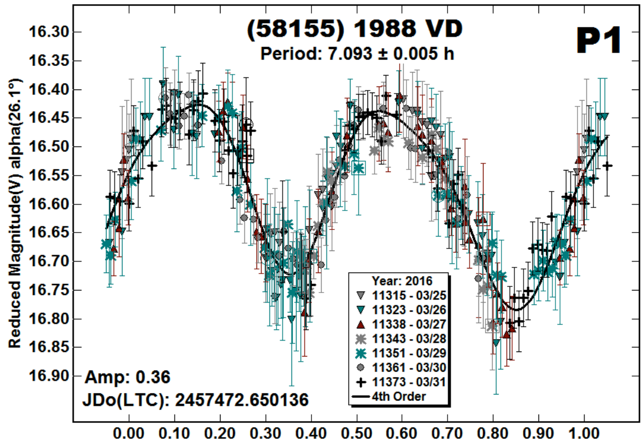


(58155) 1988 VD. This Hungaria may be another example of a wide asynchronous binary (see, *e.g.,* Jacobson *et al.*, 2014; Pravec *et al.*, 2014, 2016) or it could be a low-level tumbler (Petr Pravec, private communications; see Pravec *et al.*, 2005, 2014). There are not enough data to establish it’s pedigree with certainty.



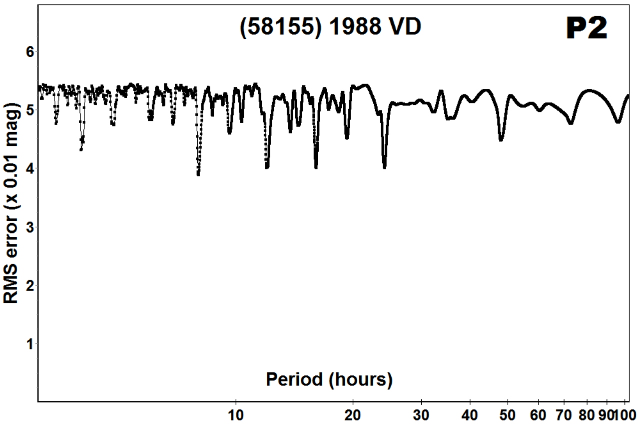


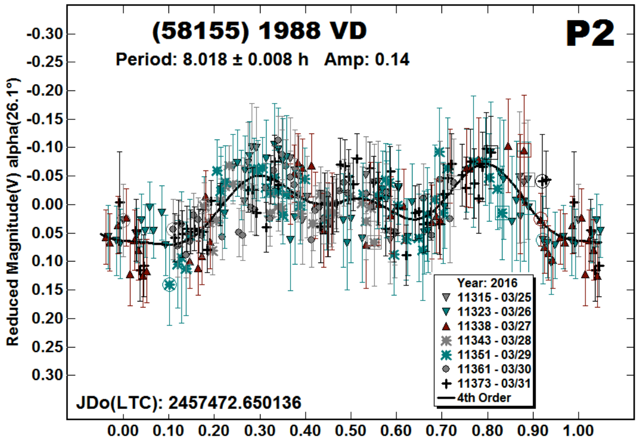
The “No Sub” lightcurve show the result of a single period search in *MPO Canopus*. The period spectrum shows a strong solution at P_1 = 7.094 h with a few others that are not harmonically related. A dual-period search in *MPO Canopus* found a strong candidate at P_2 = 8.018 h. Longer solutions in the P_2 period spectrum are harmonically related to P_2. At the very least, subtracting P_2 from the dataset significantly improved the fit for P_1.



Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Group
344	Desiderata	02/15-02/17	879	9.7,9.4	159	22	10.777	0.005	0.17	0.01	MB-I
347	Pariana	01/27-01/31	111	6.0,7.4	121	10	4.053	0.001	0.48	0.02	EUN
1196	Sheba	03/20-03/24	395	16.6,17.3	131	13	6.317	0.005	0.20	0.02	MB-M
1453	Fennia	04/01-04/05	165	31.2,31.3	122	21	^{P}4.412	0.002	0.19	0.02	H
2048	Dwornik	01/21-02/03	351	20.0,13.6	154	-7	^{P}3.780	0.002	0.02	0.01	H
2333	Porthan	03/14-03/15	227	14.9,15.2	149	14	28.0	0.2	0.38	0.05	EUN
3069	Heyrovsky	02/13-02/13	76	11.3,11.3	117	-2	6.6	0.2	0.23	0.02	MB-I
6310	Jankonke	^{15}12/19-12/26	112	27.1,25.5	130	20	3.078	0.002	0.18	0.02	H
6859	Datemasamune	02/20-03/20	538	19.7,11.7,12.0	179	13	5.2879	0.0005	0.06	0.01	H
13478	Fraunhofer	02/15-03/07	418	9.0,20.3	134	0	49.9	0.2	0.45	0.04	H
16669	Rionuevo	04/01-04/05	167	16.7,16.0	202	27	4.951	0.005	0.47	0.02	H
25332	1999 KK6	12/31-01/13	252	25.5,28.6	62	-19	2.4531	0.0002	0.1	0.01	H
27776	Cortland	02/15-02/21	250	10.7,7.7	161	-6	2.615	0.002	0.07	0.01	H
33319	Kunqu	01/25-02/06	715	10.3,16.6	115	13	105	5	0.9	0.1	H
56482	2000 GY115	02/12-02/17	192	3.7,3.6,4.0	144	-7	51.5	0.5	0.75	0.05	MB-I
58155	1988 VD	03/25-03/31	278	26.2,27.4	155	22	^{PT}7.093	0.005	0.36	0.03	H

Table II. Observing circumstances. ^{13} Observations in 2013. ^{15} Observations in 2015. ^{P} period of primary in binary system. ^{T} dominant period of a tumbler. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range). The Group column gives the orbital group to which the asteroid belongs. The definitions and values are those used in the LCDB (Warner *et al.*, 2009). H = Hungaria; MB-I/M/O = Main-belt inner/middle/outer. EUN = Eunomia





If the object is a wide binary, seeing mutual events will be highly unlikely. If tumbling, then a more extensive data set is required. In either case, it should be obtained by several observers at widely-spaced longitudes.

Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535.

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

References

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

Behrend, R. (2003, 2004, 2005, 2012) 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., Harris, A.W. (1997). "On the Revision of Radiometric Albedos and Diameters of Asteroids." *Icarus* **126**, 450-454.

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*

Higgins, D., Oey, J., Pravec, P. (2011). "Period Determination of Binary Asteroid Targets Observed at Hunters Hill Observatory: May-September 2009." *Minor Planet Bull.* **38**, 46-49.

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

Majcen, S., Wetterer, C.J. (1999). "CCD Photometry of Asteroid 347 Pariana at the US Air Force Academy Observatory." *Minor Planet Bull.* **26**, 29.

Mainzer, A., Grav, T., Bauer, J., Masiero, J., McMillan, R.S., Cutri, R.M., Walker, R., Wright, E., Eisenhardt, P., Tholen, D.J., Spahr, T., Jedicke, R., Denneau, L., DeBaun, E., Elsbury, D., Gautier, T., Gomillion, S., Hand, E., Mo, W., Watikins, J., Wilkins, A., Bryngelson, G.L., Del Pino Molia, A., Desai, S., Gomez Camus, M., Hidalgo, S.L., Konstantopoulos, I., Larsen, J.A., Maleszewski, C., Malkan, M.A., Mauduit, J.-C., Mullan, B.L., Olszewski, E.W., Pforr, J., Saro, A., Scotti, J.V., Wasserman, L.H. (2011). "NEOWISE observations of near-Earth objects: Preliminary results." *Ap. J.* **743**, A156.

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

Pravec, P., 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., Pollock, J., Husárik, M., Chiorny, V., Stephens, R. D., Durkee, R., Reddy, V., Dyvig, R., Vraštil, J., Žižka, J., Mottola, S., Hellmich, S., Oey, J., Benishek, V., Kryszczyńska, A., Higgins, D., Ries, J., Marchis, F., Baek, M., Macomber, B., Inasaridze, R., Kvaratskhelia, O., Ayvazian, V., Rumyantsev, V., Masi, G., Colas, F., Lecacheux, J., Montaigut, R., Leroy, A., Brown, P., Krzeminski, Z., Molotov, I., Reichart, D., Haislip, J., LaCluyze, A. (2016). "Binary asteroid population. 3. Secondary rotations and elongations." *Icarus* **267**, 267-295.

Stephens, R.D. (2004). "Photometry of 1196 Sheba, 1341 Edmee, 1656 Suomi, 2577 Litva, and 2612 Kathryn." *Minor Planet Bull.* **31**, 95-97.

Tholen, D.J. (1984). "Asteroid taxonomy from cluster analysis of Photometry." Doctoral Thesis. Univ. Arizona, Tucson.

Warner, B.D. (2005). "Asteroid lightcurve analysis at the Palmer Divide Observatory - winter 2004-2005." *Minor Planet Bull.* **32**, 54-58.

Warner, B.D. (2006). "Asteroid lightcurve analysis at the Palmer Divide Observatory - February - March 2006." *Minor Planet Bull.* **33**, 82-84.

Warner, B.D., Harris, A.W., Pravec, P., Stephens, R.D., Pray, D., Cooney, W., Gross, J., Terrell, D., Gajdos, S., Galad, A., Krugly, Yu. (2007). "(1453) Fennia." *CBET* **1150**.

Warner, B.D. (2008a). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: September-December 2007." *Minor Planet Bull.* **35**, 67-71.

Warner, B.D., Harris, A.W., Pravec, P., Stephens, R.D., Pray, D.P., Cooney, W.R., Jr., Gross, J., Terrell, D., Gajdos, S., Galad, A., Krugly, Yu. (2008b). "1453 Fennia: A Hungaria Binary." *Minor Planet Bull.* **35**, 73-74.

Warner, B.D. (2008c). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: December 2007 - March 2008." *Minor Planet Bull.* **35**, 95-98.

Warner, B.D. (2008d). "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. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2010a). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 June-September." *Minor Planet Bull.* **37**, 24-27.

Warner, B.D. (2010b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 September-December." *Minor Planet Bull.* **37**, 57-64.

Warner, B.D. (2011). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 March-July." *Minor Planet Bull.* **38**, 190-195.

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

Warner, B.D. (2013b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2012 September-2013 January." *Minor Planet Bull.* **40**, 71-80.

Warner, B.D. (2013c). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2013 January–March." *Minor Planet Bull.* **40**, 137-145.

Warner, B.D. (2014a). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 March-June." *Minor Planet Bull.* **41**, 235-241.

Warner, B.D., Harris, A.W., Stephens, R.D., Coley, D. (2014b). "Spin Axis Distribution of the Hungaria Asteroids via Lightcurve Inversion." *AAS DPS meeting* **#46**, id.509.12.

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.

ASTEROID LIGHTCURVES FROM ESTCORN OBSERVATORY

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We obtained lightcurves and amplitudes for 17 asteroids, 8 of which had unknown or poorly determined periods. The other 9 have known lightcurves at several oppositions and so are candidates for spin/shape analysis.

The asteroids we observed were selected from the lists of asteroid photometry (LPO) and shape/spin modeling (SSMO) opportunities given by Warner *et al*. (2016b) in the *Minor Planet Bulletin*. We selected photometry opportunities based on asteroid brightness and the modeling opportunities based on known periods of less than 4 hours.

Our observations were obtained with the three Celestron 0.35-m telescopes and SBIG CCD cameras at Etscorn Campus Observatory (Klinglesmith and Franco, 2016). The images were processed and calibrated using *MPO Canopus* 10.4.7.6 (Warner, 2015). The exposures were between 180 and 420 seconds through clear filters. 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.

For shape/spin axis modeling candidates (SSMO), Table I lists previous results, contains asteroid number and name, publication reference, date of observation, L_{PAB}, B_{PAB}, phase, period, and amplitude for previous works on each asteroid. The periods and phase angle bisector longitudes and latitudes (L_{PAB} and B_{PAB}) were obtained from the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). The information about the discovery and names was obtained from the JPL Small Body Database Search Engine (JPL, 2016).

841 Arabella is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1916 Oct 1. It is also known as 1916 AL, 1928 DJ, and 1930 YQ. This asteroid is one of the SSMO objects. We observed it on six nights between 2016 Jan 30 and Feb 6. We obtained a synodic period of 3.142 ± 0.002 h and amplitude of 0.25 ± 0.05 mag. Our period is slightly different from Binzel's result of 3.39 h (Binzel and Mulholland, 1983).

901 Brunsia is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1918 Aug 30. It is also known as 1918 EE, 1941MH, 1948 VJ, 1970 EP1, and A905 VD. This asteroid is one of the SSMO objects. We observed it on five nights between 2016 Jan 27 and Feb 6 and obtained a synodic period of 3.136 ± 0.002 h and amplitude of 0.09 ± 0.05 mag. Our result agrees with three of the previously published results, but not with Wisniewski *et al.* (1997), who reported 4.872 h.

967 Helionape is a main-belt asteroid discovered by W. Baade at Bergedorf on 1921 Nov 9. It is also known as 1921 KV and A922AB. This asteroid is one of the SSMO objects. We observed the asteroid on three nights between 2016 Mar 9-13. We obtained a synodic period of 3.232 ± 0.004 h and amplitude of 0.09 ± 0.05 mag. We agree with the two previously published periods to two significant figures (Apostolovska *et al.*, 2009; Kryszczynska *et al.*, 2012).

1077 Campanula is a main-belt asteroid discovered by K. Reinmuth at Heidelberg on 1926 Oct 6. It is also known as 1926 TK, 1957 AJ, and 1972 CB. This asteroid is one of the SSMO objects. We observed it on three nights between 2015 Dec 9-14 and obtained a synodic period of 3.850 ± 0.001 h and amplitude of 0.32 ± 0.05 mag. All of the published periods, *e.g.*, Stephens (2012; 3.852 h), are in close agreement.

1106 Cydonia is a main-belt asteroid discovered K. Reinmuth at Heidelberg on 1929 Feb 5. It is also known as 1929 CW. This asteroid is one of the LPO objects. We observed it on four nights between 2015 Dec 14 -18. We obtained a synodic period of 2.679 ± 0.001 h. and amplitude of 0.28 ± 0.05 mag. There were no other reported observations for 1106 Cydonia.

1597 Laugier is a main-belt asteroid discovered by L. Boyer at Algiers on 1949 Mar 7. It is also known as 1949 EB. This asteroid is one of the LPO objects. We observed it on three nights between 2016 Feb 26-28. We obtained a synodic period of 8.0199 ± 0.0012 h and amplitude of 0.71 ± 0.05 mag. A model by Durech *et al.* (2016) has a sidereal period of 8.02272 h.

2258 Viipuri is a main-belt asteroid discovered by Y. Vaisala at Turku on 1939 Oct 7. It is also known as 1939 TA, 1928 FL, 1940 DU, 1956 PG, 1969 ON, 1970 RS, 1972 BK, 1975 XD2, and 1979 UU. This asteroid is one of the SSMO objects. We observed the asteroid on six nights between 2016 Feb 1-10 and obtained a synodic period of 3.822 ± 0.002 h and amplitude of 0.33 ± 0.10 mag. The period is in good agreement with earlier results, *e.g.*, Waszczak *et al*. (2016; 3.8222 h).

2282 Andres Bell is a main-belt asteroid discovered by C. Torres at Cerro El Roble on 1974 Mar 22. It is also known as 1974 FE, 1931 AC1, 1951 EH2, 1962 QC, 1974 HO, and 1979 YL. We observed this object on four nights between 2016 Jan 13-18 and obtained a synodic period of 3.425 ± 0.001 h and amplitude of 0.65 ± 0.10 mag. There were no other reported observations for 2282 Andres Bell.

2556 Louise is a main-belt asteroid discovered by N. G. Thomas at Anderson Mesa Station, Lowell Observatory, on 1981 Feb 8. It is also known as 1981 CS, 1951 WK2, 1972 HV, and 1976 SN1. This asteroid is one of the LPO objects. We observed it on three nights between 2015 Feb 11-14. We obtained a synodic period of 3.808 ± 0.002 h and amplitude of 0.35 ± 0.05 mag. Alkema (2013) obtained a period of 3.809 h and amplitude of 0.39 mag.

2650 Elinor is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1931 Mar 14. It is also known as 1931 EG, 1931 DF, 1933 SX, 1950 RJ1, 1950 RN, 1950 SO, 1950 TQ4, 1954 NG, and 1978 EF6. This asteroid is one of the SSMO objects. We observed it on three nights between 2016 Jan 26-28. We obtained a synodic period of 2.466 ± 0.002 h and amplitude of 0.02 ± 0.02 mag.

Since our amplitude is so small, there is little confidence in the formal error bars for both period and amplitude. We were able to obtain previous results from Stephens (2011) from the ALCDEF database (ALCDEF, 2016). We present three plots for 2650 Elinor. The first shows Stephens' results from 2010. He obtained a period of 2.762 ± 0.002 h and amplitude of 0.18 mag. The second plot shows our results form 2016. The third plot combines the two previous results clearly showing the difference between the oppositions. The lack of amplitude for the 2016 results indicates that the pole might have been directed toward or away from the Earth at the time of our observations.

2875 Lagerkvist is a main-belt asteroid discovered by E. Bowell at Anderson Mesa Station, Lowell Observatory, on 1983 Feb 11. It is also known as 1983 CL, 1955 EF, 1966 QQ, 1969 BG, and 1981 UJ. This asteroid is one of the LPO objects. We observed it on four nights between 2016 Mar 18-27. We obtained a synodic period of 5.628 ± 0.002 h and amplitude of 0.62 ± 0.05 mag. We found no published results for this asteroid.

3829 Gunma is a main-belt asteroid discovered by T. Kojima at Chiyoda on 1988 Mar 10. It is also known as 1988 EM, 1951 GO1, 1958 TD, 1979 HX6, 1981 SU4, 1981 UY10, 1984 KG, and 1986 UE2. This asteroid is one of the LPO objects. We observed it on six nights between 2016 Feb 29 and Mar 13. We obtained a synodic period of 4.720 ± 0.001 h and amplitude of 0.25 ± 0.05 mag. The bimodal shape has unequal maxima and minima. There are no other reported observations of this object.

3870 Mayre is a main-belt asteroid discovered by E. W. Elst at La Silla on 1988 Feb 13. It is also known as 1988 CG3, 1968 QG, 1973 US4, 1977 VO1, 1981 UZ15, 1984 FJ2, and 1968 XL4. This asteroid is one of the SSMO objects. We observed the asteroid on three nights between 2015 Oct 14 and Nov 01. We obtained a synodic period of 3.992 ± 0.001 h and amplitude of 0.44 mag. We have no obvious explanation for the large discrepancy in the amplitudes of the first maximum.

3913 Cheminis is a main-belt asteroid discovered at Caussois on 1986 Dec 2. It is also known as 1986 XO2 and 1969 EW1. This asteroid is one of the SSMO objects. We observed it on five nights between 2016 Feb 5-25. We obtained a synodic period of 3.408 ± 0.002 h and amplitude of 0.17 ± 0.05 mag. All of the published periods given in the LCDB are within close agreement.

4343 Tetsuya is a main-belt asteroid discovered by Ueda and Kaneda at Kushiro on 1988 Jan 10. It is also known as 1988 AC, 1979 DS, and 1984 JQ1. This asteroid is one of the LPO objects. We observed it on two nights: 2016 Feb 16 and 17. We obtained a synodic period of 7.392 ± 0.0014 h and amplitude of 0.20 ± 0.05 mag. There are no other reported observations of this object.

6094 Hisako is a main-belt asteroid discovered by T. Hioki and S. Hayakawa at Okutama on 1990 Nov 10. It is also known as 1990 VQ1, 1971 BJ3, 1972 LE1, and 1993 HA1. This asteroid is one of the LPO objects. We observed it on four nights between 2015 Aug 4-31. We obtained a synodic period of 4.050 ± 0.002 h and amplitude of 0.22 mag. Due to the large scatter in the data there is not much confidence in the period. There are no other reported observations of this object.

(7822) 1991 CS is a main-belt asteroid discovered by R.H. McNaught at Siding Spring on 1991 Feb 13. This asteroid is one of the SSMO objects. We observed it on three nights between 2016 Feb 27-29. We obtained a synodic period of 2.390 ± 0.002 h and amplitude of 0.29 ± 0.10 mag. Our period is in good agreement with the previously published periods in the LCDB.

References

ALCDEF (2016). Asteroid raw lightcurve data web site. http://minorplanetcenter.net/light_curve2/light_curve.php

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

Apostolovska, G., Ivanova, V., Kostov,A., (2009). "CCD Photometry of 967 Helionape, 3415 Danby, (85275) 1994 LY, 2007 DT103, and 2007 TU24." *Minor Planet Bull*. **36**, 27-28.

Aymami, J.M. (2012). "CCD Photometry and Lightcurve Analysis of Main Belt Asteroids 1077 Campanula and 1151 Ithaka from Observatori Carmelita." *Minor Planet Bull*. **39**, 29.

Behrend (2001 2006, 2009, 2011), Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Binzel, R.P., Mulholland, J.D. (1983). "A photoelectric lightcurve survey of small main belt asteroids." *Icarus* **56**, 519-533.

Carbognani, A. (2011). "Lightcurves and Periods of Eighteen NEAs and MBAs." *Minor Planet Bull*. **38**, 57-63.

Chiorny, V., Galad, A., Pravec, P., Kusnirak, P., Hornoch, K., Gajdos, S., Kornos, L., Vilagi, J., Husarik, M., Kanuchova, Z., Krisandova, Z., Higgins, D., Pray, D.P., Durkee, R., Dyvig, R., Reddy, V., Oey, J., Marchis, F., Stephens, R.D. (2011). "Absolute photometry of small main-belt asteroids in 2007-2009." Planet. Space Sci. **59**, 1482-1489.

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

Ferrero, A. (2011). "Period Analysis of 996 Hilaritas, 3387 Greenberg, and 3870 Mayre." *Minor Planet Bull.* **38**, 49-50.

Franco, L., (2012). "Lightcurve Photometry and H-G Parameters for 1077 Campanula." *Minor Planet Bull*. **39**, 67-69.

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.

Higgins, D., Goncalves, R.M.D. (2007). "Asteroid Lightcurve Analysis at Hunters Hill Observatory and Collaborating Stations - June-September 2006." *Minor Planet Bull*. **34**, 16-18.

Higgins, D.J. (2011). Asteroid lightcurves web site. *http://www.david-higgins.com/Astronomy/asteroid/lightcurves.htm*

JPL (2016). JPL Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi#top*

Klinglesmith III, D.A., Franco, L. (2016). "Lightcurves for 1531 Hartmut and 4145 Maximova." *Minor Planet Bull.,* **43,** 121.

Krugly, Yu.N., Bel'skaya, I.N., Shevchenko, V.G., Chiorny, V.G., Velichko, F.P., Mottola, S., Erikson, A., Hahn, G., Nathues, A., Neukum, G., Gaftonyuk, N.M., Dotto, E. (2002). "The Near-Earth Objects Follow-up Program. IV. CCD Photometry in 1996-1999." *Icarus* **158**, 294-304.

Kryszczynska, A., Colas,F., Polinska, M., Hirsch, R., Ivanova, V., Apostolovska, G., Bilkina, B., Velichko, F.P., Kwiatkowski, Kankiewicz, P., Vachier, F., Umlenki, V., and 18 co-authors

(2012). “Do Slivan states exist in the Flora family? I. Photometric survey of the Flora region.” *Astron. Astrophys*. **546**, A72.

Pligge, Z., Hall, B., Ditteon, R. (2011). “Asteroid Lightcurve Analysis at the Oakley Observatory: 2010 September thru October.” *Minor Planet Bull*. **38**, 137-138.

Pravec, P., Wolf, M., Sarounova, L. (1998). “Lightcurves of 26 Near-Earth Asteroids.” *Icarus* **136**, 124-153.

Pravec, P., Wolf, M., Sarounova, L. (2009). *http://www.asu.cas.cz/~ppravec/neo.htm*

Stephens, R.D. (2003). “Photometry of 2134 Dennispalm, 2258 Viipuri, 3678 Mongmanwai, 4024 Ronan, and 6354 Vangelis.” *Minor Planet Bull*. **30**, 46-48.

Stephens, R.D. (2011). “Asteroids Observed from GMARS and Santana Observatories: 2010 July - September.” *Minor Planet Bull*. **38**, 23-24.

Stephens, R.D. (2012). “Asteroids Observed from GMARS and Santana Observatories: 2011 July – September.” *Minor Planet Bull*. **39**, 11-12.

Torno, S., Oliver, R.L., Ditteon, R. (2008). “Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory - October 2007.” *Minor Planet Bull*. **35**, 54-55.

Vander Haagen, G. (2009). “Lightcurves and H-G Parameters for 901 Brunsia and 946 Poesia.” *Minor Planet Bull*. **36**, 136-138.

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*

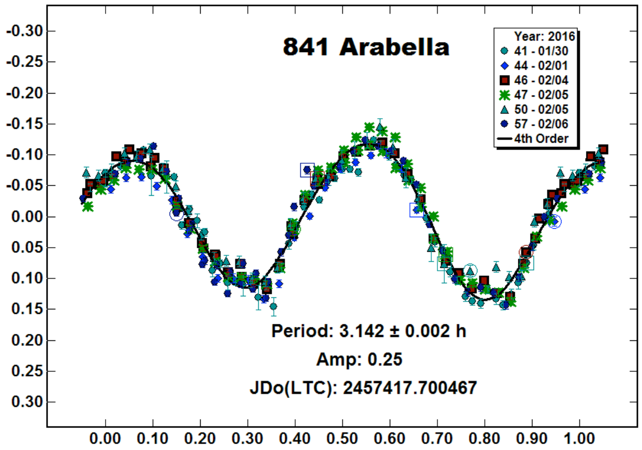
Warner, B.D. (2015). *MPO Canopus* software. *http://bdwpublishing.com/mposoftware.aspx*

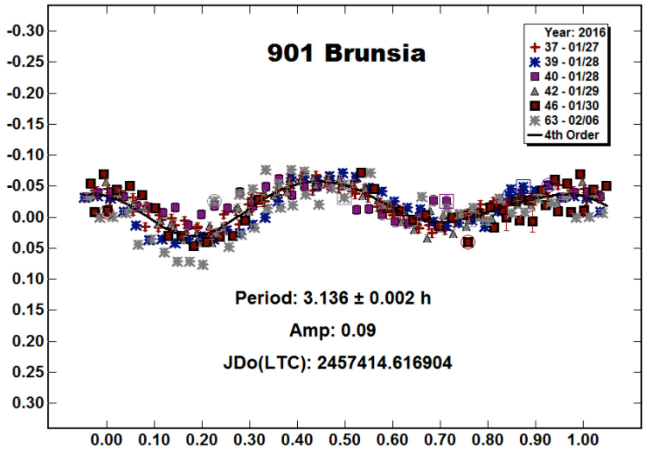
Warner, B.D. (2016a). “Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 June-September.” *Minor Planet Bull*. **43**, 66-79.

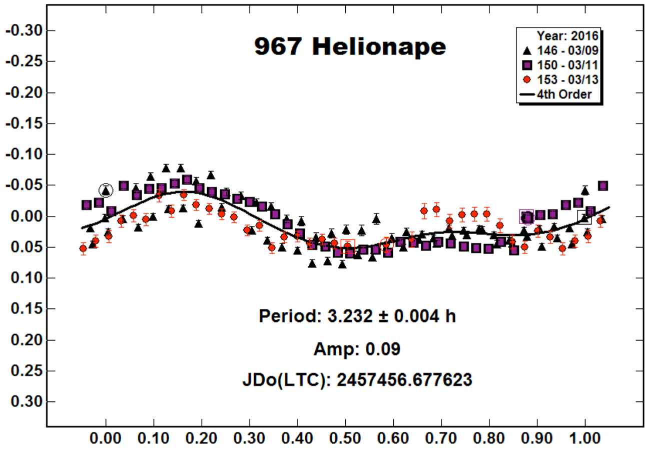
Warner, B.D., Harris, A.W., Durech, J., Benner, L.A.M., (2016b). “Lightcurve Photometric Opportunities: 2016 April-June.” *Minor Planet Bull*. **43**, 103-108.

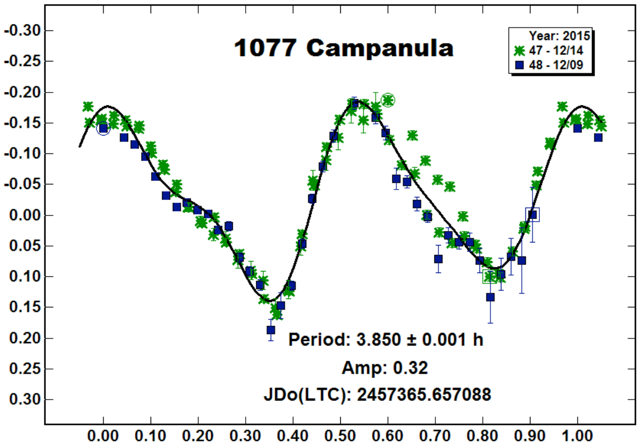
Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2016). “Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry.” *Astron. J.* **150**, A75.

Wisniewski, W.Z., Barucci, M.A., Harris, A.W., McMillian, R.S., (1997). “Photometric Observations of 125 Asteroids.” *Icarus* **126**, 395-449.








1077 Campanula
Year: 2015
47 - 12/14
48 - 12/09
Period: 3.850 ± 0.001 h
Amp: 0.32
JDo(LTC): 2457365.657088
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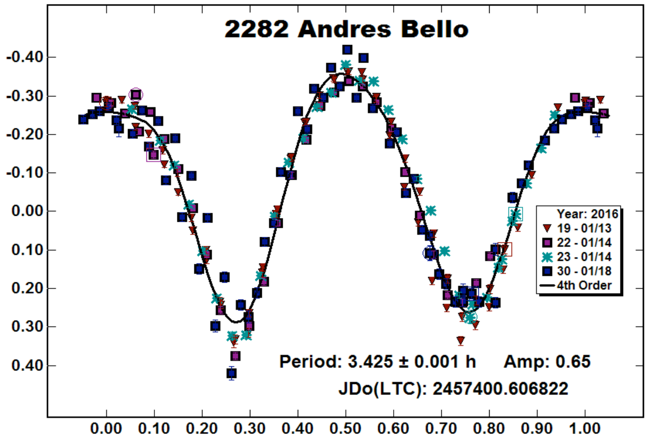
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


2282 Andres Bello
Year: 2016
19 - 01/13
22 - 01/14
23 - 01/14
30 - 01/18
4th Order
Period: 3.425 ± 0.001 h
Amp: 0.65
JDo(LTC): 2457400.606822
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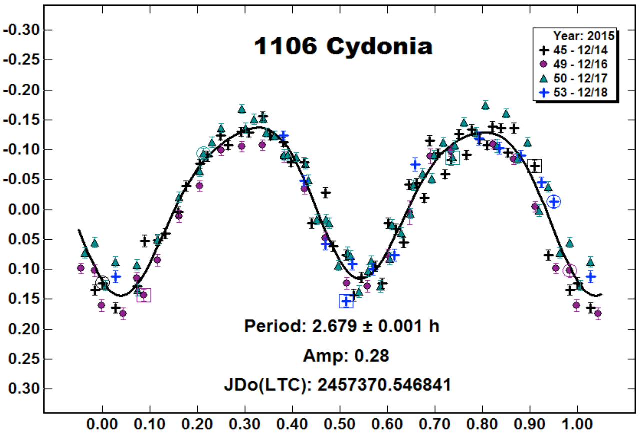
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


1106 Cydonia
Year: 2015
45 - 12/14
49 - 12/16
50 - 12/17
53 - 12/18
Period: 2.679 ± 0.001 h
Amp: 0.28
JDo(LTC): 2457370.546841
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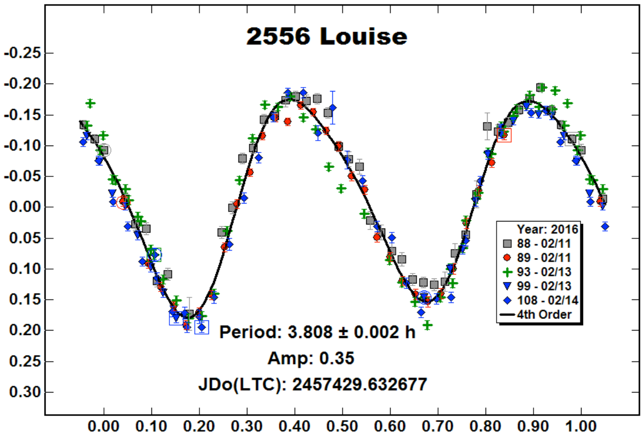
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


2556 Louise
Year: 2016
88 - 02/11
89 - 02/11
93 - 02/13
99 - 02/13
108 - 02/14
4th Order
Period: 3.808 ± 0.002 h
Amp: 0.35
JDo(LTC): 2457429.632677
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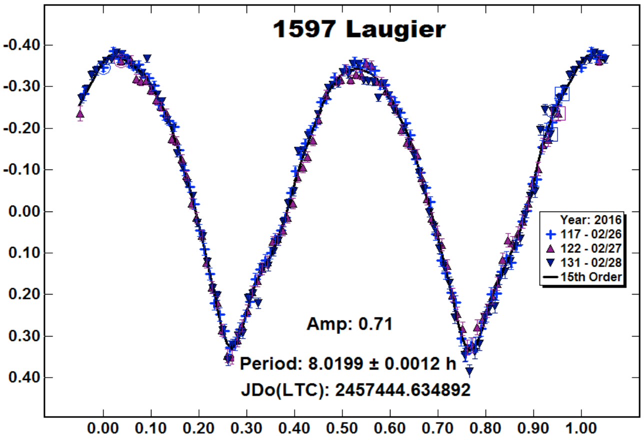
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


1597 Laugier
Year: 2016
117 - 02/26
122 - 02/27
131 - 02/28
15th Order
Amp: 0.71
Period: 8.0199 ± 0.0012 h
JDo(LTC): 2457444.634892
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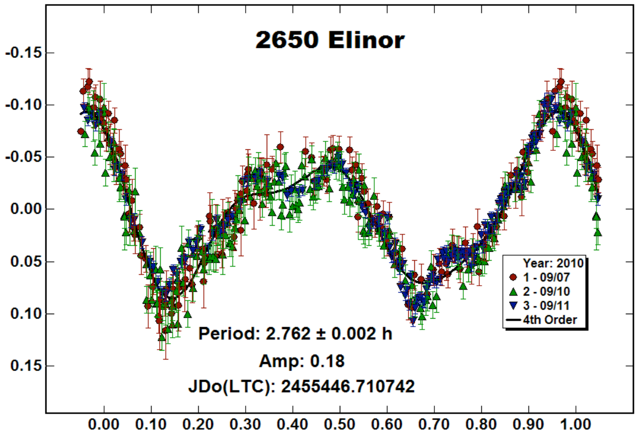
2650 Elinor
Year: 2010
1 - 09/07
2 - 09/10
3 - 09/11
4th Order
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Amp: 0.18
JDo(LTC): 2455446.710742
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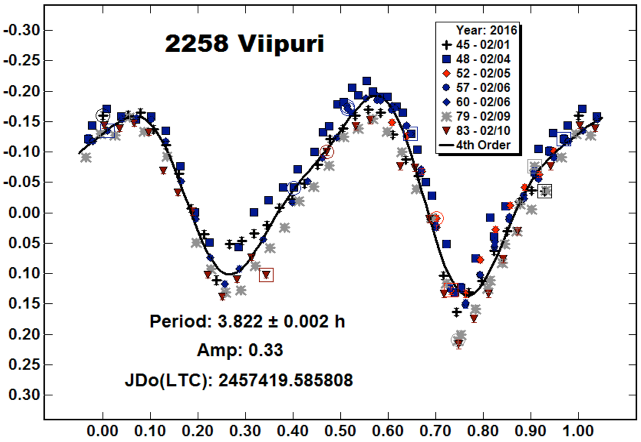
2258 Viipuri
Year: 2016
45 - 02/01
48 - 02/04
52 - 02/05
57 - 02/06
60 - 02/06
79 - 02/09
83 - 02/10
4th Order
Period: 3.822 ± 0.002 h
Amp: 0.33
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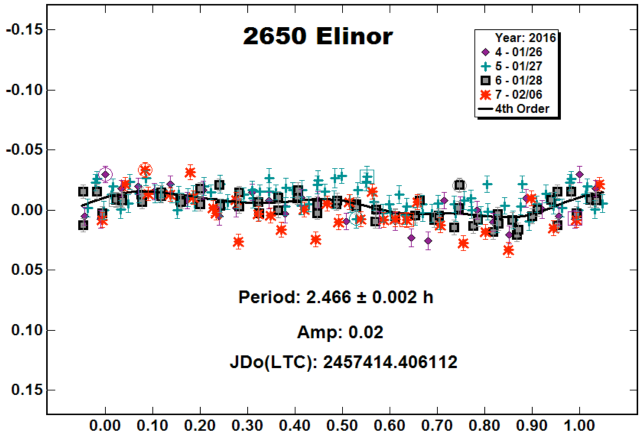
2650 Elinor
Year: 2016
4 - 01/26
5 - 01/27
6 - 01/28
7 - 02/06
4th Order
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Amp: 0.02
JDo(LTC): 2457414.406112
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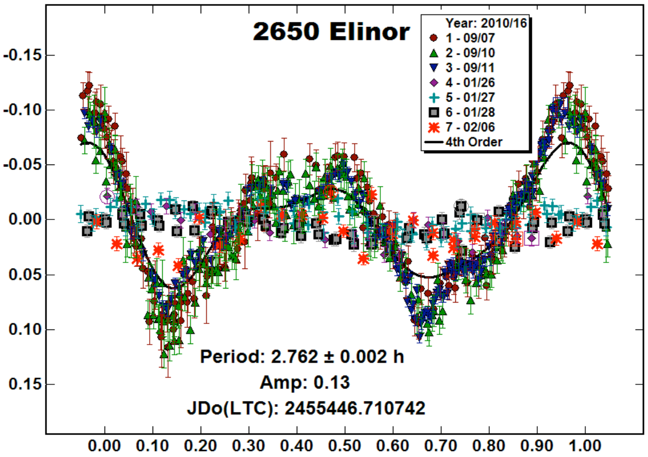
2650 Elinor
Year: 2010/16
1 - 09/07
2 - 09/10
3 - 09/11
4 - 01/26
5 - 01/27
6 - 01/28
7 - 02/06
4th Order
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
Period: 2.762 ± 0.002 h
Amp: 0.13
JDo(LTC): 2455446.710742
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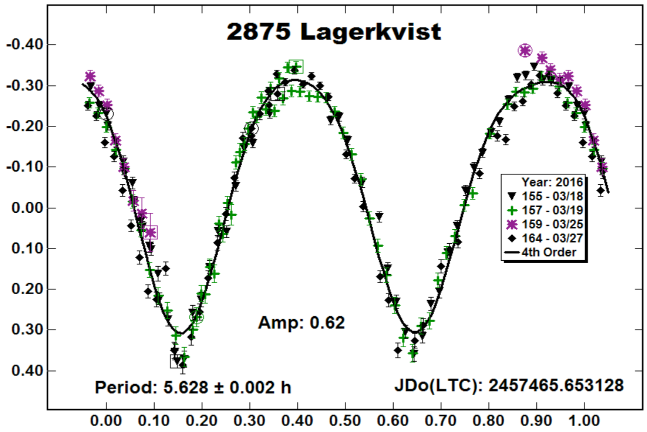
2875 Lagerkvist
Year: 2016
155 - 03/18
157 - 03/19
159 - 03/25
164 - 03/27
4th Order
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
Amp: 0.62
Period: 5.628 ± 0.002 h
JDo(LTC): 2457465.653128
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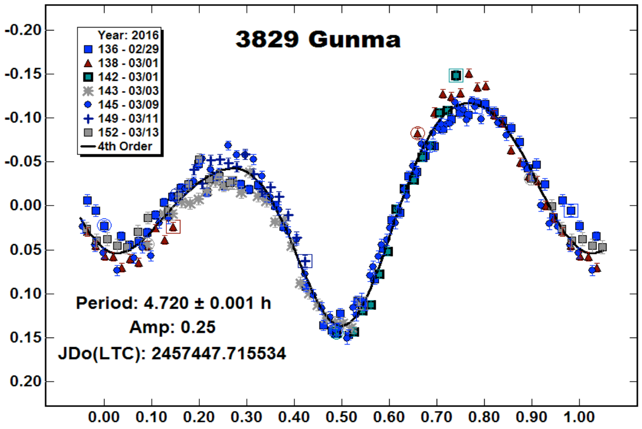
3829 Gunma
Year: 2016
136 - 02/29
138 - 03/01
142 - 03/01
143 - 03/03
145 - 03/09
149 - 03/11
152 - 03/13
4th Order
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
Period: 4.720 ± 0.001 h
Amp: 0.25
JDo(LTC): 2457447.715534
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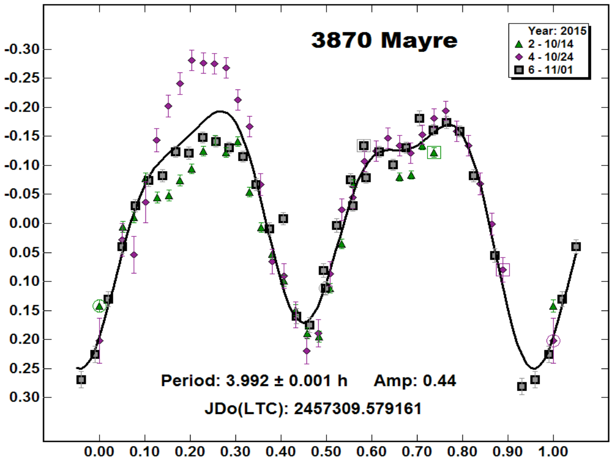
3870 Mayre
Year: 2015
2 - 10/14
4 - 10/24
6 - 11/01
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-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Period: 3.992 ± 0.001 h
Amp: 0.44
JDo(LTC): 2457309.579161
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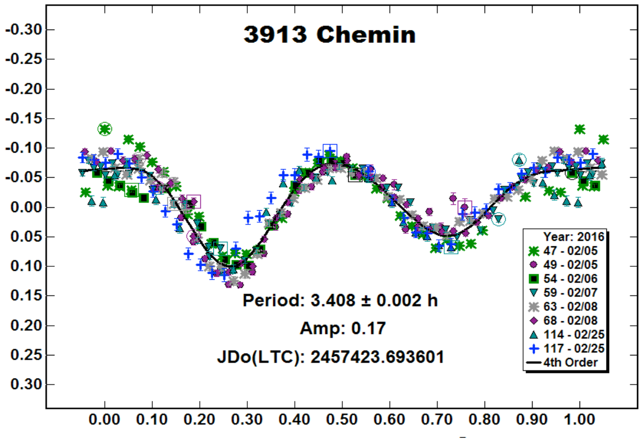
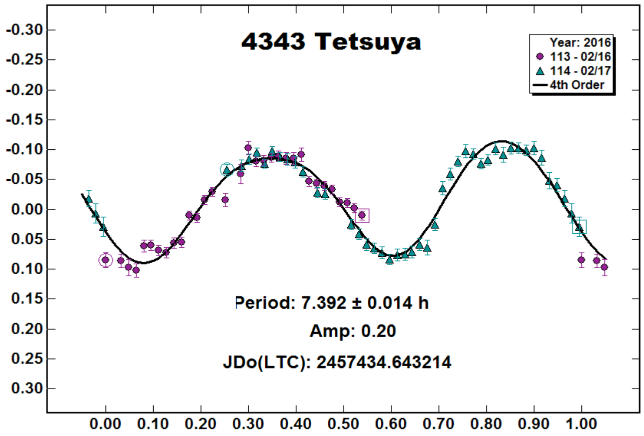
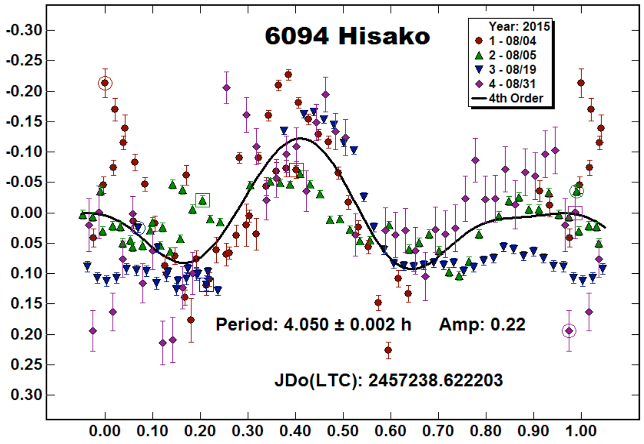
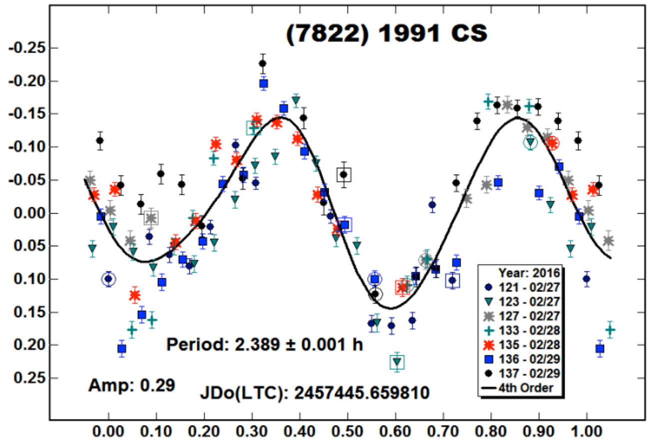

3913 Chemin
Year: 2016
47 - 02/05
49 - 02/05
54 - 02/06
59 - 02/07
63 - 02/08
68 - 02/08
114 - 02/25
117 - 02/25
4th Order
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Period: 3.408 ± 0.002 h
Amp: 0.17
JDo(LTC): 2457423.693601
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


4343 Tetsuya
Year: 2016
113 - 02/16
114 - 02/17
4th Order
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Period: 7.392 ± 0.014 h
Amp: 0.20
JDo(LTC): 2457434.643214
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


6094 Hisako
Year: 2015
1 - 08/04
2 - 08/05
3 - 08/19
4 - 08/31
4th Order
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Period: 4.050 ± 0.002 h
Amp: 0.22
JDo(LTC): 2457238.622203
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(7822) 1991 CS
Year: 2016
121 - 02/27
123 - 02/27
127 - 02/27
133 - 02/28
135 - 02/28
136 - 02/29
137 - 02/29
4th Order
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Period: 2.389 ± 0.001 h
Amp: 0.29
JDo(LTC): 2457445.659810
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

Number	Name	Reference	Date	L_{PAB}	B_{PAB}	Phase	Period	Amp
841	Arabella	This paper	2016 Jan 01	136	3.7		3.142	0.25
		Binzel 1983				0	3.39	0.26
		Kryszczynska 2012	2004 Sep 19	359	-0.3	1.4		0.25
		Kryszczynska 2012	2007 Aug 17	308	-3.4	8.4		0.22
901	Brunsia	This paper	2016 Feb 27	123	-2.9		3.136	0.09
		Wisnuewski 1997	1991 Oct 08	355	5.4	15.3	4.872	0.12
		Behrend 2001	2001 Oct 02	6.8	5.5	4.5	3.1357	0.11
		Vander Haagen 2009	2009 01 08	81.7	-0.2	13.1	3.1363	0.28
		Behrend 2011	2011 Oct 20	20.4	4.8	5.5	3.1335	0.17
967	Helionape	This paper	2016 Mar 09	179	7.1		3.232	0.09
		Torno 2008	2007 Oct 14	13	-7.4	6.8		0.2
		Apostolovska 2009	2007 Oct 16	13.1	-7.3	7.6	3.234	0.06
		Kryszcynska 2012	2007 Oct 16	13.1	-7.4	7.6		0.04
		Kryszcynska 2012	2009 Mar 24	141	6.1	17.5	3.232	0.12
1077	Campanula	This paper	2015 Dec 09	66.3	7.5		3.85	0.32
		Stephens 2012	2011 Aug 29	389	0.4	14.2	3.852	0.33
		Franco 2012	2011 Oct 10	0.4	2.7	11	3.8509	0.24
		Higgins 2011	2011 oct 18	1.5	3.1	15.2	3.847	0.4
		Aymami 2012	2011 Aug 19	354	-0.2	19	3.86	0.36
		Durech 2016	Multiple				3.8505	
2258	Viipuri	This paper	2015 Feb 01	118	0.2		3.822	0.33
		Stephens 2003	2003 Feb 19	152	-0.8	1.2	3.81	0.25
		Behrend 2006	2006 Dec 21	98	1	4.5	3.838	0.31
		Waszczak 2016	2010 Oct 24	46.7	1.9	7.5	3.8222	0.27
2650	Elinor	This paper	2016 Jan 01	11.5	12.3		2.762	0.14
		Behrend 2006	2006 Nov 22	57.3	18.9	13.2	9.087	0.12
		Stephens 2011	2010 Sep 09	6	9.2	4.4	2.762	0.18
		Pligge 2011	2010 Oct 05	7.8	12.1	18.2	2.7614	0.15
3870	Mayre	This paper	2015 Oct 14	9	2.6		3.992	0.44
		Carbognani 2011	2010 Jul 01	256	14.9	15.2	3.9915	0.44
		Ferrero 2011	2010 Jun 02	254	8.2	13.7	3.99	0.45
		Behrend	2014 May 16	213	5	12	3.9917	0.44
3913	Chemin	This paper	2016 Feb 04	151	-6.6		3.408	0.17
		Higgens 2007	2006 Sep 03	327	3.3	6.4	3.4007	0.17
		Pravec 2009	2009 Apr 01	211	27.2	22.5	3.4077	0.45
		Behrend 2009	2009 May 22	219	33	24.9	3.4086	0.53
		Chiorny 2011	2009 Apr 11	213	29.3	21.4	3.4076	0.46
7822	1991 CS	This paper	2016 Feb 27	145	-7.3		2.39	0.29
		Warner 2016a	2015 Aug 06	308	49.2	63	2.391	0.39
		Pravec 1998					2.389	0.32
		Krugly 2002					2.3897	0.26

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

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2016 JANUARY-APRIL

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(Received: 2016 April 10)

Lightcurves for 38 near-Earth asteroids (NEAs) were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 January-April. Also reported are 4 lightcurves obtained from 2014-2015 that were not previously published

CCD photometric observations of 38 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 January-April. Also included are another 4 lightcurves obtained in 2014-2015 that were not previously published. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

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

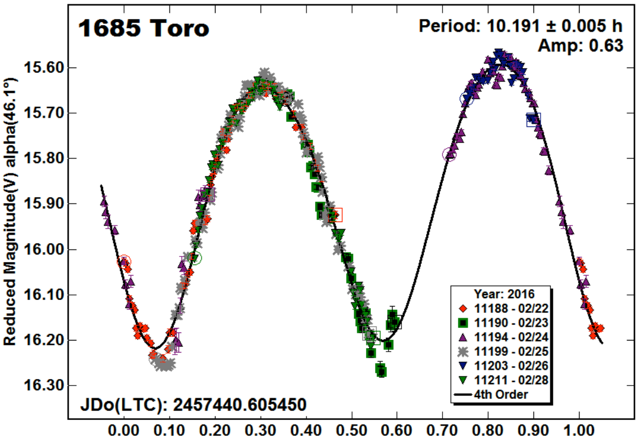
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the APASS catalog (Henden *et al*., 2009). When there were insufficient stars, the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

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

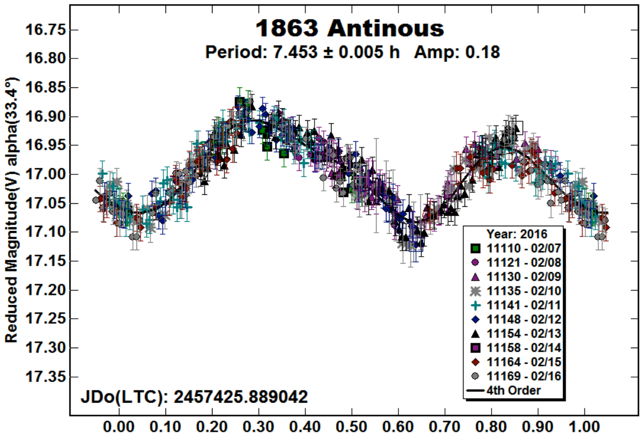
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on a specific asteroid. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

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

1685 Toro. The 2016 apparition was the second one at which the author observed Toro. At the first (Warner, 2013), two synodic periods were reported (10.205, 10.185h) as the phase angle bisector longitude changed by more than 30°. All the 2016 observations were at about the same longitude and so a single period of 10.191 h was found.

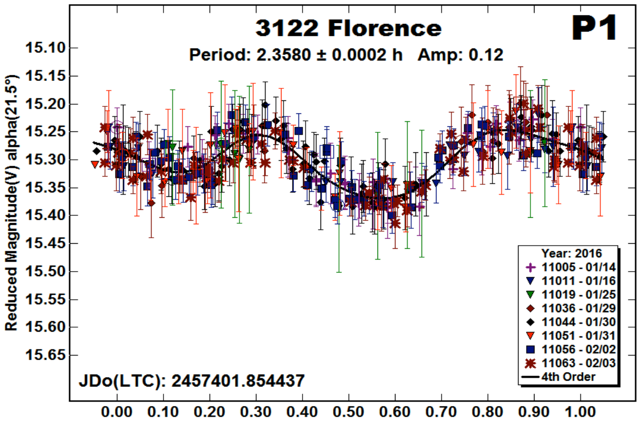


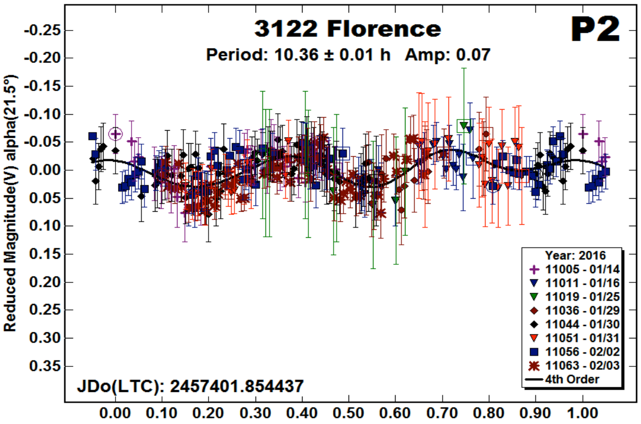
1863 Antinous. Binzel (1987) and Harris (1999) reported periods of 4.02 and 4.386 h, respectively. Both were rated "probably wrong" in the LCDB U = 1. Pravec *et al.* (1999w) found a more secure solution of 7.4568 h. The analysis of the 2016 PDS data supports the Pravec *et al*. results.



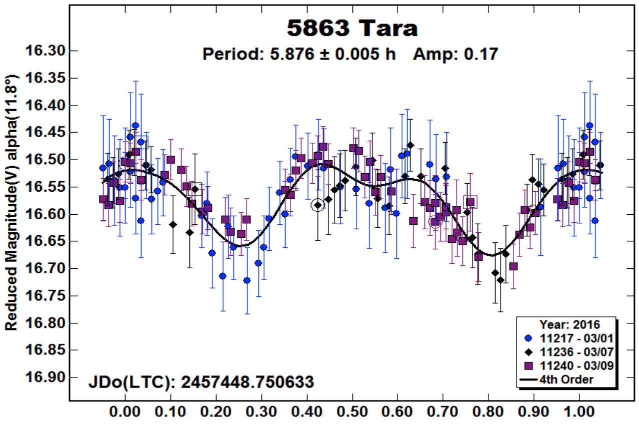
A weak second period of 28.6 ± 0.2 h was found with an amplitude of 0.03 to 0.06 mag. Subtracting this period noticeably improved the RMS fit of the primary period. This asteroid merits close scrutiny at future apparitions.

3122 Florence. The period ("P1") found from the PDS data is in good agreement with earlier results, *e.g.*, Pravec *et al.*, (2002w, 2.3581 h) and Elenin (2012, 2.359 h). No previous entry in the LCDB had a second period but one was found in the PDS data. The favored solution is 10.36 h ("P2"), although a monomodal solution at about 5.18 h cannot be formally excluded. There were no obvious signs of mutual events (occultations and/or transits), making the *unconfirmed* cause to be a satellite. If so, this could be an example of a wide asynchronous binary (see, *e.g.*, Pravec *et al.*, 2016). Future observations are planned and encouraged.

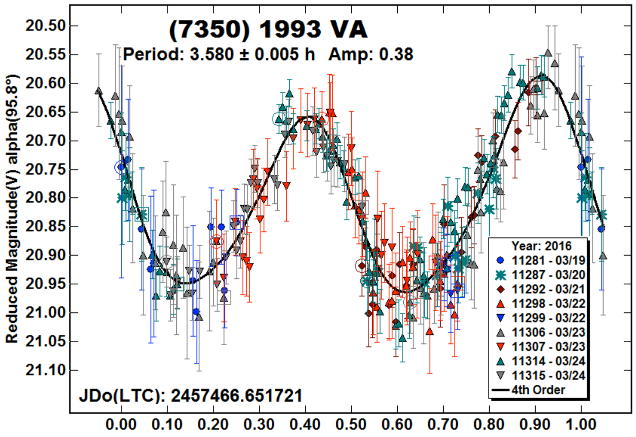




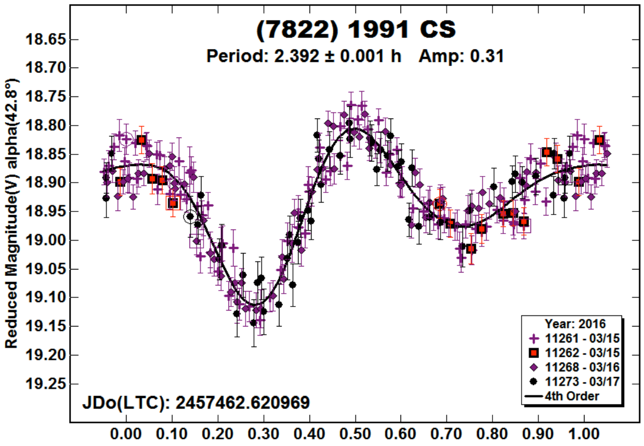
5863 Tara. There were no previous entries in the LCDB for Tara.



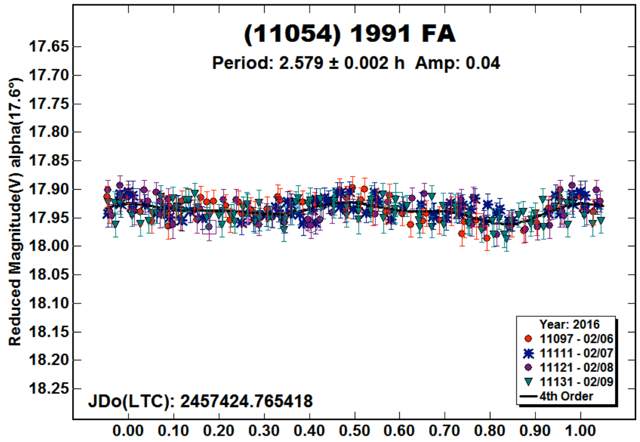
(7350) 1993 VA. Based on WISE data (Mainzer *et al.*, 2011), 1993 VA has an albedo p_V = 0.050 and diameter D = 2.36 km. There were no previous entries in the LCDB for a period.



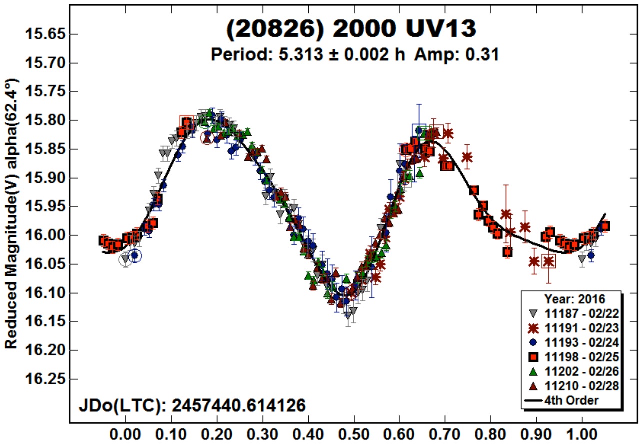
(7822) 1991 CS. Pravec *et al.* (1998a) found a period of 2.389 h for 1991 CS. The period reported here is in good agreement.



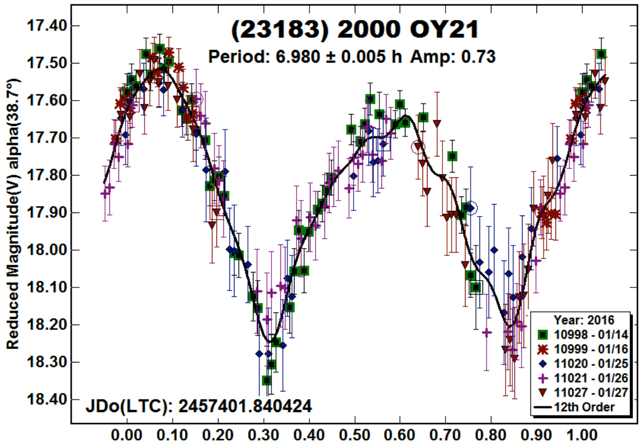
(11054) 1991 FA. Pravec *et al.* (2001w) found a period of 2.57223 hours with an amplitude of 0.08 mag. Using data obtained in 2015 Oct, Warner (2016b) found a period of 2.926 h with a not as good fit to 2.615 h. The amplitude was 0.15 mag. The 2016 February data led to a reasonably close fit to the Pravec *et al.* period, although the amplitude was only 0.04 mag and so the solution is not considered fully secure.



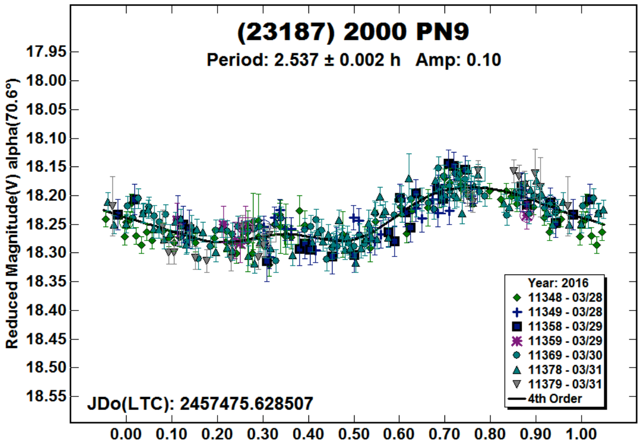
<u>(20826) 2000 UV13</u>. Pravec *et al.* (2000w) reported $P > 12$ h. This is rated U = 1+ in the LCDB, indicating the solution was not good enough for use in rotation studies. The 2016 PDS observations led to a nearly secure period of 5.313 h.



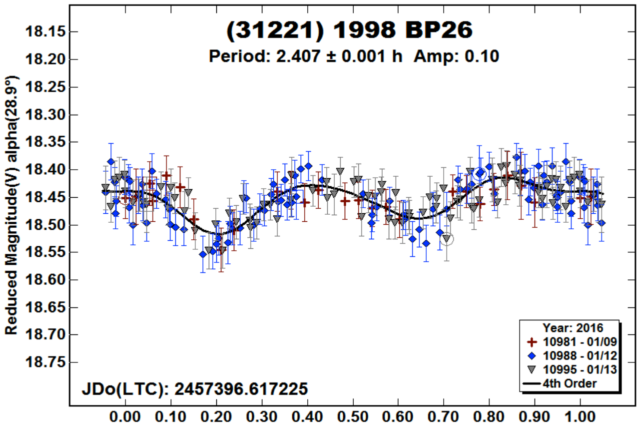
<u>(23183) 2000 OY21</u>. Skiff (2011a) found a period of 6.981 h. The period found with the 2016 PDS data is essentially the same.



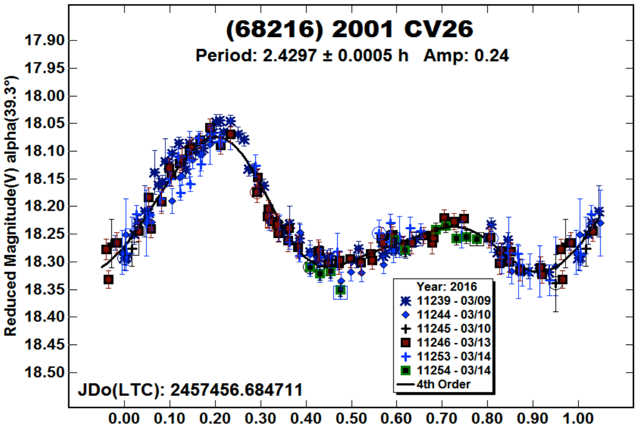
<u>(23187) 2000 PN9</u>. Previous results for 2000 PN8 include Pravec *et al.* (2001w; 2.5325 h) and Belskaya (2009, 2.5325 h). The PDS solution of $P = 2.537$ h agrees with those results if a monomodal lightcurve is adopted. Given the high phase angle, the lightcurve may be affected by shadowing effects and so a bimodal lightcurve would not necessarily be seen.



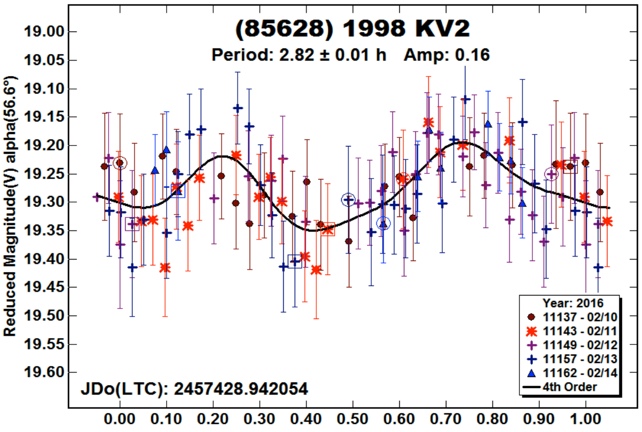
<u>(31221) 1998 BP26</u>. Hergenrother *et al.* (2009) found a period of 2.24 h for this NEA. That lightcurve is rated U = 2 in the LCDB, indicating that the period could still be wrong, but only by a factor of 1/2 to 2, depending on the modality (*e.g.*, monomodal, bimodal, etc.). The data from PDS lead to a secure result of $P = 2.407$ h.

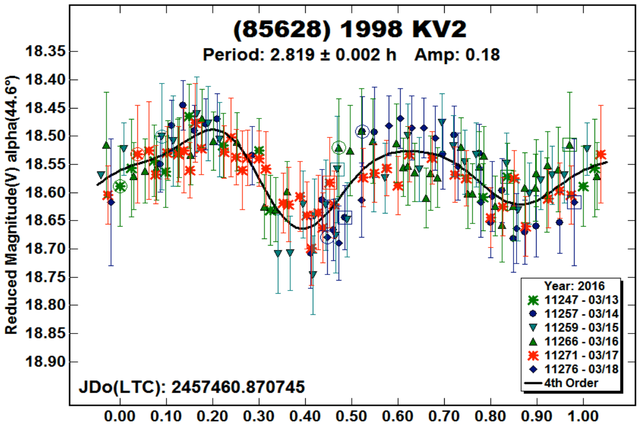


<u>(68216) 2001 CV26</u>. A period of about 2.42 h has been reported on several occasions (*e.g.*, Hicks, 2010; Polishook, 2012). Stephens *et al.* (2015) reported a possible satellite. However, radar observations in 2009 did not find evidence of such (Lance Benner, private communications in Stephens *et al.*, 2015). The period reported here agrees with the earlier single period results; there were no indications of a satellite.



<u>(85628) 1998 KV2</u>. This asteroid was observed twice in 2016.

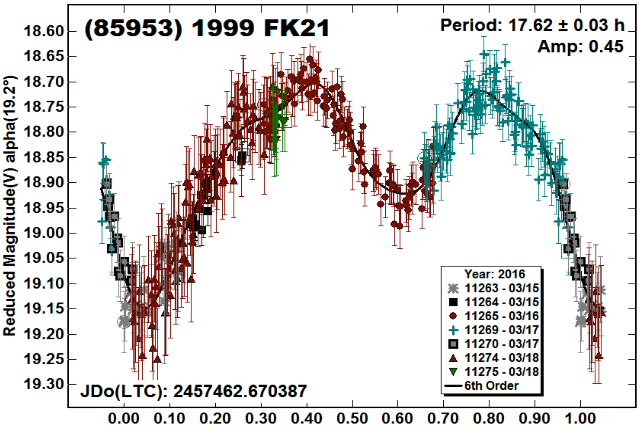




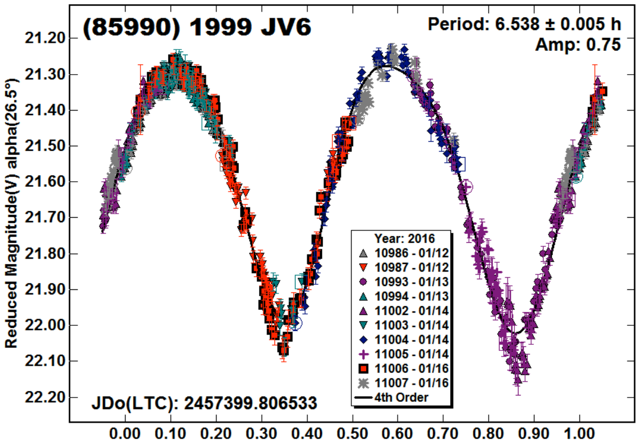
The purpose was to see how the lightcurve shape and amplitude and synodic period changed over the span of a month. In that time, the phase angle bisector longitude changed by about 18° and the phase angle decreased from 56° to 44°. As can be seen from the two lightcurves, the shape changed noticeably while the amplitude and synodic period remained about the same.

(85953) 1999 FK21. Skiff (2011b) reported a period of 28.1 h with the possibility of non-principal axis rotation, or *tumbling* (see Pravec *et al.*, 2005; 2014). The PDS data from 2016 fit a period of 17.62 h but with an unusual shape for the relatively low phase angle. When forced to a period near 28 h, the result was an unlikely trimodal result with two maximums close to one another and well-removed from the third. Skiff's data were downloaded from the ALCDEF web site (ALCDEF, 2016) to see if they were compatible with a single period of about 17.6 h. They were not, showing strong signs of tumbling within a bimodal lightcurve that required zero point offsets of ± 0.1 mag.

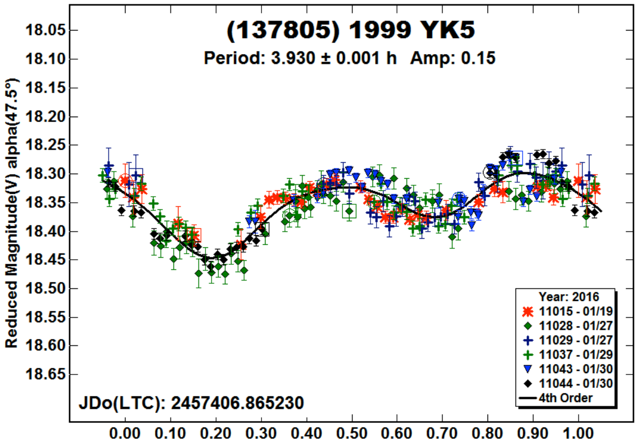
Assuming the shorter tumbling damping time formula in Pravec *et al.* (2014), the chances favor that the asteroid would be tumbling. The longer damping time formula gives about 1 Gyr for the asteroid. A more definitive solution will require a data set obtained by several observers at well-spaced longitudes at a future apparition.



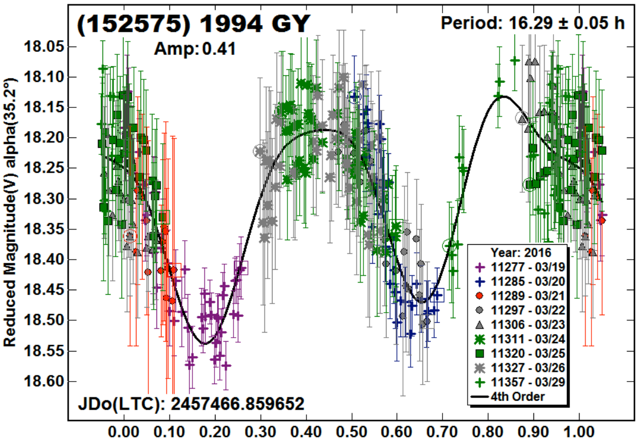
(85990) 1999 JV6. This was the third apparition at which the author observed this NEA. The previous results (Warner 2014b, 6.538 h; 2015, 6.543 h) and the most recent period of 6.538 h are in close agreement. It's unlikely the combined lightcurves will produce a good model because all the observations were at about the same phase angle bisector longitude and so the Earth-based view of the asteroid was about the same.



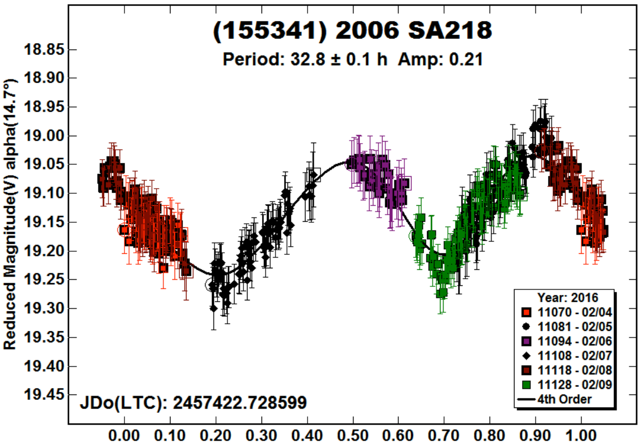
(137805) 1999 YK5. Skiff *et al.* (2012) reported an amplitude of 0.38 mag based on five data points. Since a period could not be found, no lightcurve was published. The 2016 PDS data led to a secure solution of $P = 3.930$ h and an amplitude of 0.15 mag.



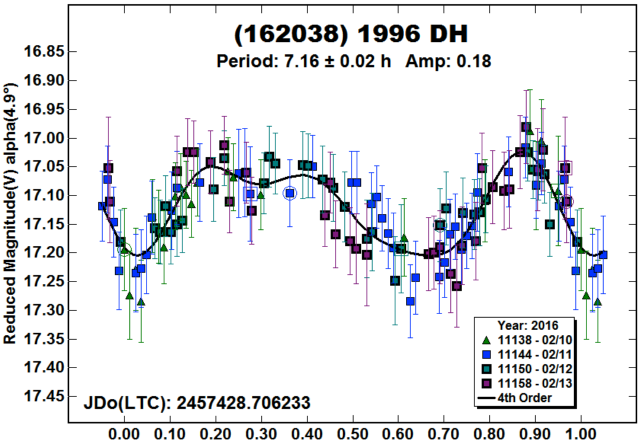
(152575) 1994 GY. Pravec *et al.* (1995) reported $P = 2.555$ h and $A = 0.06$ mag for 1994 GY. This result is rated U = 1 in the LCDB (probably wrong). Analysis of the PDS data found a period of 16.29 ± 0.05 h and amplitude of 0.41 mag. It was not possible to find a valid solution near 2.5 h with the PDS data.



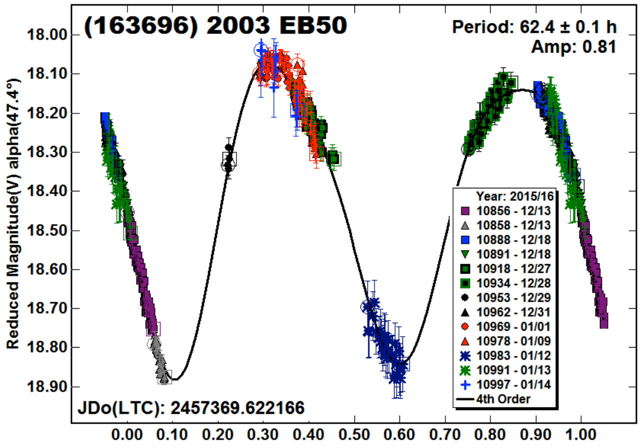
(155341) 2006 SA218. There were no previous entries in the LCDB for this NEA. The period of 32.8 h is very likely the correct one, but further observations are needed to confirm this.



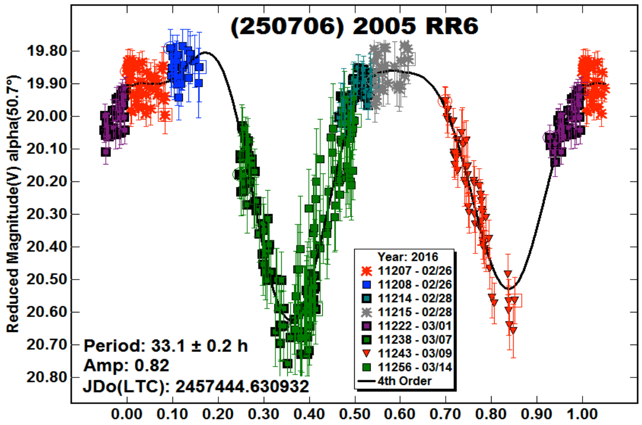
(162038) 1996 DH. The unusual shape of the lightcurve makes the period of 7.16 h somewhat uncertain. The observing circumstances repeat almost exactly every two years, including magnitude and declination, so there will be a good chance to confirm these results in the near future.

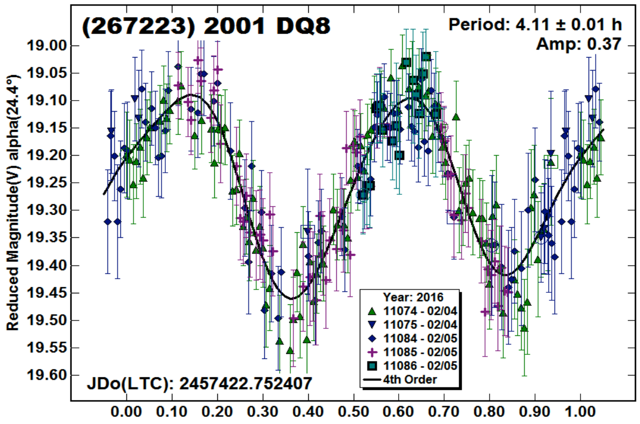


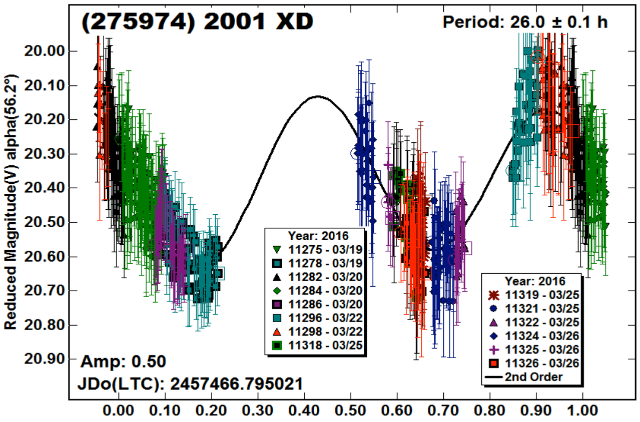
(163696) 2003 EB50. Warner (2014a) reported a period of 27.2 h and signs of tumbling. The PDS 2016 data set led to a period of 62.4 h with no obvious signs of tumbling, although there are considerable gaps in the lightcurve. Each data set could be forced to a solution found with the other. Because of the close fit to the model curve, the 62.4 h period is adopted for the time being, with the caveat that follow-up work needs to be done.



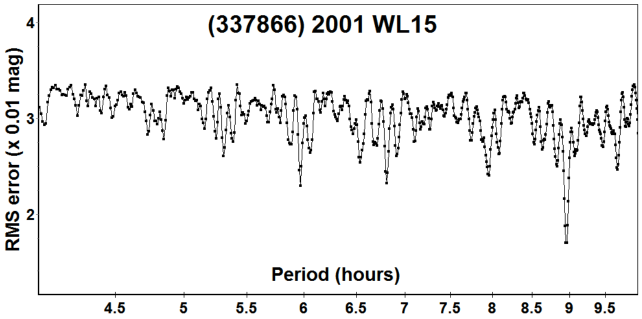
(205706) 2005 RR6; (267223) 2001 DQ8; (275974) 2001 XD. There were no previous entries in the LCDB for these asteroids.

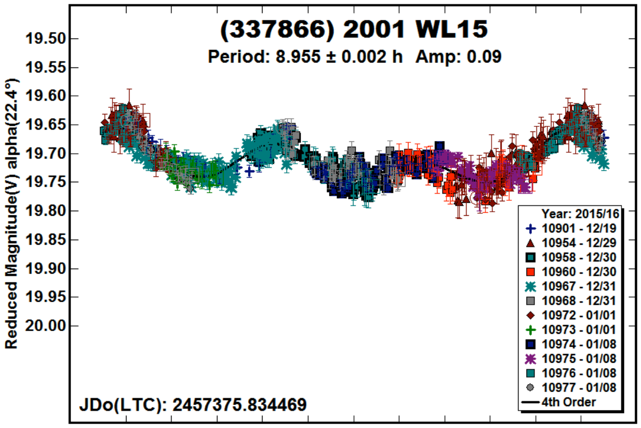






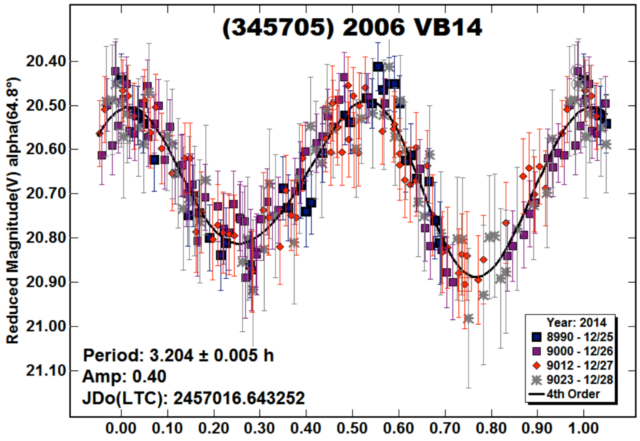
(337866) 2001 WL15.



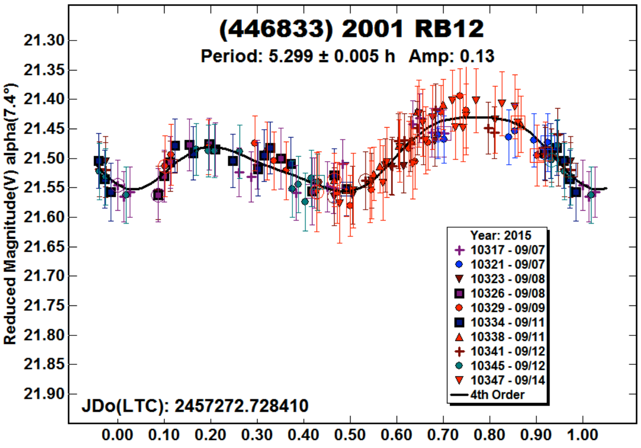


Carbognani and Buzzi (2016) reported a period of 5.1 h and amplitude of 0.13 mag based on data obtained in early 2015 December. The PDS data set spanned from 2015 mid-December into 2016 January and led to a period of 8.955 h. The period spectrum strongly favors the longer period.

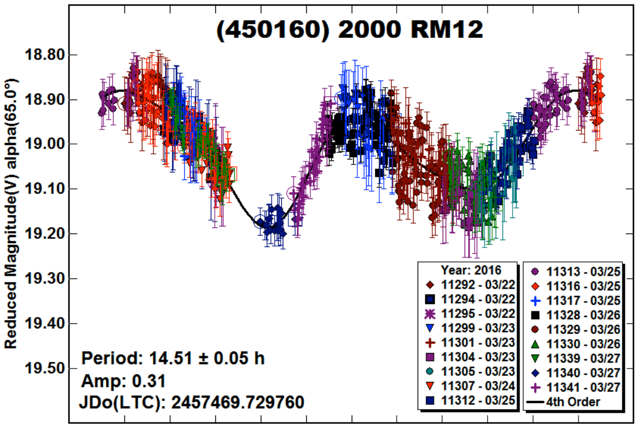
(345705) 2006 VB14. Skiff *et al*. (2012) found a period of 3.25 h. The PDS data lead to a similar result of 3.204 h with a maximum amplitude of 0.40 mag.



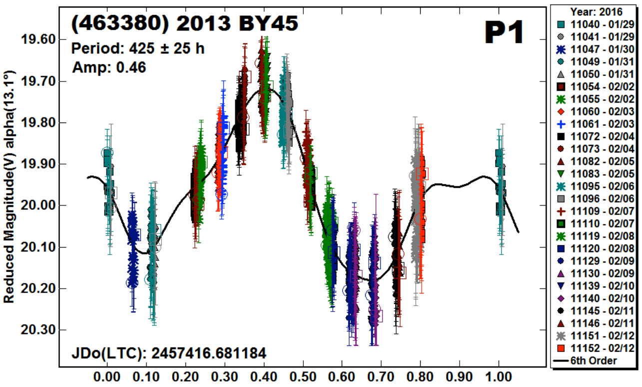
(446833) 2001 RB12. There were no previous entries in the LCDB for 2011 RB12.

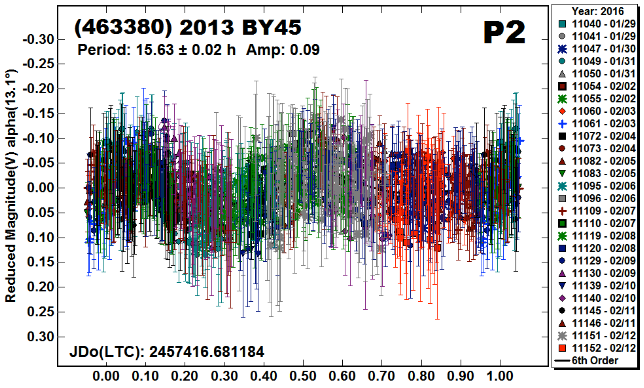


(450160) 2000 RM12. No previously published results were found for 2000 RM12, which has an estimated diameter of 1.4 km.

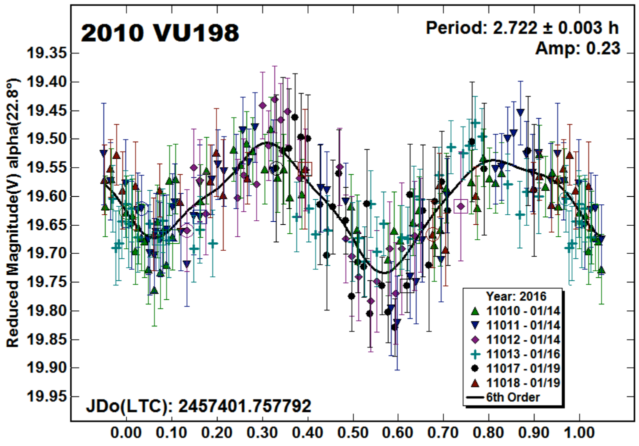


(463380) 2013 BY45. This may be another candidate for the very wide binary class (*e.g.*, Jacobson *et al.*, 2014; Warner, 2016a). In these systems, the primary has the longer period and larger amplitude. The long period component was obvious ("P1") but not so for the shorter period ("P2") because the noise in the data is about equal to the amplitude. Despite this, the second period seems valid, making it the longest second period among the ten very wide binary candidates reported so far. The chances of seeing mutual events, which would confirm a satellite, are very low since the orbital period in these systems is likely to be very long.

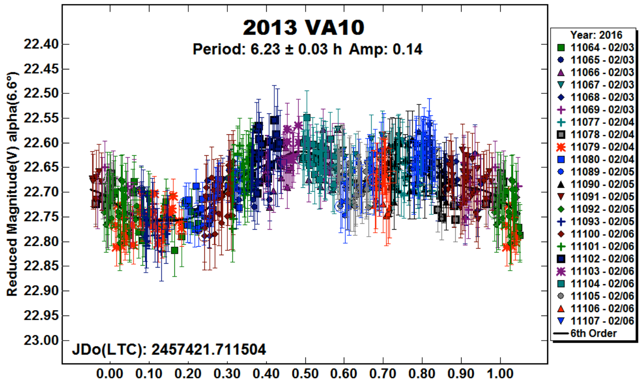


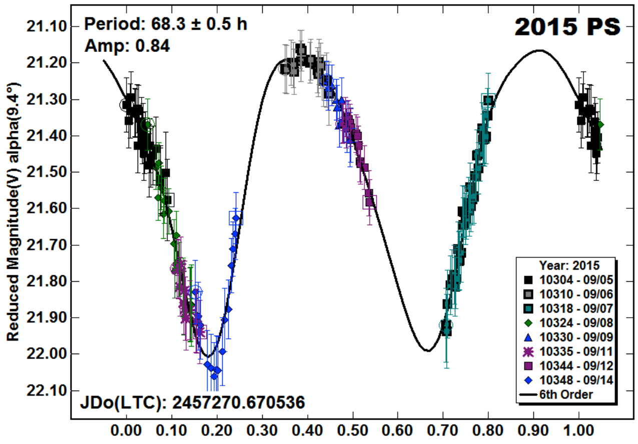


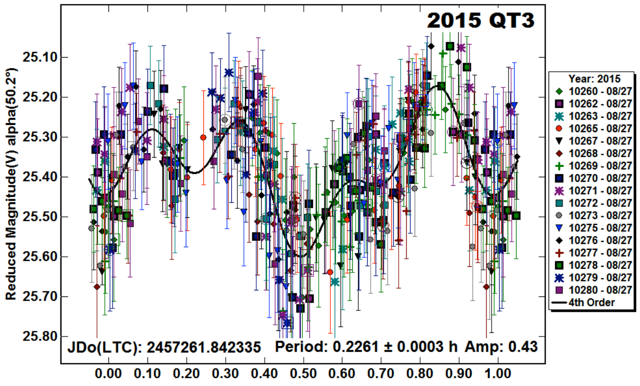
2010 VU198. There were no previous entries in the LCDB for 2010 VU198. The estimated size is about 600 meters. The period makes it a good candidate for being binary, but the size may be a little too small (see Pravec *et al.*, 2014). The check for a satellite may be a long time coming. The viewing circumstances repeat almost exactly every 23 years, meaning the next time the asteroid is V < 18 is not until 2039.



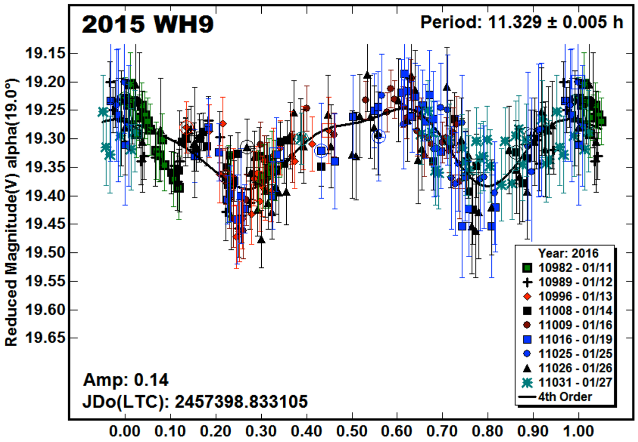
2013 VA10; 2015 PS; 2015 QT3. There were no previous entries in the LCDB for these NEAs.

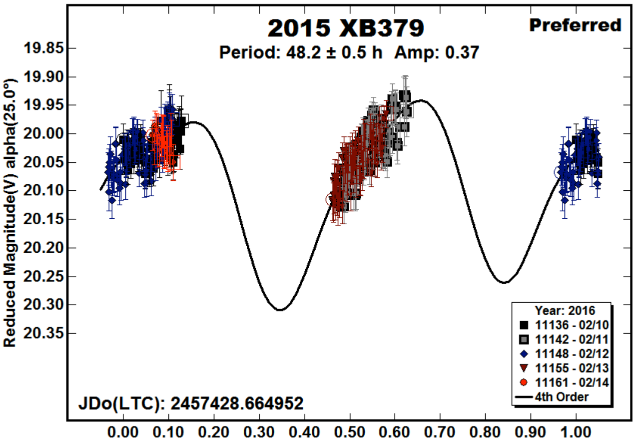


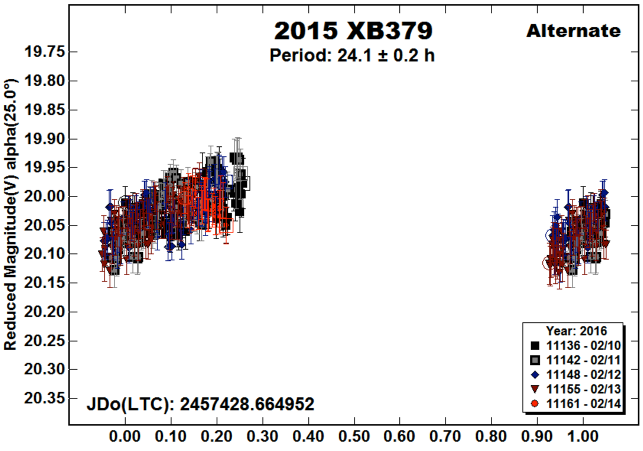




2015 WH9; 2015 XB379. There were no previous entries in the LCDB for these two asteroids. The period for 2015 XB379 is ambiguous. A monomodal second-order fit at about 24.1 h is possible, but a fourth-order bimodal lightcurve with a period of 48.2 h is preferred given the amplitude and moderate phase angle (see Harris *et al.*, 2014).

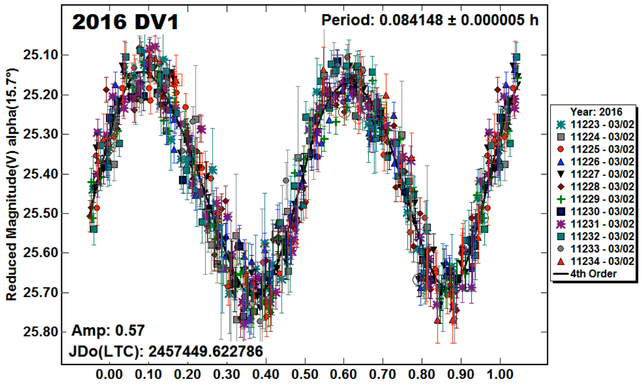




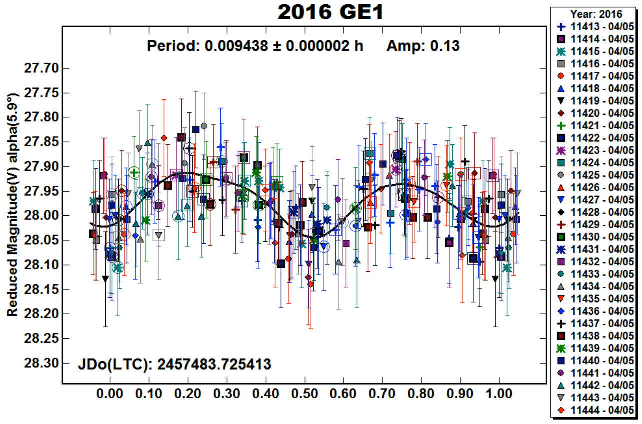


2016 DV1. As with almost all objects with $H > 21.0$ ($D \sim 200$ meters), exposures were kept as short as possible since the chances are that the asteroid is a super-fast rotator with $P < 2$ h. This is to avoid *rotational smearing* (Pravec *et al.*, 2000), which is where the exposure exceeds about 0.187x the period and so details in the lightcurve that lead to an accurate period solution are lost. Imagine taking a 1-second exposure, keeping the camera fixed, while a car passes through the field in 0.3 seconds. It might be possible to determine the color of the car, assuming it was one color, but very little or nothing about its shape or details.

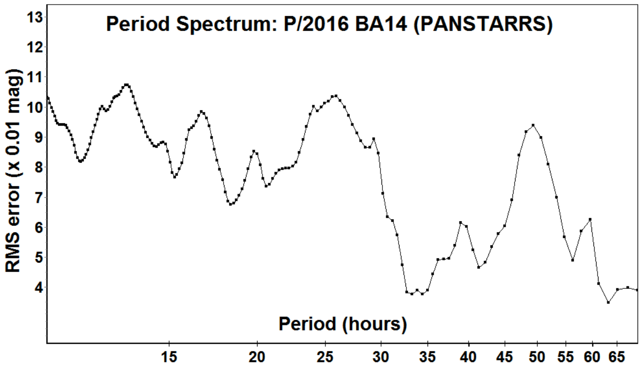
The 60-second exposures (0.198*P) just managed to meet the criteria to avoid significant rotational smearing for 2016 DV1, which had a period of about 302 seconds. There was probably some information lost but, because of the large amplitude, a secure period could be found.

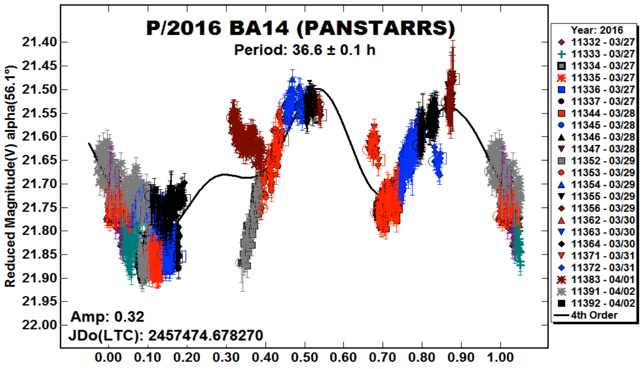


2016 GE1. This asteroid represents the other side of rotational smearing. The derived period is about 34 seconds, and so the 10-second exposures amounted to about 0.3*P. Almost certainly some information was lost, *e.g.,* photometry from astrometric submissions to the Minor Planet Center suggested a significantly larger amplitude than 0.13 mag.



P/2016 BA14 (PANSTARRS). When the observations on this object were started, its cometary nature had not yet been confirmed. Since it was a radar target, observations were continued to help with their analysis.

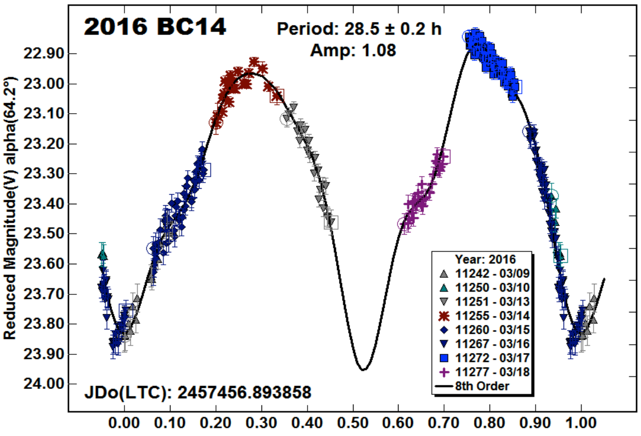




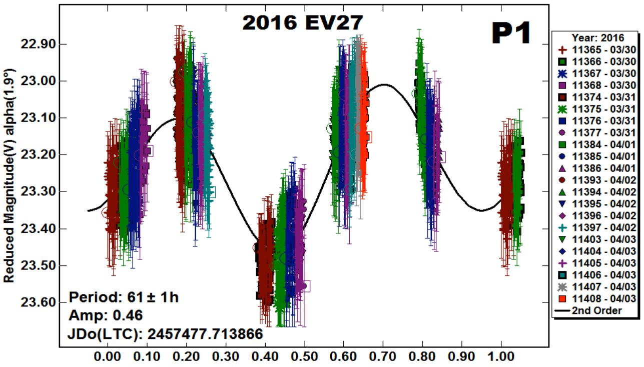
Comet lightcurves can be very difficult to interpret because changes in the coma's brightness caused by outgassing can be interpreted as shape-caused features and so incorrectly used to determine a rotation period. In fact, the raw lightcurves did show low-level scatter that would not have been otherwise expected with SNR > 100. This may have been evidence of at least some comet-like activity at the time.

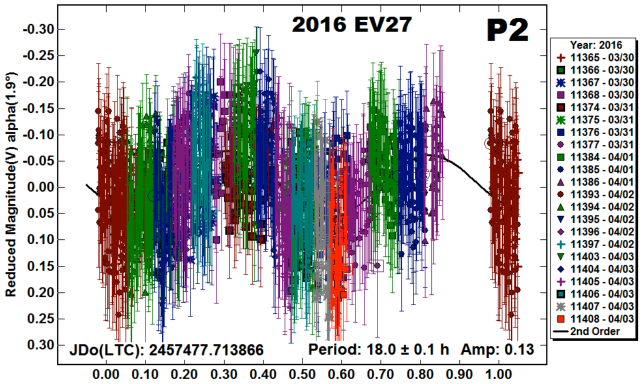
Radar data indicated a period on the order of 30-40 hours (Lance Benner, private communications) but they could not determine if the object was tumbling. The lightcurve data seem to indicate that it was. However, the data set was insufficient to determine even approximate periods of rotation and precession.

2016 BC14. There are signs that the asteroid might be in a low-level state of tumbling. However, the data set is too limited to determine this with any certainty.



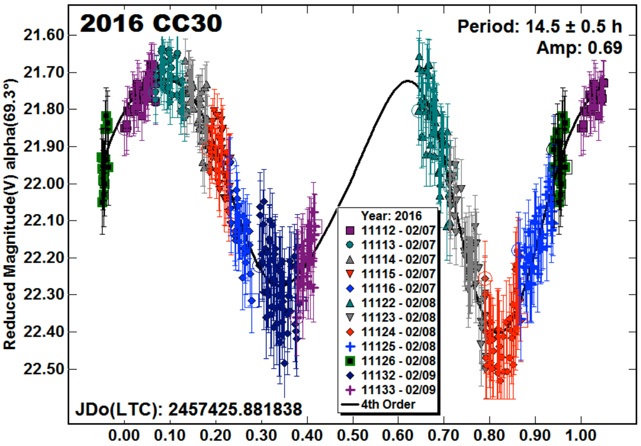
2016 EV27. The low signal-to-noise levels made analysis of this asteroid difficult. However, there does appear to be two, distinct periods within the data.

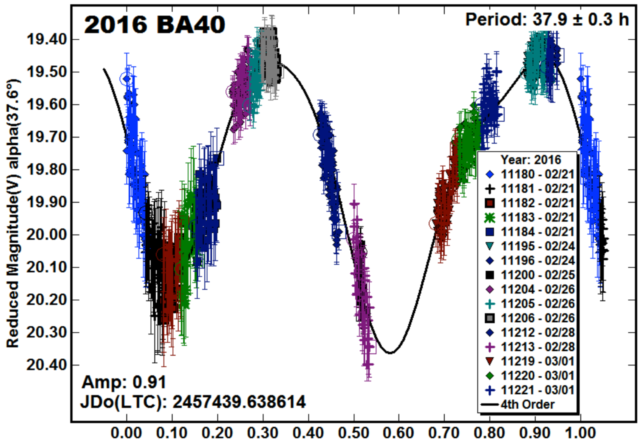




The two periods do not have a simple integer fraction and so would not seem to be harmonically related. One possibility is that this is a very wide binary (see Jacobson *et al.*, 2014). The next time the asteroid will be V < 20 is in 2047.

2016 CC30; 2016 BA40.





There were no previous entries in the LCDB for these asteroids. Assuming the revised, shorter tumbling damping times in Pravec *et al.* (2014), both are good tumbling candidates. However, there are not any obvious signs that this is the case for either asteroid.

Acknowledgements

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References

ALCDEF (2016). Minor Planet Center web site. *http://www.MinorPlanetCenter.net/light_curve*).

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

Belskaya, I.N. Fornasier, S. Krugly, Yu. (2009). "Polarimetry and BVRI photometry of the potentially hazardous near-Earth Asteroid (23187) 2000 PN9." *Icarus* **201**, 167-171.

Carbognani, A., Buzzi, L. (2016). "Asteroids Lightcurves Analysis: 2015 October-December." *Minor Planet Bull.* **43**, 160-163.

Elenin, L., Molotov, I. (2012). "Asteroids Lightcurve Analysis at the Ison-NM Observatory: 3122 Florence, (25916) 2001 CP44, (47035) 1998 WS, (137170) 1999 HF1." *Minor Planet Bull.* **39**, 101-102.

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., Bowell, E., Tholen, D.J. (1999). "Asteroid Lightcurve Observations from 1981 to 1983." *Icarus* **142**, 173-201.

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*

Hergenrother, C.W., Whiteley, R.J., Christensen, E.J. (2009). "Photometric Observations of Five Near-Earth Asteroids: (31221) 1998 BP26, (96315) 1997 AP10, (164184) 2004 BF68, 2006 VV2, and 2006 XY." *Minor Planet Bull.* **36**, 16-18.

Hicks, M., Lawrence, K., Somers, J., Foster, J. (2010). *Astronomer's Telegram* **2502**. *http://www.astronomerstelegram.org*

Jacobson, S.A., Scheeres, D.J., McMahon, J. (2014). "Formation of the Wide Asynchronous Binary Asteroid Population." *Ap. J.* **780**:60.

Mainzer, A., Grav, T., Bauer, J., Masiero, J., McMillan, R.S., Cutri, R.M., Walker, R., Wright, E., Eisenhardt, P., Tholen, D.J., Spahr, T., Jedicke, R., Denneau, L., DeBaun, E., Elsbury, D.,

Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
1685	Toro	02/22-02/28	355	46.1,15.0,44.0	153	-12	10.191	0.005	0.66	0.02	NEA
1863	Antinous	02/07-02/16	463	33.4,33.4	180	2	7.453	0.005	0.18	0.02	NEA
3122	Florence	01/14-02/03	320	21.6,12.2	156	4	[P]2.3579	0.0002	0.12	0.01	NEA
5863	Tara	03/01-03/09	131	11.8,7.6	179	3	5.876	0.005	0.17	0.03	NEA
7350	1993 VA	03/20-03/24	248	93.6,85.7	133	26	3.580	0.005	0.38	0.03	NEA
7822	1991 CS	03/15-03/17	222	42.9,44.5	146	17	2.392	0.002	0.31	0.03	NEA
11054	1991 FA	02/06-02/09	247	17.7,14.7	154	1	2.579	0.002	0.04	0.01	NEA
20826	2000 UV13	02/22-02/28	223	62.5,67.2	100	36	5.313	0.0002	0.31	0.02	NEA
23183	2000 OY21	01/14-01/27	167	38.7,34.0	157	28	6.982	0.005	0.71	0.04	NEA
23187	2000 PN9	03/28-03/31	275	70.4,66.7	138	22	2.537	0.002	0.10	0.01	NEA
31221	1998 BP26	01/09-01/13	184	28.9,28.6	109	28	2.407	0.001	0.10	0.02	NEA
53435	1999 VM40	02/14-02/15	241	21.4,21.5	127	24	5.172	0.006	0.19	0.02	NEA
68216	2001 CV26	03/09-03/14	200	39.3,36.7	155	26	2.4297	0.0005	0.24	0.02	NEA
85628	1998 KV2	02/10-02/13	103	56.7,55.8	200	21	2.82	0.01	0.16	0.03	NEA
85628	1998 KV2	03/13-03/18	153	44.7,42.0	217	18	2.819	0.002	0.18	0.02	NEA
85953	1999 FK21	03/15-03/18	380	19.4,24.3	160	-6	[T]17.62	0.05	0.45	0.03	NEA
85990	1999 JV6	01/12-01/16	685	26.2,18.0	109	-11	6.538	0.005	0.85	0.03	NEA
137805	1999 YK5	01/19-01/30	223	47.4,51.5	142	33	3.930	0.001	0.13	0.02	NEA
152575	1994 GY	03/20-03/29	296	35.1,33.9	215	7	16.28	0.05	0.34	0.04	NEA
155341	2006 SA218	02/04-02/09	386	14.8,8.5	147	-3	32.8	0.1	0.23	0.02	NEA
162038	1996 DH	02/10-02/13	121	4.9,4.6	144	-7	7.16	0.02	0.18	0.03	NEA
163696	2003 EB50	[5/6]12/13-01/14	514	47.3,40.7	64	19	62.4	0.1	0.83	0.03	NEA
205706	2005 RR6	02/26-03/14	334	50.5,36.4	133	15	33.1	0.3	0.80	0.05	NEA
267223	2001 DQ8	02/04-02/05	260	24.4,22.3	154	10	4.11	0.01	0.38	0.04	NEA
275974	2001 XD	03/20-03/26	525	59.1,84.2	203	43	26.1	0.1	0.50	0.05	NEA
337866	2001 WL15	12/18-01/08	678	22.5,21.2,24.8	106	-9	8.955	0.002	0.09	0.01	NEA
345705	2006 VB14	[14]12/25-12/28	217	64.8,67.8	49	-7	3.204	0.005	0.40	0.03	NEA
446833	2001 RB12	[15]09/07-09/14	135	7.4,16.1	345	6	5.299	0.005	0.15	0.01	NEA
450160	2000 RM12	03/22-03/27	630	64.9,57.8	141	17	14.51	0.05	0.31	0.03	NEA
463380	2013 BY45	01/29-02/12	1072	13.1,12.6,20.5	124	-1	[P]425	25	0.49	0.05	NEA
	2010 VU198	01/14-01/19	212	22.8,26.2	127	17	2.722	0.003	0.22	0.03	NEA
	2013 VA10	02/03-02/06	598	6.5,28.3	130	5	6.23	0.03	0.15	0.03	NEA
	2015 PS	[15]09/05-09/14	146	9.4,15.3	342	8	68.3	0.5	0.85	0.05	NEA
	2015 QT3	08/27-08/27	352	49.7,49.7	359	-2	0.2261	0.0002	0.44	0.03	NEA
	2015 WH9	[15]01/11-01/27	281	19.0,27.2	110	19	11.329	0.005	0.14	0.02	NEA
	2015 XB379	02/10-02/14	331	25.1,27.3	124	-2	48.2	0.5	0.18	0.02	NEA
	2016 DV1	03/02-03/02	578	18.5,18.5	153	0	0.084148	0.000005	0.56	0.04	NEA
	2016 GE1	04/05-04/05	185	11.1,11.1	201	-2	0.009438	0.000002	0.13	0.03	NEA
	P/2016 BA14	03/27-04/02	1619	56.4,61.9	193	32	[T]36.6	0.5	0.32	0.02	NEC
	2016 BC14	03/09-03/18	273	64.2,63.1,63.3	207	11	28.5	0.2	1.08	0.05	NEA
	2016 CC30	02/07-02/09	402	69.2,70.5	174	21	14.5	0.5	0.73	0.05	NEA
	2016 BA40	02/21-03/01	821	37.7,57.6	129	10	37.9	0.3	0.91	0.05	NEA
	2016 EV27	03/30-04/03	1365	2.0,19.8	194	5	[P]61	1	0.45	0.05	NEA

Table III. Observing circumstances. [14,15,5/6]Observations in 2014, 2015, 2015-2016. [T]Dominant period of a tumbler. [P]Period of the primary in a binary system. Pts is the number of data points used in the analysis. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range). Grp is the orbital group of the asteroid. See Warner *et al.* (LCDB; 2009; *Icarus* **202**, 134-146). NEC = near-Earth comet.

Gautier, T., Gomillion, S., Hand, E., Mo, W., Watikins, J., Wilkins, A., Bryngelson, G.L., Del Pino Molia, A., Desai, S., Gomez Camus, M., Hidalgo, S.L., Konstantopoulos, I., Larsen, J.A., Maleszewski, C., Malkan, M.A., Mauduit, J.-C., Mullan, B.L., Olszewski, E.W., Pforr, J., Saro, A., Scotti, J.V., Wasserman, L.H. (2011). “NEOWISE observations of near-Earth objects: Preliminary results.” *Ap. J.* **743**, A156.

Polishook, D. (2012). Spectral and spin measurement of two small and fast-rotating near-Earth asteroids.” *Minor Planet Bull.* **39**, 187-192.

Pravec, P., Wolf, M., Varady, M., Barta, P. (1995). “CCD Photometry of 6 Near-Earth Asteroids.” *Earth, Moon, and Planets* **71**, 177-187.

Pravec, P., Wolf, M., Sarounova, L. (1998a). “Lightcurves of 26 Near-Earth Asteroids.” *Icarus* **136**, 124-153.

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

Pravec, P., Wolf, M., Sarounova, L. (1999w, 2001w, 2002w). *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., 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., Pollock, J., Husárik, M., Chiorny, V., Stephens, R.D., Durkee, R., Reddy, V., Dyvig, R., Vraštil, J., Žižka, J., Mottola, S., Hellmich, S., Oey, J., Benishek, V., Kryszczyńska, A., Higgins, D., Ries, J., Marchis, F., Baek, M., Macomber, B., Inasaridze, R., Kvaratskhelia, O., Ayvazian, V., Rumyantsev, V., Masi, G., Colas, F., Lecacheux, J., Montaigut, R., Leroy, A., Brown, P., Krzeminski, Z., Molotov, I., Reichart, D., Haislip, J., LaCluyze, A. (2016). "Binary asteroid population. 3. Secondary rotations and elongations." *Icarus* **267**, 267-295.

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.

Skiff, B.A. (2011a). Posting on CALL web site. *http://www.minorplanet.info/call.html*. Plot available at *ftp://ftp.lowell.edu/pub/bas/astlc/23183.png*

Skiff, B.A. (2011b). Posting on CALL web site. *http://www.minorplanet.info/call.html*. Plot available at *ftp://ftp.lowell.edu/pub/bas/astlc/85953.png*

Skiff, B.A., Bowell, E., Koehn, B.W., Sanborn, J.J., McLelland, K.P., Warner, B.D. (2012). "Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) - 2008 May through 2008 December." *Minor Planet Bull.* **39**, 111-130.

Stephens, R.D., French, L.M., Warner, B.D., Connour, K. (2015). "Lightcurve Analysis of Two Near-Earth Asteroids." *Minor Planet Bull.* **42**, 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. Last update: 2016 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2013). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2012 June-September." *Minor Planet Bull.* **40**, 26-29.

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

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

Warner, B.D. (2015). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2015 January-March." *Minor Planet Bull.* **42**, 172-183.

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

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

THE DISCOVERY OF BINARY ASTEROID 5674 WOLFF AT ISAAC AZNAR OBSEVATORY

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We report on the discovery that minor planet 5674 Wolff is a fully-synchronous binary system with an orbital period of 93.7 ± 0.2 h. The combined primary+secondary rotation amplitude is 0.52 ± 0.02 mag. A lower limit on the secondary-to-primary mean diameter ratio is D_2/D_1 = 0.80.

5674 Wolff is a main-belt asteroid that was discovered in 1986 by E. Bowell at Anderson Mesa Station, Lowell Observatory. We found no previous reported lightcurve data for Wolff.

Aznar used a Meade LX200 GPS 0.35-m *f*/10 Schmidt-Cassegrain telescope (SCT) and SBIG STL-1001E CCD camera with adaptive optics accessory. The system produced an image scale of 1.44 arcsec/pixel. Oey made his observations with a 0.35-m SCT operating at *f*/5.9 and SBIG ST8XME CCD camera. The image scale was 0.88 arcsec/pixel. Groom's observations were made with 0.30-m SCT operating at *f*/7.4 and SBIG ST8XME CCD camera. The image scale was 0.84 arcsec/pixel. All images were unfiltered with exposures of 300 seconds each.

A library of bias, flat, and dark frames were used for image processing. Period analysis was done using *MPO Canopus* version 10.7.1.4 , which incorporates the FALC algorithm (Harris *et al.*, 1989), and *Asteroid LightCurve Analysis* software, developed by Pravec (Pravec *et al.*, 2006). Both Aznar and Oey reduced their data using the Comp Star Selector utility in *MPO Canopus* and magnitudes from the CMC-15 catalog. This catalog provides Sloan r´ and 2MASS JHK magnitudes. V and R magnitudes were derived using formulae by Dymock and Miles (2009). This method of data reduction has improved the nightly linkage errors to 0.10 mag.

Observer	Sessions	Session number
Aznar	19	1-68 (noncontiguous), 74, 76, 86, 92, 96
Oey	4	80, 94, 99, 101
Groom	4	73, 85, 90, 98

Table 1. The number of sessions and session numbers for each observer.

Aznar started observing 5674 Wolff in 2015 October and completed it in December. During that time, he discovered the typical appearance of mutual events in the lightcurves during the 19 nights of observations. He requested assistance from Oey and Groom in early December. They obtained an additional 10 nights of observations to improve the lightcurve. During the span of the observations, the asteroid moved from phase angle +5° to +28° (post opposition) while the phase angle bisector longitude (L_{PAB}) increased from 9° to 23° and the latitude (L_{PAB}) remained at about –1°. All dates and time included in this paper are in the UTC and light time corrected.

Some of the original data sets were excluded from the analysis due to low photometric quality. Within those remaining, some of individual data points were excluded because of hot pixels, clouds, or background stars. The result was a much-improved, calibrated composite lightcurve that allowed proper analysis. Two short sessions within the events were also removed since it could lead to ambiguities where they could latch on to the wrong portion of the double events. The discovery data are considered borderline despite full coverage of the overall lightcurve because the events did not have double coverage.

Figure 2 shows a composite lightcurve featuring the rotation period of the primary and mutual events of the binary system. The 0.7 mag deep “W” shape associated with the minimums of the lightcurve were double events (eclipse and occultation) that occurred every 47 hours at relatively large phase angles.

Figure 1 depicts an assumed clockwise (retrograde) system; though we note the sense of revolution is unknown. As the satellite orbits the primary (A), the first part of the double event at phase 0.25 shows the satellite occulting and moving away from the primary (B). The second part of the double event is caused when the satellite casts its shadow on the primary and then moves away from the primary (C). At phase 0.75, the first part of the “W” is when the satellite disappears and then reappears from behind the primary in an eclipse (D) followed by the second part of the “W”, which is caused by the disappearance and reemergence of the satellite from the shadow of the primary.

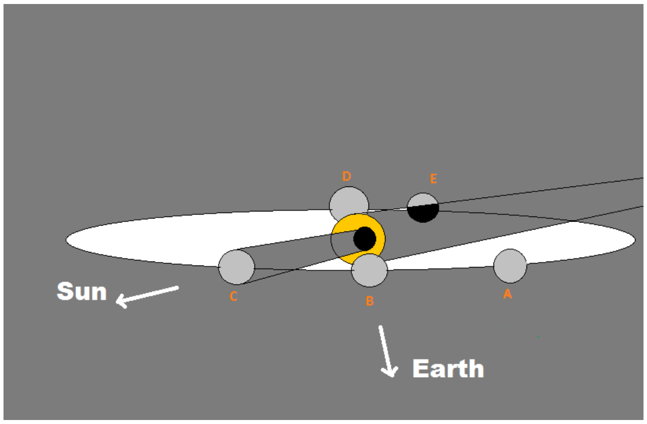

Fig 1. Diagram of the mutual events in 5674 Wolff.

The mutual events were up to 0.70 mag deep and the deepest part of the attenuation in the lightcurve shows no “flat bottom” (Pravec, 2012). This indicated partial mutual events and set the lower limit of the ratio of the satellite diameter and the primary diameter (D_2/D_1) as 0.80. The lightcurve amplitude was 0.52 mag. Since the observations were taken at relatively high phase angles, the amplitude-phase effect could distort (increase) the measured actual amplitude by up to 40%.

The total light curve amplitude was 1.22 ± 0.02 mag. The effective equatorial elongation of the primary+secondary is estimated to be about 1.4. This is likely a fully-synchronous binary system where both the primary and the secondary rotation periods are synchronized with the orbital period of the satellite at 93.7 ± 0.2 h. More observations are needed at future apparitions to further constrain the physical parameters of this interesting binary.

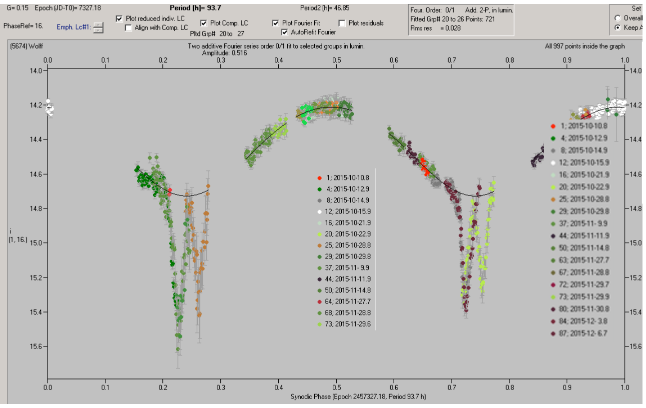

Fig. 2 Light curve plot of binary asteroid 5674 Wolff.

Acknowledgements

We would like to thank Brian Warner for his assistance in the reduction process with *MPO Canopus*. Special mention goes to the Valencian Association of Astronomy (AVA) for the technological improvements applied to the Alto Turia Astronomical Center (CAAT), which had enabled systematic observations of minor planets. 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/* Work at the Blue Mountains Observatory was supported by the 2015 Shoemaker NEO Grant.

References

Dymock, R., Miles, R. (2009). “A method for determining the V magnitude of asteroids from CCD images.” *J. Br. Astron. Assoc.* **119**, 149-156.

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., and Zeigler, K.W. (1989). “Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863.” *Icarus* **77**, 171-186.

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

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 co-authors. (2016). “Binary asteroid population. 3. Secondary rotations and elongations.” *Icarus* **267**, 267-295.

ASTEROIDS OBSERVED FROM CS3: 2016 JANUARY - MARCH

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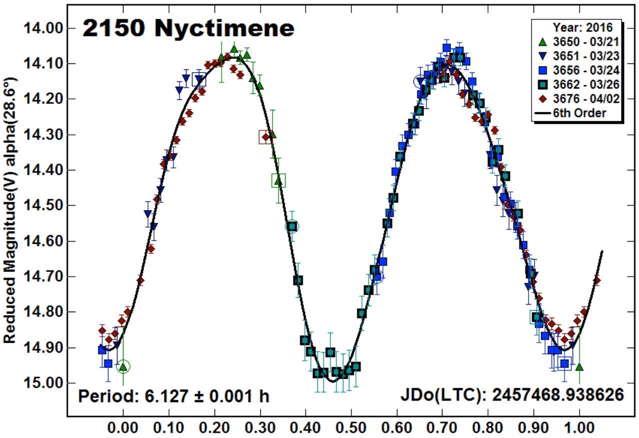
CCD photometric observations of 9 asteroids were obtained from the Center for Solar System Studies from 2016 January to March.

The Center for Solar System Studies “Trojan Station” (CS3, MPC U81) has two telescopes which are normally used in asteroid family studies such as Jovian Trojans, Hungaria family members or NEAs. During bright moon times, brighter targets are selected to keep the telescopes operating during all clear nights.

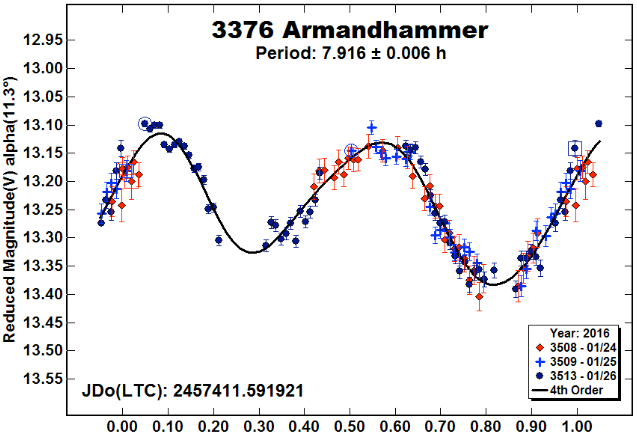
All images were made with a 0.4-m or a 0.35-m SCT using an FLI ML-Proline 1001E or FLI ML-Microline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Catalog magnitudes were generally taken from the MPOSC3 catalog, which is based on the 2MASS catalog *(http://www.ipac.caltech.edu/2mass)* but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). The nightly zero points using this catalog have been found to be consistent to about ± 0.05 magnitude, but are occasionally higher.

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

2150 Nyctimene. As part of a program of observing Hungaria asteroids to determine pole positions, Warner (2007, 2008, 2012, 2013b, and 2015) determined Nyctimene’s rotational period five times in the past, each time finding a period near 6.13 h. Observations were obtained this year are in hope of improving an ambigious pole solution model. This year’s result of 6.127 h is in good agreement with the prior results and extends the dense dataset by another two years.

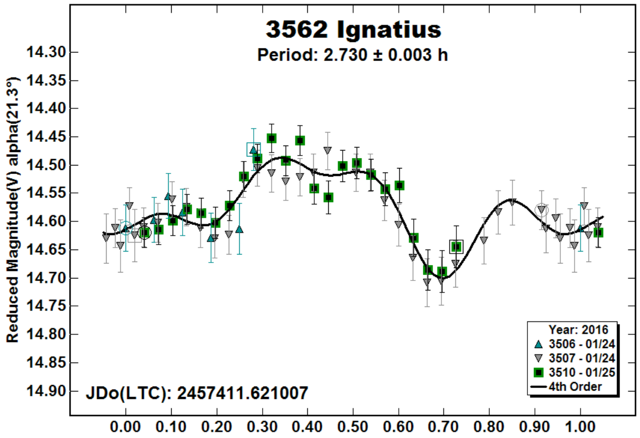


3376 Armandhammer. Pravec (2015) reported a rotational period of 7.9184 h for this Vestoid family member. Cabo (Cabo *et al*, 2015) reported a period of 6.82 h with some scatter in the resulting lightcurve. Using sparse photometry from the Palomar Transient Factory, Chang (Waszczak *et al*, 2015) reported a period of 9.4797 h. Our period of 7.916 h agrees with the Pravec results.

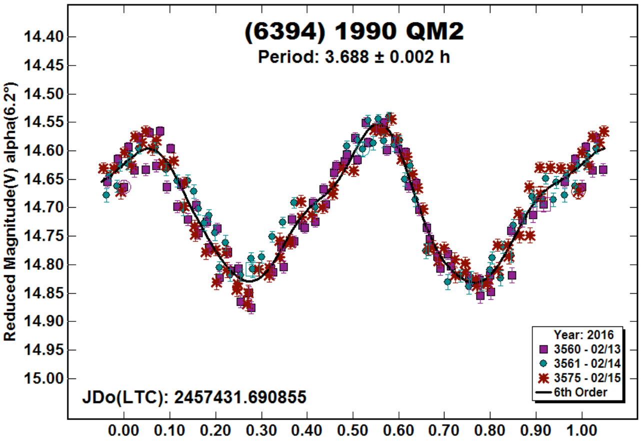


3562 Ignatius . This Vestoid was observed in 2013 April (Falese *et al* 2014) with a reported period of 2.732 h, in agreement with the findings this year. A limited run was obtained this year while waiting for the Moon to clear the primary target.

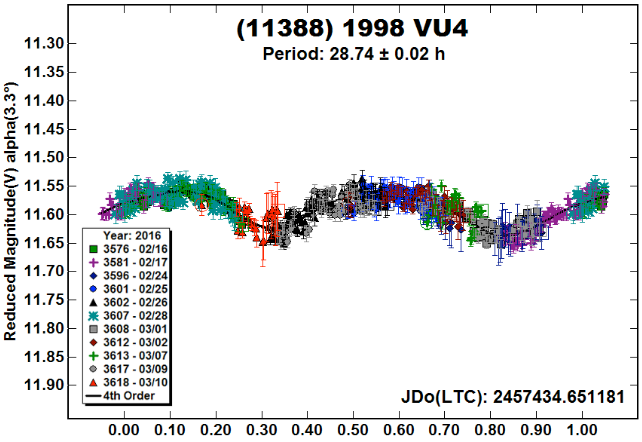
Number	Name	2016 mm\dd	Pt	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
2150	Nyctimene	03/21-04/02	13	28.6,27.0	242	15	6.127	0.001	0.91	0.03	H
3376	Armandhammer	01/24-01/26	12	11.3,12.2	101	-5	7.916	0.006	0.27	0.02	V
3562	Ignatius	01/24-01/25	63	21.3,21.7	83	0	2.73	0.003	0.21	0.02	V
6394	1990 QM2	02/13-02/15	20	6.2,5.4	150	-8	3.688	0.002	0.28	0.02	H
11388	1998 VU4	02/16-03/10	59	3.3,8.7	143	-9	28.74	0.02	0.08	0.02	HIL
13504	1988 RV12	03/13-04/01	57	1.5,6.2	173	-4	26.543	0.003	0.61	0.03	HIL
21056	1991 CA1	02/22-02/25	10	30.6,31.3	107	-1	5.6	0.01	0.26	0.03	H
29298	Cruls	02/19-02/21	13	11.0,10.0	161	11	5.207	0.005	0.26	0.03	H
32772	1986 JL	02/19-02/23	24	26.0,25.5	168	37	6.049	0.007	0.14	0.02	H

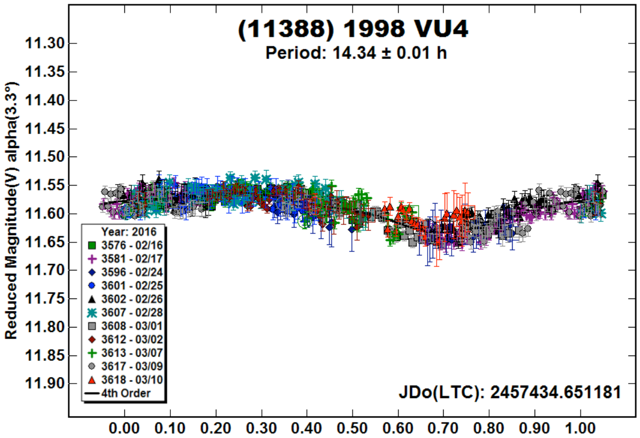


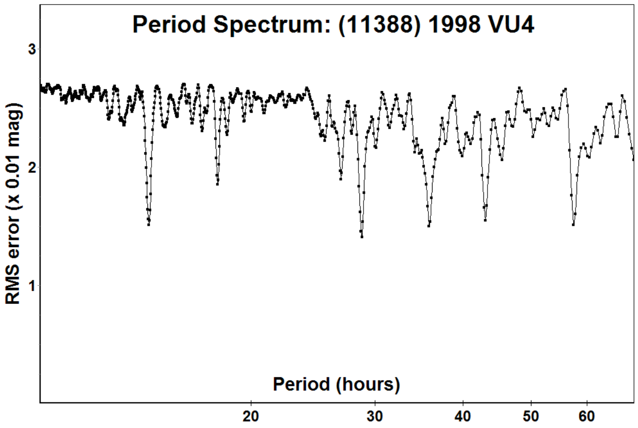
(6394) 1990 QM2. As part of his Hungaria program, Warner (2008, 2011, 2013a and 2015) observed this asteroid four times in the past finding a period of 3.6873 h. This period is in agreement with this year's results.



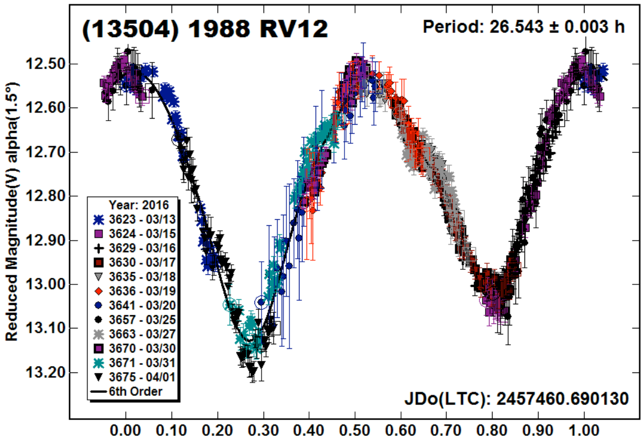
(11388) 1998 VU4. No previously reported results could be found in the asteroid lightcurve database (LCDB; Warner *et al*, 2009). With an amplitude of only 0.08 mag., it is possible that the lightcurve could have only a single extrema, or three or more extrema (Harris *et al* 2014). The RMS error on the Period Spectrum is nearly indistinguishable between 28.74 h and 14.34 h periods. The 28.74 h period is favored because it produces the classic bimodal lightcurve shape. However, further observations are needed for this Hilda to resolve possible aliases.



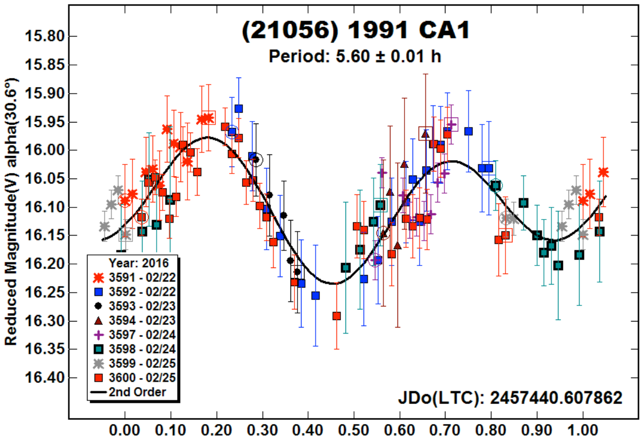




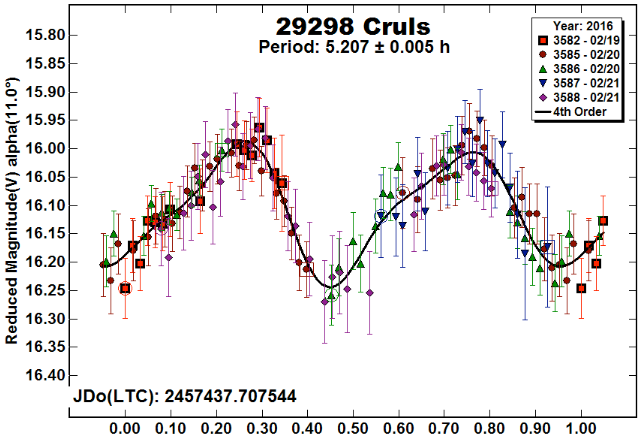
(13504) 1988 RV12. No previously reported results could be found in the asteroid lightcurve database (LCDB; Warner *et al*, 2009) for this Hilda family member.

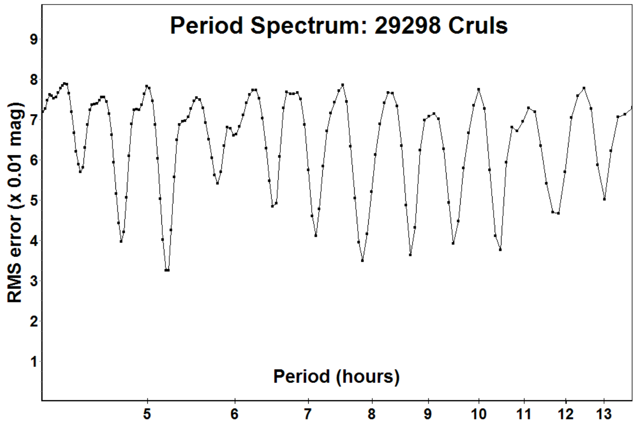


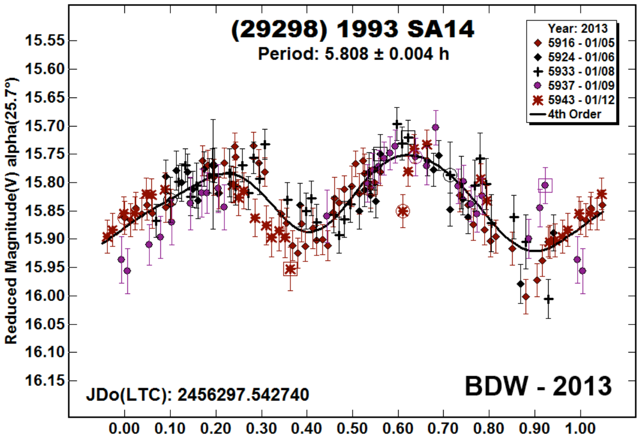
(21506) 1991 CA1. Warner (2006 and 2011) observed this Hungaria twice in the past finding a period of 5.58 h which agrees with the results found this year.

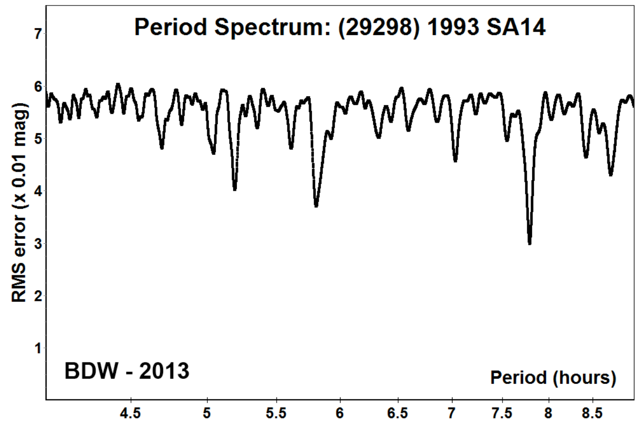


21298 Cruls. Warner (2013) observed this Hungaria in January 2013 finding a rotational period of 7.795 h with a trimodal lightcurve. This year's observations have slightly larger amplitude and favored a 5.207 h period which is a 1.5 to 1 alias of the 2013 result. While it is possible that a lightcurve with an amplitude of 0.26 mag., could have three extrema (Harris *et al*, 2014), it is more likely that the bimodal lightcurve is correct. Warner replotted his 2013 data resulting in the best fit of the 5 h range being 5.8 h. However, the Period Spectrum of his 2013 data shows the 5.2 h period as being possible. Several of the scattered data points in the Warner 2013 data are marked as being the first or last observations of that night's run; which are the most susceptible to airmass issues.

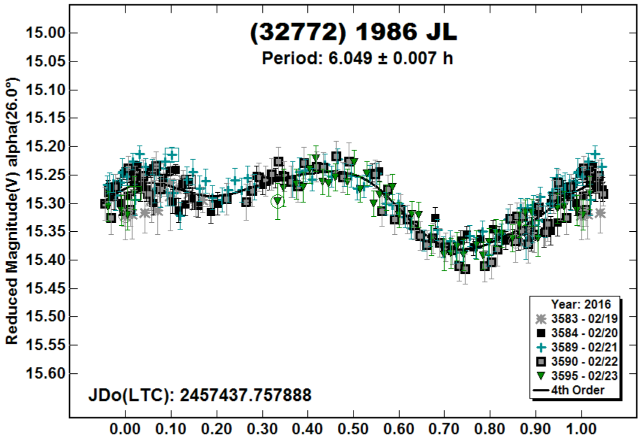








(32772) 1986 JL. Warner (2013) observed this Hungaria on Christmas Day 2012 finding a period of 6.047 h. This agrees with the period we found this year.



References

Carbo, L., Green, D., Kragh, K., Krotz, J., Meiers, A., Patino, B., Pligge, Z., Shaffer, N., Ditteon, R. (2009). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2008 October thru 2009 March." *Minor Planet Bul*. **36**, 152-157.

Falese, J., Odden, C., Prakash, P. (2014). "Lightcurve Analysis for 3562 Ignatius." *Minor Planet Bul*. **41**, 3.

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

Pravec, P. (2015). Photometric Survey for Asynchronous Binary Asteroids web site. *http://www.asu.cas.cz/~asteroid/binastphotsurvey.htm*

Warner, B.D. (2006). "Asteroid lightcurve analysis at the Palmer Divide Observatory - late 2005 and early 2006." *Minor Planet Bul*. **33**, 58-62.

Warner, B.D. (2007). "Asteroid lightcurve analysis at the Palmer Divide Observatory - June-September 2006." *Minor Planet Bul*. **34**, 8-10.

Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul*. **37**, 57-64.

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

Warner, B.D. (2011). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 March - July." *Minor Planet Bul*. **38**, 190-195.

Warner, B.D. (2012). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 June - September." *Minor Planet Bul*. **39**, 16-21.

Warner, B.D. (2013). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2013 January - March." *Minor Planet Bul*. **40**, 137-145.

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

Warner, B.D. (2014). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 June-October." *Minor Planet Bul*. **42**, 54-60.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2015 Dec. *http://www.minorplanet.info/lightcurvedatabase.html*

Waszczak, A., Chang, C., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y., Ip, W., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid lightcurves from the Palomar Transient Factory survey: Rotation periods and phase functions from sparse photometry." *Astron. Jrnl.* **150**, 75.

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This research was supported by NASA grant NNX13AP56G.

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SYNODIC PEROID DETERMINED FOR 3829 GUNMA

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(Received: 2016 April 15)

3829 Gumma was observed by the authors between 2016 February 25 and March 25. A synodic period of rotation of $P = 4.720 \pm 0.001$ h and amplitude of $A = 0.29$ mag were found.

Minor planet 3829 Gunma appeared in the *MPB Lightcurve Opportunities* list (Warner *et al.*, 2016), where it was listed as having no known period. A search of the asteroid lightcurve database (LCDB; Warner *et al.,* 2009) as of 2016 February 14 found no entries for this asteroid.

Instruments. Observer KL used a 0.20-m Newtonian telescope fitted with a coma corrector giving an effective focal length of 890 mm. The camera was a Atik 383L+ with a Kodak KAF-8300 chip and pixel size of 5.4x5.4 μm. Observer LH used a 0.28-m SCT with a 0.8x reducer and a Atik 428EX with 1932x1452 and pixel size of 4.54x4.54 μm. Observers KL and LH used timekeeping software *Dimension 4* (2015). Observer JJ used a 0.36-m SCT with a 0.65 reducer giving an effective focal length of 2430 mm. The camera was a Moravian G2-1600 with 1536x1024 pixels each 9.0x9.0 μm. Timekeeping was done with a GPS device.

Calibration. All images were calibrated with master darks and flats corresponding to different filters and binning configurations. For the calibration, JJ used *AIP4WIN* v.2.40 (Berry and Burnell, 2005). KL used *IRIS* 5.59 software (Buil, 2011) to calibrate images by LH and KL.

Photometry. The calibrated images were analyzed by KL using *MPO Canopus* (Warner, 2011). The Comp Star Selector utility of *MPO Canopus* was used to select up to five comparison stars of near solar-color for the differential photometry. Great care was exercised to find solar-color comparison stars in the fields as near as possible to B-V = 0.65 and V-R = 0.36. Equal size apertures for target and comparison stars where used to minimize the effect of changing seeing conditions. All telescopes were on German equatorial mounts and needed flipping near the meridian.

Analysis. Opposition for 3829 Gunma occurred 2016 February 29.2. The full moon on March 23 interfered with observations on February 22 and 23, causing gradients in the sky background. It was decided to treat time series before and after flipping the mounts as separate sessions in *MPO Canopus*.

This procedure made it possible to replace a comparison star too close to the gradients and to keep the number of comparison stars close to five. To the extent possible, the same comparison stars were used in the analysis of time series on all telescopes when observing on the same night. All Delta Comp (nightly zero point)

1 Date 2016	2 Session ID.	3 Obs.	4 Filter & Bin.	5 Exp. /s	6 Num. Obs.	7 Begin UT	8 End UT	9 Dur. /h	10 SPA /°	11 Note
Feb 25	1	KL	C1x1	240	48	22:47	02:14	3,5	3,28	a
Mar 19	2	KL	R1x1	240	67	19:24	00:08	4,7	10,15	
Mar 22	3	JJ	NF1x1	120	66	19:20	21:34	2,2	11,39	
Mar 22	5	JJ	NF1x1	120	31	21:49	22:54	1,1	11,42	
Mar 22	4	KL	R1x1	240	23	20:28	22:03	1,6	11,40	b
Mar 22	6	KL	R1x1	240	25	23:48	01:31	1,7	11,46	b
Mar 23	7	JJ	NF1x1	120	66	19:28	21:42	2,2	11,82	
Mar 23	10	JJ	NF1x1	120	124	21:51	02:06	4,2	11,88	
Mar 23	8	KL	R1x1	240	39	19:34	22:16	2,7	11,82	
Mar 23	11	KL	R1x1	240	32	22:44	01:00	2,3	11,88	b
Mar 23	9	LH	C2x2	240	32	21:53	23:55	2,0	11,86	
Mar 25	12	JJ	NF1x1	120	55	19:44	21:35	1,9	12,64	
Mar 25	14	KL	R2x2	240	40	20:17	23:42	3,4	12,67	

Table I. Observation details for 3829 Gunma. Column titles from left to right. 1: Calendar date [UT] at the beginning of observations, 2: *MPO Canopus* Session ID, 3: Observer initials, 4: Filter used and binning on CCD, 5: Exposure time [s], 6: Number of observations in phased plot, 7: Beginning of observations, 8: Ending of observation, 9: Session duration, 10: Solar Phase angle [°].

a) In Phased plot (figure 1) the date of session 1 is mistyped "02-26". Reason for this is unknown. b) Sessions 4, 6 and 11 by KL is omitted from phased plot due to poor photometric quality.

adjustments were within –0.050 to +0.059, except session 2, which needed an adjustment of –0.243 mag.

Due to the bright sky, sessions 4, 6, and 11 by KL were of very poor photometric quality because of the short focal length used. These sessions were omitted in the final phased plot but they support the reported period (Fig. 1).

To clarify the phase coverage and overlapping of the lightcurves, a diagram was created with Excel spreadsheet (Fig 2).

References

Berry, R., Burrnell, J. (2005). *The Handbook of Astronomical Image Processing* (second ed.). Willmann-Bell, Inc., Richmond, Virginia 23235 USA. with *AIP4Win* 2.40 software.

Buil, C. (2011). *IRIS* software, v5.59 *http://www.astrosurf.com/buil/us/iris/iris.htm*

Dimension 4 (2015). Thinking Man Software. *http://www.thinkman.com/dimension4/default.htm*

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. (2013). Bdw Publishing MPO Software, *MPO Canopus* v10.4.3.21

Warner, B.D., Harris, A.W., Pravec, P., Durech, J., Benner, L.A.M. (2016) "Lightcurve Photometry opportunities: 2016 January-March." *Minor Planet Bull*. **43**, 103-108.

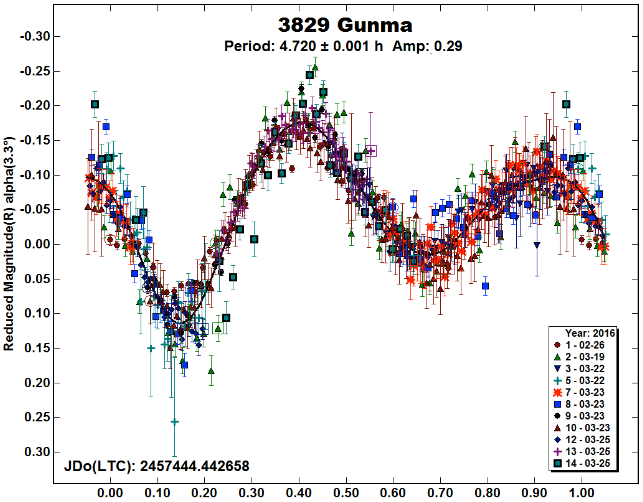

Figure1. The phased plot of selected lightcurves of 3829 Gunma with a period of *P = 4.720 ± 0.001 h and amplitude of A = 0.29 mag.*

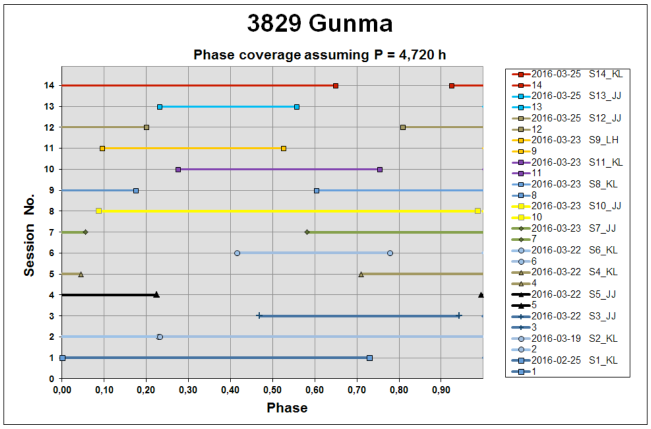

Figure 2.The diagram shows all sessions stacked vertically. For each session, a colored bar connects the times of first and last observation folded in phase space to the reported period.

TWENTY-ONE ASTEROID LIGHTCURVES AT GROUP OBSERVADORES DE ASTEROIDES (OBAS): LATE 2015 TO EARLY 2016

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We report on the photometric analysis result of 21 main-belt asteroids (MBA) done by Observadores de Asteroides (OBAS). This work is part of the Minor Planet Photometric Database task initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as additional incomplete lightcurves to help analysis at future oppositions. This is a compilation of lightcurves obtained during last quarter of 2015 and first quarter of 2016.

In this paper we publish the result of 21 asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*), which is focused on collecting lightcurves of main-belt asteroids using photometric techniques. This database shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

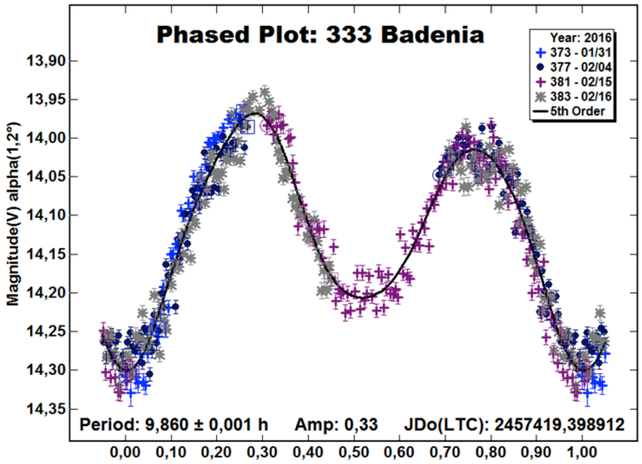
Table I shows the equipment at the observatories that participated in this work. Table II lists the individual results along with the range of dates for the observations, the number of nights that observations were made, and the phase angles.

We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the CALL website (CALL, 2015), making sure to keep the asteroid's magnitude within reach of the telescopes being used. We tried to observe asteroids at a phase angle of less than 15°, but this was not always possible. Images were measured using *MPO Canopus* (Bdw Publishing) using differential photometry. For more information about technical topics see Aznar *et al*. (2015).

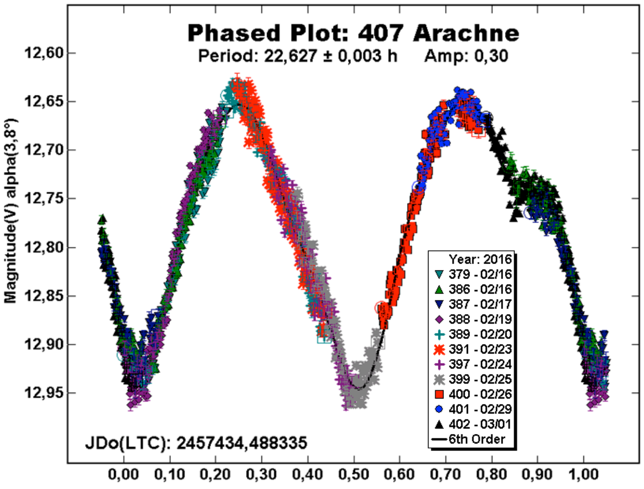
Observatory	Telescope	CCD
OIA,Obs Isaac Aznar	0.35 SCT	SBIG STL1001E+AO
POP-Puzol	0.25 SCT	SBIG ST9-XE+AO
Zonalunar	0.10 refr	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 SCT	Atik 414L+

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

333 Badenia. The rotation period for this MBA has been measured many times, *e.g.*, Behrend (2006), who found a period of 8.19 hours. OBAS observed this asteroid during four nights from 2016 Jan 31 to Feb 16. We obtained a rotation period of 9.86 ± 0.001 h and amplitude of 0.33 mag. This result is consistent the rotation period of 9.96 h and an amplitude of 0.30 mag found by Denchev *et al.* (2000).

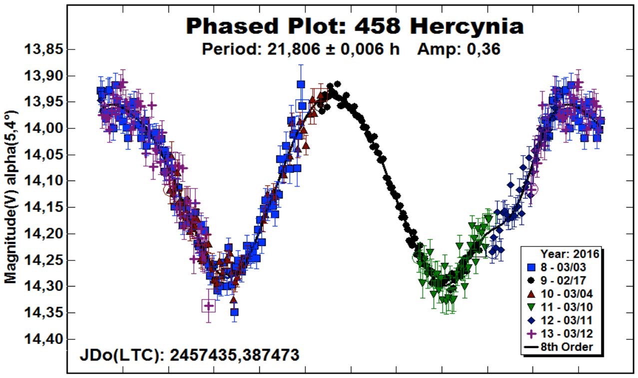


407 Arachne. Behrend (2005) found a period of 22.62 hours and amplitude of 0.31 mag. Weidenschilling, (1990), based on incomplete coverage of the lightcurve, found $P = 44.0$ hours.

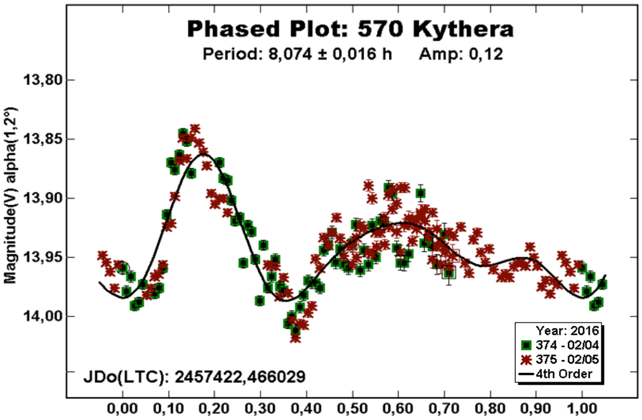


Based on ten nights of data, the analysis by the OBAS group determined a period of 22.627 ± 0.003 h, very close to Behrend's, and an amplitude of 0.30 magnitudes.

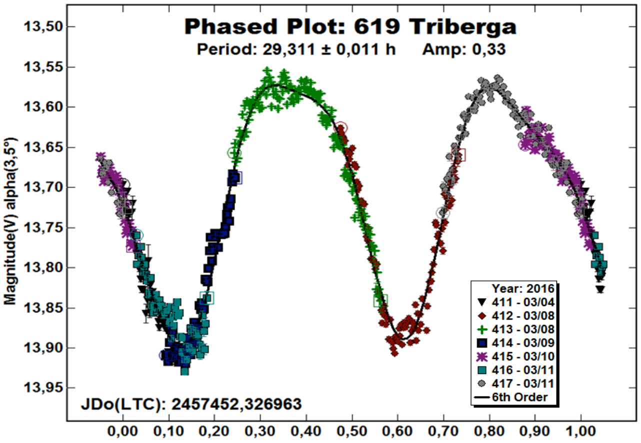
458 Hercynia. Four different rotation periods have been reported for this asteroid. We observed it on six nights in 2016 February and found a rotation period 21.806 ± 0.006 h. The lightcurve amplitude is 0.36 mag. This result is similar to Binzel (1987) who reported a period of 22.3 h and amplitude of 0.33 mag.



570 Kythera. There is no consensus on the rotation period of this asteroid. Up to five periods have been found. The most recent (Chavez, 2014) indicates a period of 10.5 h and amplitude of 0.2 mag. We found a period of 8.074 ± 0.016 h and amplitude of 0.12 mag. This result is similar only to Behrend (2004; 8.120 h).

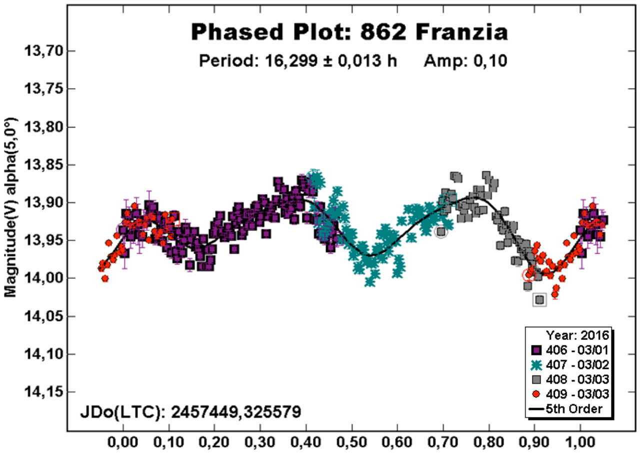


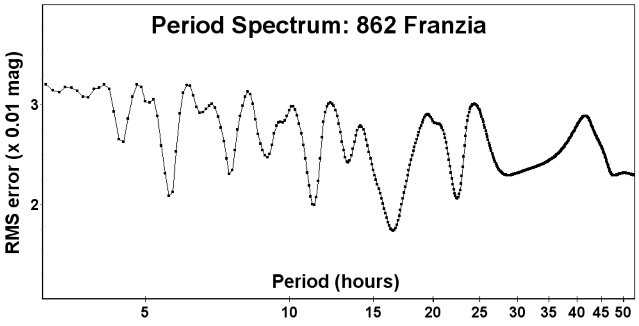
619 Triberga.



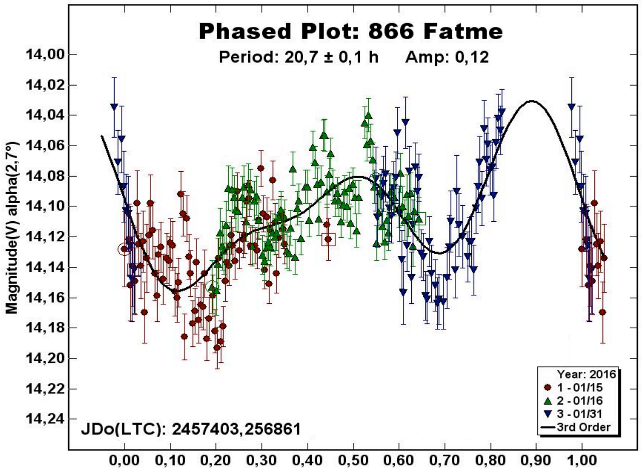
We observed Trigbera for five nights in 2016 March, which allowed us to form a complete composite lightcurve that shows a typical bimodal shape. Our analysis found a rotation period of 29.311 ± 0.011 h and amplitude of 0.12 mag. This is consistent with other previously reported periods, *e.g.*, Pray (2006a; 29.412 h), Behrend (2006; 29.411 h), and Oliver (2008, 29.37 h).

862 Franzia. This asteroid has been analyzed on many occasions. Warner (2005) found an ambiguous solution of 15.05 h, but could not rule out one of about 7.6 h. He later revised the period using the same data to 7.65 h (Warner, 2010) as well as reporting a period of 7.52 h based on data obtained in 2000. Brinsfield (2011) found 5.041 h for the period while Behrend (2011, 2015) reported 5.05 h both times. Our data from three nights in 2016 March led to a period of 16.299 ± 0.013 h with a trimodal shape and amplitude of 0.10 mag.



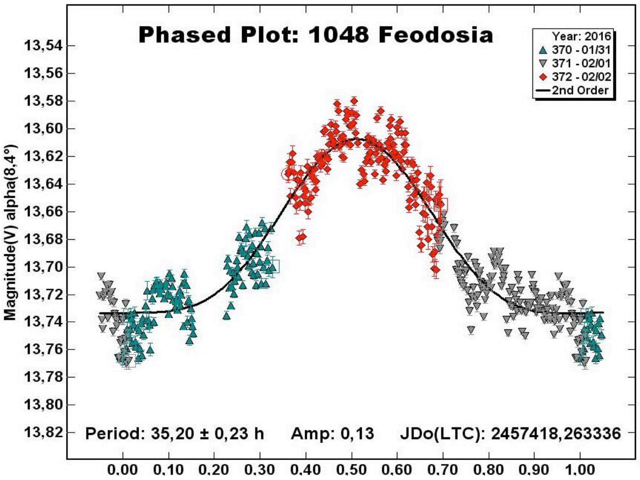


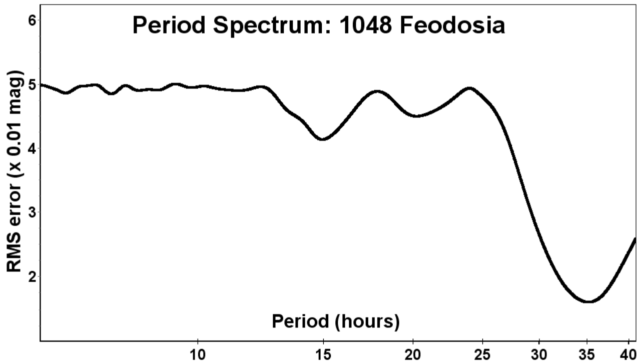
866 Fatme.



We observed Fatme on three nights between 2016 Jan 15-31. Analysis of the data found a rotation period of 20.7 ± 0.1 h. The lightcurve shows a maximum amplitude of 0.12 mag. The period is similar that reported by Stephens (2002; 20.03 h), but there is a gap on our lightcurve. We recommend working this asteroid at future oppositions.

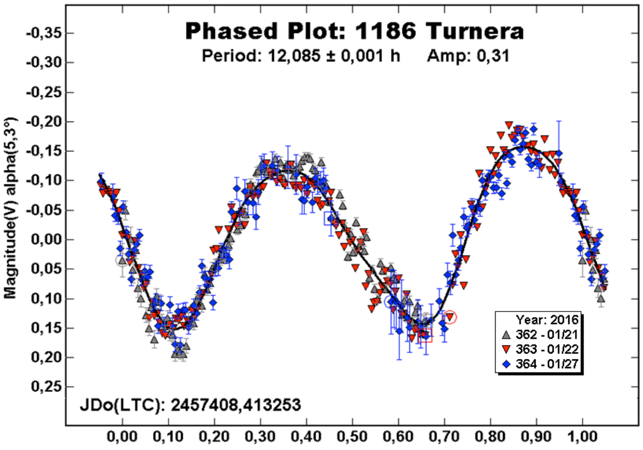
1048 Feodosia. If we assume a monomodal shape, the phased plot shows an incomplete lightcurve, with a rotation period of 35.20 ± 0.23 hours and amplitude of 0.13 magnitudes.





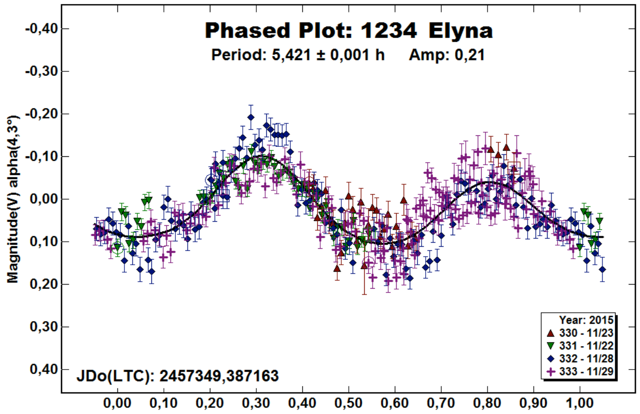
The period spectrum shows that this is the best approach. Nevertheless, this is inconsistent with other rotation periods of 10.46 h (Schober *et al*., 1994) and 23 h (Behrend, 2007). We suggest observations of this object at future oppositions.

1186 Turnera.

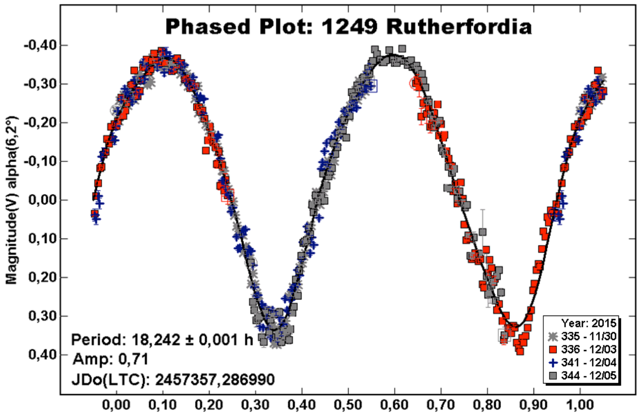


Previous periods include those from Barucci (1992; 9.41 h), Behrend (2006; 15.00 h), and Warner (2006; 12.066 h). The new OBAS observations taken during 2016 January define a period of 12.085 ± 0.001 h with an amplitude of 0.31 mag.

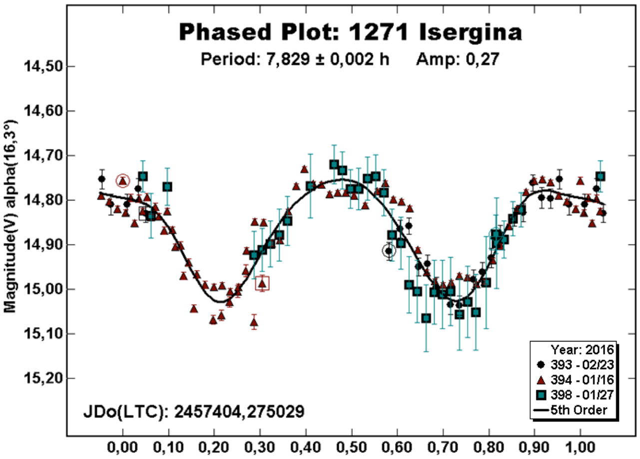
1234 Elyna. Behrend (2005) reported a rotation period of 5.9981 hours. Almost eighteen years before, Binzel (1987) reported a period of 17.6 hours. The OBAS group observed the asteroid on four nights during 2015 November. We found a rotation period of 5.421 ± 0.001 h with amplitude of 0.21 mag. The observations were made at phase angles +18.4° to +19.2° (post-opposition).



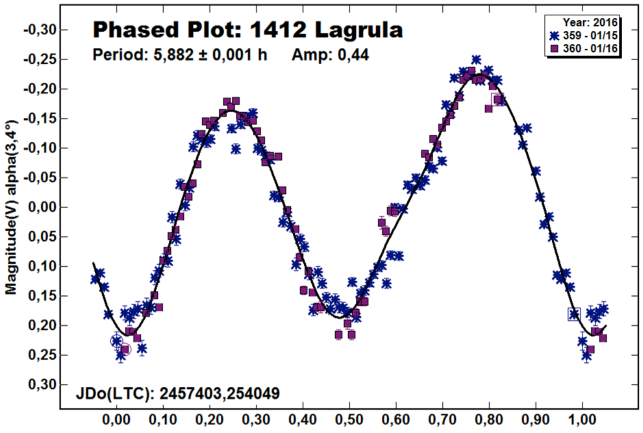
1249 Rutherfordia. The last published observations were made in 2008 (Kryszczyska *et al.*, 2012), who found a period of 18.220 h. The OBAS team observed Rutherfordia during four nights in 2015 November and December. Our analysis found a period of 18.242 ± 0.001 h with an amplitude of 0.71 mag. The period is similar to Kryszczyska *et al.* and Berhrend (2001, 2004) who found periods of 18.20 and 18.24 h, respectively.



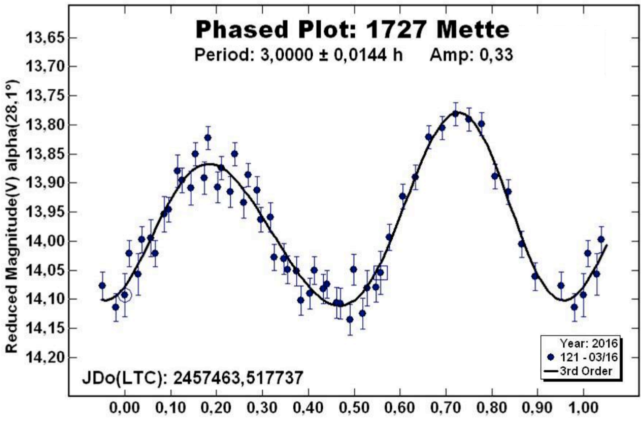
1271 Isergina. This main-belt asteroid did not have any previous entries in the LCDB. The OBAS team observed it on three nights in 2016 January and February. The phase angle ranged between +5.3° and +16.2° (post-opposition). The lightcurve shows a typical bimodal shape and has a period of 7.829 ± 0.002 h. The maximum amplitude is 0.27 mag.



1412 Lagrula. Casalnuovo (2013) found a rotation period of 5.9176 hours. In 2016 January we calculated a rotation period of 5.882 ± 0.001 hours. The lightcurve has a bimodal shape with a maximum amplitude of 0.44 mag.

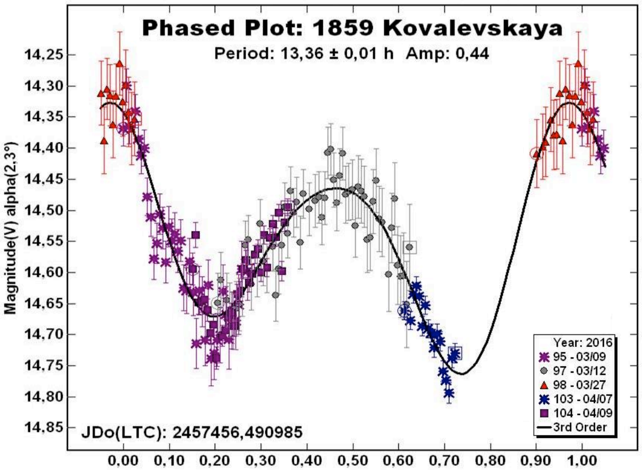


1727 Mette. This is a binary asteroid (Warner and Stephens, 2013). Its primary rotation period was first measured by Wiseniwski *et al.* (1987) and then several times after before the satellite was discovered.

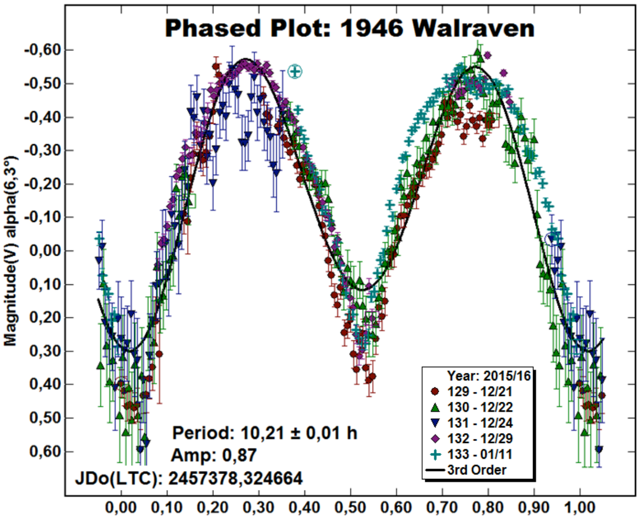


Warner *et al.* (2015a) observed the asteroid again in 2014 and found no signs of the satellite. Observations of Mette were made at the Isaac Aznar Observatory in 2016 to see if there were any deviations that would be due to a satellite. The analysis found a period of 3.0000 ± 0.0144 h with an amplitude of 0.33 mag. The data were taken on one night and there were no obvious deviations. At the time of this writing, the asteroid was in pre-opposition phase. It will be analyzed again using more data collected during the apparition.

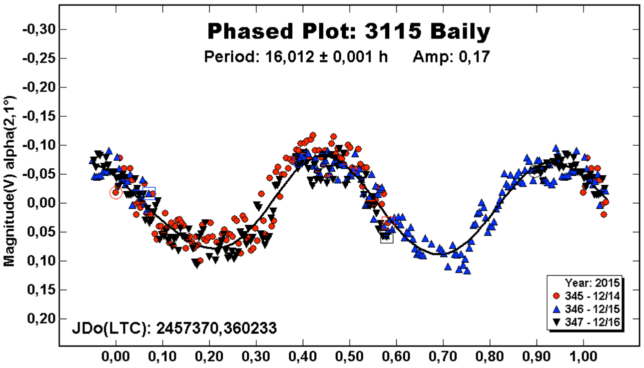
1859 Kovalevskaya. Waszczak *et al.* (2015) found a period of 11.1084 h. In 2016, we calculated a rotation period of 13.36 ± 0.01 hours with an amplitude of 0.44 magnitudes. Observations at future oppositions are needed to improve the period solution.



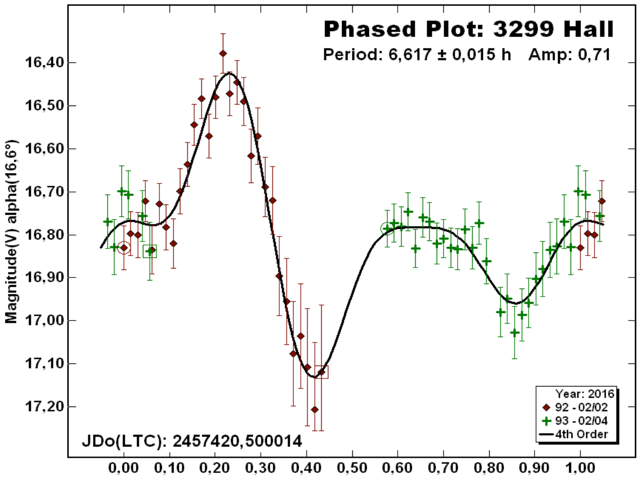
1946 Walraven. Folberth *et al*. (2012) reported a synodic rotation period of 10.22 h. The OBAS group observed the asteroid for five nights in 2015 December to 2016 January. Analysis of the data led to a period of 10.21 ± 0.01 h and maximum amplitude is 0.87 mag; both are similar to Folberth *et al.*



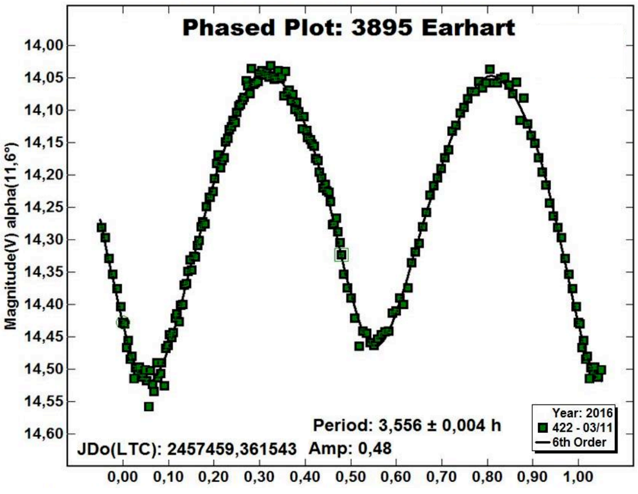
3115 Baily. This asteroid was observed by the OBAS group for three nights in 2015 December. We conclude that it has a period of 16.02 ± 0.001 h and amplitude of 0.17 mag. This is in good agreement Behrend (2006; 16.28 h) and Warner (2007; 16.22 h).



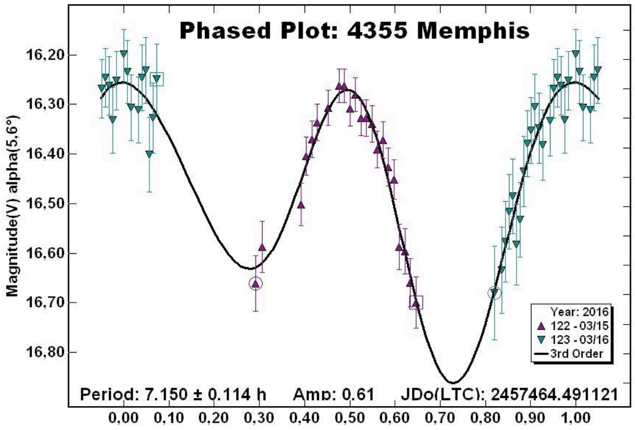
3299 Hall. This main-belt asteroid, discovered in 1980, had no published period that we could find. It was observed on two nights during 2016 February, when the angle phase was +17.0. As the plot shows, the lightcurve is incomplete. Therefore, the rotation period of 6.617 ± 0.015 h is only an approximation found by using the FALC Fourier analysis algorithm (Harris *et al.*, 1989).

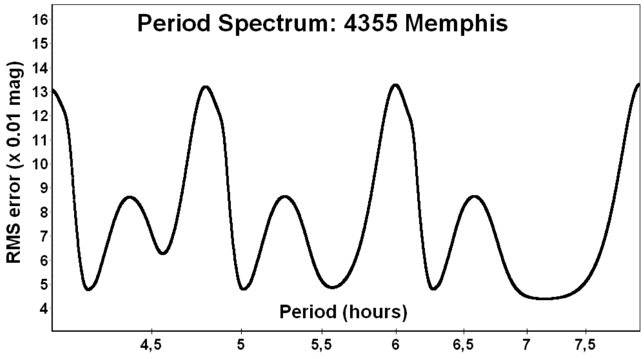


3895 Earhart. The OBAS team observed this main-belt asteroid for one night in 2015 November. Our analysis determined a period of 3.556 ± 0.004 hours. The amplitude is 0. 48 magnitudes. This result is similar with Warner (2009; 3.564 h).



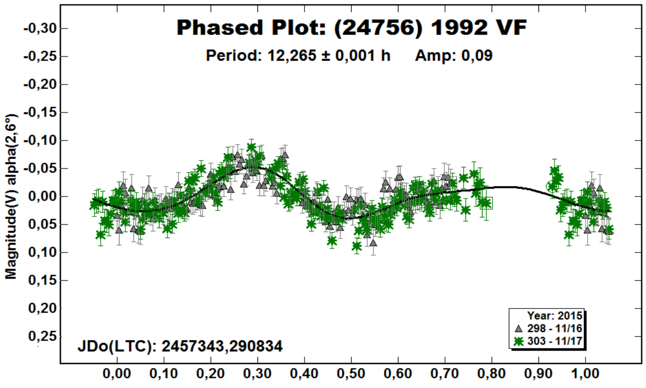
4233 Memphis. This is a main-belt asteroid discovered in 1960. There were no previous entries in the LCDB (Warner *et al.*, 2009a) for this asteroid.





Our data were obtained on two nights in 2016 March. The bimodal lightcurve, with an amplitude of 0.61 mag, indicates a rotation period of 7.150 ± 0.114 h. Although the data were not enough to get the complete lightcurve, the period spectrum shows that this could be a possible solution and so is the one we accept here.

(24756) 1992 VF. This is MBA was discovered in 1992. There were no previous entries in the LCDB. The OBAS group observed the asteroid for two nights in 2015 November. Our analysis found a period of 12.265 ± 0.001 h with and amplitude of 0.09 magnitudes.



Acknowledgements

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

Number	Name	Date Range yy/mm/dd	Nights	Period (h)	Error (h)	Amp (Mag)	Phase
333	Badenia	16/01/31 – 16/02/16	4	9.860	0.001	0.33	+1.4,+4.9
407	Arachne	16/02/16 – 16/03/01	10	22.627	0.003	0.30	+4.2,+9.8
458	Hercynia	16/03/03 - 16/03/12	6	21.806	0.006	0.36	+5.4,+8.6
570	Kythera	16/02/04 - 16/02/05	5	8.074	0.016	0.12	+1.5,+1.8
619	Triberga	16/03/04 – 16/03/11	5	29.311	0.001	0.66	-3.5,+5.1
862	Franzia	16/03/01 - 16/03/03	3	16.299	0.013	0.10	-3.6,+3.5
866	Fatme	16/01/15 - 16/02/20	4	7.93	0.001	0.05	+2.4,+13.3
1048	Feodosia	16/02/20 - 16/02/02	3	35.751	0.001	0.13	+8.3,+8.6
1186	Turnera	16/01/21 – 16/01/27	3	12.085	0.001	0.31	-5.1,-4.5
1727	Mette	16/03/16	1	3.00	0.0144	0.33	+28.1
1234	Elyna	16/11/23 - 16/11/29	4	5.421	0.001	0.21	+18.4,+19.2
1249	Rutherfordia	15/11/30 - 15/12/05	4	18.242	0.001	0.71	-6.8,-3.9
1271	Isergina	16/01/16 - 16/02/23	3	7.829	0.002	0.27	+5.3,16.2
1412	Lagrula	16/01/15 - 016/01/16	2	5.882	0.001	0.44	+3.4,+3.6
1859	Kivalevskaya	16/03/09 - 16/04/09	5	13.36	0.001	0.44	+2.3,+13.0
1946	Walraven	15/12/21 - 16/01/11	5	10.21	0.001	0.87	-6.3, +11.8
3115	Baily	15/12/14 - 15/12/16	3	16.012	0.001	0.17	-2.1,-1.1
3299	Hall	16/02/02 - 16/02/04	2	6.617	0.015	0.71	+17.0,+17.8
3895	Earhart	16/03/11	1	3.556	0.0004	0.048	-11.5
4233	Memphis	16/03/15 - 16/03/16	2	7.086	0.042	0.63	+19.9
24756	1992 VF	15/11/16 - 15/11/17	2	12.265	0.01	0.09	+2.6,+3.1

Table II. Dates of observation, number of nights, and derived periods/amplitudes. The Phase column gives the phase angle. If there are two values, they represent the phase angle on the first and last date of observation, respectively.

References

Aznar, A. (2013). “Lightcurve of 3422 Reid using star subtraction techniques.” *Minor Planet Bull*. **40**, 214-215.

Aznar, A.M., Carreno Garceran, A., Arce Mansego, E., Brines Rodrigeuz, P., Lozano de Haro, J., Fornas Silva, A., Fornas Silva, G., Mas Martinez, V., Rodrigo Chiner, O. (2016). “Twenty-three asteroid lightcurves at Observadores de Asteroids Spanish group (OBAS): 2015 October-December.” *Minor Planet Bull*. **43**, 174-181.

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

Behrend, R. (2004, 2005, 2006, 2007, 2011, 2015). 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.

Brinsfield, J.W. (2011). “Asteroid Lightcurve Analysis at the Via Capote Observatory: 1st Quarter 2011.” *Minor Planet Bull*. **38**, 154-155.

CALL (2015). Collaborative Asteroid Lightcurve Link.
http://www.MinorPlanet.info/call.html

Casalnuovo, G.B. (2013). “Lightcurve Photometry, H-G Parameters and Estimated Diameter for 1412 Lagrula” *Minor Planet Bull*. **40**, 188.

Denchev, P., Shkodrov, V., Ivanova, V. (2000). “Synodic periods of asteroids 333, 402, 481, and 800.” *Planet. Space Sci.* **48**, 983-986.

Fauerbach, M., Marks, S.A., Lucas, M.P. (2008). “Lightcurve Analysis of Ten Main-belt Asteroids.” *Minor Planet Bull*. **35**, 44-46.

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.

Hanus, J., Durech, J., Oszkiewicz, D.A., Behrend, R., Carry, B., Delbo, M., Adam, O., Afonina, V., Anquetin, R., Antonini, P., and 159 coauthors. (2016). "New and updated convex shape models of asteroids based on optical data from a large collaboration network." *Astron. Astrophys.* **586**, A108.

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.

Kryszczynska, A., Colas,F., Polinska, M., Hirsch, R., Ivanova, V., Apostolovska, G., Bilkina, B., Velichko, F.P., Kwiatkowski, Kankiewicz, P., Vachier, F., Umlenki, V., and 18 co-authors (2012). "Do Slivan states exist in the Flora family?. I. Photometric survey of the Flora region." *Astron. Astrophys*. **546**, A72.

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

Oliver, R.L., Shipley, H., Ditteon, R. (2008). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2008 March." *Minor Planet Bull*. **35**, 149-150.

Pligge, Z., Monnier, A., Pharo, J., Stolze, K., Yim, A., Ditteon, R. (2011). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2010 May." *Minor Planet Bull*. **38**, 5-7.

Pray, D.P., Pravec, P., Marchini, A., Salvaggio, F., Papini, R., Pollock, J., Caton, D., Hawkins, R., Benishek, V., Smith, A. Reigchart, D., Haislip, J. (2015). "(3433) Fehrenbach." *CBET* **4201**.

Schober, H.J., Erikson, A., Hahn, G., Lagerkvist, C.-I., Albrecht, R., Ornig, W., Schroll, A., Stadler, M. (1994). "Physical studies of asteroids. XXVIII. Lightcurves and photoelectric photometry of asteroids 2, 14, 51, 105, 181, 238, 258, 369, 377, 416, 487, 626, 679, 1048 and 2183." *Astron. Astrophys. Suppl. Ser*. **105**, 281-300.

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

Vander Haagen, G.A. (2008). "Lightcurves of Minor Planets 2118 Flagstaff (15161) 2000 FQ48, and (46436) 2002 LH5." *Minor Planet Bull*. **35**, 49.

Warner, B.D. (2006). "Asteroid lightcurve analysis at the Palmer Divide Observatory: March-June 2006." *Minor Planet Bull*. **33**, 85-88.

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. (2009). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 March-June." *Minor Planet Bull.* **36**, 172-176.

Warner, B.D. (2010). "Upon Further Review: I. An Examination of Previous Lightcurve Analysis from the Palmer Divide Observatory." *Minor Planet Bul.* **37**, 127-130.

Warner, B.D., Stephens, R.D. (2013). "1727 Mette: A New Hungaria Binary." *Minor Planet Bull.* **40**, 129-130.

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

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.

THE BINARY NATURE OF 8077 HOYLE

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Analysis of CCD photometric observations of 8077 Hoyle shows that it is a binary asteroid with a synodic period for the primary of 2.746 ± 0.001 h and an orbital period of 53.862 ± 0.026 h. The amplitude of the primary lightcurve is 0.18 mag.

CCD photometric observations of 8077 Hoyle were made at the Esctorn Campus Observatory (Klinglesmith and Franco, 2016) in 2016 March. We used one of three Celestron 0.35-m telescopes equipped with an SBIG CCD camera. The images were processed and calibrated using *MPO Canopus* 10.4.7.6 (Warner, 2015). The exposures were 420 seconds through clear filters. The multiple nightly data sets were combined with the FALC algorithm (Harris *et al.*, 1989) within *MPO Canopus* to search for the synodic period of the asteroid.

We selected 8077 Hoyle for follow-up observations from the list of spin/shape models from Warner *et al*. (2016) because it was listed as having a particularly favorable apparition. There had been three previously determined periods. Klinglesmith *et al.* (2012) reported a period of 2.746 ± 0.002 h with an amplitude of 0.20 ± 0.10 mag. Clark obtained periods of 2.270 ± 0.001 h with an amplitude of 0.20 ± 0.02 mag (2013) and 2.7296 ± 0.0004 h with an amplitude of 0.23 mag (2015). All three sets of observations were obtained over short intervals of dates and did not show indications of a satellite.

The most recent observations covered a wider range of dates, six nights from 2016 Feb 6-18, and revealed mutual events (eclipses). Using the dual period search in *MPO Canopus* (Warner, 2015), we were able to obtain a synodic period for the primary of 2.746 ± 0.001 hours and an orbital period of 53.862 ± 0.026 h. The amplitude of the primary lightcurve is 0.18 ± 0.03 mag. Petr Pravec (private communications) confirmed the determination with synodic period of 2.74574 h and an orbital period of 54.0 ± 0.1 h. The depth of the shallower eclipse gives a satellite/primary effective diameter ratio (D_2/D_1) of about 0.35, but this is uncertain due to insufficient coverage.

Acknowledgments

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References

Clark, M. (2013). "Asteroid Photometry from the Preston Gott Observatory." *Minor Planet Bull*. **40**, 131-133.

Clark, M. (2015). "Asteroid Photometry from the Preston Gott Observatory." *Minor Planet Bull.***42**, 163-166.

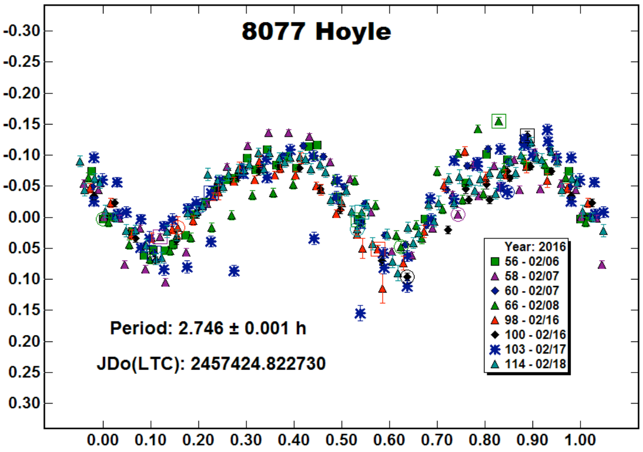
Klinglesmith III, D.A., Risley, E., Turk, J., Vargas, A., Han, X.L., Heffner, O.R., Kidd, A.W., Magnetta, B.J., Rastede, F.W. (2012). "8077 Hoyle: a Short Period Asteroid." *Minor Planet Bull*. **39**, 203.

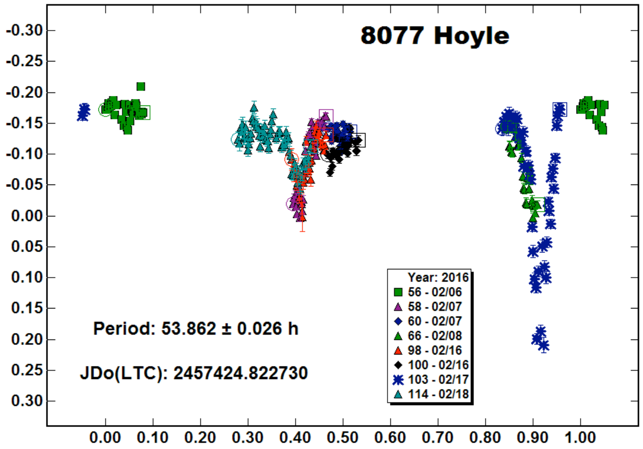
Klinglesmith III, D.A., Franco, L. (2016). "Lightcurves for 1531 Hartmut and 4145 Maximova." *Minor Planet Bull.* **43,** 121.

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.

Warner, B.D. (2015). *MPO Canopus* software.
http://bdwpublishing.com/mposoftware.aspx

Warner, B.D., Harris, A.W., Durech, J., Benner, L.A.M. (2016). "Lightcurve Photometric Opportunities: 2016 April-June." *Minor Planet Bull.* **43**, 103-108.





ROTATION PERIOD DETERMINATION FOR 871 AMNERIS

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From a total of 44 sessions of photometric measurements of asteroid 871 Amneris, a principal synodic rotation period of 78.71 ± 0.01 hours and amplitude 0.60 ± 0.05 magnitudes is found for its lightcurve. The individual sessions in the composite lightcurve show considerable variation that may be due to changes in phase angle and phase angle bisector through the long interval of observation. These changes are suggestive of shadowing within significant concavities or that some secondary "tumbling" period might be involved. However a careful search of the data reveals no evidence for the latter.

The only previous publication of a photometric study of 871 Amneris was by Pilcher (2013). He found a monotonic brightness decrease on 2013 March 17 followed by a monotonic brightness increase the next night. He surmised a rotation period near 3 to 4 days whose complete solution would require a much larger amount of telescope time than was currently available. As the next favorable opposition in 2016 approached, he requested Vladimir Benishek and Julian Oey to collaborate for coverage from a wide range of longitudes, and both kindly accepted his invitation. The three observers obtained a total of 44 sessions in the interval 2016 Jan. 15 – Mar. 29.

Pilcher at Organ Mesa Observatory used a 0.35 m f/10 Meade LX200 GPS S-C, SBIG STL-1001E CCD, unguided, clear filter. Benishek at Sopot Observatory used a 0.35 m SCT operating at f/6.3, SBIG ST-8 XME CCD. Oey used a 0.35 m SCT operating at f/5.9 and SBIG ST-8 XME CCD. Photometric measurement in the Cousins R system, lightcurve analysis, and data sharing were enabled by *MPO Canopus* software. All calibration stars had near solar colors and their magnitudes from the CMC15 catalog presented on the VizieR web site (2016) were utilized. This source provides Sloan r' magnitudes, where R = r' - 0.22, and has internal consistency within about 0.05 magnitudes. The large number of data points obtained have been binned in sets of three with time difference not exceeding five minutes to draw the lightcurves.

The multiple sessions routine in *MPO Canopus* was used to construct a lightcurve of the complete data set (Fig. 1). While a principal period of 78.71 ± 0.01 hours and amplitude 0.60 ± 0.05 magnitudes are shown definitively, there are significant deviations up to 0.15 magnitudes among the several sessions. Three different effects may all contribute to these deviations. The errors in the calibration star magnitudes are enhanced up to 0.10 magnitudes when sessions obtained with the different instrumental responses of the separate observers are combined. Illumination geometry changes the shape of the lightcurve with changes in phase angle and phase angle bisector. These can become pronounced if the object has significant concavities whose shadowing can change dramatically with small changes in these geometric parameters. Adding to these effects may be possible low amplitude tumbling, a hypothesis that can be tested with the current data.

Data are most abundant in the interval 2016 Jan. 29 to Feb. 14, during which changes in viewing geometry are small. Tumbling effects would be most easily distinguished from the other sources of deviations in this interval. A lightcurve including only sessions at least 4 hours from Jan. 29 to Feb. 14 is presented in Fig. 2. There are only two sessions (both near the second minimum) that show significant deviations: 2016-02-04.3 and 07.9. They could be due to a low amplitude tumbling, but we have to consider also possible effects of shape irregularity plus shadowing effects at one end of the long axis of the asteroid. Given that no similar features are seen at other phases in the lightcurve as we would expect for tumbling, it is likely due to shape and shadowing effects. The data are not quite conclusive with regard to possible tumbling, which we rate as PAR = 0.

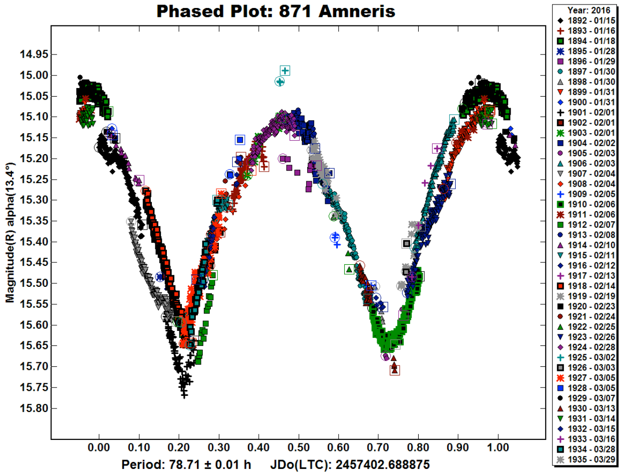

Figure 1. A lightcurve of 871 Amneris including all sessions and phased to 78.71 hours drawn with the MPO Canopus multiple sessions routine.

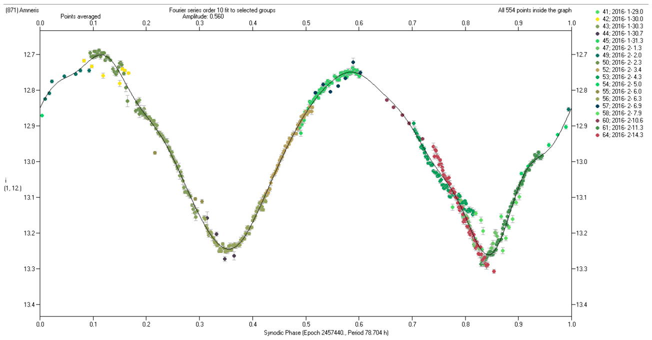

Figure 2. A lightcurve of 871 Amneris including only sessions 2016 Jan. 29 to Feb. 14.

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Reference

Pilcher, F. (2013). "Rotation Period Determinations for 102 Miriam, 108 Hecuba, 221 Eos, 255 Oppavia, 745 Mauritia, and a note on 871 Amneris." *Minor Planet Bull.* **40**, 158-160.

VizieR (2016). *http://vizier.u-strasbg.fr/viz-bin/VizieR.*

A REPORT FROM THE L5 TROJAN CAMP - LIGHTCURVES OF JOVIAN TROJAN ASTEROIDS FROM THE CENTER FOR SOLAR SYSTEM STUDIES

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Jovian Trojan asteroids larger than 30 km were studied from the Center for Solar System Studies (CS3, MPC U81). Lightcurves for 22 Trojan asteroids were between November 2015 and February 2016.

For three years CS3 has been conducting a study of Jovian Trojan asteroids. As part of this study, data is being accumulated for family rotational studies and future shape model studies. It is anticipated that for most Jovian Trojans, up to five dense lightcurves per target at oppositions well scattered about the longitudinal plane will be needed as reliable sparse data probably does not exists for Trojan asteroids at 5 AU and a low albedo. To date, CS3 has obtained three or more dense lightcurves on over a dozen Jovian Trojans.

All images were made with a 0.4-m or a 0.35-m SCT using an FLI-1001E or a SBIG STL-1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied to the science frames prior to measurement.

Image processing, measurement and period analysis was done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins V magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

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

Number	Name	2015 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Dia.
1172	Aneas	01/27-01/31	18	3.8,4.4	110	-13	8.681	0.003	0.4	0.02	118
1173	Anchises	02/08-02/16	47	7.3,8.2	95	1	11.595	0.002	0.61	0.02	100
1867	Deiphobus	11/12-11/24	70	9.0,7.5	102	3	58.62	0.03	0.22	0.02	118
2207	Antenor	02/05-02/07	20	5.5,5.9	109	-5	7.906	0.009	0.09	0.01	98
2357	Phereclos	01/14-01/27	24	2.1,4.6	103	-3	14.345	0.004	0.18	0.02	95
2674	Pandarus	11/12-11/15	23	8.3,7.9	96	-2	8.461	0.003	0.49	0.02	74
2893	Peiroos	11/09-11/11	90	7.5,7.2	89	-7	8.99	0.01	0.31	0.02	87
2895	Memnon	01/16-01/26	15	2.5,3.6	113	-11	7.509	0.006	0.08	0.02	57
3317	Paris	02/04-02/06	17	5.3,5.5	107	-14	7.048	0.005	0.11	0.02	119
3451	Mentor	12/23-12/31	25	7.2,6.3	125	-23	7.696	0.001	0.19	0.02	126
3708	1974 FV1	01/13-01/14	13	0.6,0.4	115	-1	6.55	0.01	0.2	0.02	76
4348	Poulydamas	01/29-02/03	14	4.8,5.7	106	-8	9.941	0.006	0.27	0.02	82
4707	Khryses	02/02-02/04	93	2.4,2.8	121	1	6.852	0.005	0.47	0.02	38
4709	Ennomos	12/28-01/12	37	5.6,4.2	118	-20	12.267	0.002	0.45	0.02	91
4715	1989 TS1	12/24-12/27	16	4.8,4.5	105	20	8.792	0.005	0.53	0.02	62
4722	Agelaos	02/07-02/12	19	6.2,7.1	107	7	18.438	0.014	0.19	0.02	50
4791	Iphidamas	12/18-12/21	20	1.7,1.3	91	-5	9.696	0.006	0.31	0.02	50
4867	Polites	01/08-01/13	27	4.6,4.7	108	23	11.235	0.006	0.15	0.02	57
5130	Ilioneus	11/16-11/21	28	4.2,3.2	74	-3	14.783	0.007	0.29	0.02	61
11089	1994 CS8	11/05-11/08	91	5.3,4.8	68	-6	7.72	0.01	0.46	0.02	37
15977	1998 MA11	12/01-12/30	40	4.3,3.4,5.	81	-15	250	5	0.3	0.1	44
22180	2000 YZ	11/22-12/07	11	7.5,5.2	95	-14	19.39	0.02	0.23	0.03	40

1172 Aneas. Mottola (Mottola *et al*., 2011) previously found a rotational period of 8.708 h. We observed this Trojan in 2010 and 2014 finding periods of 8.705 h and 8.701 h. The period we found this year agrees with those results.

1173 Anchises. The last time a rotational period was determined was in July 1986 by one of this paper's authors (French 1987). The rotational period we found this year of 11.595 is in agreement.

1867 Deiphobus. French (1987) also observed Deiphobus in 1986 determining that the period exceeded 24 h. Mottola (Mottola *et al*., 2011) studied this Trojan in 1994 reporting a period of 58.66 h. The result this year of 58.62 h is in good agreement with the Mottola finding.

2207 Antenor. Mottola (Mottola *et al*., 2011) observed this Trojan in 1989 and 1996, finding periods of 7.977 h and 7.965 h respectively. Using sparse photometry from the Palomar Transient Factory, Chang (Waszczak *et al*., 2015) reported a period of 7.9656 h. Our period of 7.906 h agrees with those results.

2357 Phereclos. Mottola (Mottola *et al*., 2011) observed Phereclos in 1994 and 2010 each time finding periods of about 14.4 h. Our 2016 observations resulting in a rotational period of 14.345 h are consistent with those results.

2674 Pandarus. A rotational period for Pandarus has only been found once before in 1986. One of the authors (French 1987) reported a period of 8.480 h. The period found this year of 8.461 h is in good agreement.

2893 Peiroos. Peiroos was previously observed in 1989 (Gonano 1990) with a reported period of 8.96 h, in agreement with our result of 8.99 h.

2895 Memnon. This Trojan has been well observed over the years. Binzel (Binzel 1992), Mottola (Mottola *et al*., 2011), and this paper's authors (Stephens *et al* 2015) each reported periods near 7.05 h, in agreement with this year's findings.

3317 Paris. This is the first opposition we studied this Trojan. However, Binzel has extensively studied Paris (Binzel 1992). Periods were also reported by Mottola (Mottola *et al*., 2011) and Behrend (Behrend 2016). All reported finding a period of 7.082 h. The results this year of 7.048 h is in substantial agreement with those findings.

3451 Mentor. Mentor is a well-studied Trojan. Periods near 7.7 h have been reported by Sauppe (Sauppe *et al* 2007), Duffard (Duffard *et al*., 2008), Melita (Melita *et al*., 2010), this paper's authors (Stephens *et al* 2014), and Chang (Waszczak *et al* 2015). Our period this year agrees with those results.

(3708) 1974 FV1. Mottola (Mottola *et al*., 2011) observed this Trojan in 1993 finding a period of 6.553 h. We observed it last year (Stephens *et al*., 2016) reporting a period of 6.520 h. The result this year confirms these previous results.

4348 Poulydamas. Poulydamas has been observed three times in the past. Mottola (Mottola *et al*., 2011), the authors (Stephens *et al* 2015), and Chang (Waszczak *et al*., 2015) each found periods near 9.9 h. Our result this year of 9.941 h is similar to those previously found.

4707 Khryses. This Trojan so far has been the exclusive domain of the authors of this paper (Stephens *et al*., 2014 and 2015). Our period this year of 6.852 is in good agreement with our previous findings.

4709 Ennomos. We observed this Trojan in 2015 (Stephens *et al* 2015), confirming the previous results from Mottola (Mottola *et al*., 2011) and Shevchenko (Shevchenko *et al* 2012). This year's observations is in agreement with those results

(4715) 1989 TS1. Results for this Trojan have been reported three times in the past. Mottola (Mottola *et al*., 2011), the authors (Stephens *et al* 2015), and Chang (Waszczak *et al*., 2015) each found periods near 8.8 h, similar to our findings this year.

4722 Agelaos. Mottola (Mottola *et al*., 2011) observed this Trojan in 2002 reporting a rotational period of 18.61 h. Using sparse photometry from the Palomar Transient Factory, Chang (Waszczak *et al* 2015) reported a period of 18.4557 h. Our period of 18.438 h is similar to the Chang period.

4791 Iphidamas. Iphidamas was observed by Mottola (Mottola *et al*., 2011) in 1991 and 1993 finding periods of about 9.57 h and 9.727 h respectively. We observed Iphidamas in 2015 (Stephens *et al*., 2015) and determined a rotational period of 9.650 h. Our result this year of 9.696 h is similar to those results.

4867 Polites. We observed Polites three times since 2010 (French *et al* 2011), (Stephens *et al*., 2014 and 2015) finding rotational periods near 11.24 h. This year's result of 11.235 h is similar to those findings.

5130 Ilioneus. Rotational periods for Ilioneus have been determined twice before. Mottola (Mottola *et al*., 2011) observed it in 1994 reporting a period of 14.768 h. Using sparse photometry from the Palomar Transient Factory, Chang (Waszczak *et al*., 2015) reported a period of 14.7429 h. Our period this year of 14.783 agrees with those results.

(11089) 1994 CS8. We observed this Trojan in 2013 and 2014 (Stephens *et al*., 2014 and 2015). In both cases, we found the rotational period to be 7.72 h, identical to this year's results.

(15977) 1998 MA11. We observed this Trojan over three nights in 2013 resulting in an almost featureless lightcurve with an amplitude of only 0.05 mag. In 2015, we were able to observe it on 16 nights spanning a month. Through the first 10 sessions to December18, the lightcurve was suggestive of having a 750 h period. But the last six sessions would not follow the trend of the lightcurve. Plotting the last 12 sessions starting on December 12 suggests the asteroid has a nonprincipal axis of rotation (tumbling) with a primary period of about 250 h, which we are reporting here. With the long primary period, we could not get enough data to derive any secondary frequencies before changing phase angle becomes an issue.

(22180) 2000 YZ. We observed this Trojan twice before (French *et al*., 2012 and Stephens *et al*., 2014) finding rotational periods of 19.40 h both times. This year's result of 19.39 h is in agreement.

Acknowledgements

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References

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

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

Duffard, R. D., Melita, M., Ortiz, J. L., Licandro, J., Williams, I. P., Jones, D., (2008). "Light-Curve Survey of the Trojan Asteroids." *Asteroids, Comets, Meteors* 2008 held July 14-18, 2008 in Baltimore, Maryland. LPI Contribution No. 1405, paper id. 8187.

French, L.M. (1987). "Rotation properties of four L5 Trojan asteroids from CCD photometry." *Icarus* **72**, 325-341.

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., Wasserman, L.H. (2012). "Photometry of 17 Jovian Trojan Asteroids." *Minor Planet Bul.* **39**, 183-187.

Gonano, M., Mottola, S., Neukum, G., di Martino, M. (1990). "Physical study of outer belt asteroids." *Proceedings of the Topical Meeting of the Interdisciplinary Scientific Commission B /Meetings B2, B3, and B5/ of the COSPAR 28th Plenary Meeting, The Hague, Netherlands, June 25-July 6, 1990.* A92-18651 05-12.

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.

Melita, M.D., Duffard, R., Williams, I.P., Jones, D.C., Licandro, J., Ortiz, J.L. (2010). "Lightcurves of 6 Jupiter Trojan asteroids." *Planetary and Space Science* **58**, Issue 7-8, p. 1035-1039.

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. Jrnl.* **170**, 32.

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

Shevchenko, V.G., Slyusarev, I.G., Belskaya, I.N. (2012). "Albedo of the Trojan Asteroid 4709 Ennomos." *Asteroids, Comets, Meteors* **2012**, Proceedings of the conference held May 16-20, 2012 in Niigata, Japan.

Stephens, R.D., French, L.M., Davitt, C., Coley, D.R. (2014). "At the Scaean Gates: Observations Jovian Trojan Asteroids, July-December 2013." *Minor Planet Bul.* **41**, 95-100.

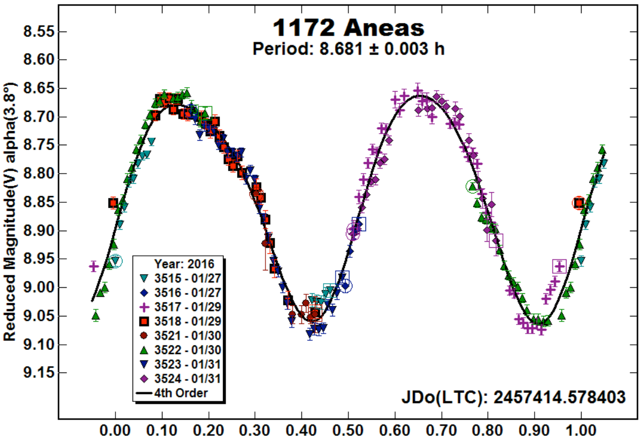
Stephens, R.D., Coley, D.R., French, L.M. (2015). "Dispatches from the Trojan Camp - Jovian Trojan L5 Asteroids Observed from CS3: 2014 October - 2015 January." *Minor Planet Bul.* **42**, 216-224.

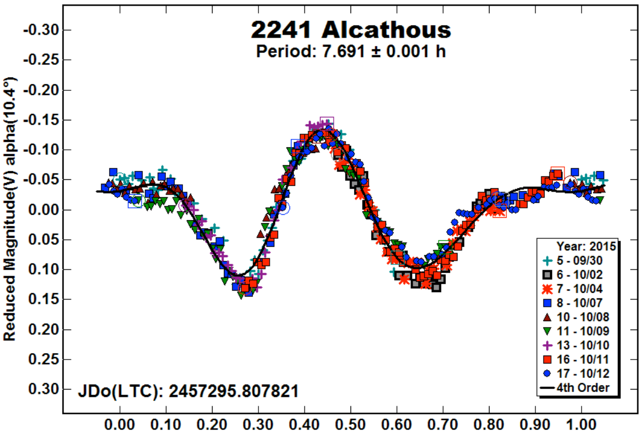
Stephens, R.D., Coley, D.R., French, L.M. (2016). "Large L5 Jovian Trojan Asteroid Lightcurves from the Center for Solar System Studies." *Minor Planet Bul.* **43**, 15-22.

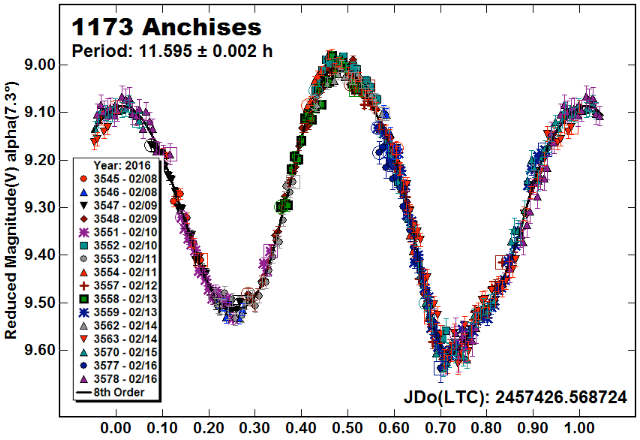
Warner, B.D., (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul.* **34**, 113-119.

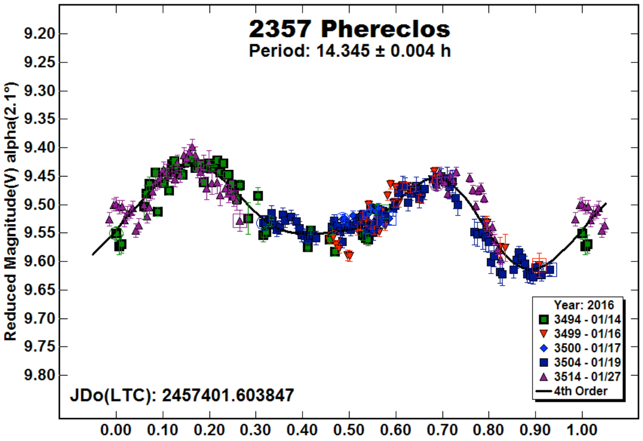
Warner, B.D., Harris, A.W., Pravec, P. (2009). *Icarus* **202**, 134-146. Updated 2015 February 7. *http://www.minorplanet.info/lightcurvedatabase.html.*

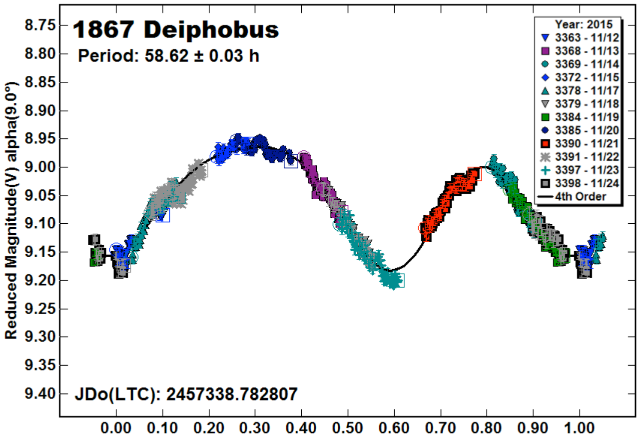
Waszczak, A., Chang, C., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y., Ip, W., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid lightcurves from the Palomar Transient Factory survey: Rotation periods and phase functions from sparse photometry." *Astron. Jrnl.* **150**, 75.

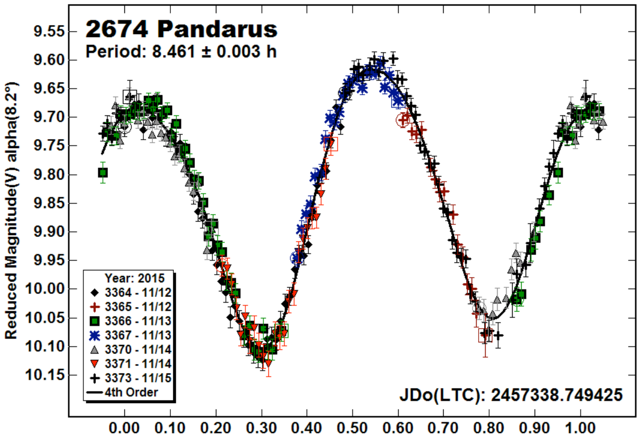

1172 Aneas
Period: 8.681 ± 0.003 h
Reduced Magnitude(V) alpha(3.8°)
8.55
8.60
8.65
8.70
8.75
8.80
8.85
8.90
8.95
9.00
9.05
9.10
9.15
Year: 2016
3515 - 01/27
3516 - 01/27
3517 - 01/29
3518 - 01/29
3521 - 01/30
3522 - 01/30
3523 - 01/31
3524 - 01/31
4th Order
JDo(LTC): 2457414.578403
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

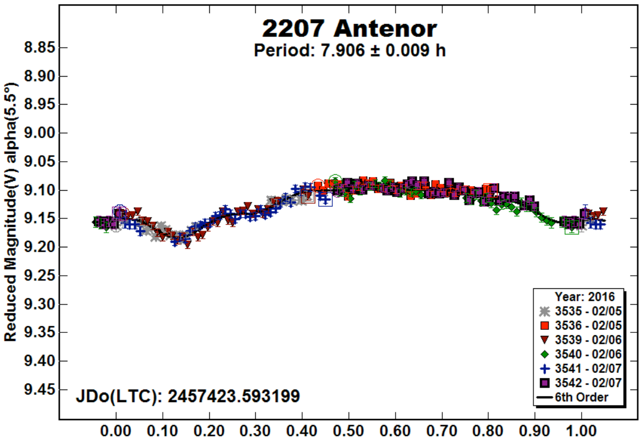

2241 Alcathous
Period: 7.691 ± 0.001 h
Reduced Magnitude(V) alpha(10.4°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2015
5 - 09/30
6 - 10/02
7 - 10/04
8 - 10/07
10 - 10/08
11 - 10/09
13 - 10/10
16 - 10/11
17 - 10/12
4th Order
JDo(LTC): 2457295.807821
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

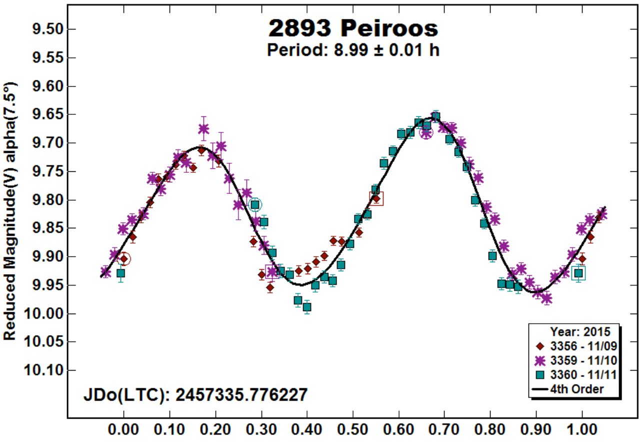

1173 Anchises
Period: 11.595 ± 0.002 h
Reduced Magnitude(V) alpha(7.3°)
9.00
9.10
9.20
9.30
9.40
9.50
9.60
Year: 2016
3545 - 02/08
3546 - 02/08
3547 - 02/09
3548 - 02/09
3551 - 02/10
3552 - 02/10
3553 - 02/11
3554 - 02/11
3557 - 02/12
3558 - 02/13
3559 - 02/13
3562 - 02/14
3563 - 02/14
3570 - 02/15
3577 - 02/16
3578 - 02/16
8th Order
JDo(LTC): 2457426.568724
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

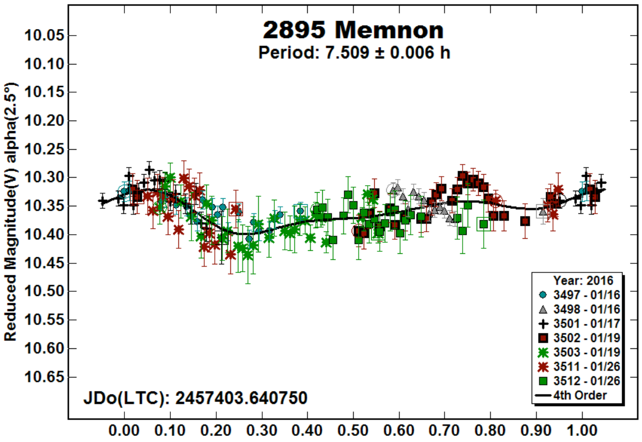

2357 Phereclos
Period: 14.345 ± 0.004 h
Reduced Magnitude(V) alpha(2.1°)
9.20
9.25
9.30
9.35
9.40
9.45
9.50
9.55
9.60
9.65
9.70
9.75
9.80
Year: 2016
3494 - 01/14
3499 - 01/16
3500 - 01/17
3504 - 01/19
3514 - 01/27
4th Order
JDo(LTC): 2457401.603847
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

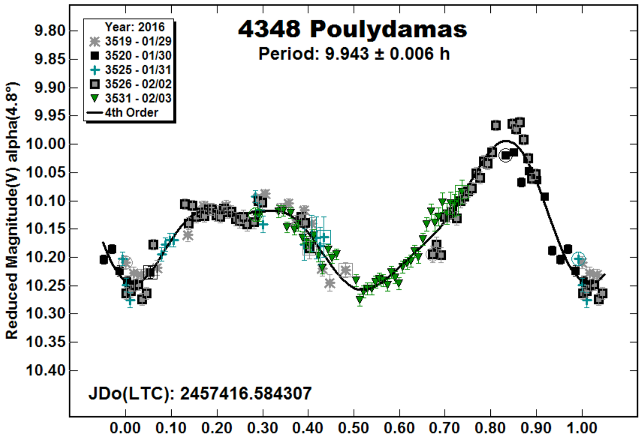

1867 Deiphobus
Period: 58.62 ± 0.03 h
Reduced Magnitude(V) alpha(9.0°)
8.75
8.80
8.85
8.90
8.95
9.00
9.05
9.10
9.15
9.20
9.25
9.30
9.35
9.40
Year: 2015
3363 - 11/12
3368 - 11/13
3369 - 11/14
3372 - 11/15
3378 - 11/17
3379 - 11/18
3384 - 11/19
3385 - 11/20
3390 - 11/21
3391 - 11/22
3397 - 11/23
3398 - 11/24
4th Order
JDo(LTC): 2457338.782807
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

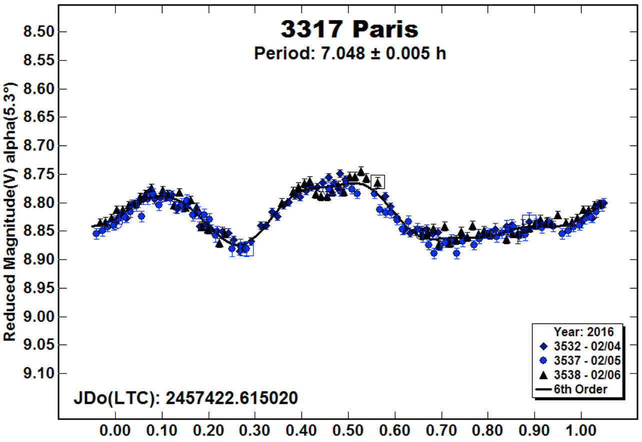

2674 Pandarus
Period: 8.461 ± 0.003 h
Reduced Magnitude(V) alpha(8.2°)
9.55
9.60
9.65
9.70
9.75
9.80
9.85
9.90
9.95
10.00
10.05
10.10
10.15
Year: 2015
3364 - 11/12
3365 - 11/12
3366 - 11/13
3367 - 11/13
3370 - 11/14
3371 - 11/14
3373 - 11/15
4th Order
JDo(LTC): 2457338.749425
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

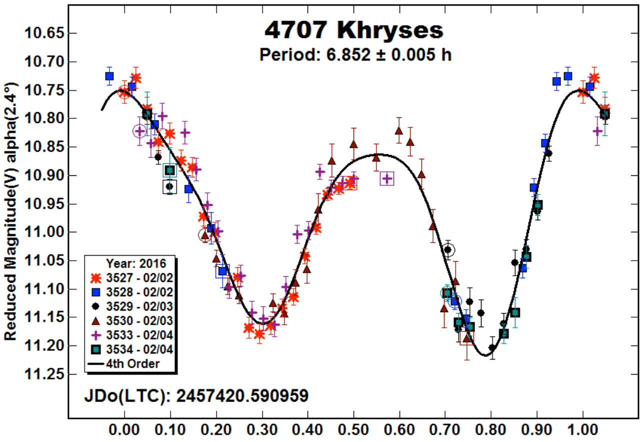

2207 Antenor
Period: 7.906 ± 0.009 h
Reduced Magnitude(V) alpha(5.5°)
8.85
8.90
8.95
9.00
9.05
9.10
9.15
9.20
9.25
9.30
9.35
9.40
9.45
Year: 2016
3535 - 02/05
3536 - 02/05
3539 - 02/06
3540 - 02/06
3541 - 02/07
3542 - 02/07
6th Order
JDo(LTC): 2457423.593199
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

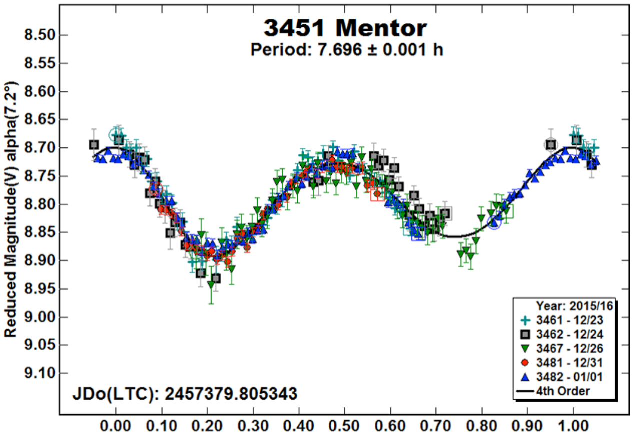

2893 Peiroos
Period: 8.99 ± 0.01 h
Reduced Magnitude(V) alpha(7.5°)
9.50
9.55
9.60
9.65
9.70
9.75
9.80
9.85
9.90
9.95
10.00
10.05
10.10
Year: 2015
3356 - 11/09
3359 - 11/10
3360 - 11/11
4th Order
JDo(LTC): 2457335.776227
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

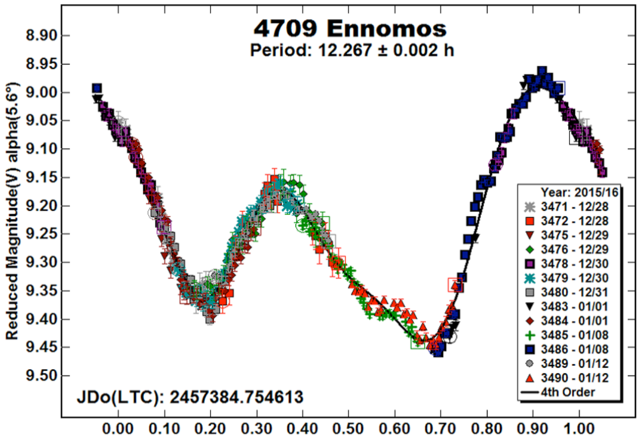

2895 Memnon
Period: 7.509 ± 0.006 h
Reduced Magnitude(V) alpha(2.5°)
10.05 10.10 10.15 10.20 10.25 10.30 10.35 10.40 10.45 10.50 10.55 10.60 10.65
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457403.640750
Year: 2016
3497 - 01/16
3498 - 01/16
3501 - 01/17
3502 - 01/19
3503 - 01/19
3511 - 01/26
3512 - 01/26
4th Order

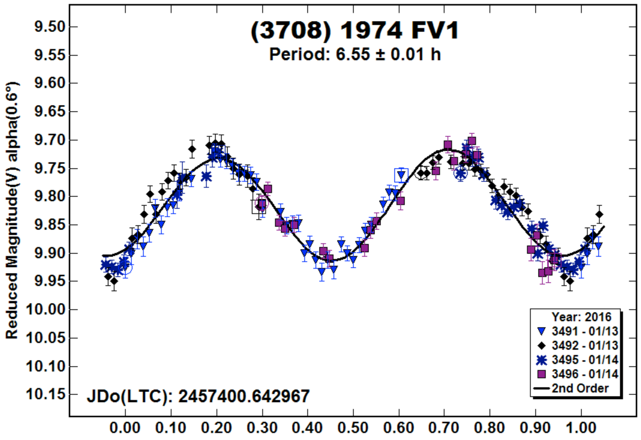

4348 Poulydamas
Period: 9.943 ± 0.006 h
Reduced Magnitude(V) alpha(4.8°)
9.80 9.85 9.90 9.95 10.00 10.05 10.10 10.15 10.20 10.25 10.30 10.35 10.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457416.584307
Year: 2016
3519 - 01/29
3520 - 01/30
3525 - 01/31
3526 - 02/02
3531 - 02/03
4th Order

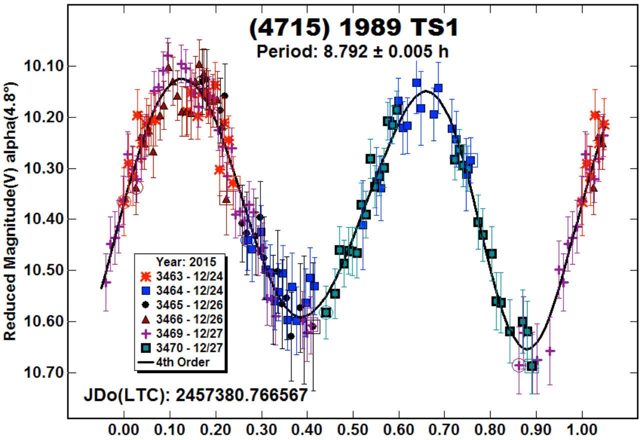

3317 Paris
Period: 7.048 ± 0.005 h
Reduced Magnitude(V) alpha(5.3°)
8.50 8.55 8.60 8.65 8.70 8.75 8.80 8.85 8.90 8.95 9.00 9.05 9.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457422.615020
Year: 2016
3532 - 02/04
3537 - 02/05
3538 - 02/06
6th Order

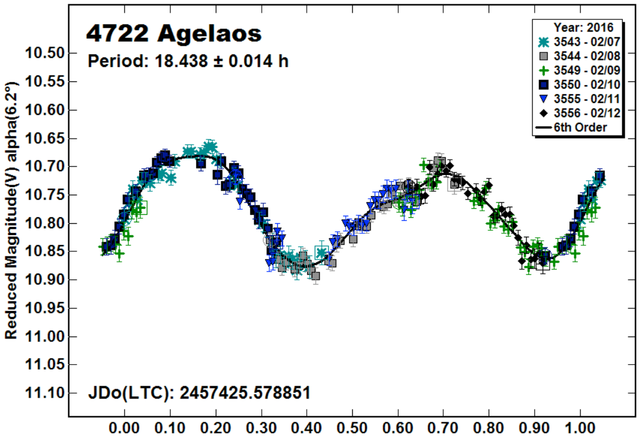

4707 Khryses
Period: 6.852 ± 0.005 h
Reduced Magnitude(V) alpha(2.4°)
10.65 10.70 10.75 10.80 10.85 10.90 10.95 11.00 11.05 11.10 11.15 11.20 11.25
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457420.590959
Year: 2016
3527 - 02/02
3528 - 02/02
3529 - 02/03
3530 - 02/03
3533 - 02/04
3534 - 02/04
4th Order

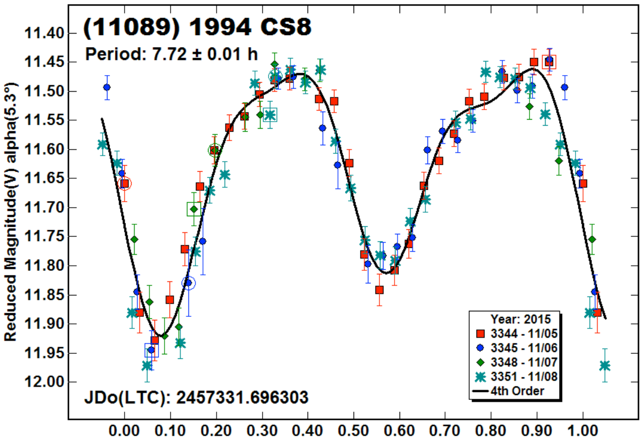

3451 Mentor
Period: 7.696 ± 0.001 h
Reduced Magnitude(V) alpha(7.2°)
8.50 8.55 8.60 8.65 8.70 8.75 8.80 8.85 8.90 8.95 9.00 9.05 9.10
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457379.805343
Year: 2015/16
3461 - 12/23
3462 - 12/24
3467 - 12/26
3481 - 12/31
3482 - 01/01
4th Order

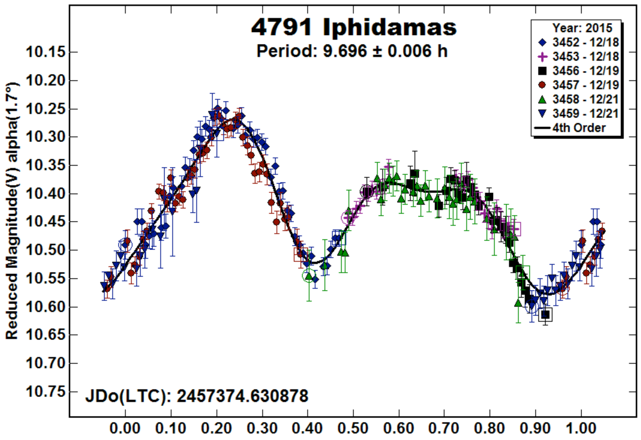

4709 Ennomos
Period: 12.267 ± 0.002 h
Reduced Magnitude(V) alpha(5.6°)
8.90 8.95 9.00 9.05 9.10 9.15 9.20 9.25 9.30 9.35 9.40 9.45 9.50
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457384.754613
Year: 2015/16
3471 - 12/28
3472 - 12/28
3475 - 12/29
3476 - 12/29
3478 - 12/30
3479 - 12/30
3480 - 12/31
3483 - 01/01
3484 - 01/01
3485 - 01/08
3486 - 01/08
3489 - 01/12
3490 - 01/12
4th Order

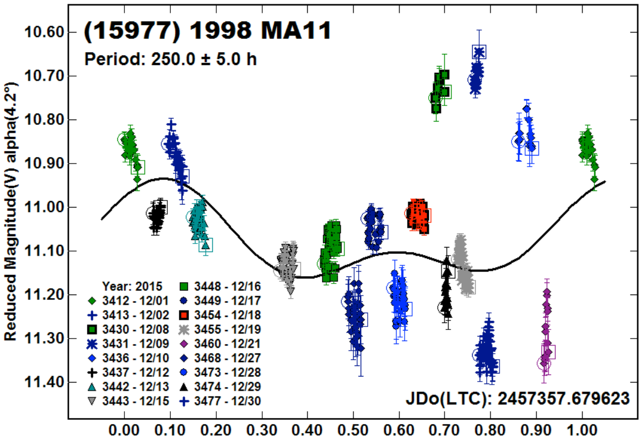

(3708) 1974 FV1
Period: 6.55 ± 0.01 h
Reduced Magnitude(V) alpha(0.6°)
9.50 9.55 9.60 9.65 9.70 9.75 9.80 9.85 9.90 9.95 10.00 10.05 10.10 10.15
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457400.642967
Year: 2016
3491 - 01/13
3492 - 01/13
3495 - 01/14
3496 - 01/14
2nd Order

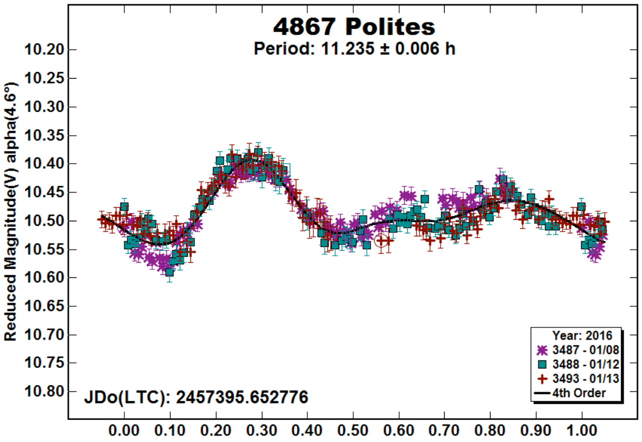

(4715) 1989 TS1
Period: 8.792 ± 0.005 h
Reduced Magnitude(V) alpha(4.8°)
10.10 10.20 10.30 10.40 10.50 10.60 10.70
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2457380.766567
Year: 2015
3463 - 12/24
3464 - 12/24
3465 - 12/26
3466 - 12/26
3469 - 12/27
3470 - 12/27
4th Order

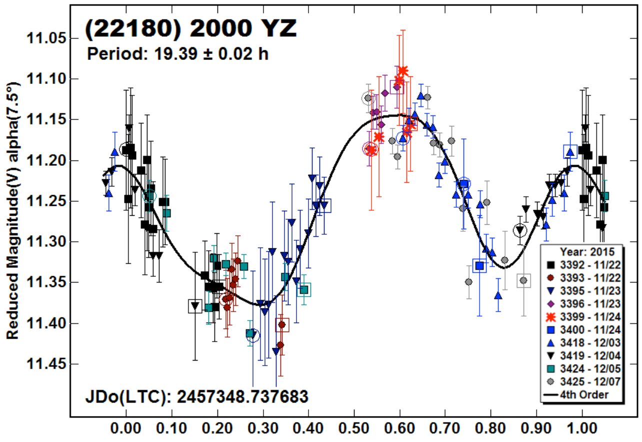

4722 Agelaos
Period: 18.438 ± 0.014 h
Year: 2016
3543 - 02/07
3544 - 02/08
3549 - 02/09
3550 - 02/10
3555 - 02/11
3556 - 02/12
6th Order
Reduced Magnitude(V) alpha(6.2°)
JDo(LTC): 2457425.578851
10.50
10.55
10.60
10.65
10.70
10.75
10.80
10.85
10.90
10.95
11.00
11.05
11.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

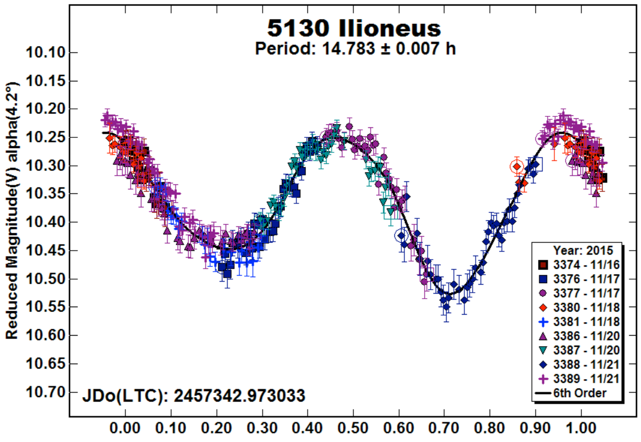

(11089) 1994 CS8
Period: 7.72 ± 0.01 h
Year: 2015
3344 - 11/05
3345 - 11/06
3348 - 11/07
3351 - 11/08
4th Order
Reduced Magnitude(V) alpha(5.3°)
JDo(LTC): 2457331.696303
11.40
11.45
11.50
11.55
11.60
11.65
11.70
11.75
11.80
11.85
11.90
11.95
12.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


4791 Iphidamas
Period: 9.696 ± 0.006 h
Year: 2015
3452 - 12/18
3453 - 12/18
3456 - 12/19
3457 - 12/19
3458 - 12/21
3459 - 12/21
4th Order
Reduced Magnitude(V) alpha(1.7°)
JDo(LTC): 2457374.630878
10.15
10.20
10.25
10.30
10.35
10.40
10.45
10.50
10.55
10.60
10.65
10.70
10.75
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(15977) 1998 MA11
Period: 250.0 ± 5.0 h
Year: 2015
3412 - 12/01
3413 - 12/02
3430 - 12/08
3431 - 12/09
3436 - 12/10
3437 - 12/12
3442 - 12/13
3443 - 12/15
3448 - 12/16
3449 - 12/17
3454 - 12/18
3455 - 12/19
3460 - 12/21
3468 - 12/27
3473 - 12/28
3474 - 12/29
3477 - 12/30
Reduced Magnitude(V) alpha(4.2°)
JDo(LTC): 2457357.679623
10.60
10.70
10.80
10.90
11.00
11.10
11.20
11.30
11.40
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


4867 Polites
Period: 11.235 ± 0.006 h
Year: 2016
3487 - 01/08
3488 - 01/12
3493 - 01/13
4th Order
Reduced Magnitude(V) alpha(4.6°)
JDo(LTC): 2457395.652776
10.20
10.25
10.30
10.35
10.40
10.45
10.50
10.55
10.60
10.65
10.70
10.75
10.80
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(22180) 2000 YZ
Period: 19.39 ± 0.02 h
Year: 2015
3392 - 11/22
3393 - 11/22
3395 - 11/23
3396 - 11/23
3399 - 11/24
3400 - 11/24
3418 - 12/03
3419 - 12/04
3424 - 12/05
3425 - 12/07
4th Order
Reduced Magnitude(V) alpha(7.5°)
JDo(LTC): 2457348.737683
11.05
11.10
11.15
11.20
11.25
11.30
11.35
11.40
11.45
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


5130 Ilioneus
Period: 14.783 ± 0.007 h
Year: 2015
3374 - 11/16
3376 - 11/17
3377 - 11/17
3380 - 11/18
3381 - 11/18
3386 - 11/20
3387 - 11/20
3388 - 11/21
3389 - 11/21
6th Order
Reduced Magnitude(V) alpha(4.2°)
JDo(LTC): 2457342.973033
10.10
10.15
10.20
10.25
10.30
10.35
10.40
10.45
10.50
10.55
10.60
10.65
10.70
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

TARGET ASTEROIDS! OBSERVING CAMPAIGNS FOR JULY THROUGH SEPTEMBER 2016

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Asteroid campaigns to be conducted by the *Target Asteroids!* program during the July-September 2016 quarter are described. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and easier to observe for small telescope users and 2) analogous to (101955) Bennu and (162173) Ryugu, targets of the OSIRIS-REx and Hayabusa-2 sample return missions.

Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for robotic sample return. The program also focuses on the study of asteroids that are analogous to (101955) Bennu and (162173) Ryugu, the target asteroids of the NASA OSIRIS-REx and JAXA Hayabusa-2 sample return missions respectively. Most target asteroids are near-Earth asteroids (NEA) though observations of relevant Main Belt asteroids (MBA) are also requested. Even though many of the observable objects in this program are faint, acquiring a large number of low S/N observations allows many important parameters to be determined. For example, an asteroid's phase function can be measured by obtaining photometry taken over a wide range of phase angles. The albedo can be constrained from the phase angle observations, as there is a direct correlation between phase function and albedo Belskaya and Shevchenko (2000). The absolute magnitude can be estimated by extrapolating the phase function to a phase angle of 0°. By combining the albedo and absolute magnitude, the size of the object can be estimated.

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

Current Campaigns

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

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

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

Asteroid Number	Name	Peak V Mag	Time of Peak Brightness
(7350)	1993 VA	19.6	early Jul
(162173)	Ryugu	18.6	late Jul
(163249)	2002 GT	19.6	late Sep
(173664)	2001 JU2	17.8	early Jul
(307564)	2003 FQ6	18.3	early Aug
(311925)	2007 BF72	18.6	early Jul
(382758)	2003 GY	19.7	late Sep
(457663)	2009 DN1	19.5	early Aug
	2015 JF11	17.6	early Aug

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

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

*http://www.minorplanetcenter.net/iau/MPEph/MPEph.htm*l

or the *Target Asteroids!* specific site created by Tomas Vorobjov and Sergio Foglia of the International Astronomical Search Collaboration (IASC) at *http://iasc.scibuff.com/osiris-rex.php*

Analog Carbonaceous Main Belt Asteroid Campaigns

(24) Themis (a=3.14 AU, e=0.13, i=0.8°, H = 7.1)
The target asteroids of the OSIRIS-REx and Hayabusa-2 missions originated in the inner part of the Main Belt (between 2.0 and 2.55 AU) on low inclination orbits. Though not an inner Belt object, *Target Asteroids!* is continuing a campaign on (24) Themis as it is a carbonaceous asteroid and analog of Bennu and Ryugu.

Themis is a large ~200 km carbonaceous Main Belt asteroid and ranks in the top 30 largest Main Belt asteroids. IR observations have detected evidence of water ice and organics on its surface (Campins et al. 2010, Rivkin and Emery 2010). Themis is also the parent of the Themis asteroid family. Some members of the Themis family have exhibited cometary activity confirming the presence of ices. On August 16 it reaches a minimum phase angle of 0.3 and peak brightness of V = 11.9. It has a rotation period of 8.4 hours with a low amplitude of ~0.15 magnitudes.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	22 09	-12 23	2.79	3.52	12.8	12	129
07/11	22 06	-12 40	2.69	3.52	12.6	10	139
07/21	22 01	-13 06	2.61	3.53	12.4	8	150
07/31	21 55	-13 39	2.55	3.53	12.3	5	161
08/10	21 48	-14 16	2.52	3.53	12.1	2	172
08/20	21 41	-14 53	2.52	3.53	12.0	1	175
08/30	21 34	-15 28	2.54	3.53	12.2	4	164
09/09	21 27	-15 57	2.60	3.52	12.4	7	152
09/19	21 22	-16 18	2.68	3.52	12.6	10	141
09/29	21 19	-16 30	2.78	3.52	12.7	12	131

Near-Earth Asteroid Campaign Targets

(3200) Phaethon (a=1.27 AU, e=0.89, i=22.2°, H = 14.6)
Phaethon is well known as the parent object of the Geminid meteor shower. Whether the shower was produced by cometary activity or a series of splitting events, the Geminids are now one of the strongest annual showers. Recently Phaethon has been observed to

display comet-like activity around perihelion (Jewitt et al. 2013, Li and Jewitt 2013). It is a B-type asteroid making it an easily observable analog to Bennu, the OSIRIS-REx target. Though carbonaceous, it is not as dark as many other carbonaceous asteroids (albedo 0.11). A rotation period of 3.60 h and amplitude of up to 0.34 magnitudes have been measured for this 5 km near-Earth asteroid (Ansdell et al. 2014).

This year, Phaethon is first observable in early to mid-September as moving away from the Sun. Peak brightness will be V = 15.1 in early October. Observable phase angles range from a high of ~120° (depending on how quickly it can be acquired after receding from the bright twilight sky) to a minimum of 32° when it becomes fainter than V = 17.0 in mid-November. Phaethon will be even easier for observation in late 2017 when it peaks at V = 10.7.

DATE	RA	DEC	Δ	r	V	PH	Elong
09/09	10 55	+38 04	0.51	0.64	17.1	121	32
09/19	11 10	+57 42	0.42	0.84	16.0	98	56
09/29	12 38	+79 16	0.40	1.02	15.3	75	81

(154244) 2002 KL6 (a=2.31 AU, e=0.55, i=3.2°, H = 17.4)
2002 KL6 is a Q or Sq type asteroid with a rotation period of 4.6 h and large amplitude of >1 magnitude (Galad et al. 2010, Koehn et al. 2014). It will be bright and observable for many months. It becomes brighter than V = 18 in late April 2016 with a peak brightness of V = 13.7 on July 18 and stays brighter than V = 18 till early November. The phase angle starts at 19° on April 28, reaches a minimum of 6° in late May, a maximum of 68° in early August and another minimum in mid-October at 1°. Color photometry over a large range of phase angles will determine if it experiences phase angle dependent color changes.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	17 09	+06 52	0.11	1.11	14.3	33	142
07/11	17 57	+21 32	0.08	1.07	13.9	45	131
07/21	19 52	+40 48	0.07	1.05	13.8	58	118
07/31	22 51	+47 14	0.08	1.04	14.3	67	108
08/10	00 39	+40 50	0.10	1.05	14.9	68	107
08/20	01 25	+34 05	0.13	1.07	15.4	61	112
08/30	01 44	+28 43	0.17	1.10	15.6	52	121
09/09	01 50	+24 10	0.20	1.15	15.8	41	131
09/19	01 47	+20 05	0.24	1.20	16.0	30	143
09/29	01 40	+16 22	0.28	1.26	16.1	19	156

(357024) 1999 YR14 (a=1.65 AU, e=0.40, i=3.7°, H = 19.1)
Little is known of this near-Earth asteroid. It becomes brighter than V = 18 on July 13. The phase angle increases from 22° on July 25 to 93° at the end of September. Peak brightness is V = 14.9 on August 27. Photometry of all types is encouraged to determine this object's taxonomy, rotation period and phase angles.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	21 15	-29 34	0.37	1.34	18.8	26	145
07/11	21 32	-30 35	0.30	1.28	18.1	24	150
07/21	21 52	-31 46	0.23	1.22	17.4	22	153
07/31	22 19	-32 55	0.17	1.17	16.7	23	154
08/10	23 01	-33 22	0.12	1.12	15.9	26	151
08/20	00 19	-30 26	0.08	1.08	15.2	35	143
08/30	02 36	-15 14	0.06	1.04	15.0	57	121
09/09	04 56	+09 22	0.07	1.01	16.1	84	93
09/19	06 19	+22 22	0.09	1.00	17.3	93	82
09/29	07 07	+27 44	0.13	0.99	17.9	92	81

References

Ansdell, M., Meech, K.J., Hainaut, O., Buie, M.W., Kaluna, H., Bauer, J., Dundon, L. (2014). "Refined Rotational Period, Pole Solution, and Shape Model for (3200) Phaethon". *Astrophysical Journal* **793**, id. 50.

Belskaya, I., Shevchenko, V. (2000). "The Opposition Effect of Asteroids." *Icarus* **147**, 94-105.

Campins, H., Hargrove, K., Pinilla-Alonso, N., Howell, E.S., Kelley, M.S., Licandro, J., Mothé-Diniz, T., Fernández, Y., Ziffer, J. (2010). "Water Ice and Organics on the Surface of the Asteroid 24 Themis". *Nature* **464**, 1320–1321.

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

Hergenrother, C., Hill, D. (2013). "The OSIRIS-REx *Target Asteroids!* Project: A Small Telescope Initiative to Characterize Potential Spacecraft Mission Target Asteroids." *Minor Planet Bulletin* **40**, 164-166.

Jewitt, D., Li, J., Agarwal, J. (2013). "The Dust Tail of Asteroid (3200) Phaethon." *Astrophys. J. L.* **771**, article id. L36.

Koehn, B.W., Bowell, E.G., Skiff, B.A., Sanborn, J.J., McLelland, K.P., Pravec, P., Warner, B.D. (2014). "Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) – 2009 January through 2009 June". *Minor Planet Bulletin* **41**, 286-300.

Li, J., Jewitt, D. (2013). "Recurrent Perihelion Activity in (3200) Phaethon." *Astronomical Journal* **145**, article id. 154.

Rivkin, A.S., Emery, J.P. (2010). "Detection of ice and organics on an asteroidal surface". *Nature* **464**, 1322–132

LIGHTCURVES FOR ASTEROIDS 3998 TEZUKA AND 10399 NISHIHARIMA

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Photometric observations revealed the following lightcurve periods and amplitudes for two main-belt asteroids: 3998 Tezuka, 3.07 ± 0.04 h, 0.43 mag; 10399 Nishiharima, 6.50 ± 0.03 h, 0.24 mag.

We report on photometric measurements of two main-belt asteroids: 3998 Tezuka and 10399 Nishiharima. Observations of 3998 Tezuka were made on 2015 September 4 using a remote iTelescope.net telescope (T17). The details of the telescope and camera are shown in Table I and the observation details are given in Table II. The observations of 10399 Nishiharima were made from 2015 August 22 through September 22. We used iTelescope.net remote internet telescopes T17, T7, T11, T16, T18, and T21, as well as the telescope at Nishi-Harima Astronomical Observatory (NHAO). The details of the telescopes and cameras are shown in Table III and the observation details are given in Table IV.

Name	D(m)	fl(mm)	Camera	Location
T17	0.43	2912	FLI-PLI4710	Siding Spring(AU)

Table I. Tezuka observation equipment list

UT Date	Time	Telescope	Ph	Points	Filter
Sep 04	12:02-16:42	T17	2.4°	74	R

Table II. Tezuka observations list

Name	D(m)	fl(mm)	Camera	Location
T7	0.43	2929	STL-11000M	Nerpio(Spain)
T11	0.51	2280	FLI-PLI11002M	New Mexico(USA)
T16	0.15	1095	STL-11000M	Nerpio(Spain)
T17	0.43	2912	FLI-PLI4710	SidingSpring(AU)
T18	0.318	2541	STXL-6303E	Nerpio(Spain)
T21	0.431	1940	FLI-PL6303E	New Mexico(USA)
NHAO	0.60	7200	STL-1001E	Sayo(JPN)

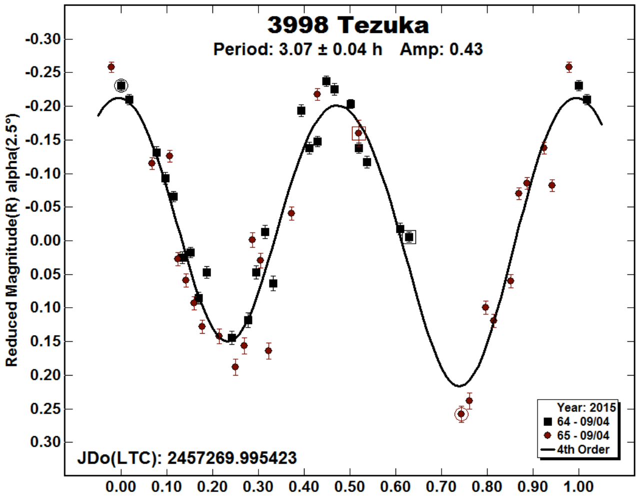
Table III. Nishiharima observation equipment list

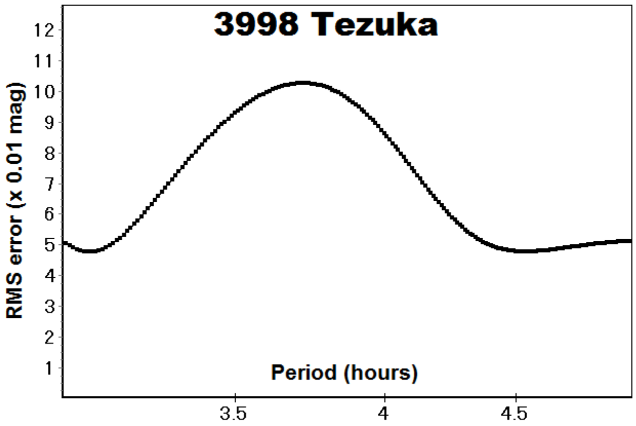
UT Date	Time	Telescope	Ph	Points	Filter
Aug 22	3:33-3:57	T16	9.7°	7	R
Aug 22	13:02-16:58	T17	9.7°	62	R
Aug 22	4:50-8:28	T21	9.7°	13	R
Aug 26	1:20-3:34	T7	7.8°	35	R
Aug 26	8:02-9:57	T11	7.8°	34	R
Aug 26	7:30-7:58	T21	7.8°	9	R
Aug 27	14:03-19:07	T17	7.3°	81	R
Aug 27	22:03-3:03	T18	7.3°	72	R
Sep 9	22:03-2:06	T7	2.5°	46	R
Sep 10	10:51-15:58	T17	2.6°	75	R
Sep 21	9:09-10:55	T17	7.1°	15	R
Sep 21	10:47-17:26	NHAO	7.1°	81	R
Sep 22	9:07-14:36	T17	7.6°	80	R

Table IV. Nishiharima observations list

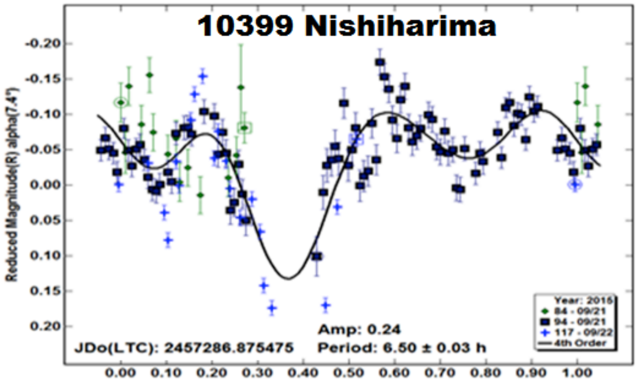
All images were 1x1 binning with a Johnson-Cousins R-band filter. Measurements were made using *MPO Canopus* (Warner, 2011), which employs differential aperture photometry to produce the raw data. Period analysis was also done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989).

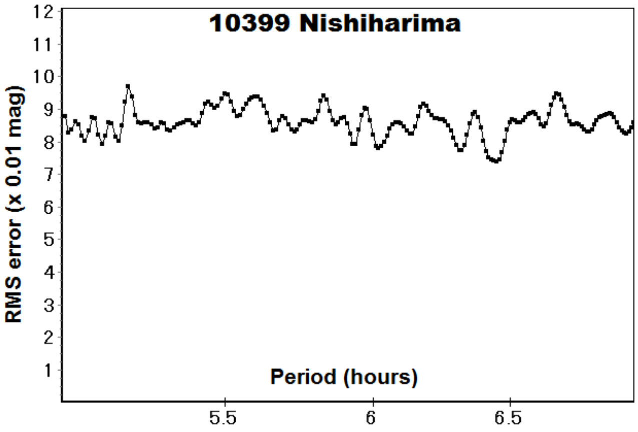
3998 Tezuka. The combined data set consists of 236 data points. We found that the period is 3.07 ± 0.04 h and the amplitude is 0.43 mag. LeCrone *et al.* (2006) reported a period of 3.0789 h. This matched with our result. It was concluded that the rotation period of the main belt asteroid 3998 Tezuka is static.





10399 Nishiharima. The combined data set consists of 446 data points. We found a period of 6.50 ± 0.03 h and amplitude of 0.24 mag. We found no previously reported results, so this appears to be the first set of observations recorded.





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References

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.

LeCrone, C., Duncan, A., Hudson, E., Johnson, J., Mulhihill, A., Reichert, C., Ditteon, R. (2006). "2005-2006 fall observing campaign at Rose-Hulman Institute of Technology." *Minor Planet Bull*. **33**, 66-67.

Warner, B.D. (2011). MPO software. *MPO Canopus* v10.2.1.0. Bdw Publishing. *http//www.MinorPlanetObserver.com/*

MINOR PLANET 1016 ANITRA: A LIKELY ASYNCHRONOUS BINARY

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Analysis of photometry data for 1016 Anitra using a single period analysis shows a lightcurve with a period of 5.9296 hours and amplitude of 0.30 mag, with short period fluctuations. A simultaneous two-period analysis of the data found two smooth bimodal lightcurves with periods and amplitudes of P_1 = 5.92951 h, A_1 = 0.30 mag and P_2 = 2.609143 h, A_2 = 0.10 mag. These results are interpreted as the rotation of the two components of an asynchronous binary system. Four additional attenuations were observed that may have been caused by satellite mutual events, but those data were insufficient to yield an orbital period.

Several previous photometric investigations have been made of 1016 Anitra: Alkema (2013; 5.929 hours), Kryszczynska *et al.* (2012; 5.9288 h), Menke (2005; 5.930 h), Pray *et al.* (2006; 5.928 h), and Schmidt (2016; 5.9301 h). Amplitudes ranged from 0.28 to 0.50 mag. All the published lightcurves showed significant deviations over intervals of about one hour that did not repeat in subsequent 5.93 hour cycles.

Pilcher obtained observations on several nights beginning on 2015 Sep 17 at the Organ Mesa Observatory. These sessions established the presence of two superimposed periods near 5.9295 hours and 2.6091 hours. At Pilcher's request, Benishek and Odden, contributed additional sessions through Dec 31 to further refine the results. The Danish team of Lang, Jacobsen, Kristensen, and Larsen independently obtained observations from 2015 Oct 2 to Dec 7. The two teams agreed to combine their observations. All observers made photometric measurements and calibrations to the MPOSC3 R magnitude system with *MPO Canopus* software. Table I lists the equipment used by the observers.

Obs	Telescope	CCD Camera
Pilcher	0.35-m f/10 SCT	SBIG STL-1001E
Benishek	0.35-m f/6.3 SCT	SBIG ST-8XME
Jacobsen	0.36-m f/7 SCT	Moravian G2-1600
Kristensen	0.28-m f/6.3 SCT	ATIK 428EXM
Lang	0.20-m f/4.5 Newt	ATIK 383L
Larsen	0.30-m f/10 ACF	SBIG ST-8XME
Odden	0.40-m f/8 R-C	Andor Tech iKon DW436 C

Table I. Equipment used by observers. SCT: Schmidt-Cassegrain, Newt: Newtonian reflector; ACF: Meade Advanced Coma Free; R-C: Ritchey-Chretien.

All sessions in the combined data set exhibit the two superimposed periods. Four sessions by Benishek, to be described later, show additional deep attenuations of several hours duration.

This is the first time that the presence of two superimposed periods for 1016 Anitra was recognized. For a system in which the two periods are not very different, Pravec developed software that solves for both periods simultaneously. This is a more accurate and rigorous process than solving for the periods sequentially.

Using the entire data set that ranged from 2015 Sep 17 to Dec 31, we found P_1 = 5.92951 h, A_1 = 0.30 mag and P_2 = 2.609143 h, A_2 = 0.10 mag. The two lightcurve components are strictly additive over a short enough time that they can be considered constant. There is no signal in the linear combination of the two frequencies. The absence of this signal indicates that the asteroid is not "tumbling", *i.e.*, is not in non-principal axis rotation (NPAR).

For most single period asteroids, the synodic period, amplitude, and lightcurve shape change over a large range of phase angles. The same applied for the two components of the lightcurve for 1016 Anitra. These are outlined in Table II.

Separate plots, each covering a subrange of dates, are provided to show the changes of the two components as the phase angle ranged from 18° pre-opposition to 29° post-opposition. In all short interval cases, the lightcurves are very smooth except for the attenuations, showing that the two components have been completely separated.

The existence of two separate periods suggests that 1016 Anitra is a fairly wide binary for which tidal forces have been too weak to synchronize the periods within the lifetime of the binary system. In this case, occultation/transit/shadow mutual events would occur only in the event that the orbital plane is close to the line of sight, making it unlikely that they would be observed. However,

Dates (mm/dd/2015)	P1 (hours)	P1 Err (hours)	Amp1 (mag)	P2 (hours)	P2 Err (hours)	Amp2 (mag)	Phase (deg)
09/17.4 - 10/02.3	5.92943	0.00001	0.30	2.60922	0.000005	0.10	-18 to -11
10/10.9 - 10/19.8	5.9294	0.0001	0.25	2.6091	0.0001	0.09	-07 to -02
10/31.8 - 11/11.8	5.9295	0.0001	0.28	2.60885	0.00005	0.10	+07 to +14
11/12.8 - 11/22.0	5.92960	0.00002	0.33	2.6092	0.0001	0.11	+14 to +19
12/03.8 - 12/31.8	5.9300	0.0001	0.41	2.60934	0.00005	0.12	+23 to +29
09/17.4 - 12/31.8	**5.92951**	**0.00001**	**0.30**	**2.609143**	**0.000005**	**0.10**	**-18 to +29**

Table II The evolution of the synodic periods and amplitudes for the two components of the lightcurve for Anitra. In the last column, a negative value indicates pre-opposition while a positive value indicates post-opposition

Benishek observed four attenuations that are suggestive of mutual events (see Table III).

Date (2015)	Start JD	Dur (d)	Depth (mag)
Nov 4	2457331.35	0.19	0.15
Nov 12	2457339.39	0.03	0.10
Dec 22	2457379.17	0.05	0.15
Dec 28	2457385.24	0.37	0.5

Table III. Details of suspected events observed by Benishek.

Each of these attenuations superficially resembles a satellite mutual event. However, we are unable to see any discernible pattern that might represent the orbital revolution period of the satellite. All comparison stars were checked for variability; none were found. Also, no interfering artifacts could be found on the affected CCD frames that could lead to faults in photometric measurements and produce false attenuations. Therefore, we are confident that the attenuations are intrinsic to the target. We simply report their observational circumstances and leave their confirmation and interpretation to future investigators.

The limited coverage doesn't allow a unique attribution of the events; they may belong to one of the two known bodies or they may belong to a third body in the system. Whichever satellite produced the events, its orbital revolution period is likely on an order of 10 days, but a unique solution is not possible from the available data. Note that there could be as many as four events per orbital period: primary and secondary eclipses and primary and secondary occultations between the primary and the satellite producing the mutual events. If the system is ternary, the lightcurves would be even more complex due to events stemming from the second satellite.

For a fairly wide binary it may be possible to resolve the two components with adaptive optics on a large telescope. Data from such studies would both define the orbit and, with the assumption of equal albedos, the relative sizes of the two components. Pravec and Scheirich (2012) have explained a procedure by which all of these system parameters might be obtained from the Gaia satellite database by basing their argument on the premise that the center of light that determines any astrometric position depends upon the ratio of areas, or squares of the radii, of the two components. The orbital motion of the system barycenter, or center of mass, depends upon the ratio of volumes, or cubes of the radii, of the two components. The center of light therefore describes an elliptical path about the barycenter. The separation of these two centers is greatest when the ratio of diameters Ds/Dp = 0.5, assuming equal densities and albedos. The deviation from pure center of mass motion can be detected with Gaia data. Adaptive optics requires scheduling of telescope time on a large telescope that may be difficult to obtain. The Gaia database is accessible to anyone working in the field, and this study recommends that special attention be given to 1016 Anitra.

We conclude that this is very likely another case of a semi-wide asteroid system with an asynchronous satellite, but we do not have sufficient data to describe it completely.

References

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

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.

Kryszczynska, A., Colas, F., Polinska, M., Hirsch, R., Ivanova, V., Apostolovska, G., Bilkina, B., Velichko, F.P., Kwiatkowski, T., Kankiewicz, P. and 20 coauthors. (2012). "Do Slivan states exist in the Flora family? I. Photometric survey of the Flora region." *Astron. Astrophys.* **546**, A72.

Menke, J.L. (2005). "Lightcurves and Periods for Asteroids 471 Papagena, 675 Ludmilla, 1016 Anitra, 1127 Mimi, 1165 Imprinetta, 1171 Rusthawelia, and 2283 Burke." *Minor Planet Bull.* **32**, 64-66.

Pravec, P., Scheirich, P. (2012). "Small binary asteroids and prospects for their observation with Gaia." *Planet. Space Sci.* **73**, 56-61.

Pray, D.P., Galad, A., Gajdos, S., Vilagi, J., Cooney, W., Gross, J., Terrel, D., Higgins, D., Husarik, M., Kusnirak, P. (2006). "Lightcurve Analysis of Asteroids 53, 698, 1016, 1523, 1950, 4608, 5080, 6170, 7760, 8213, 11271, 14257, 15350 and 17509." *Minor Planet Bull.* **33**, 92-95.

Schmidt, R. (2016). "NIR Minor Planet Photometry from Burleith Observatory, 2015." *Minor Planet Bulletin* **43**, 129-131.

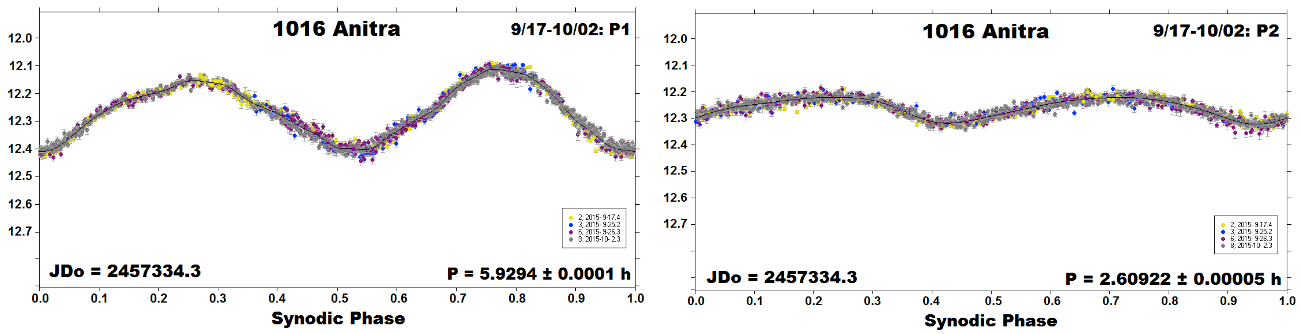

Figure 1. Lightcurves of primary (P1) and secondary (P2) periods for the interval 2015 Sep 17 to Oct 2, phase angles -18 to -11 degrees.

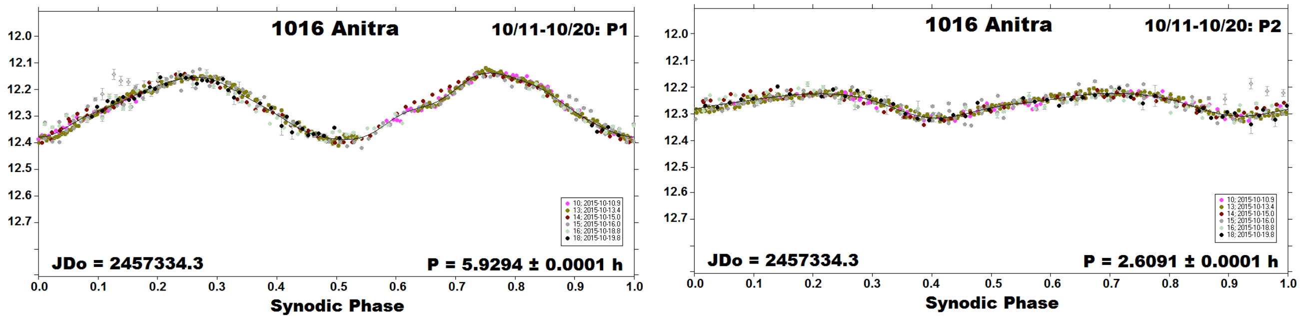

Figure 2. Lightcurves of primary (P1) and secondary (P2) periods for the interval 2015 Oct 11-20, phase angles -7 to -2 degrees.

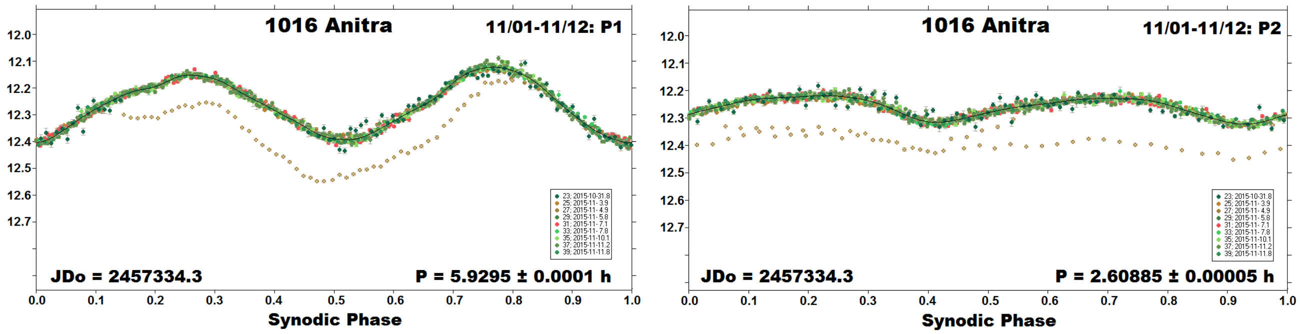

Figure 3. Lightcurves of primary (P1) and secondary (P2) periods for the interval 2015 Nov 1-12, phase angles +7 to +14 degrees.

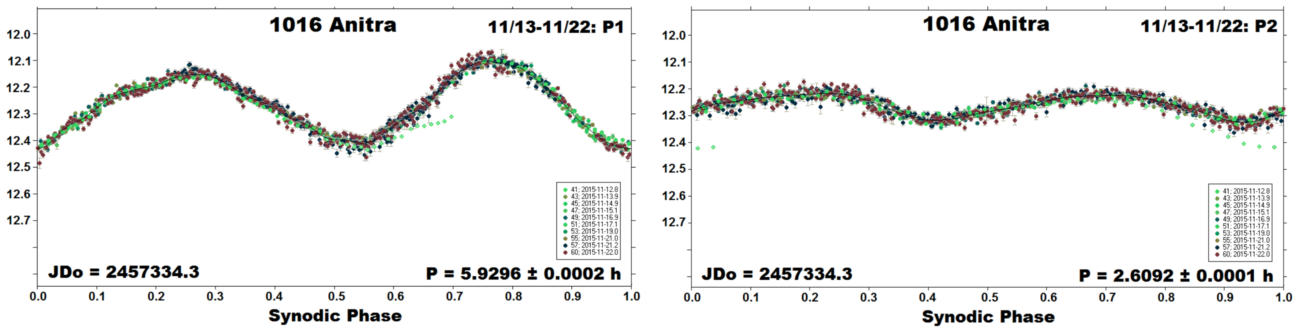

Figure 4. Lightcurves of primary (P1) and secondary (P2) periods for the interval 2015 Nov 13-22, phase angles +14 to +19 degrees.

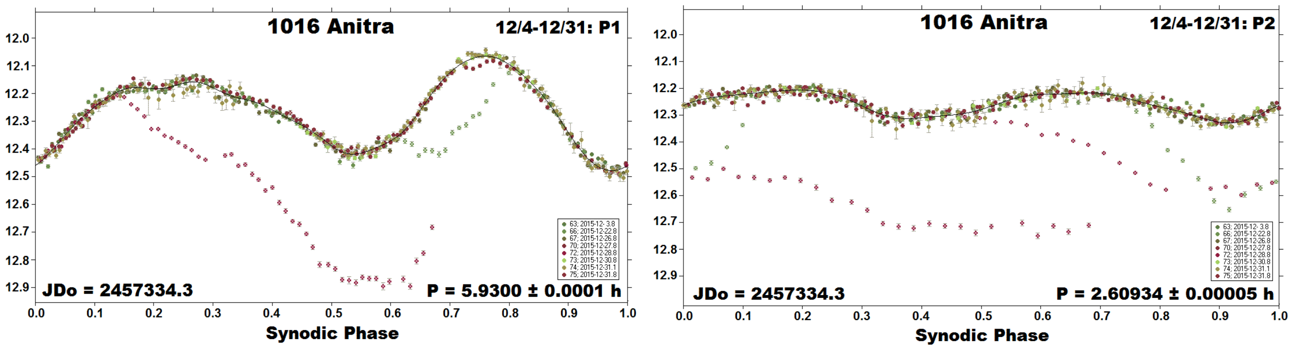

Figure 5. Lightcurves of primary (P1) and secondary (P2) periods for the interval 2015 Dec 4-31, phase angles +23 to +29 degrees.

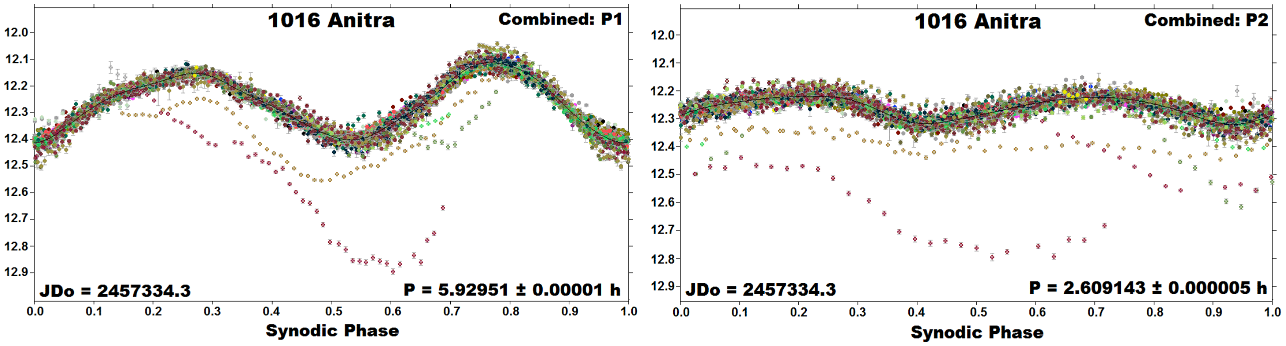

Figure 6. Lightcurve of primary (P1) and secondary (P2) using the combined data set from 2015 Sep 17 to Dec 31.

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2016 JULY-SEPTEMBER

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

We present several lists of asteroids that are prime targets for photometry during the period 2016 July-September.

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

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

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

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

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

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

http://www.minorplanetcenter.net/light_curve

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

Now that many backyard astronomers and small colleges have access to larger telescopes, we have expanded the photometry opportunities and spin axis lists to include asteroids reaching V = 15.5 or a maximum of about 45 objects, whichever comes first.

In both of those lists, a line in *italics text* indicates a near-Earth asteroid (NEA). In the spin axis list, a line in **bold text** indicates a particularly favorable apparition. To keep the number of objects manageable, the opportunities list includes only those objects reaching a particularly favorable apparition, meaning they could all be set in bold text.

Lightcurve/Photometry Opportunities

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

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
20899	2000 XB3	07 02.8	14.7	-30		0.04	
1233	Kobresia	07 04.3	14.3	-24	27.83	0.32-0.34	2
1618	Dawn	07 07.5	14.6	-23	43.19	0.38	2+
3253	Gradie	07 10.2	14.5	-35	6.293	0.54	2
5167	Joeharms	07 10.5	14.8	-50			
3774	Megumi	07 12.2	15.0	-22		0.11	
6916	Lewispearce	07 12.5	14.1	-37	23.4971	0.25	2
1195	Orangia	07 15.6	14.5	-18	6.1667	0.20	2
1622	Chacornac	07 16.2	13.8	-34	12.206	0.24-0.25	2
10374	Etampes	07 19.9	14.6	-10	11.54	0.23-0.35	1
1858	Lobachevskij	07 20.3	14.8	-19	5.413	0.30-0.48	2+
3500	Kobayashi	07 20.7	13.8	-23	5.6064	0.60	2
15286	1991 RJ22	07 20.8	14.7	-20			
12721	1991 PB	07 22.3	14.7	-17			
2614	Torrence	07 23.3	14.7	-24			
1266	Tone	07 24.1	14.0	-28	7.4	0.06-0.12	2
2349	Kurchenko	07 28.0	14.4	-15	8.6219	0.06	2
1288	Santa	08 01.8	14.9	-16	8.28	0.46	2
5661	Hildebrand	08 05.5	14.9	-18	13.61	0.21	2
2536	Kozyrev	08 06.5	13.9	-11	7.188	0.52	2+
20601	1999 RD197	08 06.7	14.9	-16	3.3432	0.18-0.19	2
1361	Leuschneria	08 10.9	14.7	+0	12.0893	0.75	2
4049	Noragal'	08 11.8	14.7	-18	9.2	0.35	2+
2286	Fesenkov	08 13.0	14.4	-17	5.4038	0.23	2
1731	Smuts	08 15.3	14.0	-12	12.5	0.08	2
437	Rhodia	08 17.1	11.8	+1	56.	0.06-0.38	1
2109	Dhotel	08 19.7	13.8	-9	32.	0.3	1
4336	Jasniewicz	08 22.2	15.0	-17			
17770	Baume	08 28.2	14.8	-16	3.26	0.20	2
845	Naema	08 28.6	14.1	-27	20.892	0.16	2
3925	Tret'yakov	08 29.0	14.3	-6			
2281	Biela	08 30.5	14.6	-7	4.9289	0.09	2
2108	Otto Schmidt	08 31.1	15.0	-6	15.24	0.09	1
2451	Dollfus	08 31.4	14.4	-7	48.	0.1	1
11787	Baumanka	09 01.2	14.8	-15			
2264	Sabrina	09 01.9	13.9	-8	43.41	0.30	2
8778	1931 TD3	09 04.4	14.5	-23	3.833	0.51	2
1975	Pikelner	09 04.5	14.9	-6			
8739	Morihisa	09 05.2	15.0	-14			
18284	Tsereteli	09 06.0	15.0	-4			
999	Zachia	09 08.1	13.0	+8	22.77	0.3	2
3283	Skorina	09 09.2	14.7	-7			
5681	Bakulev	09 12.0	14.8	+1			
7295	Brozovic	09 12.0	14.9	-2			
3687	Dzus	09 12.4	14.2	+18	7.44	0.1	1
1945	Wesselink	09 15.7	14.8	-6	3.5457	0.45	2
23587	Abukumado	09 21.1	14.7	+0			
1055	Tynka	09 23.9	13.1	-5	11.893	0.06-0.33	2
319	Leona	09 27.0	13.7	+2	9.6	0.03-0.10	1

Low Phase Angle Opportunities

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

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

to get more details about a specific asteroid.

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

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

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

Num	Name	Date	α	V	Dec	Period	Amp	U
462	Eriphyla	07 04.4	0.17	12.7	-23	8.64	0.11-0.39	3
980	Anacostia	07 10.9	0.64	10.7	-21	20.117	0.05-0.21	3
44	Nysa	07 15.2	0.68	10.6	-20	6.422	0.20-0.55	3
868	Lova	07 19.4	0.17	13.7	-21	41.3	0.40	2
111	Ate	07 21.7	0.33	11.7	-21	22.072	0.08-0.13	3
64	Angelina	07 25.1	0.10	11.6	-20	8.752	0.04-0.42	3
122	Gerda	07 26.5	0.59	12.4	-17	10.685	0.10-0.26	3
740	Cantabia	07 28.4	0.81	13.6	-21	64.453	0.16	3
184	Dejopeja	07 29.7	0.23	12.8	-19	6.455	0.25-0.30	3
20	Massalia	08 01.3	0.42	9.9	-17	8.098	0.15-0.27	3
226	Weringia	08 06.2	0.28	12.0	-16	11.147	0.08-0.38	3
159	Aemilia	08 09.1	0.12	12.7	-16	24.476	0.17-0.26	3
1251	Hedera	08 09.8	0.27	13.1	-15	19.900	0.41-0.61	3-
24	Themis	08 16.1	0.29	11.9	-15	8.374	0.09-0.14	3
1098	Hakone	08 17.5	0.65	13.7	-15	7.142	0.35-0.40	3
208	Lacrimosa	08 18.0	0.58	12.8	-15	14.085	0.15-0.33	3
4613	Mamoru	08 19.4	0.25	13.9	-13	5.388	0.41	3
1682	Karel	08 20.9	0.21	13.6	-12	3.375	0.27-0.47	3
949	Hel	08 21.5	0.66	14.0	-10	10.862	0.12-0.14	2
227	Philosophia	08 23.4	0.34	13.2	-10	52.98	0.06-0.20	2
149	Medusa	08 24.0	0.13	12.7	-11	26.023	0.47-0.56	3
2264	Sabrina	09 01.9	0.12	13.8	-08	43.41	0.30	2
167	Urda	09 11.1	0.08	12.6	-05	13.07	0.24-0.39	3
388	Charybdis	09 11.6	0.35	12.2	-05	9.516	0.14-0.25	3
385	Ilmatar	09 11.7	0.46	11.8	-03	62.35	0.50	3
1084	Tamariwa	09 14.2	0.72	13.7	-02	6.196	0.25-0.42	3
73	Klytia	09 19.2	0.28	12.1	-02	8.297	0.26-0.35	3
114	Kassandra	09 21.5	0.63	12.3	-02	10.743	0.12-0.25	3
298	Baptistina	09 24.8	0.50	13.9	+00	16.23	0.10-0.25	3
319	Leona	09 27.0	0.09	13.7	+02	9.6	0.03-0.10	1

Shape/Spin Modeling Opportunities

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

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

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

Included in the list below are objects that:

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

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

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
658	Asteria	07 01.7	14.5	-25	21.034	0.22-0.32	3
53	Kalypso	07 02.0	13.2	-18	9.036	0.09-0.14	3
643	Scheherezade	07 04.3	14.8	-13	14.161	0.23-0.36	3
1100	**Arnica**	**07 07.9**	**14.3**	**-23**	**14.535**	**0.13-0.28**	**3**
980	**Anacostia**	**07 11.1**	**10.7**	**-21**	**20.117**	**0.05-0.21**	**3**
359	Georgia	07 14.8	12.0	-33	5.537	0.15-0.54	3
217	**Eudora**	**07 15.3**	**12.0**	**-6**	**25.272**	**0.08-0.31**	**3**
1499	**Pori**	**07 17.4**	**14.0**	**-3**	**3.36**	**0.11-0.28**	**3**
607	Jenny	07 20.4	13.6	-17	8.521	0.17-0.26	3
111	Ate	07 21.7	11.7	-21	22.072	0.08-0.13	3
1107	Lictoria	07 26.8	14.4	-21	8.5616	0.16-0.30	3
2189	**Zaragoza**	**07 26.9**	**14.3**	**-17**	**4.9281**	**0.17-0.27**	**3**
779	**Nina**	**07 28.0**	**10.1**	**-9**	**11.186**	**0.06-0.32**	**3**
1817	Katanga	07 28.7	14.2	-45	8.481	0.22-0.42	3
326	Tamara	07 29.6	12.1	-59	14.445	0.10-0.27	3
59	Elpis	07 30.8	11.4	-9	13.69	0.10-0.23	3
2346	Lilio	08 01.3	14.3	-8	3.029	0.20-0.31	3
558	Carmen	08 02.2	13.1	-15	11.387	0.20-0.31	3
295	Theresia	08 05.0	14.0	-15	10.73	0.11-0.22	3-
2144	Marietta	08 05.8	14.8	-16	5.489	0.40-0.44	3-
1293	**Sonja**	**08 07.4**	**14.3**	**-4**	**2.878**	**0.14-0.21**	**3**
151	Abundantia	08 08.1	12.7	-26	9.864	0.03-0.20	3
608	**Adolfine**	**08 08.3**	**14.4**	**-11**	**8.3458**	**0.16-0.37**	**3**
159	Aemilia	08 09.1	12.7	-16	24.476	0.17-0.26	3
535	Montague	08 09.4	12.8	-24	10.2482	0.18-0.25	3
300	Geraldina	08 10.4	13.9	-16	6.8423	0.15-0.32	3
1754	**Cunningham**	**08 10.7**	**14.6**	**-8**	**7.7416**	**0.08-0.17**	**3**
14465	**1993 NB**	**08 12.6**	**14.1**	**-20**	**4.9703**	**0.49-0.69**	**3**
1443	**Ruppina**	**08 14.4**	**14.5**	**-13**	**5.88**	**0.34-0.35**	**3**
696	Leonora	08 21.8	13.2	-3	26.8964	0.04-0.31	3
1116	Catriona	08 22.8	14.1	-24	8.832	0.09-0.20	3
1028	Lydina	08 26.6	14.5	-23	11.68	0.22-0.70	3
663	Gerlinde	08 26.7	14.4	+13	10.251	0.19-0.35	3
4132	Bartok	08 29.4	14.9	+3	3.297	0.32-0.41	3
1675	Simonida	08 29.7	14.5	-19	5.2885	0.16-0.65	3
775	Lumiere	09 01.3	14.6	+0	6.103	0.19-0.28	3
420	Bertholda	09 04.2	13.3	+1	11.04	0.24-0.29	3
1113	Katja	09 06.2	13.6	+0	18.465	0.08-0.17	3
3105	**Stumpff**	**09 11.3**	**14.0**	**-10**	**5.0369**	**0.32-0.37**	**3**
388	**Charybdis**	**09 11.6**	**12.2**	**-5**	**9.516**	**0.14-0.25**	**3**
67	**Asia**	**09 12.9**	**10.3**	**+2**	**15.853**	**0.15-0.26**	**3**
1084	Tamariwa	09 14.1	13.7	-2	6.1961	0.25-0.42	3
145	Adeona	09 15.9	12.3	-21	15.071	0.04-0.15	3
909	Ulla	09 16.6	13.7	-14	8.73	0.08-0.24	3
653	Berenike	09 16.7	13.7	-12	12.4886	0.03-0.11	3
191	**Kolga**	**09 20.6**	**12.5**	**-6**	**17.604**	**0.21-0.40**	**3**
114	Kassandra	09 21.5	12.3	-2	10.7431	0.12-0.25	3
1848	Delvaux	09 24.7	14.7	+2	3.637	0.57-0.68	3
298	Baptistina	09 24.8	13.9	+0	16.23	0.10-0.25	3
1046	Edwin	09 25.6	14.4	-1	5.2906	0.14-0.27	3

Radar-Optical Opportunities

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

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

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

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

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

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

http://www.minorplanetcenter.net/iau/rss/mpc_feeds.html

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

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

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

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

About YORP Acceleration

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

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

Name	Grp	Period	App	Last	Bin	R SNR
2002 KL6	NEA	4.610	1	2009	N	**354**
2010 NY65	NEA	-	-	-	-	**62**
2005 ND7	NEA	-	-	-	-	8
2009 YG	NEA	-	-	-	-	24
Eger	NEA	5.7509	6	2014	N	177
2002 NW16	NEA	-	-	-	-	12
1997 WU22	NEA	9.345	3	2013	N	14
1999 YR14	NEA	-	-	-	-	996
Cacus	NEA	3.7538	4	2009	N	18

Table I. Summary of radar-optical opportunities in 2016 Jul-Sep. Data from the asteroid lightcurve database (Warner *et al.*, 2009; *Icarus* **202**, 134-146).

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

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

The estimate in Table I is based on using the Arecibo radar, the current MPCORB absolute magnitude (*H*), a period of 3.0 hours if it's not known, and the approximate minimum Earth distance while the asteroid is within the declination limits of Arecibo.

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

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

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

(154244) 2002 KL6 (Jul-Aug, *H* = 17.5)

The period for this 940 meter NEA was found to be about 4.61 h during the last favorable apparition in 2009 (Galad *et al.*, 2010, *MPB* **37**, 9-15; Koehn *et al.*, 2014, *MPB* **41**, 286-300). A point of interest is that Thomas *et al*. (2014, *Icarus* **228**, 217-246) classified this as a type Q (between a V and S type). This is a very rare type with one of the few others being 1862 Apollo.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	17 09.4	+06 53	0.11	1.11	14.3	33.8	143	147	-0.16	+26
07/06	17 28.2	+13 21	0.10	1.09	14.1	39.2	137	128	+0.03	+24
07/11	17 57.4	+21 33	0.08	1.07	13.9	45.0	132	82	+0.41	+21
07/16	18 43.1	+31 18	0.07	1.06	13.7	51.3	125	58	+0.85	+15
07/21	19 52.6	+40 50	0.07	1.05	13.8	58.0	119	57	-0.99	+7
07/26	21 23.4	+46 42	0.07	1.04	14.0	64.0	112	66	-0.61	-3
07/31	22 51.7	+47 15	0.08	1.04	14.3	67.7	108	89	-0.10	-11
08/05	23 57.0	+44 32	0.09	1.04	14.7	68.7	107	125	+0.05	-17
08/10	00 39.8	+40 51	0.10	1.05	14.9	67.5	107	141	+0.43	-22
08/15	01 07.5	+37 17	0.12	1.06	15.2	64.9	109	106	+0.87	-25

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

With an estimated diameter of 150 meters, this NEA is a super-fast rotator candidate. In such cases and the rotation period is not known – as in this case, keep the exposures as short a possible until there is a sense of the rotation period. To avoid what's called *rotational smearing*, exposures should be Exp < 0.187*Period (see Pravec *et al.*, 2000, *Icarus* **147**, 477-486).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/25	11 59.1	+37 57	0.03	1.01	17.7	105.7	73	142	-0.79	+75
06/26	13 10.2	+35 54	0.03	1.01	17.2	92.3	86	137	-0.69	+80
06/27	14 04.9	+32 21	0.03	1.02	17.0	81.3	97	136	-0.59	+73
06/28	14 44.2	+28 37	0.04	1.03	17.0	72.7	105	137	-0.47	+65
06/29	15 12.2	+25 18	0.04	1.03	17.1	66.3	111	140	-0.36	+58
06/30	15 32.8	+22 32	0.05	1.04	17.3	61.4	116	144	-0.25	+53
07/01	15 48.3	+20 15	0.06	1.05	17.4	57.7	120	145	-0.16	+49
07/02	16 00.3	+18 22	0.06	1.05	17.6	54.8	122	144	-0.08	+46
07/03	16 09.8	+16 48	0.07	1.06	17.8	52.5	124	140	-0.03	+43
07/04	16 17.6	+15 29	0.08	1.06	17.9	50.7	126	133	+0.00	+41

(363814) 2005 ND7 (Jul, *H* = 17.8)

The period is unknown. While a radar SNR < 10 is projected, this is too good a photometry opportunity to miss. Assuming a typical albedo for NEAs of $p_v = 0.2$, the estimated diameter is 800 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	19 45.0	+10 38	0.34	1.31	17.3	28.1	143	111	-0.16	-7
07/03	19 40.1	+07 33	0.32	1.29	17.0	25.3	147	138	-0.03	-7
07/05	19 34.3	+03 52	0.29	1.28	16.7	22.0	152	158	+0.01	-8
07/07	19 27.5	-00 32	0.27	1.27	16.4	18.0	157	150	+0.08	-8
07/09	19 19.4	-05 47	0.25	1.26	16.0	13.4	163	126	+0.22	-9
07/11	19 09.8	-11 54	0.23	1.24	15.7	8.6	169	99	+0.41	-9
07/13	18 58.3	-18 54	0.22	1.23	15.4	6.6	172	72	+0.59	-10
07/15	18 44.5	-26 37	0.21	1.22	15.5	11.0	167	45	+0.77	-10
07/17	18 27.7	-34 42	0.20	1.21	15.7	18.3	158	23	+0.91	-11
07/19	18 07.2	-42 41	0.21	1.20	15.9	26.2	149	27	+0.99	-11

(359369) 2009 YG (Jul-Aug, *H* = 18.5)

The period is unknown for this 600 meter NEA. Observations at high phase angles may produce unexpected lightcurve shapes and amplitudes due to shadowing effects. If you follow the object over a week or more, you should probably split the data set into subsets where the phase angle does not change by more than 15°.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/20	13 13.2	+03 07	0.17	1.00	17.9	91.7	78	102	-1.00	+65
07/22	13 48.0	-00 41	0.17	1.02	17.7	84.3	86	119	-0.95	+59
07/24	14 22.5	-04 26	0.18	1.04	17.5	76.8	93	137	-0.81	+52
07/26	14 55.7	-07 54	0.18	1.06	17.4	69.8	101	156	-0.61	+44
07/28	15 26.3	-10 54	0.19	1.09	17.4	63.5	107	176	-0.38	+37
07/30	15 53.8	-13 24	0.21	1.11	17.4	58.0	112	162	-0.18	+30
08/01	16 18.2	-15 25	0.23	1.13	17.5	53.4	116	140	-0.04	+24
08/03	16 39.5	-17 00	0.24	1.16	17.6	49.7	120	118	+0.00	+19
08/05	16 58.2	-18 15	0.27	1.18	17.7	46.6	122	97	+0.05	+15
08/07	17 14.5	-19 13	0.29	1.20	17.9	44.1	124	76	+0.17	+11

3103 Eger (Jul-Sep, *H* = 14.3)

The period is 5.710156 ± 0.000007 h – as of JD 24446617.0. Durech *et al.* (2012, *A&A* **547**:A10) reported a YORP-induced change of +4.2 ms/year, *i.e.*, the asteroid is slowing down. Additional observations can help confirm and/or improve this result.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	22 22.0	+10 35	0.38	1.23	15.5	47.7	116	74	-0.16	-38
07/11	23 08.7	+08 35	0.29	1.18	14.9	50.6	117	158	+0.41	-46
07/21	00 18.3	+03 24	0.23	1.12	14.4	56.4	113	54	-0.99	-58
07/31	01 58.5	-05 58	0.19	1.07	14.3	67.9	102	66	-0.10	-64
08/10	03 50.3	-15 29	0.20	1.02	14.8	81.5	87	148	+0.43	-47
08/20	05 19.2	-20 23	0.25	0.98	15.5	89.9	76	88	-0.97	-29
08/30	06 20.0	-21 50	0.31	0.95	16.0	92.5	70	51	-0.06	-16
09/09	07 03.4	-21 42	0.38	0.92	16.4	91.6	66	128	+0.46	-7
09/19	07 37.6	-20 51	0.45	0.91	16.6	88.8	65	91	-0.93	+0
09/29	08 07.1	-19 41	0.51	0.91	16.7	85.1	65	50	-0.04	+7

(452389) 2002 NW16 (Jul-Sep, *H* = 18.0)

The estimated size of 2002 NW16 is 750 meters. The period is unknown. The best time to observe the asteroid will be when it's well away from the galactic plane, *i.e.*, most of July.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	00 19.1	-10 06	0.24	1.08	17.5	68.4	99	52	-0.16	-71
07/11	00 28.9	+01 31	0.22	1.08	17.2	66.8	102	179	+0.41	-61
07/21	00 35.4	+14 25	0.21	1.09	17.1	64.9	104	62	-0.99	-48
07/31	00 37.6	+27 50	0.20	1.09	17.0	63.1	107	75	-0.10	-35
08/10	00 33.7	+40 36	0.21	1.09	17.0	61.6	108	140	+0.43	-22
08/20	00 21.3	+51 37	0.21	1.10	17.0	60.6	109	58	-0.97	-11
08/30	23 56.7	+60 09	0.23	1.10	17.1	59.8	109	95	-0.06	-2
09/09	23 18.1	+65 48	0.24	1.11	17.3	59.2	109	109	+0.46	+5
09/19	22 31.3	+68 32	0.26	1.11	17.4	58.6	109	69	-0.93	+9
09/29	21 49.7	+68 47	0.27	1.12	17.5	57.9	109	104	-0.04	+11

(16834) 1997 WU22 (Jul-Sep, *H* = 15.6)

The period for this 1.75 km NEA is 9.345 h. Several reported albedos average p_v ~ 0.4, which is double the usual estimated albedo and is more consistent with type E asteroids (Warner *et al.*, 2009, *Icarus* **202**, 134-146).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	10 11.9	+09 57	0.37	0.84	17.1	107.8	52	98	-0.16	+49
07/11	11 12.8	+16 14	0.30	0.88	16.8	109.3	55	26	+0.41	+65
07/21	12 36.0	+24 20	0.26	0.93	16.3	102.9	63	127	-0.99	+86
07/31	14 19.7	+30 36	0.25	0.99	15.7	89.5	76	107	-0.10	+70
08/10	15 59.8	+31 42	0.28	1.05	15.5	74.6	90	47	+0.43	+49
08/20	17 16.3	+29 07	0.33	1.12	15.7	62.7	101	93	-0.97	+32
08/30	18 10.8	+25 18	0.40	1.19	15.9	54.1	107	125	-0.06	+20
09/09	18 51.5	+21 27	0.47	1.26	16.3	48.2	111	50	+0.46	+10
09/19	19 24.1	+18 00	0.56	1.33	16.7	44.3	113	93	-0.93	+1
09/29	19 52.0	+15 04	0.66	1.39	17.1	41.7	112	129	-0.04	-6

(357024) 1999 YR14 (Jul-Sep, *H* = 19.1)

The period is unknown for the 450-meter 1999 YR14. The ephemeris service on the Minor Planet Center site gives a maximum sky motion of about 12 arcsec/min at the first of September. Given the magnitude at the time, it should be possible to get good SNRs without the asteroid trailing.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	21 16.0	-29 35	0.37	1.34	18.8	26.0	145	99	-0.16	-43
07/11	21 32.9	-30 35	0.30	1.28	18.1	23.7	150	127	+0.41	-47
07/21	21 52.6	-31 46	0.23	1.22	17.4	22.2	153	22	-0.99	-51
07/31	22 19.2	-32 55	0.17	1.17	16.7	22.6	154	122	-0.10	-57
08/10	23 01.5	-33 23	0.12	1.12	15.9	26.0	151	113	+0.43	-66
08/20	00 19.9	-30 27	0.08	1.08	15.2	34.9	143	29	-0.97	-82
08/30	02 37.1	-15 15	0.06	1.04	15.0	56.8	121	95	-0.06	-63
09/09	04 56.5	+09 22	0.06	1.01	16.1	83.8	93	172	+0.46	-20
09/19	06 19.9	+22 22	0.09	1.00	17.3	93.0	82	68	-0.93	+3
09/29	07 07.8	+27 44	0.13	0.99	17.9	91.5	81	59	-0.04	+16

161989 Cacus (Aug-Oct, *H* = 17.1)

The period is 3.7538 h, but that was determined more than a decade ago (Pravec *et al.*, 2003). The minimum reported amplitude is *A* = 0.8 mag, indicating a highly-elongated shape. Here again, high phase angles may make for unusual lightcurves. Even large amplitudes at such phase angles don't necessarily assure a bimodal lightcurve. More than once, a monomodal lightcurve proved correct after confirming data from radar were obtained.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
08/20	14 39.7	+25 55	0.34	0.93	17.9	93.4	67	128	-0.97	+66
08/25	15 03.8	+20 17	0.30	0.95	17.7	93.0	70	142	-0.52	+59
08/30	15 29.8	+13 12	0.28	0.96	17.5	91.7	72	98	-0.06	+51
09/04	15 57.8	+04 37	0.26	0.98	17.2	89.3	76	48	+0.07	+40
09/09	16 28.2	-05 10	0.24	0.99	17.0	85.9	80	12	+0.46	+29
09/14	17 01.1	-15 21	0.24	1.01	16.9	81.8	84	59	+0.90	+16
09/19	17 36.0	-24 54	0.25	1.03	16.9	77.4	88	122	-0.93	+4
09/24	18 12.6	-32 56	0.27	1.05	16.9	73.4	92	164	-0.43	-7
09/29	18 49.7	-39 08	0.30	1.06	17.1	70.0	94	115	-0.04	-16
10/04	19 26.3	-43 33	0.33	1.08	17.2	67.0	95	67	+0.08	-24

IN THIS ISSUE

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

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The deadline for the next issue (43-4) is July 15, 2016. The deadline for issue 44-1 is October 15, 2016.