THE MINOR PLANET BULLETIN

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

VOLUME 42, NUMBER 2, A.D. 2015 APRIL-JUNE

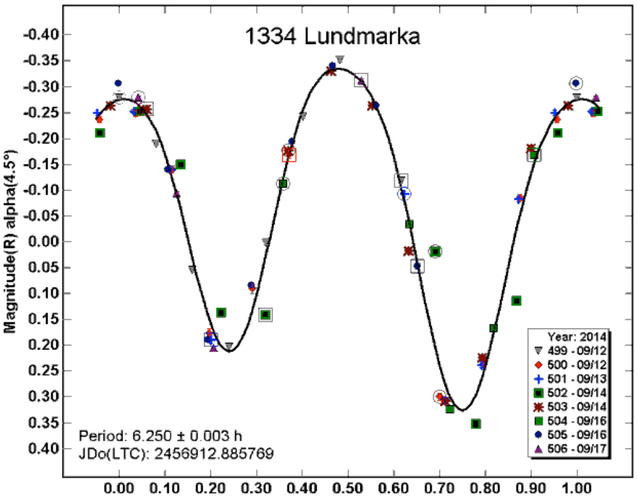
ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2014 SEPTEMBER

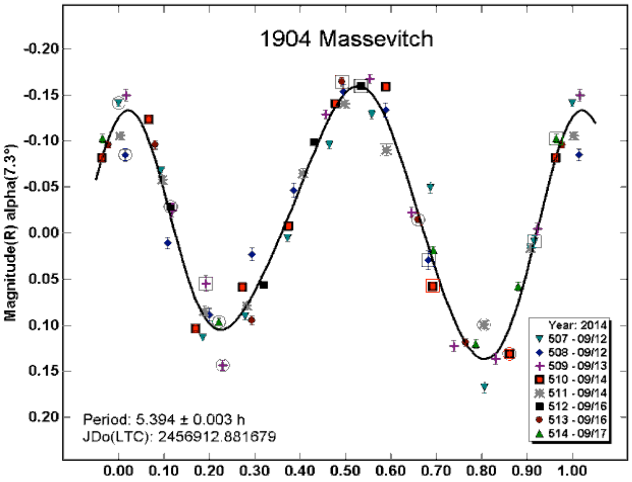
Lucas Bohn, Brianna Hibbler, Gregory Stein, Richard Ditteon
Rose-Hulman Institute of Technology, CM 171
5500 Wabash Avenue, Terre Haute, IN 47803, USA
ditteon@rose-hulman.edu

(Received: 24 November)

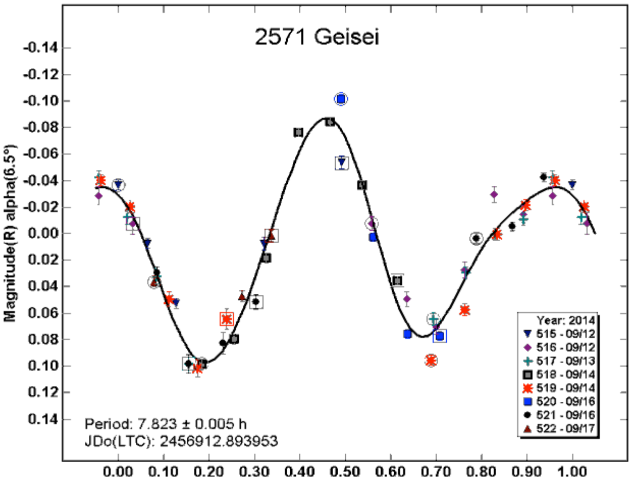
Photometric data were collected over the course of seven nights in 2014 September for eight asteroids: 1334 Lundmarka, 1904 Massevitch, 2571 Geisei, 2699 Kalinin, 3197 Weissman, 7837 Mutsumi, 14927 Satoshi, and (29769) 1999 CE28.

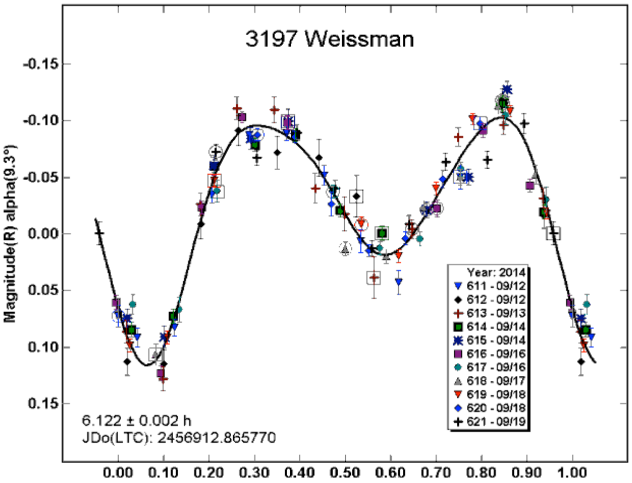
Eight asteroids were remotely observed from the Oakley Southern Sky Observatory in New South Wales, Australia. The observations were made on 2014 September 12-14, 16-19 using a 0.50-m *f*/8.3 Ritchey-Chretien optical tube assembly on a Paramount ME mount and SBIG STX-16803 CCD camera, binned 3x3, with a luminance filter. Exposure times ranged from 90 to 180 sec depending on the magnitude of the target. The resulting image scale was 1.34 arcseconds per pixel. Raw images were processed in *MaxIm DL* 6 using twilight flats, bias, and dark frames. *MPO Canopus* was used to measure the processed images and produce lightcurves. In order to maximize the potential for data collection, target asteroids were selected based upon their position in the sky approximately one hour after sunset. Only asteroids with no previously published results were targeted. Lightcurves were produced for 1334 Lundmarka, 1904 Massevitch, 2571 Geisei, 3197 Weissman, and (29769) 1999 CE28. Data for 2699 Kalinin, 7837 Mutsumi, and 14927 Satoshi were insufficient for us to determine rotation periods and reasonable lightcurves; for these asteroids, only magnitude variations are reported.

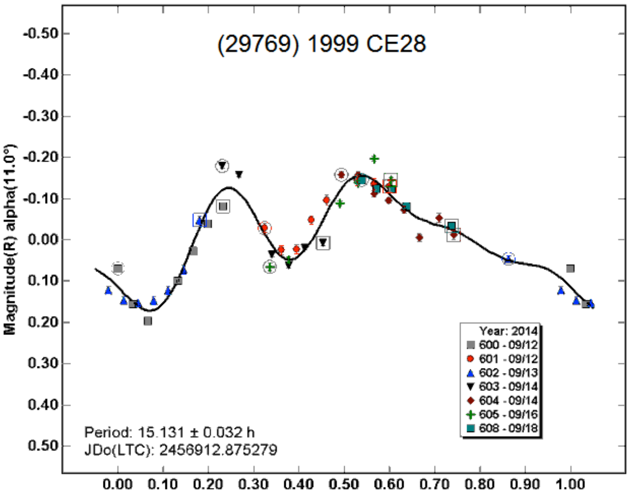




Number	Name	Dates (2014/09/DD)	Data Points	Period (h)	P.E. (h)	Amp (mag)	A.E. (mag)
1334	Lundmarka	12-14, 16-17	55	6.250	0.003	0.70	0.03
1904	Massevitch	12-14, 16-17	61	5.394	0.003	0.30	0.04
2571	Geisei	12-14, 16-17	54	7.823	0.005	0.20	0.04
2699	Kalinin	12-14, 16-19	112			0.40	0.08
3197	Weissman	12-14, 16-19	99	6.122	0.002	0.25	0.03
7837	Mutsumi	12-14, 16-19	94			0.2	0.1
14927	Satoshi	12-14, 16-19	90			0.5	0.1
29769	1999 CE28	12-14, 16, 18	48	15.131	0.03	0.35	0.04







ROTATION PERIOD DETERMINATION FOR 1110 JAROSLAWA

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

Andrea Ferrero
Bigmuskie Observatory
via Italo Aresca 12, 14047 Mombercelli, Asti, ITALY

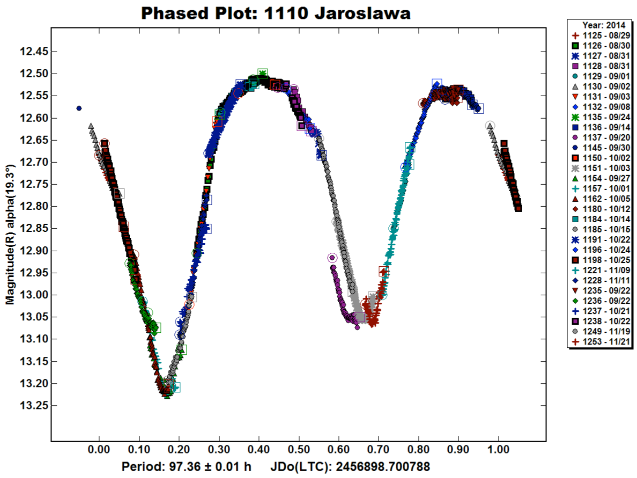
Daniel A. Klinglesmith III, Jesse Hanowell
New Mexico Institute of Mining and Technology
Etscorn Campus Observatory
801 Leroy Place
Socorro, NM 87801 USA

(Received: 7 December)

On the basis of more than two months of photometric observations we find for 1110 Jaroslawa synodic rotation period near 97.4 hours and amplitude near 0.65 magnitudes. We find evidence of changes in amplitude and synodic period with changing phase angle and phase angle bisector, but were not able to obtain sufficient observations to document these completely.

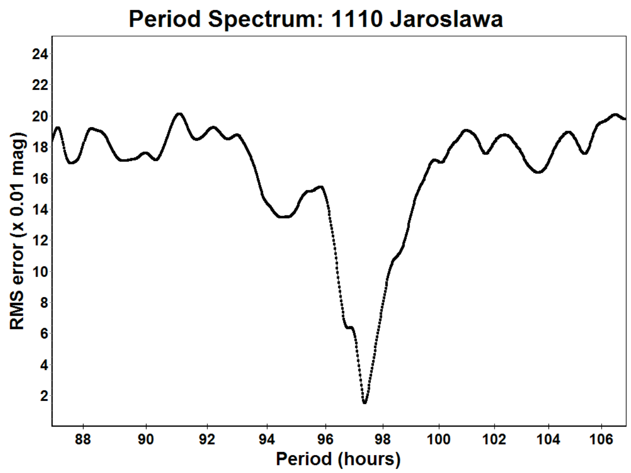
Four observers, Andrea Ferrero, Jesse Hanowell, Daniel Klinglesmith III, and Frederick Pilcher all contributed lightcurves with clear or R filters. Their telescopes and CCDs are: Ferrero, 30 cm Ritchey-Chretien, SBIG ST9; Klinglesmith and Hanowell, Celestron 35 cm f/11 Schmidt-Cassegrain, SBIG STL-1001E; Pilcher, 35 cm Meade Schmidt-Cassegrain, SBIG STL-1001E. A total of 31 sessions by these observers are included in the present study. Six other contributed sessions have not been used because they duplicated other sessions or had large internal misfits that might be related to the meridian flip of the German equatorial mounting.

Previous period determinations are by Behrend (2004), 80 hours; Clark (2007), 9.41 hours; and Clark (2013), 94.432 hours. The new observations 2014 Aug. 29 – Nov. 21 clearly define a period 97.36 ± 0.01 hours with amplitude 0.65 ± 0.05 magnitudes. That this period is definitive is shown on our presented period spectrum from 87 hours to 107 hours. The observations include a range of phase angles from 19 degrees Aug. 29 to a minimum of 6 degrees Sept. 27 to 27 degrees Nov. 21. For most asteroids the amplitude increases with increasing phase angle, and this behavior can be seen by careful examination of the lightcurve. For sessions on the steeply ascending or descending segments at the same lightcurve phase at different phase angles different slopes can be seen by careful inspection. All calibration magnitudes were converted to their Sloan r' values in the CMC15 catalog (VizieR, 2014) and then converted to their values in the Cousins R system by R = r' - 0.22 (Dymock and Miles, 2009). The internal consistency of CMC15 r' catalog magnitudes is usually better than 0.05 magnitudes. Due partly to differences introduced by the different light paths and CCD detectors of the several telescopes and CCDs, but largely to changes in lightcurve shape caused by the changing phase angles and phase angle bisectors, it was necessary to adjust magnitudes of some sessions up or down by as much as 0.1 magnitude to provide the best fit presented by our accompanying lightcurve. Data points have been binned in groups of 5 separated by no more than 10 minutes to reduce their number and make the lightcurve easier to inspect. While we claim our rotation period is secure, we accept that our amplitude of 0.65 magnitudes is poorly determined, perhaps by more than 0.05 magnitudes.



Although they are ignored in many investigations, appreciable changes in synodic period frequently do occur with changing phase angle bisector. These show clearly on our lightcurve near phase 0.67 where no single period can link the minima observed on Sept. 20, Oct. 3, and Nov. 21. A period of 98.5 hours is found when only the two sessions of Sept. 20 and Oct. 3 are included, and a period of 97.5 hours is found for the two sessions of Oct. 3 and Nov. 21. The former, since it covers a short time interval of only 13 days, we consider to be less accurate. Again we were not able to obtain enough observations to fully document these changes. They indicate, however, that while the rotation period found including all sessions may still be considered secure, it is not highly accurate. We suggest that a period of 97.4 hours and error ± 0.3 hours is a conservative representation of our results.

Our period of 97.4 hours is inconsistent with, and rules out, all previous period determinations. In particular a period of 97.4 hours is slightly greater than 4 Earth days and the rotational phase observed from a single station at intervals of four days or a multiple thereof circulates slowly to the left. This leftward circulation is clearly seen with all data sets from each station. For the 94.432 hour period by Clark (2013), the analogous circulation would be slowly to the right. Our new observations have falsified an assumption of any period slightly less than 4 Earth days.



Acknowledgment

The authors thank Petr Pravec for analyzing our data and finding no evidence of tumbling.

References

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

Clark, M. (2007). “Lightcurve Results for 1318 Nerina, 2222 Lermontov, 3015 Candy, 3089 Oujianquan, 3155 Lee, 6410 Fujiwara, 6500 Kodaira, (8290) 1992 NP, 9566 Rykhlova, (42923) 1999 SR18, and 2001 FY.” *Minor Planet Bull.* **34**, 19-22.

Clark, M. (2013). “Lightcurve Analysis of 1110 Jaroslawa and 13643 Takushi.” *Minor Planet Bull.* **40**, 11-12.

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

VizieR (2014). *http://vizier.u-strasbg.fr/viz-bin/VizieR.*

ROTATION PERIOD DETERMINATIONS FOR 254 AUGUSTA, 465 ALEKTO, 477 ITALIA, 515 ATHALIA, AND 1061 PAEONIA

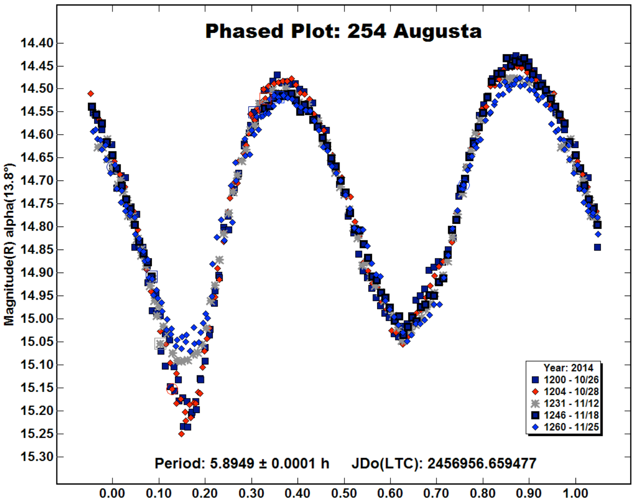
Frederick Pilcher
4438 Organ Mesa Loop
Las Cruces, New Mexico 88011 USA
fpilcher35@gmail.com

(Received: 30 December)

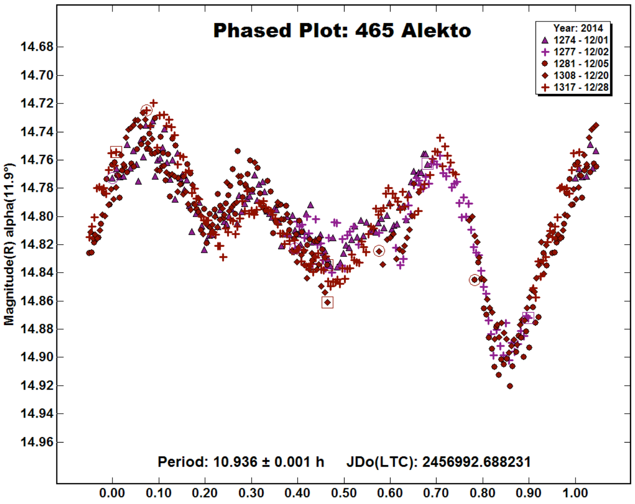
Synodic rotation periods and amplitudes have been found for 254 Augusta 5.8949± 0.0001 hours, 0.75 to 0.58 magnitudes; 465 Alekto, 10.936 ± 0.001 hours, 0.14 ± 0.02 magnitudes with 3 maxima and minima per cycle; 477 Italia 19.413 ± 0.001 hours, 0.20 to 0.15 magnitudes with 3 very unequal maxima and minima per cycle; 515 Athalia 10.636 ± 0.001 hours, 0.21 ± 0.02 magnitudes; and 1061 Paeonia, 7.9971 ± 0.0001 hours, 1.00 ± 0.05 magnitudes.

Observations to produce these determinations 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. All exposures are 60 second exposure time, 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.

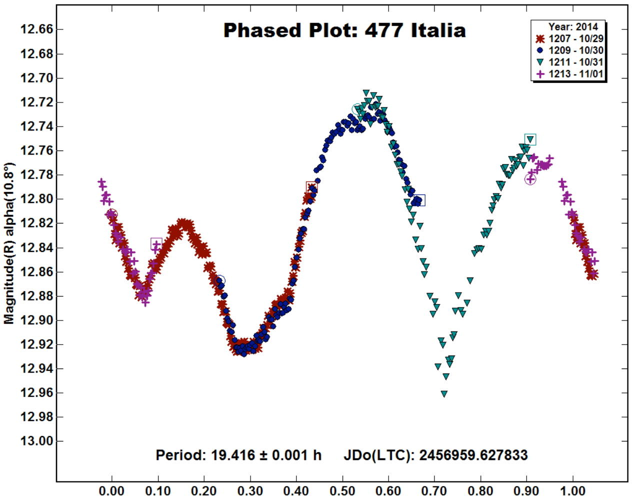
254 Augusta. The only previous period determination is an approximate 6.0 hours by Lagerkvist (1978). New observations on 5 nights 2014 Oct. 26 - Nov. 25 provide a good fit to a lightcurve phased to 5.8949 ± 0.0001 hours. The amplitude decreased from 0.75 magnitudes Oct. 26 at phase angle 14 degrees to 0.58 magnitudes Nov. 25 at phase angle 2 degrees. This period is consistent with Lagerkvist (1978).

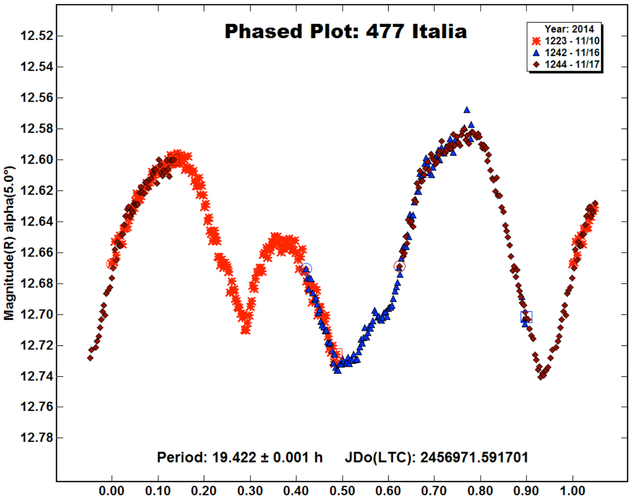


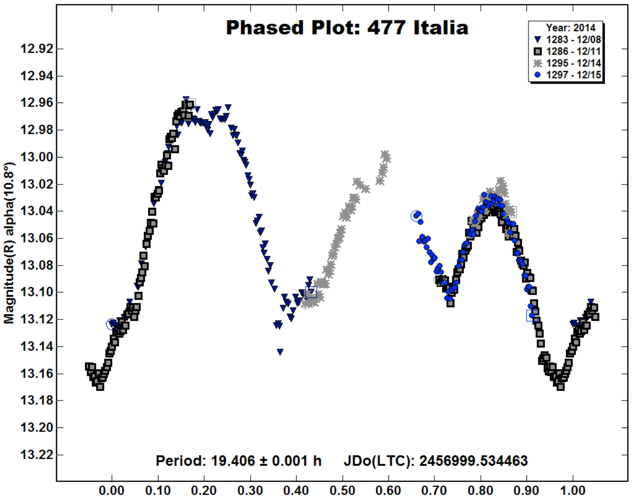
465 Alekto. The only previous period determination is by this writer (Pilcher, 2013) who obtained a period of 10.938 hours with three very unequal maxima and minima per cycle. New observations on 5 nights 2014 Dec. 1 – 28 provide a good fit to a lightcurve phased to the almost identical value of 10.936 ± 0.001 hours, also with three very unequal maxima and minima per cycle with shapes similar to those found in 2012. The year 2012 and year 2014 observations were separately phased to their respective double periods. In both cases the two sides of the double period lightcurves are the same within photometric accuracy. A highly irregular lightcurve exhibiting this symmetry requires a shape model which is both very irregular and symmetric over a 180 degree rotation. The probability that a real asteroid could possess such irregular symmetry is extremely small. The double period may be confidently rejected.

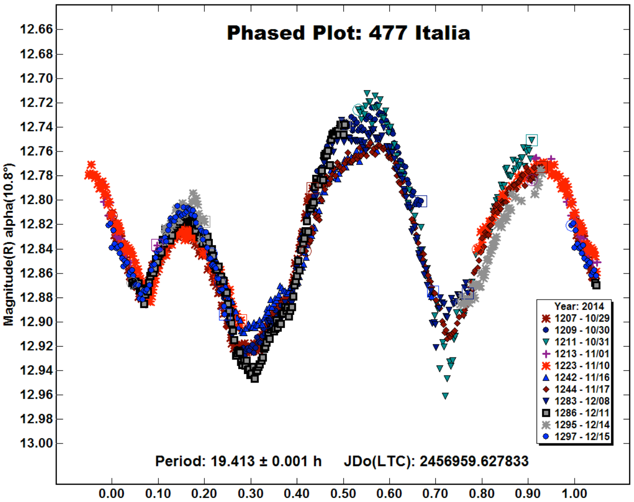


477 Italia. Previous period determinations are by Behrend (2003) and again (2005), on both data sets finding a period of 19.42 hours. Four sessions covering the complete lightcurve were obtained on consecutive nights 2014 Oct. 29 – Nov. 1 near phase angle 10 degrees and provide a good fit to a lightcurve phased to 19.416 hours with amplitude 0.20 ± 0.02 magnitudes. A second sequence of three sessions covering the complete lightcurve was obtained 2014 Nov. 10-17 near phase angle 5 degrees and provide a good fit to a lightcurve phased to 19.422 hours with amplitude 0.15 ± 0.02 magnitudes. A third sequence of four sessions 2014 Dec. 8 - 15 near phase angle 12 degrees covers about 95% of the lightcurve and provides a good fit to a period 19.406 hours with amplitude 0.20 ± 0.02 magnitudes. The accuracy of all of these periods is reduced because they each cover a short time interval. When all eleven sessions are plotted on a single lightcurve the change in lightcurve shape with changing phase angle is clearly shown, and the best fit period of 19.413 hours with amplitude 0.20 ± 0.03 magnitudes and three unequal maxima and minima per cycle should be considered as more accurate and is adopted as our value. These shape changes also appear on corresponding sections of the double period lightcurve. This is strong evidence that they are indeed the consequence of changing phase angle, and help to enable the double period to be confidently rejected. The period of 19.413 hours from the new observations is fully consistent with previously published results, and the complex shape of the lightcurve is similar to that presented by Behrend (2003).

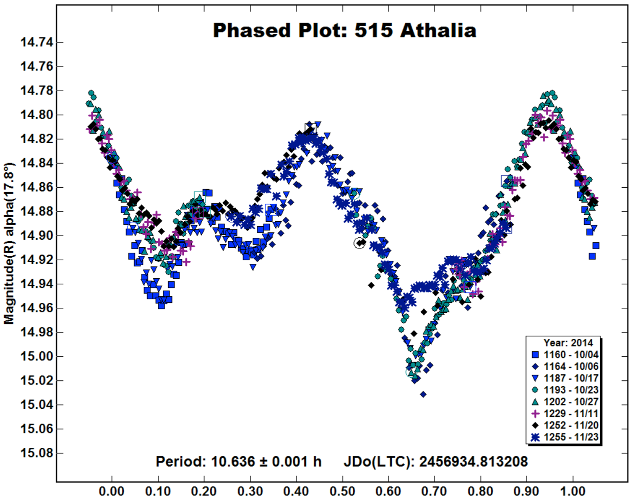




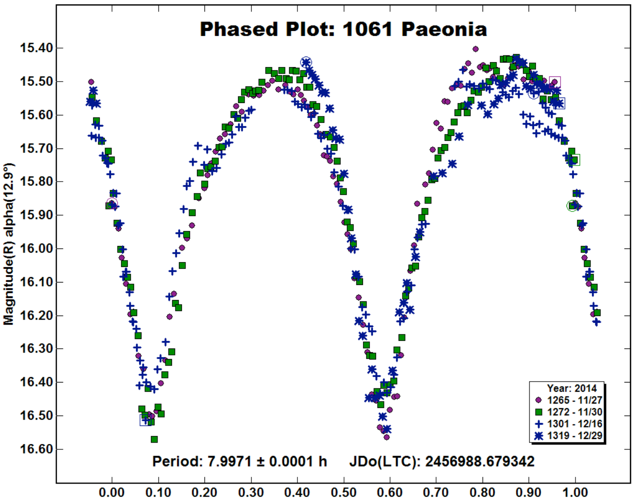




515 Athalia. The Asteroid Lightcurve Data Base (Warner et al., 2014) shows no previous observations. New observations on 8 nights 2014 Oct. 4 at phase angle 18 degrees to Nov. 23 at phase angle 2 degrees provide a good fit to a somewhat asymmetric lightcurve phased to 10.636 ± 0.001 hours and amplitude 0.21± 0.02 magnitudes. As is frequently encountered with observations over a large range of phase angles, the overall form of the lightcurve remained nearly the same while the amplitude decreased significantly with decreasing phase angle. The double period lightcurve has complete phase coverage with the two sides the same within photometric accuracy and changes with phase angle that are found at corresponding sections. The double period may be confidently rejected.



1061 Paeonia. The only previous observations are by this writer (Pilcher, 1987), who by visual observations did little except find a large amplitude and fairly short period. New CCD observations on 4 nights 2014 Nov. 27 - Dec. 29 provide a good fit to a bimodal lightcurve with period 7.9971± 0.0001 hours and amplitude 1.00 ± 0.05 magnitudes, very large as was expected, and full phase coverage. The night to night misfit among the lightcurves is as large as 0.1 magnitude. This is in part due to the usual changes of shape with phase angle, but in larger part due to the faintness of the target and its being in a crowded Milky Way star field with faint field stars being possibly overlooked during the star subtraction procedure. These misfits are much smaller than the 1.0 magnitude amplitude of the lightcurve. Due to this large amplitude, no period solution except the bimodal one shown here is realistic.



References

Behrend, R. (2003). 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*

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

Pilcher, F. (1987). "General Report of Period Observations by the ALPO Minor Planets Section for the Year 1986." *Minor Planet Bull.* **14**, 23-28.

Pilcher, F. (2013). "Lightcurves and derived rotation periods for 18 Melpomene, 38 Leda, and 465 Alekto." *Minor Planet Bull.* **40**, 33.

Warner, B. D., Harris, A. W., Pravec, P. (2009). *Icarus* **202**, 134-146, Updated 2014 Sept. 07.
http://www.minorplanet.info/lightcurvedatabase.html

PHOTOMETRIC STUDIES OF 1 CERES AND 12 VICTORIA

Frank J Melillo
Holtsville, Observatory
14 Glen-Hollow Dr., E-16
Holtsville, NY 11742
FrankJ12@aol.com

(Received: 31 December)

Photometric studies of 1 Ceres were made between 2014 April-May and of 12 Victoria in 2014 September, respectively.

Observations of 1 Ceres and 12 Victoria were made at the Holtsville Observatory located on Long Island, NY, 50 miles east of New York City. Table I gives the dates and time of the observations.

Asteroid	Date (UT) yyyy/mm/dd	Time (UT)	Amp (mag)
Ceres	2014/04/25	2:05-6:35	0.05
Ceres	2014/04/28	2:25-4:10	0.04
Ceres	2014/05/05	1:25-5:55	0.05
Ceres	2014/05/07	1:20-5:40	0.05
Victoria	2014/09/18	1:20-5:40	0.16
Victoria	2014/09/19	1:45-4:20	0.11
Victoria	2014/09/20	2:10-3:55	0.12
Victoria	2014/09/24	1:55-5:45	0.17

Table I. Dates and times (UT) of observations for 1 Ceres and 12 Victoria.

1 Ceres. Ceres was selected for photometry work because of the pending arrival of the Dawn spacecraft in 2015 March. The apparition in 2014 was the last apparition before the spacecraft visit. Ceres was the first asteroid in the Solar System to be discovered by an Italian astronomer Guiseppe Piazzi of the Palermo Observatory on 1801 January 1. Ceres is a C-type asteroid with an equatorial radius 490 km and 455 km at polar radius (Erard *et al.*, 2005). The near spheroidal shape might explain why its lightcurve amplitude is always small.

Ceres was monitored using a 0.25-m *f*/10 Meade LX-200 telescope and SSP-3 OPTEC photometer with V filter. A total of 83 measurements were made over four nights using a 10-second integration time. The star 84 Virginis (V = 5.34) was used as a comparison star. The star was within 2 degrees of Ceres throughout the observations, which minimized the air mass difference and extinction corrections. The actual magnitude of Ceres was found by finding the brightness ratio between it and the star, converting the ratio to magnitudes, and adding the result to the known magnitude of the comp star. Ceres' magnitude was determined to be at V = 7.06 on April 25 but dimmed to V ~ 7.30 on May 7. This was due to a slight increase of distance between Ceres and the earth after opposition.

The dwarf planet was monitored for 4.5 hours on three of four nights (April 28 was cut short by clouds). The photometry results were quite consistent. The amplitude was also very small, possibly about 0.04 ± 0.01 mag. There was no definite pattern to determine if there is a maximum and/or minimum. It has a well-known rotation period of 9.078 h (see Warner *et al.*, 2009). Because the runs covered only about half a rotation, it was difficult to determine the period with high precision. Based on Fourier analysis of the data (Brian D. Warner, private communications) a period of P = 9.19 h is adopted for this paper.

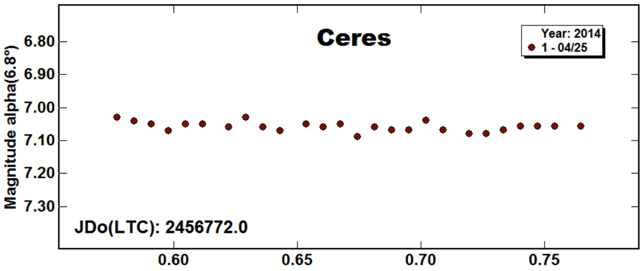


Figure 1. The raw lightcurve for 1 Ceres on 2014 April 25.

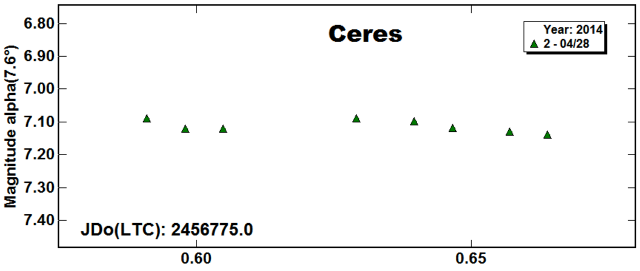


Figure 2. The raw lightcurve for 1 Ceres on 2014 April 28.

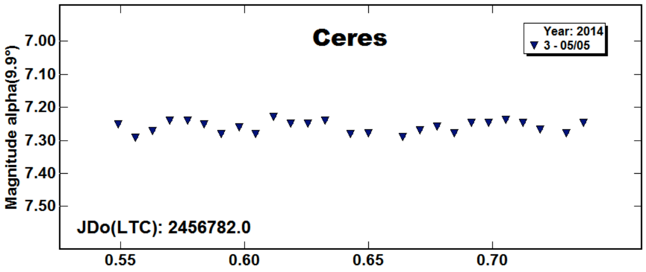


Figure 3. The raw lightcurve for 1 Ceres on 2014 May 5.

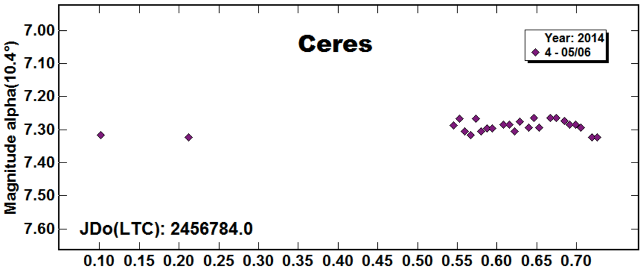


Figure 4. The raw lightcurve for 1 Ceres on 2014 May 7.

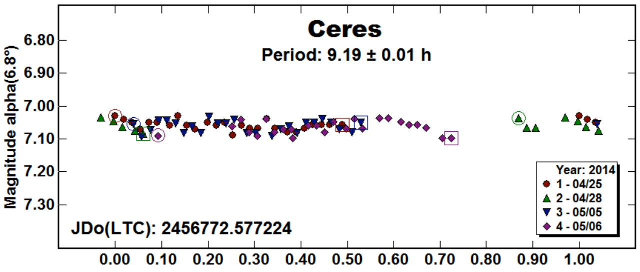


Figure 5. Fourier analysis of the combined data set for Ceres gives a period of 9.19 h. Other solutions at about 8.8 and 10.4 h cannot be formally excluded.

12 Victoria. Victoria is an S-type asteroid discovered by John Russell Hind on 1850 September 13. Its amplitude at different apparitions is known to have a range of 0.04-0.42 mag (Warner *et al.*, 2009), implying a less spheroidal shape than for Ceres. The rotation period of about 8.66 h has been measured several times (Warner *et al.*, 2009).

Victoria was monitored with a 200-mm telephoto lens working at *f*/8 and Starlight Xpress MX-5 CCD camera that were piggybacked on a 0.25-m telescope. The shorter focal length made it easier to find comparison stars. HD 213635 in Pegasus (V = 9.12) was chosen for these observations. The star and Victoria were within one degree of one another throughout the observations.

The asteroid was imaged every 10 minutes each night of the observing run for a total of 60 images. Exposures were 20 seconds, unfiltered. A dark frame was added before the photometric readings. Starlight Xpress *Star 2000* software was used for photometry work with a 9-pixel square box aperture. The software automatically determined the ratio between HD 213635 and Victoria once the photometric readings were established. Only the difference in magnitude was given. Unfortunately, a V filter was not available at the time, but the observations were made to determine the amplitude of the lightcurve, not the asteroid's actual magnitude.

Assuming a period of 8.66 h, the four nights of data covered the entire visible surface of Victoria. Fourier analysis of the full data set (Brian D. Warner, private communications) favors a solution of 8.64 h (Figure 10).

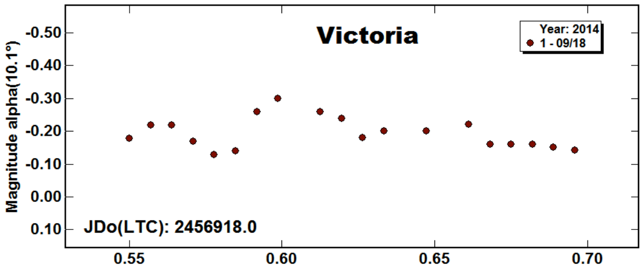


Figure 6. The raw lightcurve for 12 Victoria on 2014 Sept 18.

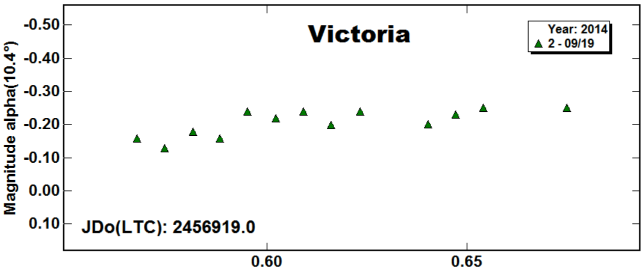


Figure 7. The raw lightcurve for 12 Victoria on 2014 Sept 19.

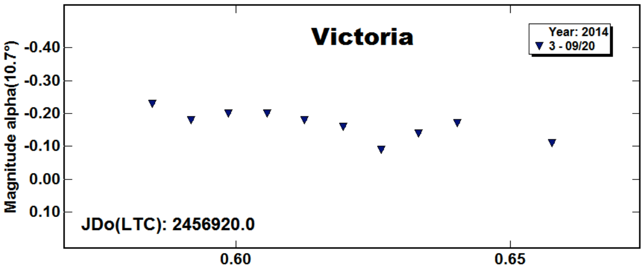


Figure 8. The raw lightcurve for 12 Victoria on 2014 Sept 20.

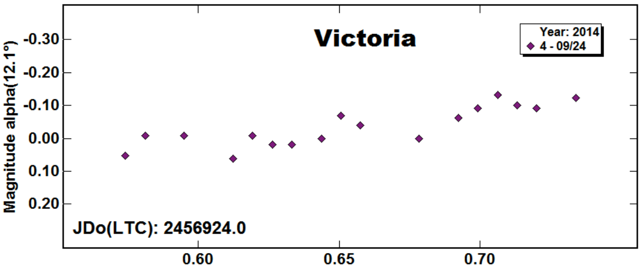


Figure 9. The raw lightcurve for 12 Victoria on 2014 Sept 24.

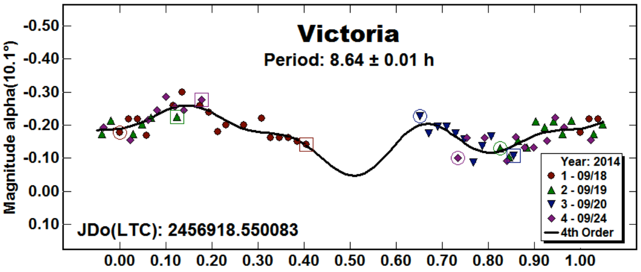


Figure 10. The combined lightcurve for 12 Victoria phased to the period of 8.64 h found using Fourier analysis.

References

Erard, S, Forni, O, Ollivier, M. et al. (2005), "The 2004 Opposition of Ceres Observed with Adaptive Optics on the VLT". Lunar and Planetary Science XXXVI.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 Dec. 20. *http://www.minorplanet.info/lightcurvedatabase.html*

PRELIMINARY SHAPE AND SPIN AXIS MODELS FOR TWO ASTEROIDS

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

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

(Received: 2 January)

A combination of dense lightcurves obtained by the authors over several apparitions and sparse data was used to model shapes for two asteroids: the Mars-crosser (21028) 1989 TO and Hungaria member (32814) 1990 XZ. For 1989 TO, a reasonably reliable spin axis and period of (86°, 0°, 3.66527 h) was found, although one of (292°, –62°, 3.66527 h) cannot be formally excluded. The solution for 1990 XZ is ambiguous. While two solutions are presented, they are not considered very reliable determinations.

Despite having dense lightcurves from only a small number of apparitions (see Slivan, 2013) for Mars-crosser (21028) 1989 TO and Hungaria member (32814) 1990 XZ, we nonetheless attempted to use lightcurve inversion (see, e.g., Hanus and Durech (2012), and references therein) to try to derive at least preliminary spin axis models for the two asteroids, i.e., determine the ecliptic coordinates of each asteroid's north pole. A natural consequence of this process is to derive a shape for the asteroid and a model lightcurve. The latter can be used to compare against actual data to help determine the quality of the solution.

Aside from obtaining the dense lightcurves over the past few years, the first step for each asteroid was to obtain raw sparse data observations from various surveys by using the AstDyS-2 site (*http://hamilton.dm.unipi.it/astdys2/*). From these, only data from the Catalina Sky Survey and USNO-Flagstaff were extracted, since they are considered among the more reliable (internally consistent) data available (Hanus *et al.*, 2011). The data were further filtered by plotting them in reduced magnitude versus phase angle plot (e.g., Figure 3) where obvious outliers were removed. This is somewhat arbitrary in the case of large amplitude objects since the large variations from a general solution may be real and not just random scatter. The degree of scatter is also affected by forcing the value for the phase slope parameter (*G*) to the default of 0.15, or allowing the solution to float and find a "true" value for *G*. In the two cases here, we used the results from allowing the solution to float.

Once the sparse data set was ready, it was combined with our dense lightcurves using *MPO LCInvert*, a Windows-based program developed by Warner that incorporates the algorithms developed by Kaasalainen *et al*. (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values. Ideally, the lowest χ^2 value should be at least 10% lower than the second lowest value, e.g., 1.0 versus 1.15. This is not often the case, especially when data set covers only a few years and/or a small number of apparitions. Figure 4 shows a representative case of a χ^2 vs. period plot.

After a period is found, a search for the spin axis pole is made by using the period corresponding to the lowest χ^2 and forcing the pole solution to one of 315 distinct longitude-latitude pairs. The period, however, is allowed to "float". This leads to a plot similar to Figure 5, which is an equal area projection of the ecliptic sphere. The colors range from deep blue (lowest χ^2) to bright red with a deep red zone representing the highest χ^2 value.

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

A final search for a spin axis is made using the lowest value in each island (assuming it's possible to define one or more islands). Here the longitude and latitude are allowed to float as well as the period. The spin axis parameters are then used to generate a final shape and spin axis model. Figure 6 shows an example of what is called the "4-vane" shape model, which shows the asteroid as viewed from its two poles and in its equatorial planes at different rotations about the Z-axis. It's important to note that, unless using well-calibrated (absolute) data throughout, the lightcurve inversion process poorly constrains the height (Z-axis) of the asteroid. Therefore, the asteroid could actually be flatter or more spheroidal than shown in the 4-vane image. Figures 7 and 8 show the model lightcurve (black) for specific dates versus the actual lightcurve (red). Naturally, the two lightcurves for any given data should closely match.

Individual Results

(21028) 1989 TO. Warner *et al.* (2008) reported a synodic period of 3.6644 h based on observations in late 2007 (Figure 1). The phase angle bisector longitude (L_{PAB}; see Harris *et al.*, 1984) at the time was approximately 81° and the amplitude 0.12 mag. Stephens observed the asteroid in 2014 October, finding a period of 3.664 h (Figure 2) with an amplitude of 0.37 mag. The L_{PAB} was about 26° at the time.

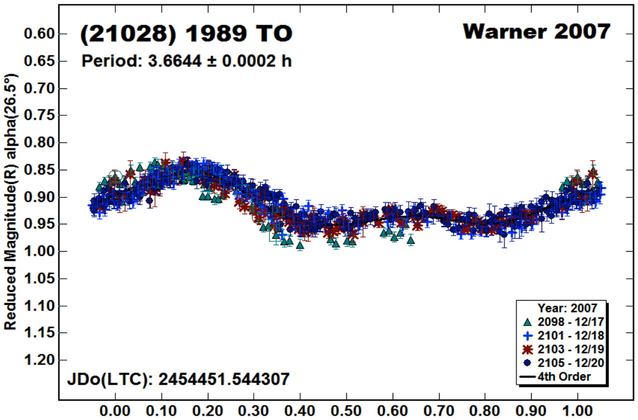


Figure 1. The amplitude of the lightcurve for 1989 TO was 0.12 mag at L_{PAB} ~ 81°.

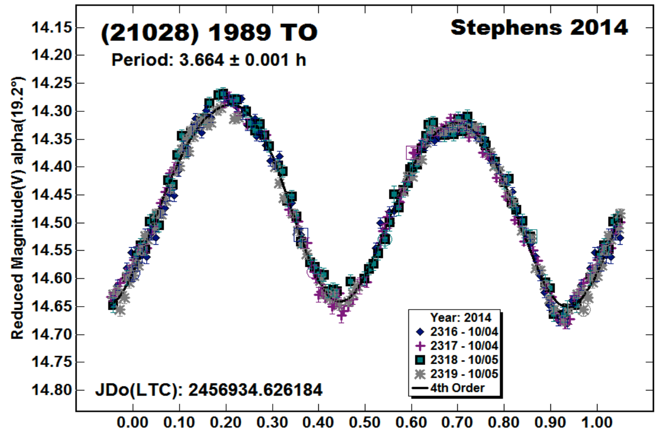


Figure 2. At LPAB ~ 26°, the amplitude of the lightcurve for 1989 TO was 0.37 mag.

The significant differences in the lightcurves leads to at least two broad conclusions: the asteroid has a somewhat elongated shape and the spin axis pole is in the vicinity of ecliptic longitude 81° (or 261°). The first conclusion is based on the amplitude of 0.37 mag. in 2014. Assuming an equatorial view, this gives an a/b ratio of ~1.4:1.

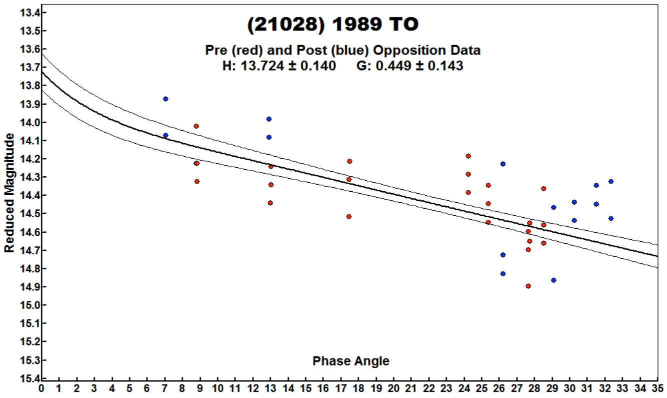


Figure 3. A magnitude-phase angle plot for 1980 TO using data from the Catalina Sky Survey.

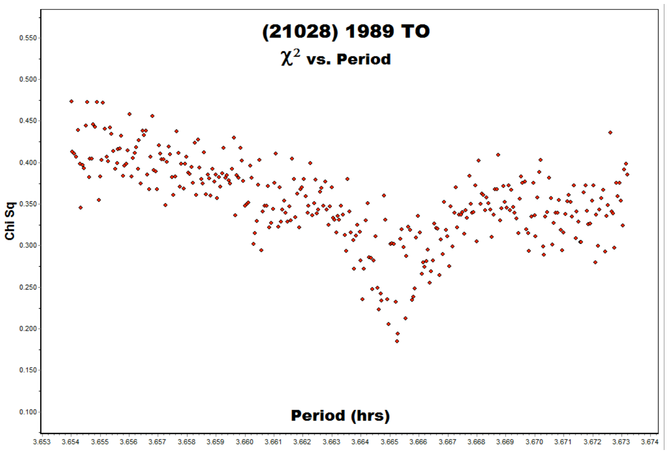


Figure 4. A plot of χ^2 versus period for 1989 TO. While the minimum is sharply defined, it is still not quite unique, which makes the resulting pole and shape model uncertain.

The conclusion about the ecliptic longitude of the pole comes from the fact that the amplitude is significantly less at some viewing aspects, implying a more "pole-on" view than when the lightcurve amplitude is greater.

The period plot in Figure 4 shows a sharp minimum. This makes the period associated with the lowest χ^2 more likely the right one. However, the second-lowest value is well within 10%.

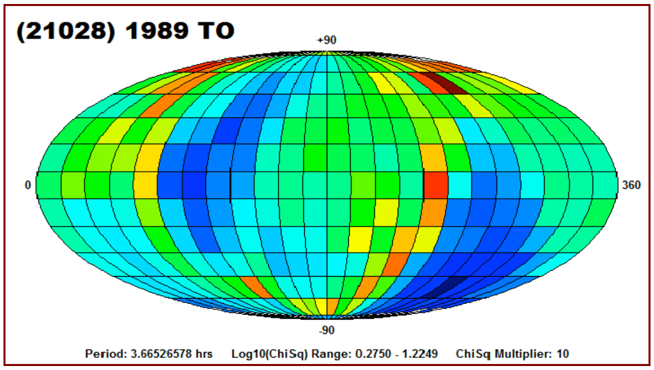


Figure 5. A pole search plot for 1989 TO shows two "islands" that represent likely solutions.

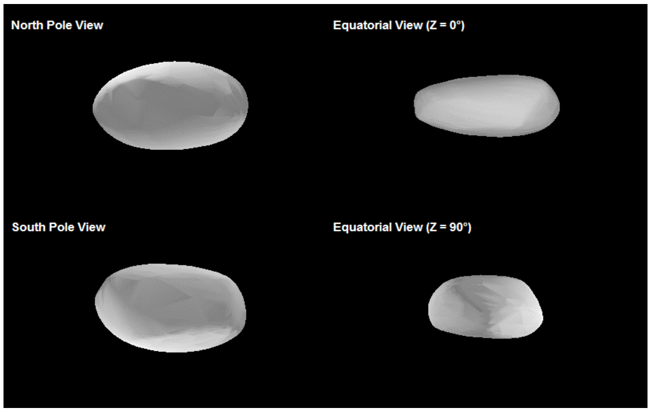


Figure 6. Four views of 1989 TO. On the left are views from the north and south poles. On the right are views in the asteroid's equatorial plane, one at 0° rotation and the other at 90° rotation about the Z-axis. The elongated shape is expected given the lightcurve amplitude of 0.37 mag in 2014.

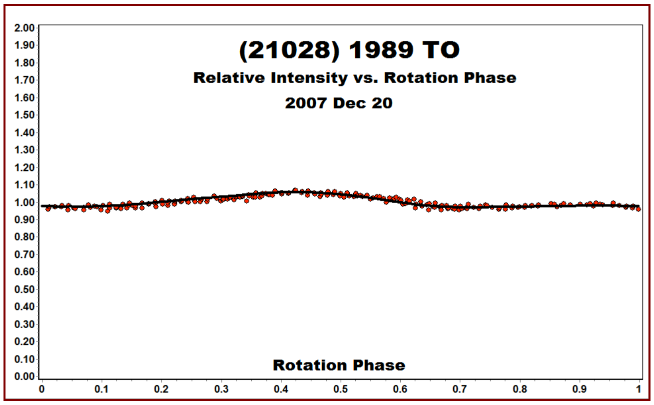


Figure 7. The model lightcurve (black) for 1989 TO versus the data (red) in 2007 December. The vertical axis gives the relative intensity of the data points, not the magnitude.

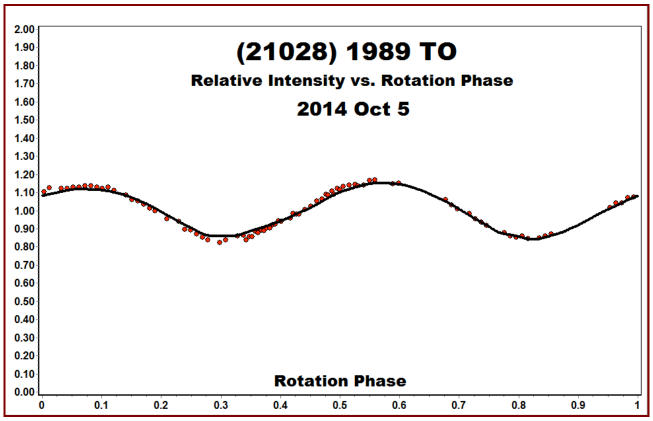


Figure 8. The model lightcurve (black) for 1989 TO versus the data (red) in 2014 October. The vertical axis gives the relative intensity of the data points, not the magnitude.

The model curves in Figures 7 and 8 are from the solution for (86°, 0°, 3.66527 h) although the fits to the model based on (292°, –62°, 3.66527 h) are essentially identical. In both cases, the estimated error for the pole is a circle of about 10° radius and 0.00002 h for the period.

In the end, we chose (86°, 0°, 3.66527 h) based on the fact that the lightcurve amplitude changed significantly with L_{PAB}. If the asteroid's pole were closer to one of the ecliptic poles, the variation due to different viewing aspects would not be as great as when the asteroid pole was closer to the ecliptic plane. In first case, the viewing aspect would be somewhat equatorial for all viewing aspects (values of LPAB) while, for the second case, the viewing aspect would range from nearly pole-on to nearly equatorial and so a wider range of lightcurve amplitudes. The choice is supported by observations in 2014 September by Pravec *et al.* (2014), who reported an even larger amplitude at LPAB ~ 24°. Despite these arguments, the other solution cannot be formally excluded and data from future apparitions are required to resolve the ambiguity.

A general warning coming from this analysis is that when observing an asteroid close to pole-on, the solution loses sensitivity to rotational phase. Thus the period and the pole orientation become highly correlated, and the uncertainty in either quantity is bigger than the uncorrelated error bars. Put another way, if a pole longitude solution is also near the L_{PAB} of a given data set and the amplitude is about the same as one with another aspect that is close to a right angle with the first, then either the asteroid is nearly spheroidal or the solution is likely wrong. For example, if the amplitude of the lightcurves in 2007 and 2014 had been similar, the adopted solution for the pole given below would be suspect, especially since the asteroid is known not to be nearly spheroidal.

(32814) 1990 XZ. Warner (2007) found a period of 2.8509 h for this Hungaria member (Figure 9). Stephens found a period of 2.84 h based on observations in 2013 April (Figure 10). Warner (2015) observed the asteroid at a third apparition in 2014 September (Figure 11).

While the shape of the lightcurves varies somewhat, the change in amplitude is not significant; it is important to consider how much of the amplitude change is due to phase angle. In Figure 9, the phase angle is significantly lower than in Figure 11. Therefore, it's not possible to say exactly how much of the amplitude change is due to viewing aspect and how much is due to the known relation of increasing amplitude with increasing phase angle.

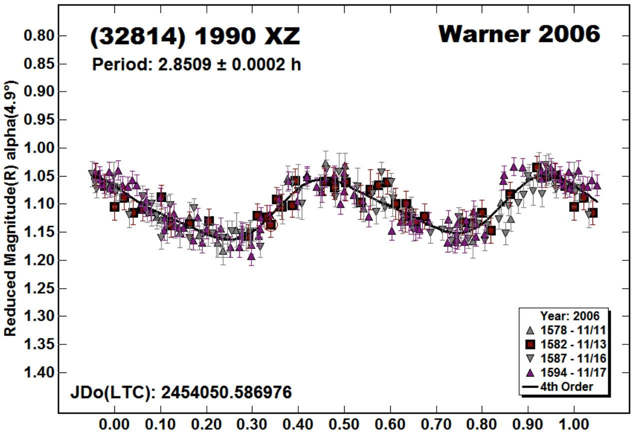


Figure 9. Lightcurve for 1990 XZ from observations by Warner in 2006 at L_{PAB} ~55° and α ~5°. The amplitude is 0.13 mag.

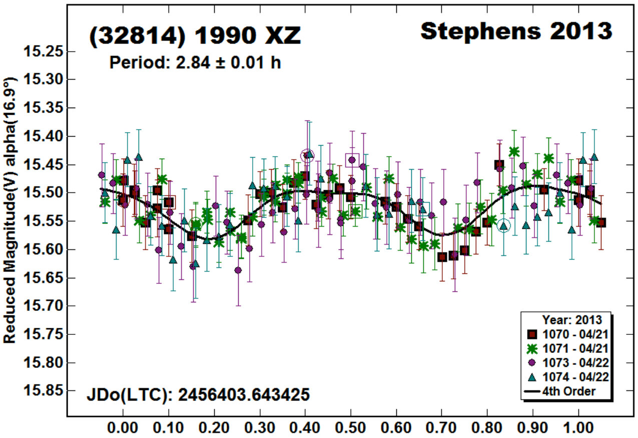


Figure 10. The lightcurve for 1990 XZ by Stephens in 2013 at LPAB ~190° and α ~17°. The amplitude is 0.09 mag.

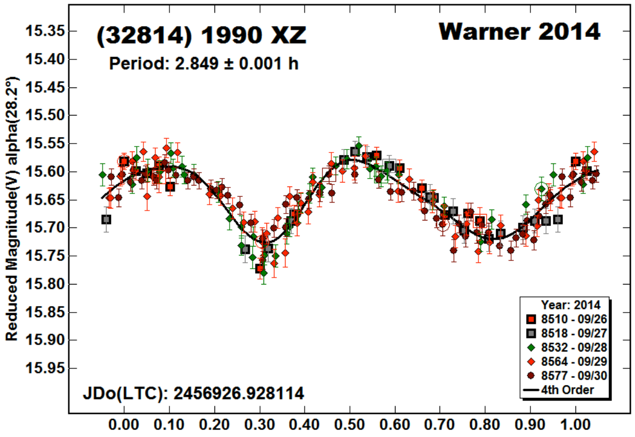


Figure 11. The lightcurve for 1990 XZ by Warner in 2014 at LPAB ~45° and α ~28°. The amplitude is 0.15 mag.

Before the data from 2014 were available an attempt was made to model the asteroid using the data from 2006 and 2013 along with sparse data from the Catalina Sky Survey. Figure 12 shows the pole search plot for that search. While there are two islands of deeper blue, there are almost no yellows or reds, indicating that the two islands barely rise above the "sea" of other solutions.

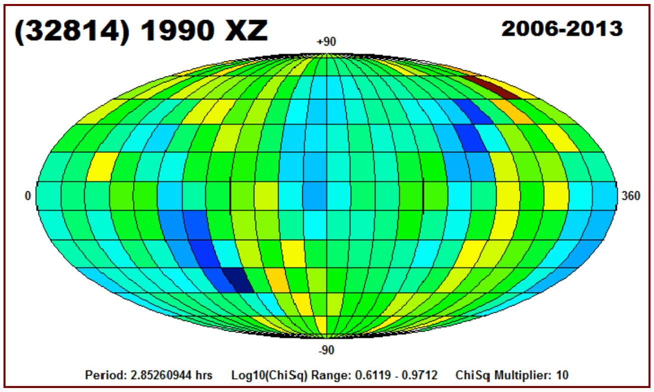


Figure 12. A pole search plot for 1990 XZ using dense data from 2006-2013 shows two possible poles. See the text for additional discussion.

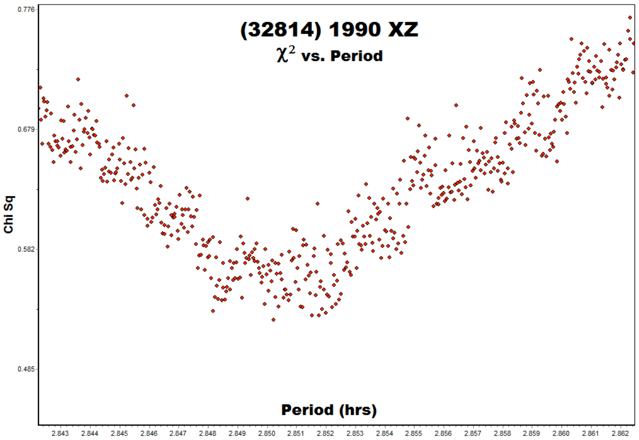


Figure 13. The χ^2 versus period plot for 1990 XZ lacks a sharp minimum and a number of periods within 10% of the lowest value. A definitive pole search is unlikely in this case.

Hopes for the 2014 data providing a more definitive solution were squelched when the period search plot showed no clear minimum value, i.e., there were a number of periods almost equally valid as the one with the lowest χ^2 value.

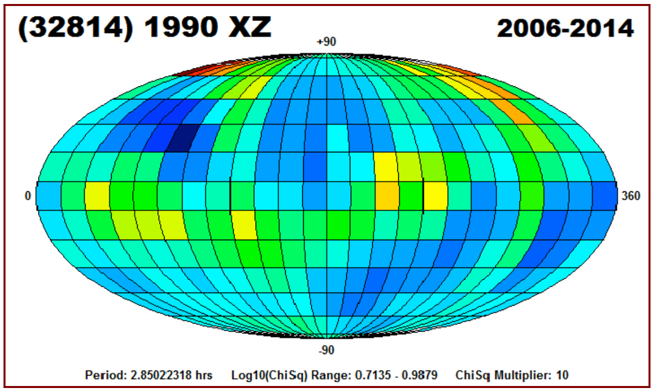


Figure 14. The pole search plot for 1990 XZ after incorporating the data from 2014 appears to be even more ambiguous that in Figure 12.

As expected, the pole search plot (Figure 14) did not show any sharply-defined solutions and, in fact, appears to be even more ambiguous than when not using the data from 2014. It's worth noting that the pre-2014 best-fit period was 2.85261 h while the post-2014 best-fit period is 2.85022 h, or a change of 0.0024 h. That is a substantial difference and shows the weakness of either period solution.

Despite the uncertainties, we decided to generate final spin axis and shape models centered on the two main "islands" as determined from the lowest χ^2 value in the first two clumps of solutions. This produced solutions of (71°, +34°, 2.85022 h) and (320°, –20°, 2.85022 h). As before, the estimated error for the pole is a circle of 10° radius and 0.00002 h for the period. Only the results from the first solution are shown below.

Figure 15 shows the 4-vane view. The shape is unrealistic in that the b/c ratio is less than 1. As noted above, without absolute data, the height of the Z-axis (c in an abc ellipsoid) is not well-constrained. Using *LCInvert*, it's possible to force the a/c and b/c ratios to be greater than 1, i.e., shorten the Z-axis. However, the fit of the model lightcurves to the actual data can quickly diverge.

Given the low amplitude of the lightcurves at all apparitions, it would seem likely that 1) the asteroid is nearly spheroidal – as shown in the 4-vane shape model, and 2) that the pole is possibly closer to the ecliptic poles than the ecliptic plane. However, with a nearly spheroidal shape, that is very difficult to prove.

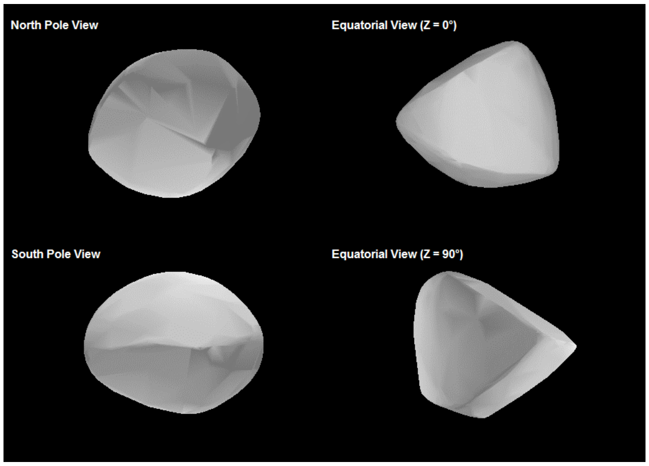


Figure 15. The results for 1990 XZ show an unrealistic shape where b/c < 1.

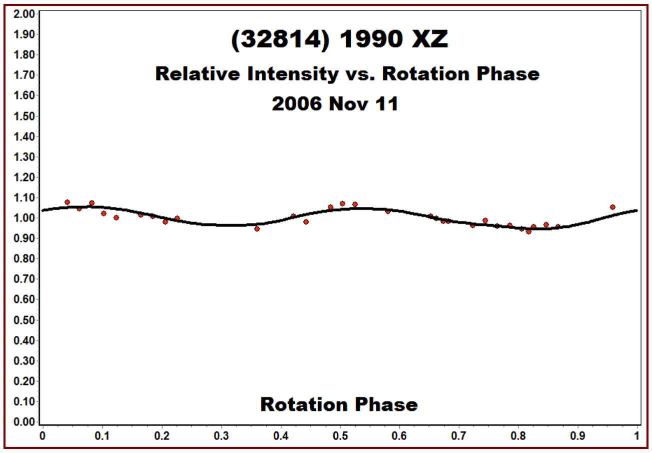


Figure 16. The plot for 1990 XZ in 2006 November shows the relative intensity, not magnitudes, versus rotation phase of the model lightcurve (black) versus the actual lightcurve (red).

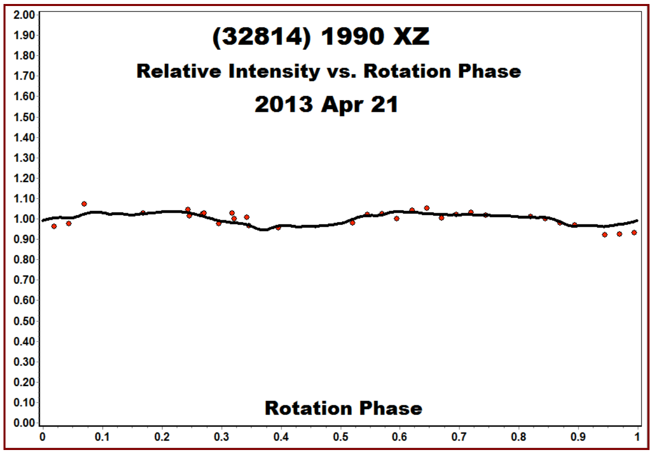


Figure 17. The intensity versus phase from 2013 April is even flatter than in 2006.

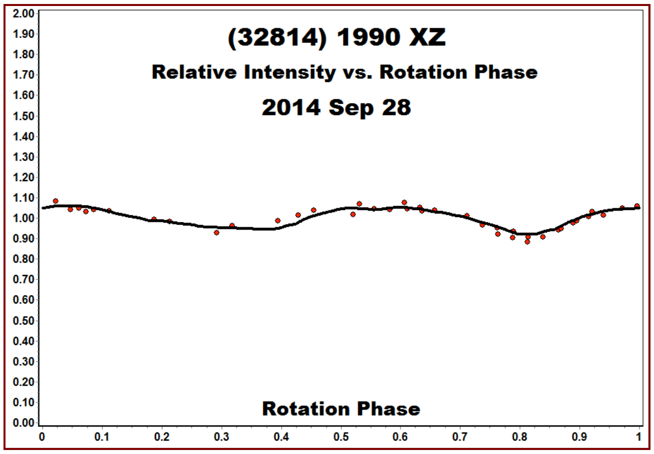


Figure 18. The shape of the intensity versus rotation phase plot shows a larger variation than before. However, this may be due more to the asteroid being at a significantly larger phase angle than the other apparitions than due to viewing aspect.

Conclusions

These two cases clearly cry out for "more data!" although the results for (21028) 1989 TO are more encouraging than for (32814) 1990 XZ. The next favorable Opposition for 1989 TO is 2019 March, and northern hemisphere observers will get a favorable opposition of 1990 XZ in January 2018.

Given the elongated shape for 1989 TO, it seems much more likely that a reliable solution can be eventually found. It should also be considered that the shape, period, and estimated size for 1990 XZ, about 3.5 km, makes it a good candidate for being a binary. Future observers should keep this possibility in mind.

References

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

Hanus, J., Durech, J. (2012). "The potential of sparse photometric data in asteroid shape modeling." *Planetary and Space Science* **73**, 75-79.

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

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

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

Pravec, P., Wolf, M., Sarounova, L. (2014). *http://www.asu.cas.cz/~ppravec/neo.htm*

Slivan, S.M. (2013). "Epoch Data in Sidereal Period Determination. II. Combining Epochs from Different Apparitions." *Minor Planet Bul.* **40**, 45-48.

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

Warner, B.D., Husarik, M., Pravec, P. (2008). "Lightcurve Analysis of (21028) 1989 TO." *Minor Planet Bul*. **35**, 75-76.

Warner, B.D. (2015). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 June-October." *Minor Planet Bul*. **42**, 41-53.

ROTATION PERIOD DETERMINATION OF 2554 SKIFF AND 3107 WEAVER

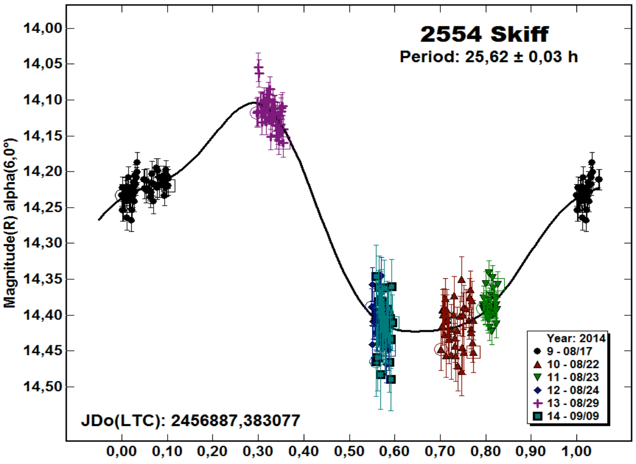
Angelo Tomassini, Maurizio Scardella, Fabio Zampetti
ATA (Associazione Tuscolana di Astronomia)
F. Fuligni Observatory (MPC code D06)
Via Lazio, 14 - località Pratoni del Vivaro – 00040
Rocca di Papa (RM) – ITALY
nikkor5@gmail.com

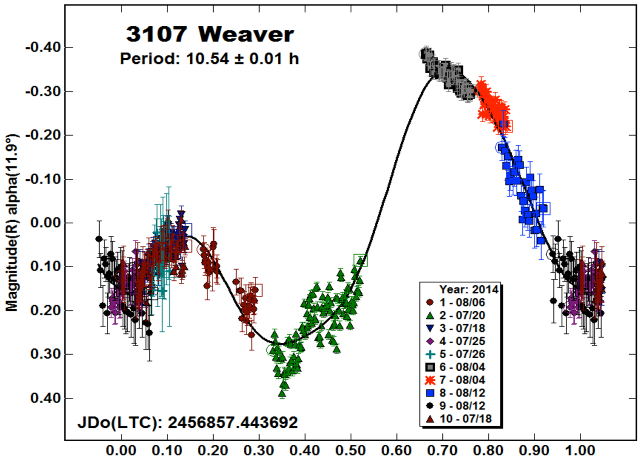
(Received: 5 January)

The main-belt asteroid 2554 Skiff and 3107 Weaver were observed over several nights throughout 2014 July-August in order to determine their synodic rotation periods. Lightcurve analysis found: 2554 Skiff, P = 25.62 ± 0.03 h, A = 0.32 mag; 3107 Weaver, P = 10.54 ± 0.01 h, A = 0.63 mag.

The main-belt asteroids 2554 Skiff and 3107 Weaver were selected from a list prepared by Warner *et al.* (2014). All the observations were carried out at F. Fuligni Observatory, not far from Rome (Italy), using a 0.35-m *f*/10 Meade ACF telescope and SBIG ST8-XE CCD camera with Bessel R filter. All images were calibrated with dark frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012).

For 2554 Skiff, we found a synodic period P = 25.62 ± 0.03 h and amplitude A = 0.32 mag. For 3107 Weaver, the results were P = 10.54 ± 0.01 h, A = 0.63 mag.





Acknowledgements

We would like to thank Maurizio Cervoni (ATA research team) for his help in taking light and dark frames during all over the period of observation.

References

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

Warner, B.D., Harris, A.W., Durech, J., Benner, L.A.M. (2014). "Lightcurve Photometry Opportunities: 2014 July-September." *Minor Planet Bull.* **41**, 199-201. Web search page: *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*

ASTEROIDS AT ETSCORN CAMPUS OBSERVATORY: 2014 SEPTEMBER - DECEMBER

Daniel A. Klinglesmith, Austin DeHart,
Jesse Hanowell,. Sebastian Hendrickx
Etscorn Campus Observatory
New Mexico Tech
101 East Road
Socorro, NM USA 87801
dklinglesmith@mro.nmt.edu

(Received: 4 January)

We observed ten asteroids during a three-month period in 2014. Six of the targets had no reported synodic period while four were observed in an attempt to improve their previously published periods.

Observations were obtained at the Etscorn Campus Observatory (ECO, 2014) with our three Celestron 0.35-m Schmidt-Cassegrain telescopes (SCT) on Software Bisque Paramount ME mounts (SB, 2014). Two of the telescopes used SBIG STL-1001E CCDs that have 1024x1024 24-micron pixels. The scale was 1.25 arc seconds/pixel. This provides a 22x22 arc minute field of view. The third C-14 used an SBIG ST-10XME with an Optec 0.5x focal reducer. The ST-10XME was binned 2x2, providing an image of 1092x736 13.6-micron pixels. The scale was 1.28 arc seconds/pixel. This provided a 20x16 arc minute field of view.

The asteroid images were obtained through a clear filter. Exposure times varied between 3 and 5 minutes depending on the brightness of the object. Each evening a series of 11 dome flats was obtained and combined into a master flat with a median filter. The telescopes were controlled with Software Bisque's *TheSky6* (SB, 2014) and the CCDs were controlled with *CCDsoft* V5 (SB, 2014). The images were dark subtracted and flat field corrected using image processing tools within *MPO Canopus* version 10.4.6.5 (Warner, 2014). The multi-night data sets for each asteroid were combined with the FALC routine (Harris *et al.*, 1989) within *MPO Canopus* to provide synodic periods for each asteroid.

All of the observed asteroids were selected from the lightcurve data base (LCDB; Warner *et al.*, 2009) as being in a favorable position to observe in three-month period. Three of the asteroids, 746 Marlu, 2649 Oongaq, and 4909 Couteau have known periods with a U value of less than 3 (see Warner *et al.*, 2009). Information about asteroid discovery dates and names were obtained for the JPL small bodies Database, JPLSDB (2014).

746 Marlu is a main-belt asteroid discovered by F. Kaiser at Heidelberg on 1913 Mar 1. It also known as 1913 QY, 1926WA, 1975 XN. We observed it on five nights between 2014 Oct 6-15. We obtained a *synodic* period of 7.787 ± 0.001 h and an amplitude of 0.22 ± 0.05 mag. The data covered the complete lightcurve. Harris *et al.* (1992) obtained a period of 7.787 h with an amplitude of 0.23 mag. Hanus *et al.* (2011) obtained a *sidereal* period of 7.787 ± 0.005 h with no mention of an amplitude.

1463 Nordenmarkia is a main-belt asteroid discovered by Y. Vaisala at Turku on 1938 Feb 6. It is also known as 1938 CB, 1925 UB, 1925 WJ, 1927 DC, 1930 QE, and 1950 FD. We observed it on six nights between 2014 Oct 6-16. We found a period of 5.918 ± 0.001 h and an amplitude of 0.17 ± 0.05 mag.

2390 Nezarka is a main-belt asteroid discovered by Z. Vavrova at Klet on 1980 Aug 14. It is also known as 1980 PA1, 1942 RS, A904 RC. We observed it on seven nights between 2014 Sep 24 and Oct 5. We obtained a period of 11.349 ± 0.001 h and amplitude of 0.42 ± 0.10 mag.

2649 Oongaq is a main-belt asteroid discovered by E. Bowell at Anderson Mesa Station of Lowell Observatory on 1980 Nov 29. It is also known as 1980 WA, 1933 SB1, 1959 XE and 1963 US. Behrend (2005) reported a period of 8.64 h based on data obtained by Poncy. We observed it between 2014 Oct 6-15 for five nights. We obtained a period of 7.786 ± 0.001 h and an amplitude of 0.46 ± 0.05 mag.

2693 Yan'an is a main-belt asteroid discovered by Purple Mountain Observatory at Nanking on 1977 Nov 3. It is also known as 1977 VM1, 1937 WE, 1947 XA and 1967 UF. We observed it on three nights between 2014 Nov 29 and Dec 1. We found a period of 3.841 ± 0.001 h and an amplitude of 0.12 ± 0.02 mag. Unpublished observations from 2004 obtained from R. A. Koff (2004) give the same period but with an amplitude of only 0.05 mag. The difference may be the result of looking at a different orientation of the asteroid as it rotates. The phase angle bisector longitude (L_{PAB}) and latitude (B_{PAB}) for our observations were 60.7° and +0.7°, respectively. They were 75.1° and +3.5° at the time of Koff's 2004 observations.

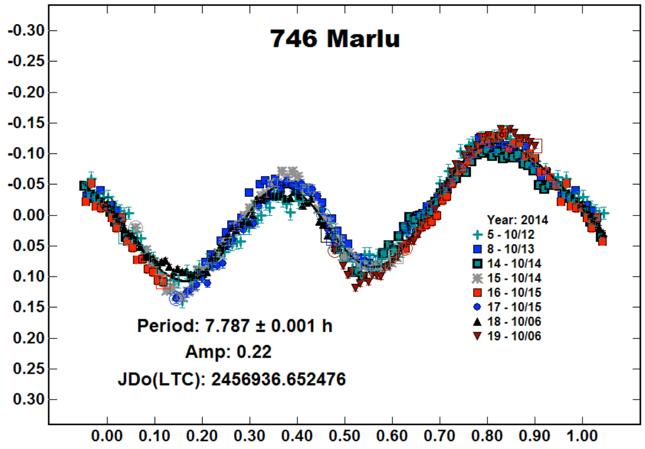
3730 Hurban is a main-belt asteroid discovered by M. Antal at Piszekesteto on 1983 Dec 4. It is also known as 1983 XM1, 1955 QB, 1962 BE, 1973 QV, 1982 OC and A919 QA. We observed it on seven nights between 2014 Oct 31 and 2014 Nov 11. We found a period of 4.649 ± 0.001 h and amplitude of 0.22 ± 0.05 mag.

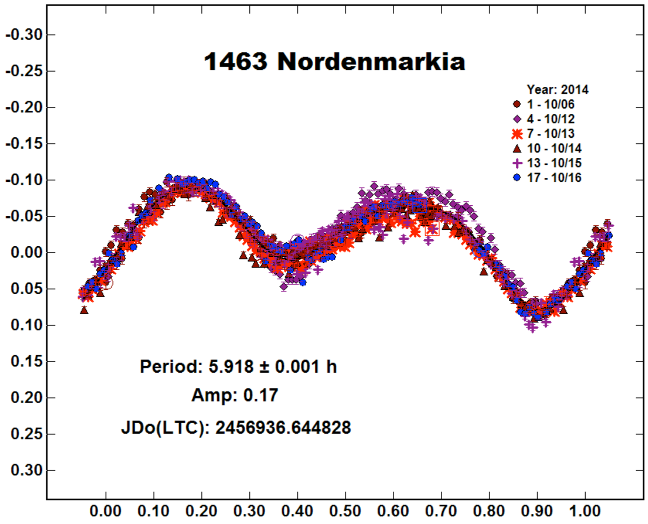
4909 Couteau is a main-belt asteroid discovered by M. Laugier at Nice on 1949 Sep 28. It is also known as 1949 SA1, 1949 SD, 1949 TJ, 1949 UG1, 1959 NK, 1966 QO, 1973 SW3 and 1990 RA. Pravec (2014) reports a period of 5.054 ± 0.001 h and amplitude of 1.05 mag. Clark (2015) reported a period of 5.0505 ± 0.0001 h and amplitude of 1.04 ± 0.03 mag. His observations were obtained 2014 Aug 3-19. We observed it on seven nights between 2014 Sep 10 and Oct 1. We found a period of 5.051 ± 0.001 h and amplitude of 1.07 ± 0.2 mag. Our magnitude uncertainty is large because of the differences in the deeper minimum at a phase of 0.7.

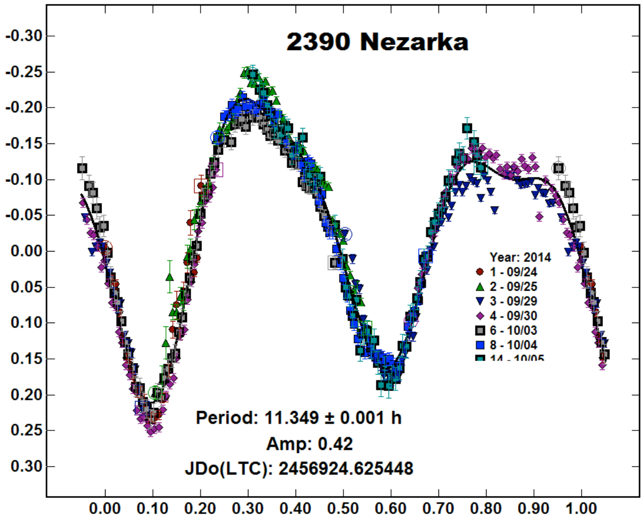
(6509) 1983 CQ3 is a main-belt asteroid discovered by G. DeSanctis at La Silla on 1983 Feb 12. It is also known as 1983 CQ3, 1967 RD, 1972 VQ1, 1976 OG, 1990 HF5 and 1991 YB. We observed it on six nights between 2014 Nov 12-24. We obtained a period of 14.115 ± 0.003 h and amplitude of 0.17 ± 0.10 mag. The minimum magnitude at phase 0.2 variation is on the order of 0.10 mag. The minimum was getting deeper with time.

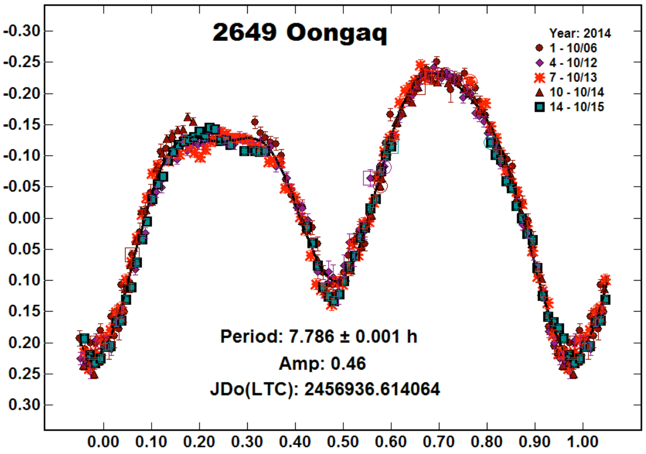
10645 Brac is a main-belt asteroid discovered by K. Korlevic at Visnjan on 1999 Mar 14. It is also known as 1999 ES4, 1962 TN, 1968 BF, 1975 TJ1, 1980 YK, 1986 EH5 and 1988 SX4. We observed it on eight nights between 2014 Oct 20-28. We found a period of 2.785 ± 0.005 h and amplitude of 0.31 ± 0.10 mag.

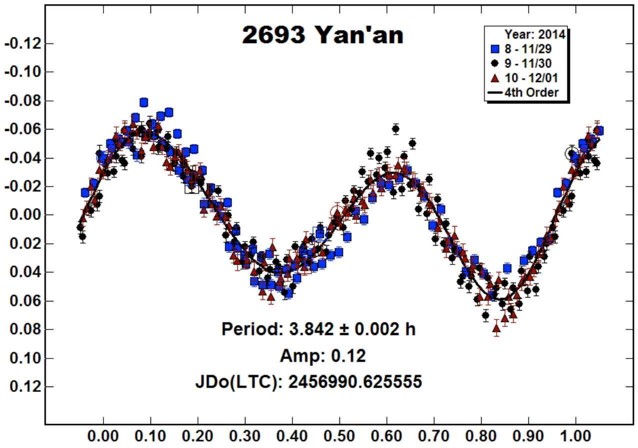
(31723) 1999 JT61 is a main-belt asteroid discovered by Linear at Socorro (MPC 704) on 1999 May 10. It is also known as 1992 UV3, 1998 GZ1. We observed it on seven nights between 2014 Nov 24 and Dec 1. We obtained a period of 8.231 ± 0.002 h and amplitude of 0.21 ± 0.10 mag. There appears to be a 0.07 mag. difference in the minimum at phase 0.14 and 0.6. With a much clearer separation at phase 0.6

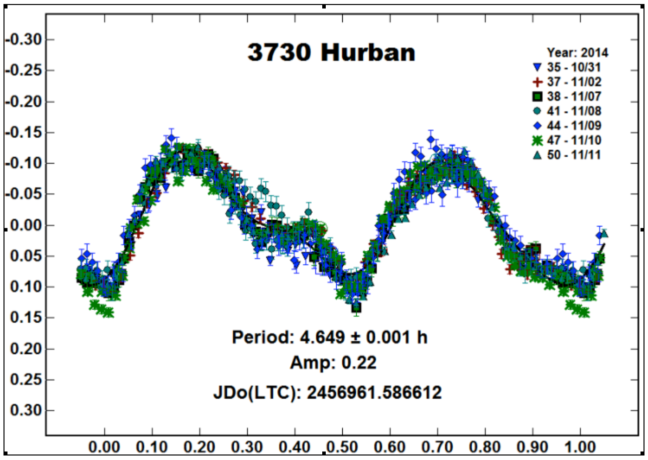


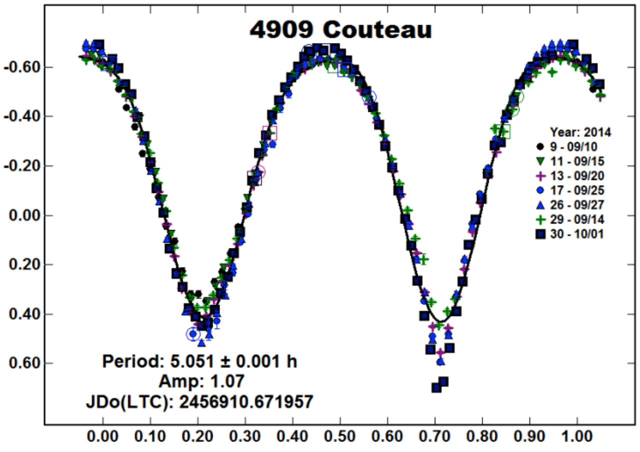


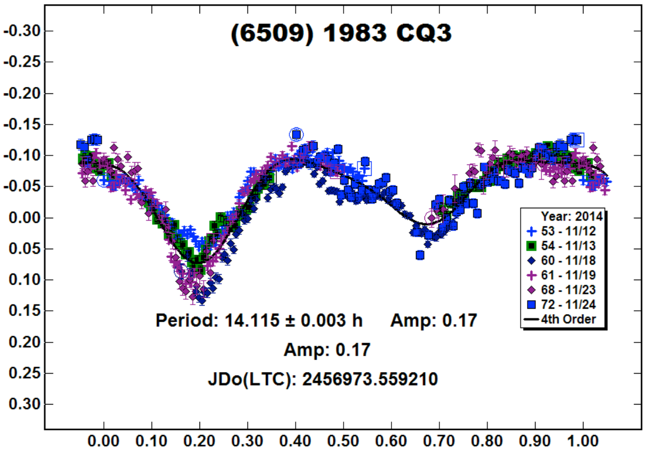


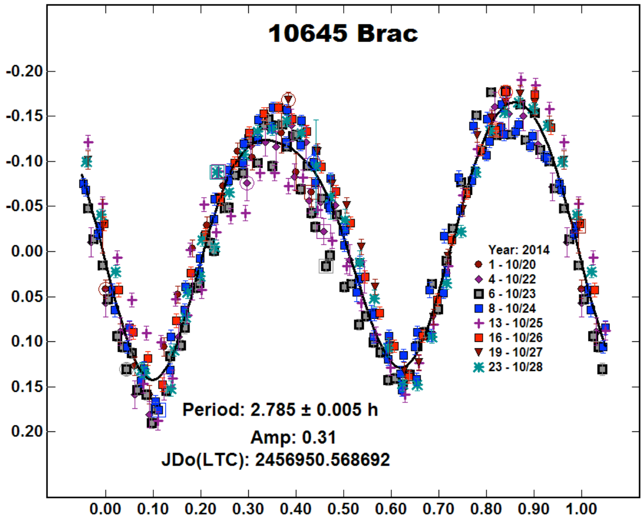


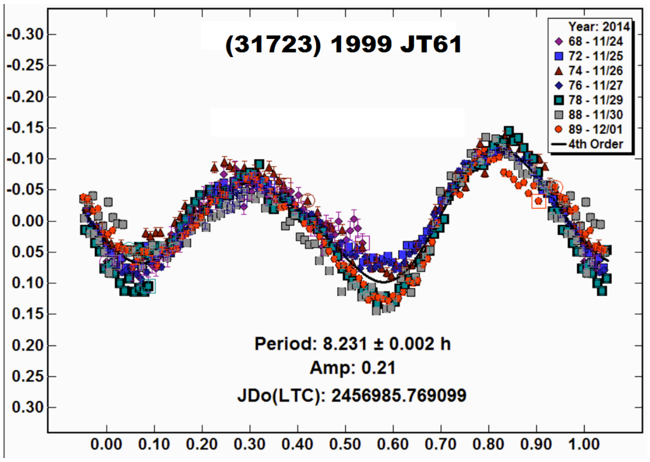












References

Behrend,R. (2005). *http://obswww.unige.ch/~behrend/page_cou.html*

Clark, M. (2015). "Asteroid Photometry from the Preston Gott Observatory." *Minor Planet Bull.*, **42**(1), 15-20.

ECO (2014). Etscorn Campus Observatory. *http://www.mro.nmt.edu/education-outreach/etscorn-campus-observatory*

Hanus, J., Durech, J., Broz, M., Warner, B.D., Pilcher, F., Stephens, R., Oey, J., Bernansconi, L., Causulli, S., Behrend, R., Polishook, D., Henych, T., Lehky, M., Yoshida, F., Ito, T. (2011). "A study of asteroid pole-latitude distribution based on extended set of shape models derived from lightcurve inversion method." *Astron. Astrophys.* **530**, A134.

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., Young, J., Dockweiler, T., Gibson, J., Poutanen, M., Bowell, E. (1992). "Asteroid Lightcurve observations from 1981." *Icarus* **94**, 115-147.

JPLSDB (2015). "Small Body Database Search Engine." *http://ssd.jpl.nasa.gov/sbdb_query.cgi*

Kopff, R.A. (2004). Photometry data from MPC ALCDEF database (retrieved 2014 Dec 01). *http://www.MinorPlanetCenter.net/light_curve*

Pravec, P., Wolf, M., Sarounova, L. (2014). *http://www.asu.cas.cz/~ppravec/neo.htm*

SB (2014). Software Bisque, Golden, CO. *http://www.bisque.com/sc/*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 September 7. *http://www.MinorPlanet.info/lightcurvedatabase.html*

Warner. B.D. (2014). *MPO Canopus* software. *http://www.bdwpublishing.com*

ASTEROIDS OBSERVED FROM CS3: 2014 OCTOBER - DECEMBER

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

(Received: 8 January)

CCD photometric observations of 8 asteroids were obtained from the Center for Solar System Studies from 2014 October to December.

During this calendar quarter, the Center for Solar System Studies (CS3, MPC U81) focused on studying Jupiter Trojan asteroids. During the few days near the Full Moon when the Trojans were too dim to observe, brighter asteroids further away from the moon were selected to provide data for future shape modeling. These targets were selected where exposures could be kept short and the project can be completed in a few days.

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. 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). 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.

453 Tea. This asteroid has been studied several times in the past, often with the amplitude so low as to make the reported period ambiguous. The two most secure results found in the Asteroid lightcurve database (LCDB; Warner *et al*., 2011) are 6.811 h from Kryszczunska (Kryszczunska *et al.,* 2012) and 6.812 h from Licchelli (Licchelli 2006). Licchelli reported a bimodal curve with an amplitude of 0.30 mag. The result from this opposition only has an amplitude of 0.12 mag. suggesting that its orientation may be somewhat pole-on. That said, the resulting lightcurve and period is in good agreement with the Kryszczunska and Licchelli results.

475 Ocllo. Ocllo has previously had a dense data, high amplitude result published (Pilcher 2011). This result is in good agreement with that previously published result.

549 Jessonda. Behrend (Behrend 2014) reported a period of 2.97 h in 2002 and 2.9709 h in 2009. Warner revised his previously

Numbe	Name	2014 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
453	Tea	11/07-11/08	209	21.2,21.4	357	-1	6.799	0.005	0.12	0.01	FLOR
475	Ocllo	11/03-11/04	232	8.3,8.9	30	0	7.29	0.005	0.19	0.01	MC
549	Jessonda	11/05-11/06	298	20.5,20.1	78	4	2.964	0.002	0.06	0.01	MB-M
757	Portlandi	11/05-11/06	590	16.2,16.6	13	0	6.579	0.002	0.03	0.02	V
802	Epyaxa	11/07-11/08	326	15.2,15.6	17	2	4.389	0.001	0.55	0.02	FLOR
6500	Kodaira	10/10-10/12	251	17.8,18.5	341	11	5.4	0.001	0.78	0.02	MC
18899	2000 JQ2	05/31-07/08	1028	11.3,30.0	245	19	222	0.5	0.13	0.03	PHO
31832	2000 AP59	09/26-10/03	941	6.3,8.9	90	8	-				MC

reported period to 2.971 h. At this opposition, the amplitude was only 0.05 mag. suggesting a pole-on orientation. With such a low amplitude, by itself this lightcurve could not reliably determine the rotation period. However, it supports the previously determined periods. The phase angle bisector longitude (L_{PAB}; see Harris *et al.*, 1984) this year was approximately 78°, not that different from the Warner observations at 55°. It will take data obtained at several more oppositions to be able to construct a shape model.

757 Portlandia. Behrend (Behrend 2014) reported a period of 6.5837 h in 2005 and Lagerkvist (Lagerkvist *et al* 1998) reported a period of 6.58 h with an amplitude of 0.5 mag. and a unique single extrema in 1996. This year's results also show a unique lightcurve with multiple extema similar to the Behrend lightcurve and an amplitude of 0.35 mag.

802 Epyaxa. Hanus (Hanus *et al* 2011) previously determined pole-latitude and a shape model for Wright. Its sidereal rotational period was found to be 5.2896 h. Since there was a favorable opposition in 2014, more observations were obtained to improve the shape model. The synodic period of 5.290 h is in good agreement with the previous result.

6500 Kodaira. This asteroid has been twice observed by Clark (Clark, 2007 and 2011) reporting periods of 5.496 h and 5.3988 h. The period determined this year is in good agreement with the later result.

(18899) 2000 JQ2. With the long rotational period, it is not surprising that there is no previously reported period for this asteroid in the Asteroid lightcurve database (LCDB; Warner *et al.*, 2009).

(31832) 2000 AP59. There is no previously reported period for this asteroid in the Asteroid lightcurve database (LCDB; Warner *et al.*, 2009). This Mars Crossing asteroid show clear evidence of tumbling, but insufficient data could be obtained to derive primary and secondary periods. By applying arbitrary zero point adjustments, a period of about 64 h could be forced.

References

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

Clark, M. (2007). "Lightcurve Results for 1318 Nerina, 222 Lermontov 3015 Candy, 3089 Oujianquan, 3155 Lee, 6410 Fujiwara, 6500 Kodaira, (8290) 1992 NP, 9566 Rykhlova, (42923) 1999 SR18, and 2001 FY." *Minor Planet Bul.* **34**, 19-22.

Clark, M. (2011). "Asteroid Lightcurves from the Preston Gott and McDonald Observatories." *Minor Planet Bul.* **38**, 187-189.

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.

Kryszczynska, A., Colas, F., Polinska, M., Hirsch, R., Ivanova, V., Apostolovska, G., Bilkina, B., Velichko, F.P., Kwiatkowski, T., Kankiewicz, P., Vachier, F., Umlenski, V., Michalowski, T., Marciniak, A., Maury, A., Kaminski, K., Fagas, M., Dimitrov, W., Borczyk, W., Sobkowiak, K., Lecacheux, J., Behrend, R., Klotz, A., Bernasconi, L., Crippa, R., Manzini, F., Poncy, R., Antonini, P., Oszkiewicz, D., Santana-Ros, T. (2012). "Do Slivan states exist in the Flora family?. I. Photometric survey of the Flora region." *Astron. Astrophys.* **72**, 51.

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

Pilcher, F. (2011). "Rotation Period Determinations for 25 Phocaea, 140 Siwa, 149 Medusa 186 Celuta, 475 Ocllo, 574 Reginhild, and 603 Timandra." *Minor Planet Bul.* **38**, 78-78.

Warner, B.D. (2011). "Upon Further Review: VI. An Examination of Previous Lightcurve Analysis from the Palmer Divide Observatory." *Minor Planet Bul.* **38**, 96-101.

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

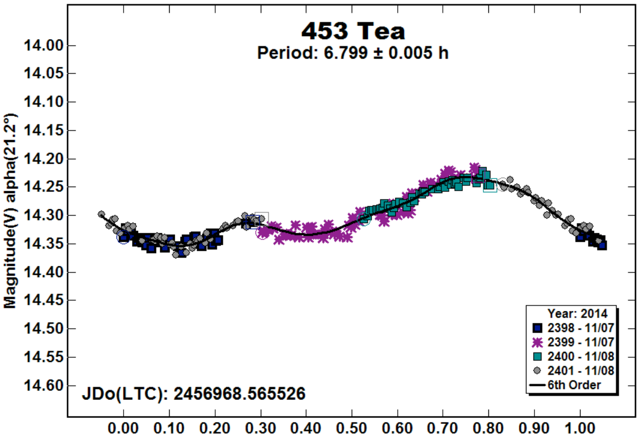
Warner, B.D. (2009). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 September-December." *Minor Planet Bul.* **34**, 113-119.

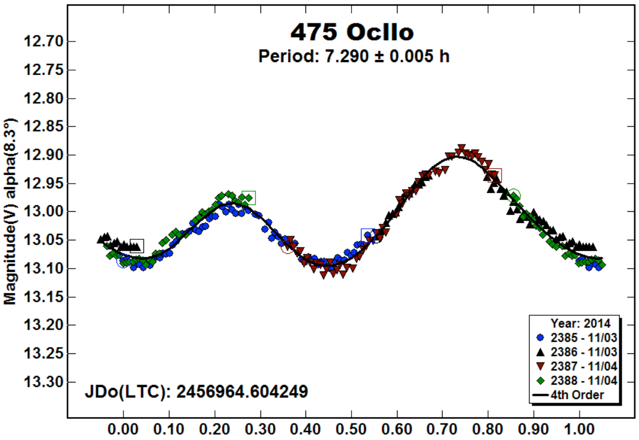
Warner, B.D., Stephens, R.D., Harris, A.W. (2011). "Save the Lightcurves." *Minor Planet Bul.* **33**, 172-174.

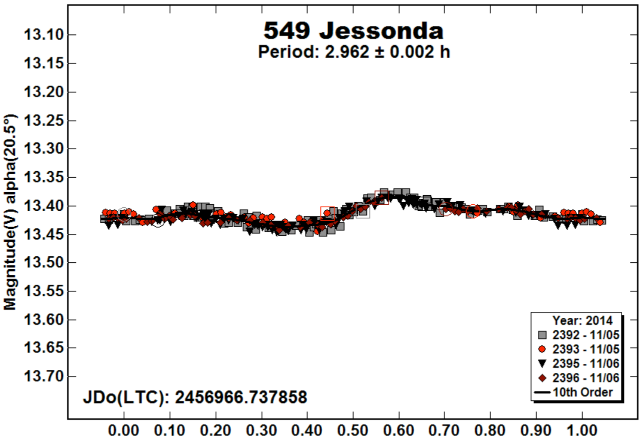
Warner, B.D., Harris, A.W., Pravec, P. (2009). *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html.*

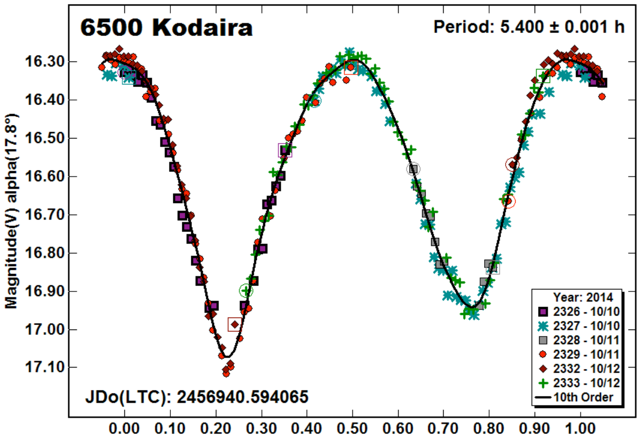
Acknowledgements

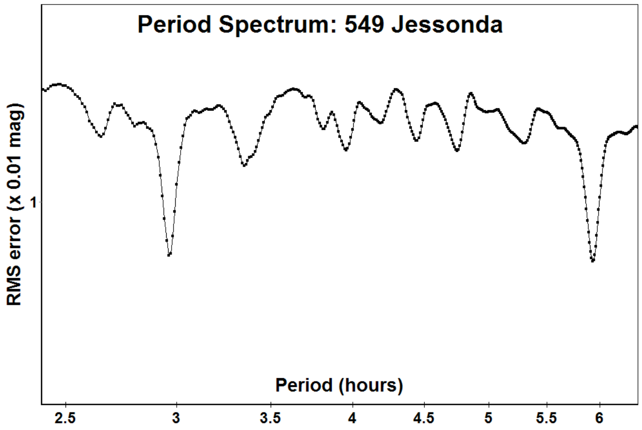
This research was supported by NASA grant NNX13AP56G. The purchase of the FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society.

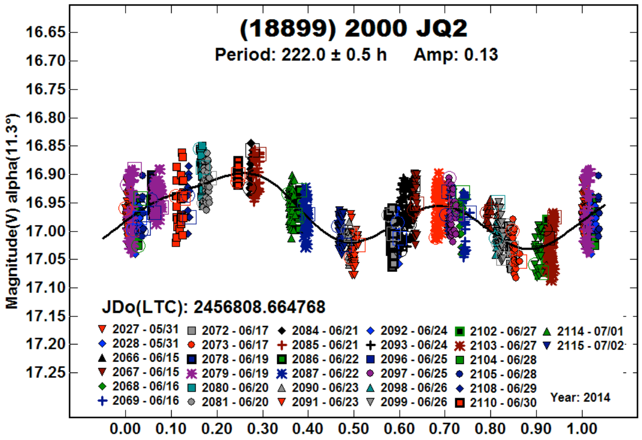


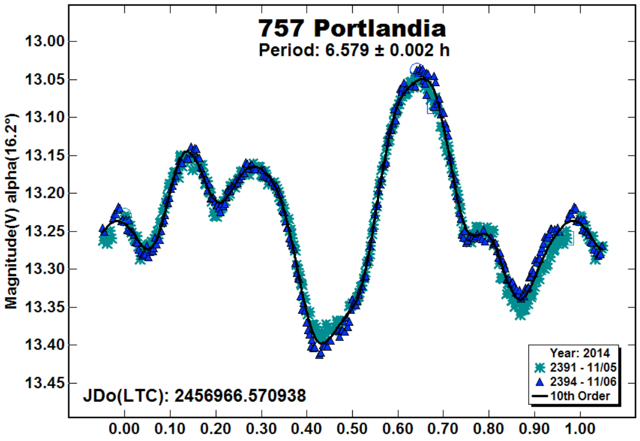


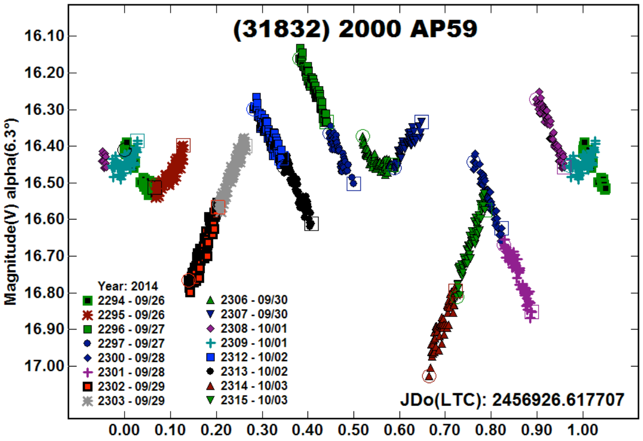

549 Jessonda
Period: 2.962 ± 0.002 h
Magnitude(V) alpha(20.5°)
13.10
13.15
13.20
13.25
13.30
13.35
13.40
13.45
13.50
13.55
13.60
13.65
13.70
Year: 2014
2392 - 11/05
2393 - 11/05
2395 - 11/06
2396 - 11/06
10th Order
JDo(LTC): 2456966.737858
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

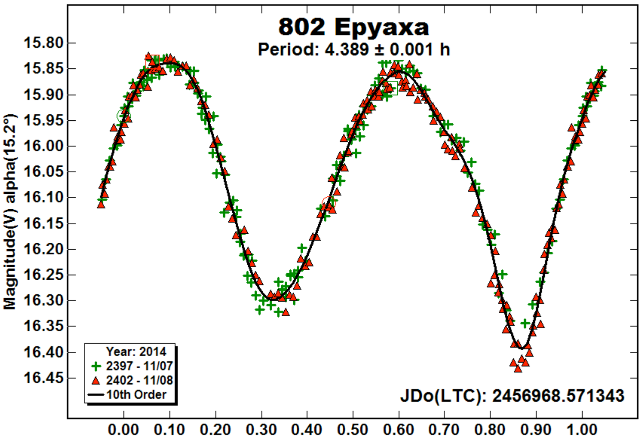

6500 Kodaira
Period: 5.400 ± 0.001 h
Magnitude(V) alpha(17.8°)
16.30
16.40
16.50
16.60
16.70
16.80
16.90
17.00
17.10
Year: 2014
2326 - 10/10
2327 - 10/10
2328 - 10/11
2329 - 10/11
2332 - 10/12
2333 - 10/12
10th Order
JDo(LTC): 2456940.594065
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

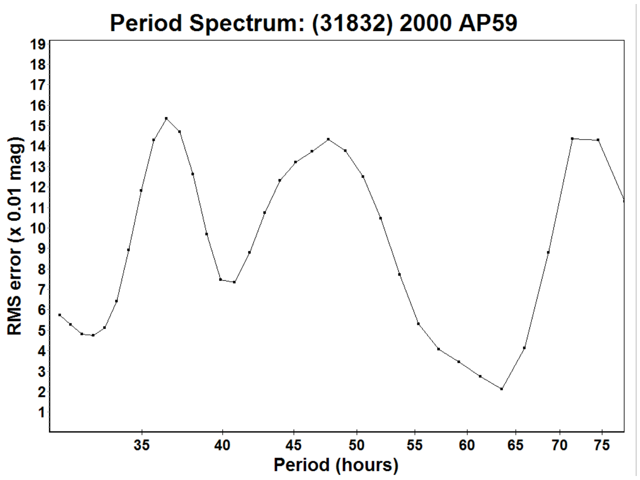

Period Spectrum: 549 Jessonda
RMS error (x 0.01 mag)
1
Period (hours)
2.5 3 3.5 4 4.5 5 5.5 6


(18899) 2000 JQ2
Period: 222.0 ± 0.5 h Amp: 0.13
Magnitude(V) alpha(11.3°)
16.65
16.70
16.75
16.80
16.85
16.90
16.95
17.00
17.05
17.10
17.15
17.20
17.25
JDo(LTC): 2456808.664768
2027 - 05/31
2028 - 05/31
2066 - 06/15
2067 - 06/15
2068 - 06/16
2069 - 06/16
2072 - 06/17
2073 - 06/17
2078 - 06/19
2079 - 06/19
2080 - 06/20
2081 - 06/20
2084 - 06/21
2085 - 06/21
2086 - 06/22
2087 - 06/22
2090 - 06/23
2091 - 06/23
2092 - 06/24
2093 - 06/24
2096 - 06/25
2097 - 06/25
2098 - 06/26
2099 - 06/26
2102 - 06/27
2103 - 06/27
2104 - 06/28
2105 - 06/28
2108 - 06/29
2110 - 06/30
2114 - 07/01
2115 - 07/02
Year: 2014
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


757 Portlandia
Period: 6.579 ± 0.002 h
Magnitude(V) alpha(16.2°)
13.00
13.05
13.10
13.15
13.20
13.25
13.30
13.35
13.40
13.45
Year: 2014
2391 - 11/05
2394 - 11/06
10th Order
JDo(LTC): 2456966.570938
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(31832) 2000 AP59
Magnitude(V) alpha(6.3°)
16.10
16.20
16.30
16.40
16.50
16.60
16.70
16.80
16.90
17.00
Year: 2014
2294 - 09/26
2295 - 09/26
2296 - 09/27
2297 - 09/27
2300 - 09/28
2301 - 09/28
2302 - 09/29
2303 - 09/29
2306 - 09/30
2307 - 09/30
2308 - 10/01
2309 - 10/01
2312 - 10/02
2313 - 10/02
2314 - 10/03
2315 - 10/03
JDo(LTC): 2456926.617707
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


802 Epyaxa
Period: 4.389 ± 0.001 h
Magnitude(V) alpha(15.2°)
15.80
15.85
15.90
15.95
16.00
16.05
16.10
16.15
16.20
16.25
16.30
16.35
16.40
16.45
Year: 2014
2397 - 11/07
2402 - 11/08
10th Order
JDo(LTC): 2456968.571343
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


Period Spectrum: (31832) 2000 AP59
RMS error (x 0.01 mag)
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
Period (hours)
35 40 45 50 55 60 65 70 75

LIGHTCURVES OF ASTEROIDS 4271 NOVOSIBIRSK AND 6335 NICOLERAPPAPORT

Abigail L. Becker
Texas A&M University–Commerce
P.O. Box 3011
Commerce, TX 75429-3011

Kent Montgomery, Mai Huynh, Isaiah Santistevan
Texas A&M University–Commerce

(Received: 8 January)

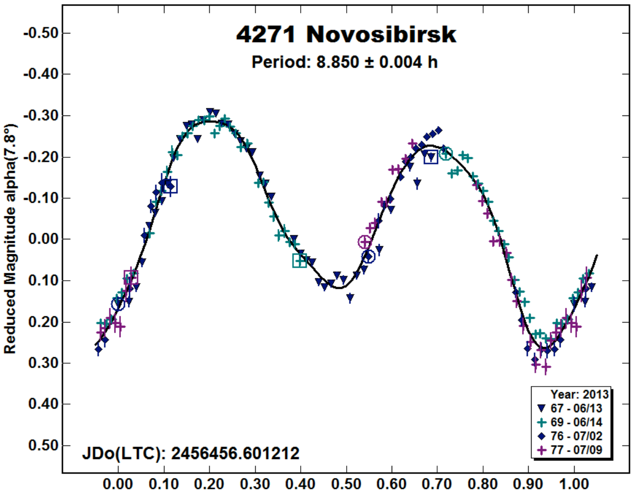
Lightcurves were determined for two main-belt asteroids, 4271 Novosibirsk and 6335 Nicolerappaport. 4271 Novosibirsk was found to have a rotation period of 8.850 ± 0.004 hours and lightcurve amplitude of 0.52 mag. 6335 Nicolerappaport was found to have a period of 4.272 ± 0.003 hours and lightcurve amplitude of 0.36 mag.

The purpose of this study was to image two asteroids in order to determine their rotational periods. Multiple nights of CCD observations were analyzed using differential photometry to determine the lightcurves for the asteroids 4271 Novosibirsk and 6335 Nicolerappaport.

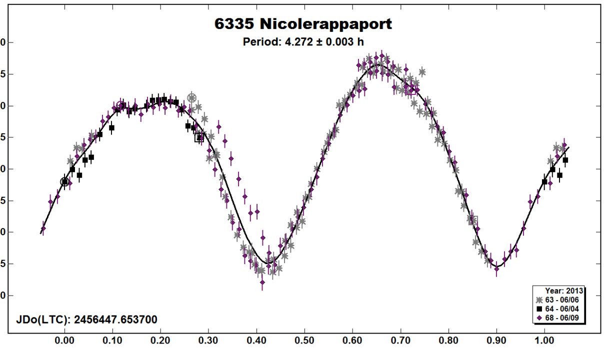
4271 Novosibirsk is a main-belt asteroid with an absolute magnitude of H = 11.8 (JPL, 2013a). The asteroid's orbit has a semi-major axis of 3.013 AU, an inclination of 10.92°, and an eccentricity of 0.094. Its composition is currently unknown (JPL, 2013a). 6335 Nicolerappaport is also a main-belt asteroid with an absolute magnitude of 12.9 (JPL, 2013b). The orbital characteristics are: semi-major axis of 2.637 AU, inclination of 13.92°, and eccentricity of 0.149. The composition is currently unknown (JPL, 2013b).

Calibration images were obtained each night and the images were reduced in *Maxim DL* using flat field, bias, and dark images. Twilight flat field images were taken for the SARA north telescope and dome flat-field images were taken for the A&M-Commerce observatory. Dark frames used the same exposure as the asteroid images. After image reduction, differential photometry was used to determine the brightness of the asteroid using *MPO Canopus* v10.2.1.0 (Warner, 2011). 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. Using these differential magnitudes and plotting them versus time allowed the creation of lightcurves for each asteroid. A Fourier transform method was applied to determine the rotation period of the asteroid as well as the error in the period.

<u>4271 Novosibirsk</u>**.** 4271 Novosibirsk was imaged in 2013 on June 12 and 13 and July 2 and 9 at the Texas A&M-University Commerce Observatory, which houses a 0.4-m telescope with an SBIG STX-16803 CCD camera. Exposures were 300 seconds through a clear filter. Over the four nights, 160 images of the asteroid were obtained and analyzed. Several data points were removed because the asteroid passed by or in front of a star. From the lightcurve, Novosibirsk was found to have a period of 8.850 ± 0.004 hours and lightcurve amplitude of 0.52 mag. The estimated error in the photometry is 0.011 magnitudes. A search of the Astrophysics Data System and the Asteroid Lightcurve Database (LCDB; Warner *et al*., 2009) did not find previously reported results.



<u>6335 Nicolerappaport</u>**.** Nicolerappaport was imaged on 2013 June 5, 7, and 10 using the 0.9-m Southeastern Association for Research in Astronomy (SARA) North telescope at Kitt Peak National Observatory and Apogee CCD camera. Images were 180 seconds taken through an infrared blocking filter. Over the three nights, 250 images of the asteroid were obtained and analyzed. Several data points were removed due to the asteroid passing near or directly in front of a star. The estimated photometric errors were 0.023 magnitudes. From the lightcurve for 6335 Nicolerappaport, the rotational period was found to be 4.272 ± 0.003 hours. The amplitude of the lightcurve is 0.36 mag. A search of the Astrophysics Data System and the Asteroid Lightcurve Database (LCDB; Warner *et al*., 2009) did not find any previously reported results.



References

JPL (2013a). JPL Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=4271*

JPL (2013b). JPL Small-Body Database Browser. *http://ssd.jpl.nasa.gov/sbdb.cgi?sstr=6335*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2015 Jan 15. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2011). *MPO Canopus* software Version 10.2.1.0 Bdw Publishing. *http//www.MinorPlanetObserver.com*

ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2014 OCTOBER-DECEMBER

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

(Received: 8 January)

Lightcurves for 18 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2014 October through December. All but one of the asteroids were a member of the Hungaria orbital group or collisional family, observed as follow-up to previous apparitions to check for undiscovered satellites, to improve previous binary discovery parameters, or to obtain data for spin axis and shape modeling.

CCD photometric observations of 18 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2014 October through December. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

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

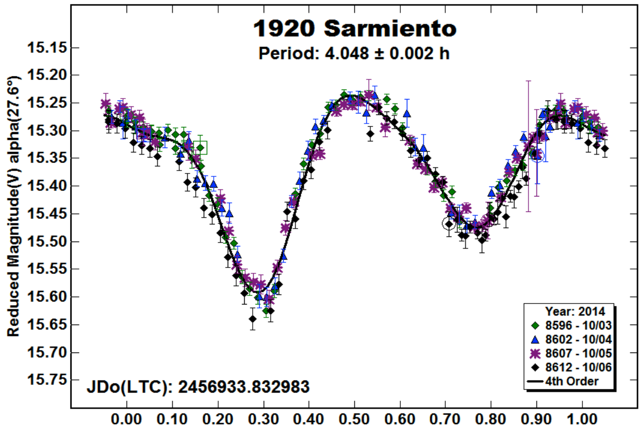
Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the 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 (2007c). When possible, magnitudes are taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag. This consistency is critical to analysis of long period and/or tumbling asteroids. 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.

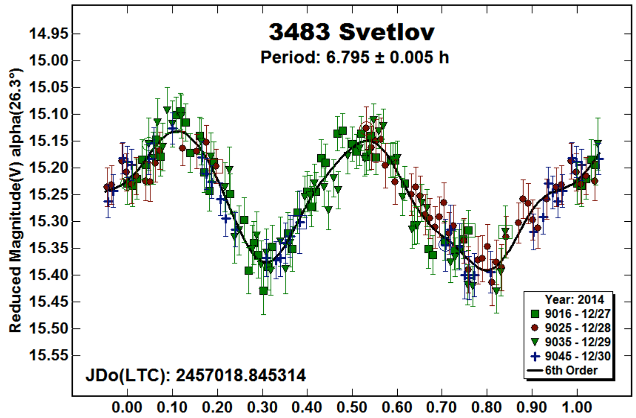
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

For a number of the asteroids, the additional dense lightcurves allowed finding a preliminary shape and spin axis model. Those results will be presented in a future paper.

1920 Sarmiento. The results from the most recent observations are in good agreement with previous results: Warner (2007b; 4.0501 h) and Stephens *et al.* (2014; 4.038 h).



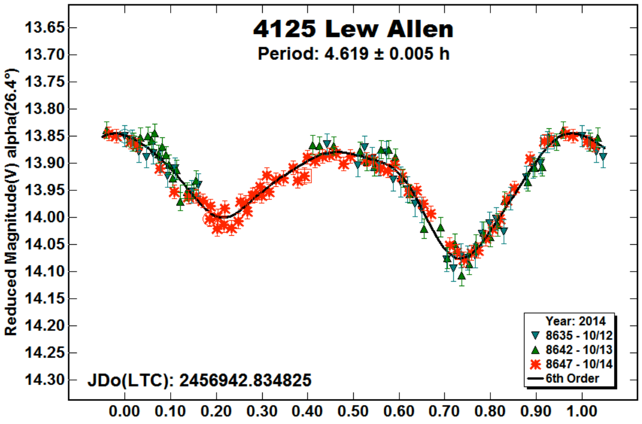
3483 Svetlov. This was the third apparition at which Svetlov was observed by the author. Previous results were 6.790 h (Warner, 2010c) and 6.811 h (Warner, 2012c), both in good agreement with the results obtained from the 2014 observations.



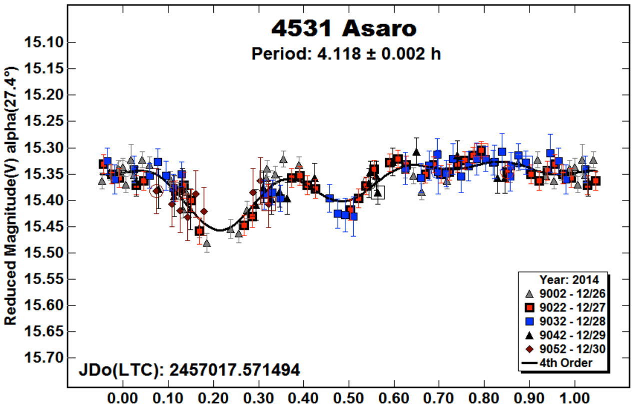
4125 Lew Allen. Previous results from the author include Warner (2007b, 4.628 h; 2010a, 4.625 h; 2012a, 4.629 h). The period of 4.619 h found using the 2014 October observations is in good agreement with those earlier results.

Number	Name	2014 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Group
1920	Sarmiento	10/03-10/06	210	27.6,26.5	45	-18	4.048	0.02	0.35	0.02	H
3483	Svetlov	12/27-12/30	175	26.3,25.8	149	23	6.795	0.005	0.24	0.03	H
4125	Lew Allen	10/12-10/14	138	26.5,25.9	60	21	4.619	0.005	0.23	0.02	H
4531	Asaro	12/26-12/30	132	27.4,28.3	54	26	4.118	0.002	0.18	0.02	H
4713	Steel	12/27-12/30	186	21.0,20.0	131	11	5.203	0.002	0.38	0.02	H
4765	Wasserburg	12/26-12/30	183	24.7,25.7	49	-8	3.664	0.003	0.1	0.01	H
5841	Stone	10/16-10/20	151	23.8,25.5	352	11	2.88	0.001	0.11	0.01	H
9387	Tweedledee	10/16-10/20	183	27.1,28.4	343	13	3.531	0.001	0.13	0.02	H
15786	1993 RS	10/06-10/12	200	33.3,0.5,32.9	63	18	6.82	0.02	0.14	0.02	H
15786	1993 RS	^{2006}10/24-10/31	241	16.0,18.3	24	21	6.82	0.01	0.13	0.01	H
15786	1993 RS	^{2010}01/21-02/13	201	17.6,14.7	134	21	6.48	0.01	0.08	0.01	H
20392	Mikeshepard	11/20-11/25	186	8.1,6.2	79	-1	29.2	0.5	0.75	0.05	MB-O
24654	Fossett	11/04-11/06	185	12.5,11.6	56	-16	6.007	0.003	0.52	0.04	H
25076	1998 QM98	09/25-10/12	724	15.4,8.3	22	-7	58.3^{T}	0.5	0.35	0.1	H
40229	1998 TO3	10/02-10/04	178	9.1,8.1	19	-9	2.664	0.002	0.12	0.02	H
54234	2000 JD16	10/29-11/04	169	10.4,6.3	47	6	2.664	0.002	0.13	0.02	H
68553	2001 XF68	10/08-10/10	191	23.6,23.2	36	25	3.13	0.01	0.22	0.03	H
70030	Margaretmiller	10/26-10/29	248	15.3,15.4	34	24	4.331	0.002	0.42	0.03	H
96518	1998 RO3	10/01-10/03	141	7.6,8.8	1	7	6.62	0.05	0.11	0.02	H
99395	2002 AB19	10/09-10/12	150	20.9,20.1	36	22	7.08	0.05	0.29	0.03	H

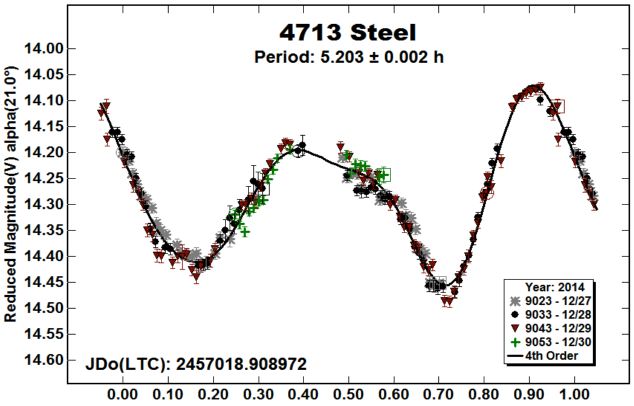
Table II. Observing circumstances. ^{T} indicates a possible period for a tumbling asteroid. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly 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;l MB-O = outer main-belt.



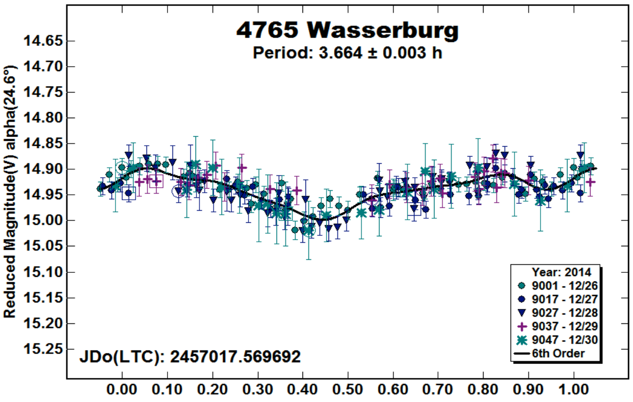
4531 Asaro. This was the third apparition for this Hungaria by the author. The most recent observations from 2014 December lead to a period of 4.118 h, in a good agreement with earlier results (Warner; 2013b; 2015)



4713 Steel. Behrend (2002) found a period of 5.186 h for this Hungaria. The author found similar results at two subsequent apparitions (Warner, 2010c, 5.199 h; 2012b, 5.193 h) and from the 2014 Dec observations (5.203 h).

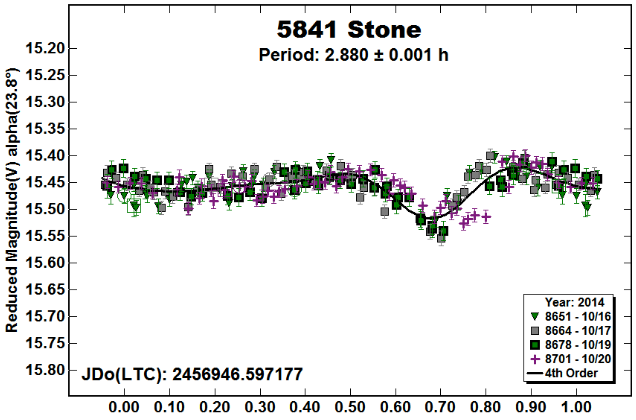


4765 Wasserburg. The period for Wasserburg is well-determined, based on observations by Warner (2010b, 2013c) and Pravec *et al.* (2010, 2013).

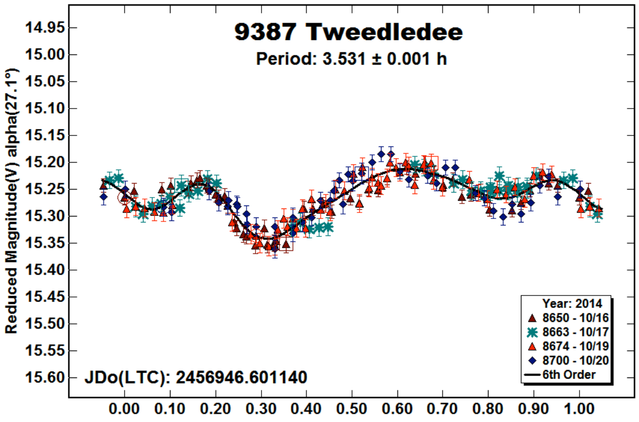


No signs of a suspected satellite (Warner, 2013c) were seen in the 2014 December observations.

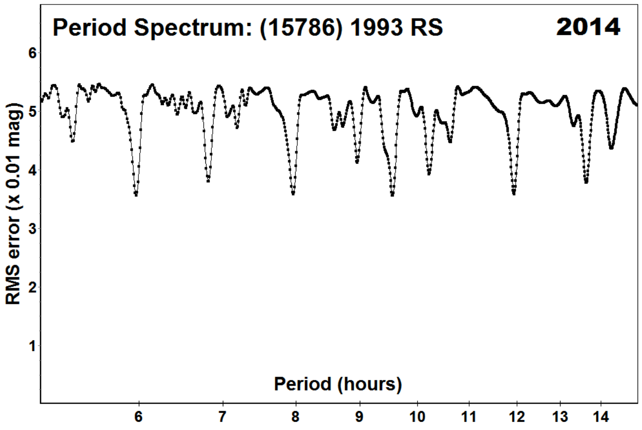
5841 Stone. The period of 2.880 h from 2014 October observations is in good agreement with previous results from the author (Warner, 2007a; 2010a; 2013a; 2015).



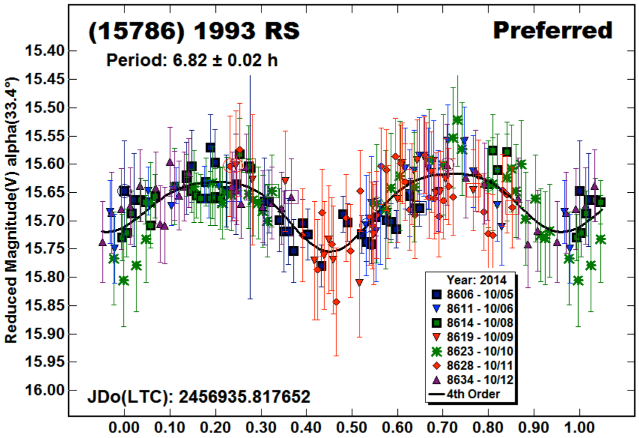
9387 Tweedledee. The results from 2014 October are similar to those from, e.g., Warner (2013a) and Stephens (2015).

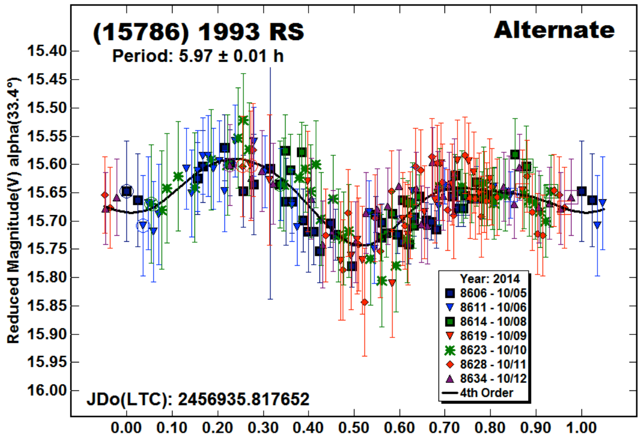


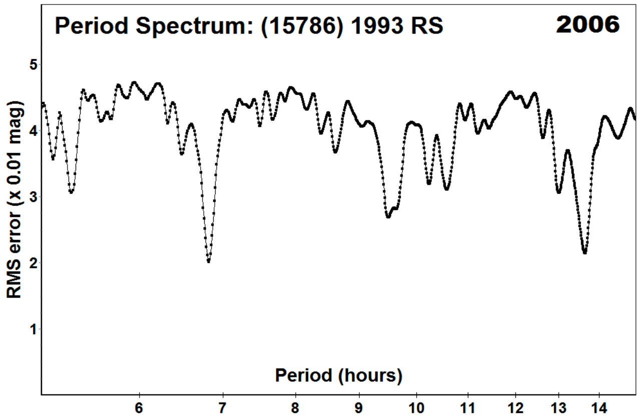
(15786) 1993 RS. Previous results include 13.62 h (Warner, 2007b) and 13.84 h (Warner, 2010b). The initial results from the 2014 October data favored other solutions and so the new and previous data were re-examined to see if the ambiguities could be resolved. First, a look at the 2014 results.



The period spectrum for the 2014 data is highly ambiguous, showing several periods of nearly equal probability. Presuming that the reanalysis of earlier data is correct, the preferred period from the 2014 observations is 6.82 h. However, a period of 5.97 h cannot be formally excluded. The situation is complicated by the somewhat high phase angle of 33° and the amplitude of only 0.14 mag. As discussed in Harris *et al.* (2014), the presumption of a bimodal lightcurve is not always correct under these circumstances. Furthermore, both periods are nearly commensurate with an Earth day, the difference between the two being 0.5 rotations over 24 hours. Despite these considerations, the longer period of about 13.6 h was ruled out because it would require a complex quadramodal lightcurve. This is not entirely impossible but considered unlikely in this circumstance.

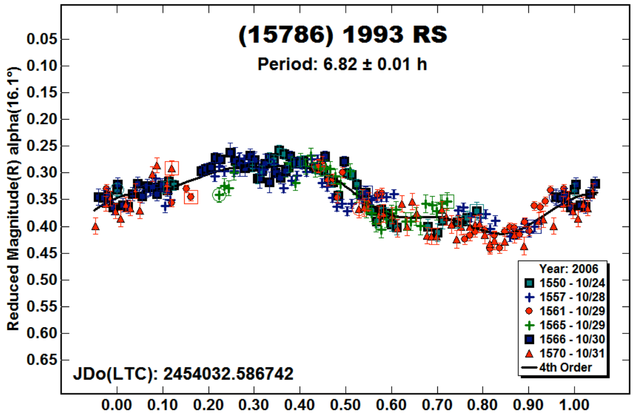




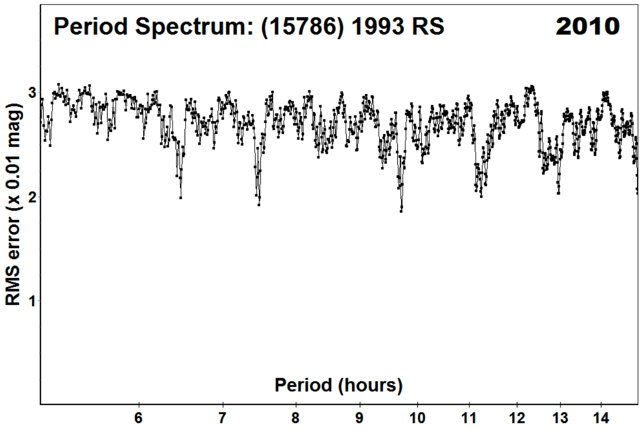


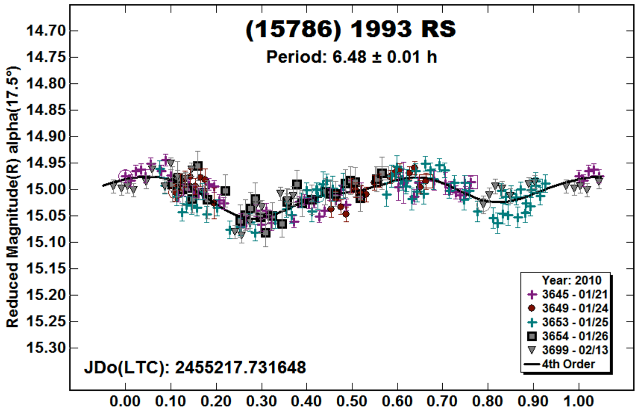
Looking at the 2006 data, the period spectrum gives further justification for adopting a period of 6.82 h over 5.97 h. However, it does not exclude the 13.62 h period first reported in Warner (2007b). Adopting a period of 6.82 h for the 2006 requires accepting a monomodal lightcurve. Again, from Harris *et al.*

(2014), this is not unreasonable given the phase angle and low amplitude of 0.13 mag.



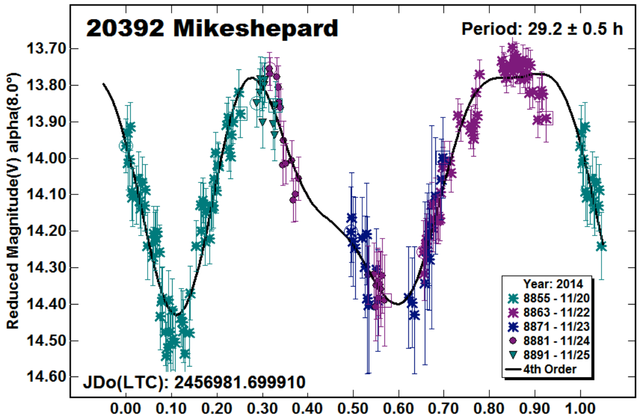
The period spectrum from the 2010 data set was also ambiguous, but again seemed to reject the 5.97 h period. However, yet another pair of solutions was revealed: 6.48 h (monomodal) and 12.96 h (bimodal). The difference between 6.48 h and 6.82 h is 0.2 rotations per 24 hours, so it's not likely the difference is a simple mismatch of halves of a symmetrical lightcurve, i.e. a *rotational alias*.



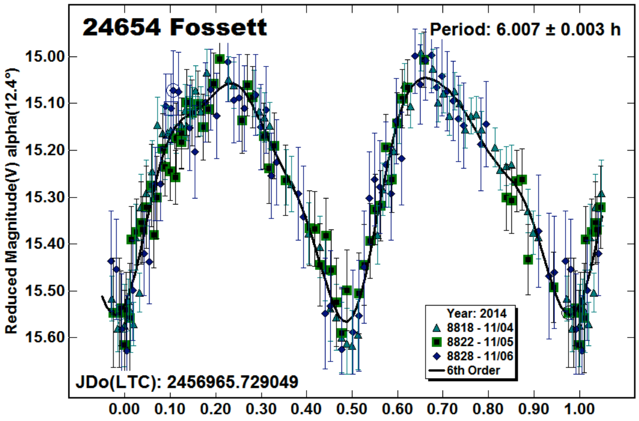


Zero point adjustments on the order of 0.02 mag and less were tried to see, if nothing else, the 2010 data could be forced to a period closer to 6.8 h. Those efforts proved fruitless. The period for 1993 RS must be considered uncertain although it is more likely that the period is in the range of 6.5-6.9 h than 13.6-13.9 h.

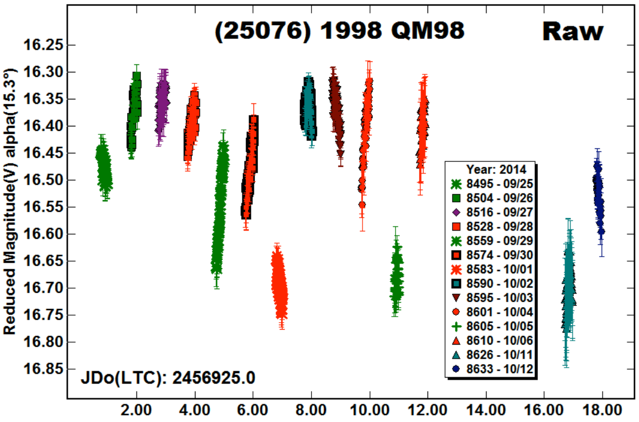
20392 Mikeshepard. There were no previously reported periods for this outer main-belt asteroid. It was observed in honor of its namesake, a noted radar observer and frequent collaborator, who concentrates on M-type asteroids.



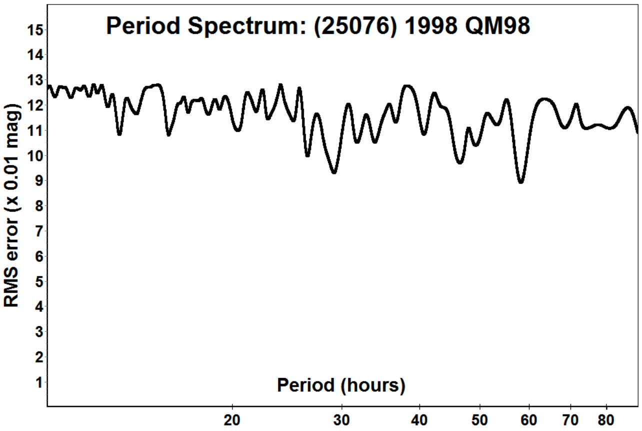
24654 Fossett. The period of 6.007 h closely agrees with previous results from Pravec *et al.* (2005b), Warner (2010a), and Stephens (2014a).

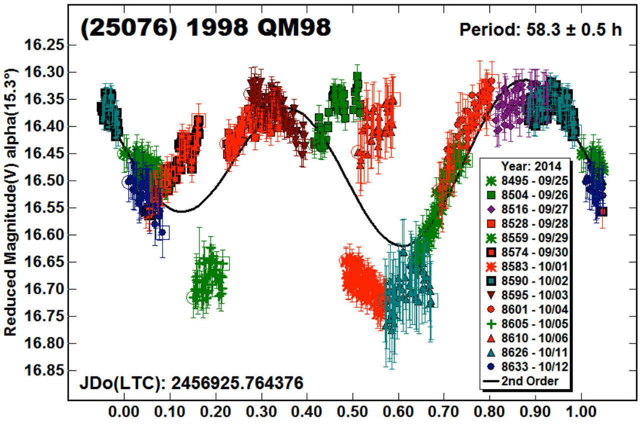


(25076) 1998 QM98. The raw plot of the 2014 data covering almost three weeks in 2014 shows not only a long period but signs of being in non-principal axis rotation (NPAR). See Pravec *et al.* (2005a, 2014) for a detailed discussion of "tumbling" asteroids.

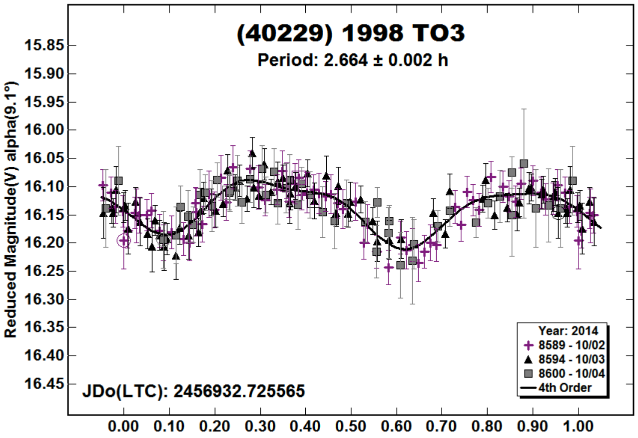


The period spectrum from *MPO Canopus* shows a two solutions near 30 and 60 hours. A lightcurve was generated that forced the solution to a range near 60 hours. This clearly demonstrates the probability of tumbling action. The data were sent to Petr Pravec (private communications) who agreed that the asteroid was tumbling but he could not find a reliable dominant period.

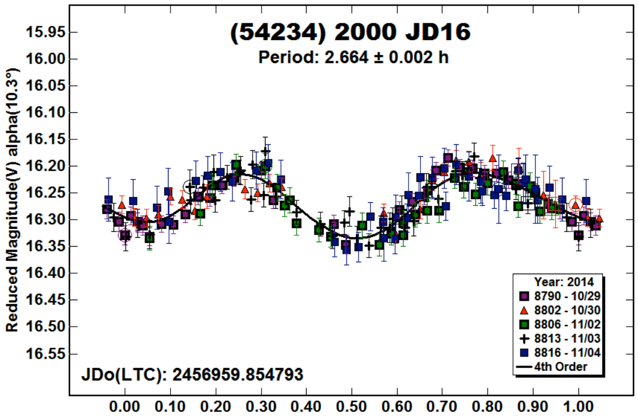




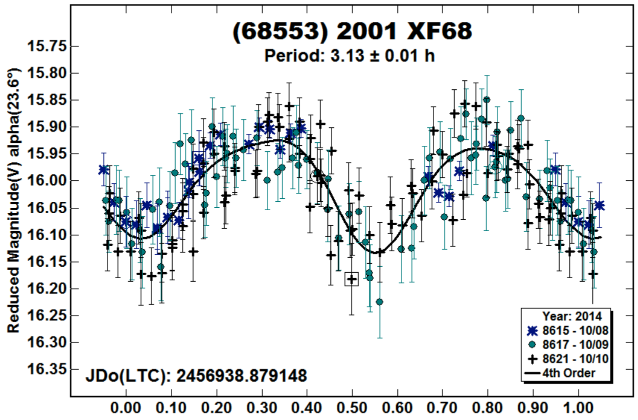
(40229) 1998 TO3. There were no previous entries in the LCDB for 1998 TO. The short period, amplitude, and lightcurve shape make it a good candidate for being a binary. No signs of a satellite were seen, i.e., attenuations due to occultations and/or eclipses or a second period. Observations at future apparitions are encouraged. The next chance is 2016 May when the asteroid is at V ~ 17.5 and –49° declination.



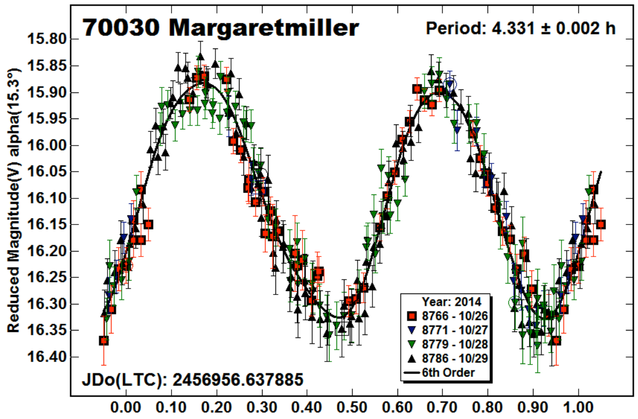
(54234) 2000 JD16. Warner (2012a) found a period of 6.059 h for 2000 JD16, a period that is wholly inconsistent with data from 2014 October-November. The data set from 2011 was sparse in comparison and did not cover as wide a range of dates as the 2014 data set. Therefore, the period of 2.664 h reported here is considered correct and the longer period should be rejected. Here, too, the period, amplitude, and lightcurve shape make this a potential binary. The next opportunity is 2016 June at V ~ 17.7 and –9° declination.



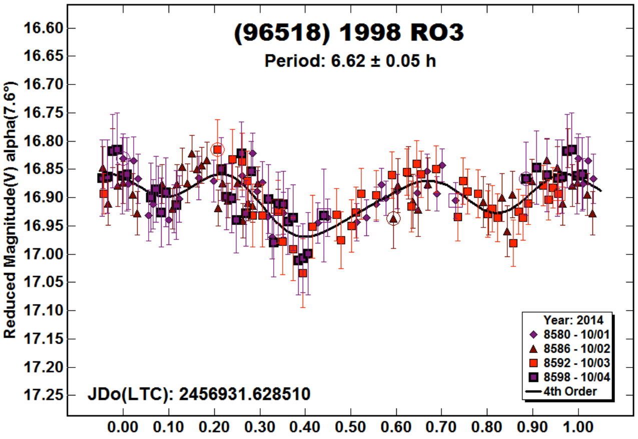
(68553) 2001 XF68. There were no previous entries in the LCDB for this asteroid.



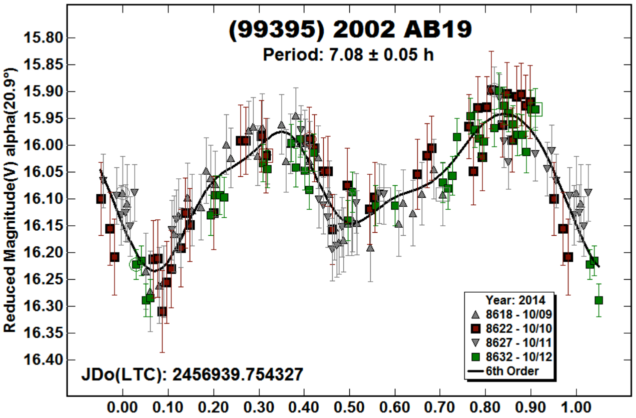
70030 Margaretmiller. This is a suspected binary (Warner, 2012a). No signs of a satellite were found in the 2014 October data set.



(96518) 1998 RO3. The period spectrum strongly favored the solution of 6.62 h, which was adopted despite the unusual shape of the lightcurve. This reasonable based on Harris *et al*. (2014) in that lightcurves with amplitudes of only 0.10 mag or so cannot be assumed to be simple or bimodal, even at low phase angles.



<u>(99395) 2002 AB19</u>. There were no previous entries in the LCDB for 2002 AB19.



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-1210099.

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

References

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

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

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.

Hanus, J., Durech, J., Broz, M., Warner, B.D., Pilcher, F., Stephens, R., Oey, J., Bernasconi, L., Casulli, S., Behrend, R., and 5 coauthors (2011). "A study of asteroid pole-latitude distribution based on an extended set of shape models derived by the lightcurve inversion method." *Astron. Astrophys*. **530**, A134.

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

Masiero, J.R., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Dailey, J., Eisenhardt, P.R.M., McMillan, R.S., Spahr, T.B., Skrutskie, M.F., and 8 coauthors (2011). "Main Belt Asteroids with WISE/NEOWISE. I. Preliminary Albedos and Diameters." *Astrophys. J.* **741**, A98.

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. (2005a). "Tumbling asteroids." *Icarus* **173**, 108-131.

Pravec, P., Wolf, M., Sarounova, L. (2005b, 2010, 2013). *http://www.asu.cas.cz/~ppravec/neo.htm*

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.

Stephens, R.D., Coley, D., Warner, B.D. (2014a). "Collaborative Asteroid Lightcurve Analysis at the Center for Solar System Studies: 2013 April-June." *Minor Planet Bul*. **41**, 8-13.

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

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

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

Warner, B.D. (2007c). "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.

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

Warner, B.D. (2010b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 December - 2010 March." *Minor Planet Bul*. **37**, 112-118.

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

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

Warner, B.D (2012b). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 September - December.” *Minor Planet Bul.* **39**, 69-80.

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

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

Warner, B.D. (2013b). “Asteriod Lightcurve Analysis at the Palmer Divide Observatory: 2013 February - March. The Final Report..” *Minor Planet Bul.* **40**, 217-220.

Warner, B.D., Stephens, R.D. (2013c). “One New and One Suspected Hungaria Binary Asteroid.” *Minor Planet Bul.* **40**, 221-223.

Warner, B.D. (2015). “Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 June-October.” *Minor Planet Bul.* **42**, 54-60.

LIGHTCURVE ANALYSIS FOR 2824 FRANKE AND 3883 VERBANO

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

Alessandro Marchini
Astronomical Observatory, University of Siena
via Roma 56, 53100, Siena, ITALY

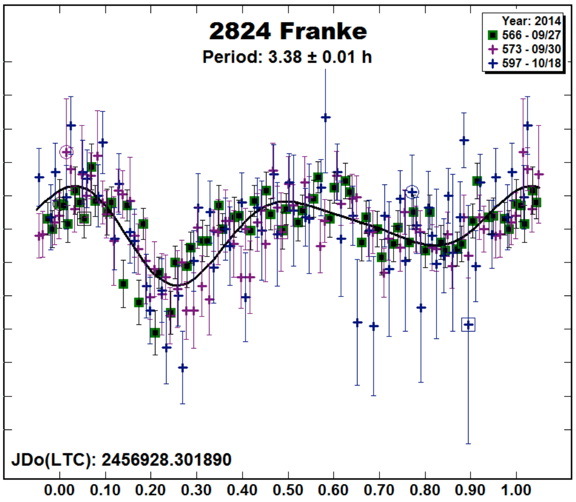
Riccardo Papini
Carpione Observatory (K49)
Spedaletto, Florence, ITALY

(Received: 11 January)

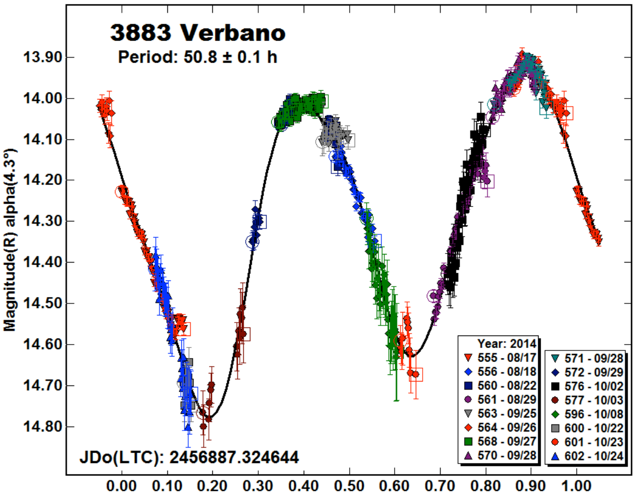
Photometric observations of two main-belt asteroids were made over nineteen nights during 2014 August-October to determine their synodic rotation periods and lightcurve amplitudes: 2824 Franke (*P* = 3.38 ± 0.01 h, *A* = 0.06 ± 0.03 mag) and 3883 Verbano (*P* = 50.8 ± 0.1 h, *A* = 0.85 ± 0.03 mag).

CCD photometric observations of two main-belt asteroids were made on nineteen nights from 2014 August 17 to October 24. Images were obtained at Balzaretto Observatory (A81) with a 0.20-m *f*/5.5 SCT and SBIG ST7-XME CCD. At the Astronomical Observatory of the University of Siena, a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope and SBIG STL-6303E CCD were used. The Carpione Observatory (K49) used a 0.25-m *f*/10 SCT and SBIG ST9-XE CCD. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2013). All unfiltered images were calibrated with dark and flat-field frames. The asteroid magnitude was reduced to R-band, using near-solar color index comparison stars that were selected using the Comp Star Selector feature in *MPO Canopus*.

<u>2824 Franke.</u> This main-belt asteroid was selected from the “Potential Lightcurve Targets” web site (Warner, 2014) and observed on three nights over a time span of 21 days. The derived synodic period is *P* = 3.38 ± 0.01 h with an amplitude of *A* = 0.06 ± 0.03 mag.



<u>3883 Verbano</u>. This main-belt asteroid was selected from the “Potential Lightcurve Targets” web site (Warner, 2014) and observed on sixteen nights over a time span of 68 days. The derived synodic period is *P* = 50.8 ± 0.1 h with a amplitude of *A* = 0.85 ± 0.03 mag.



References

Warner, B.D. (2013). MPO Software, MPO Canopus version 10.4.3.17. Bdw Publishing. *http://www.bdwpublishing.com*

Warner, B.D. (2014). “Potential Lightcurve Targets”. *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2014 OCTOBER-DECEMBER

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

(Received: 9 January)

Lightcurves for 43 near-Earth asteroids (NEAs) were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2014 October through December.

CCD photometric observations of 43 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2014 October through December. Table I lists the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

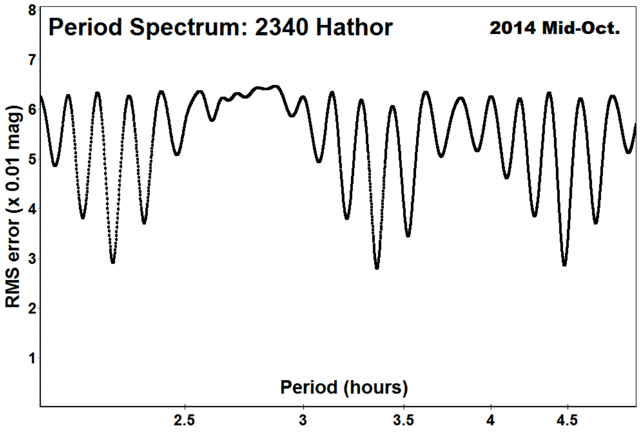
All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposure duration varied depending on the asteroid's brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid.

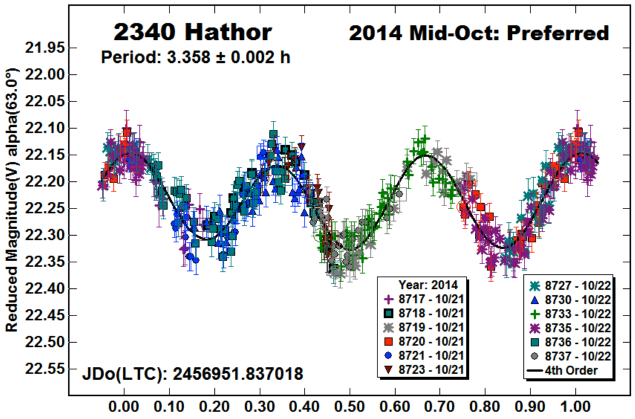
Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the 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). When possible, magnitudes are taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag. This consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

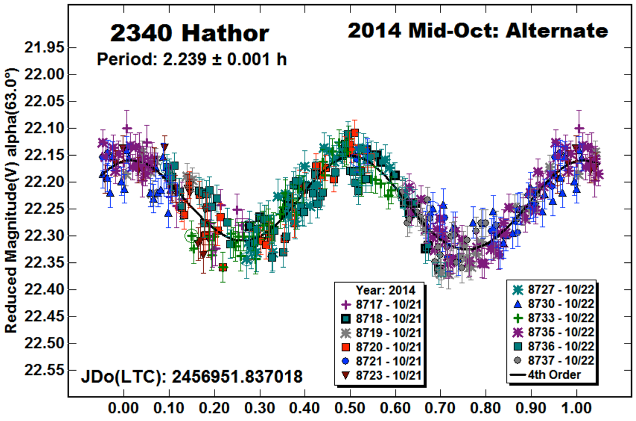
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances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

2340 Hathor. Initial observations in 2014 mid-October found two possible results, as seen in the period spectrum.

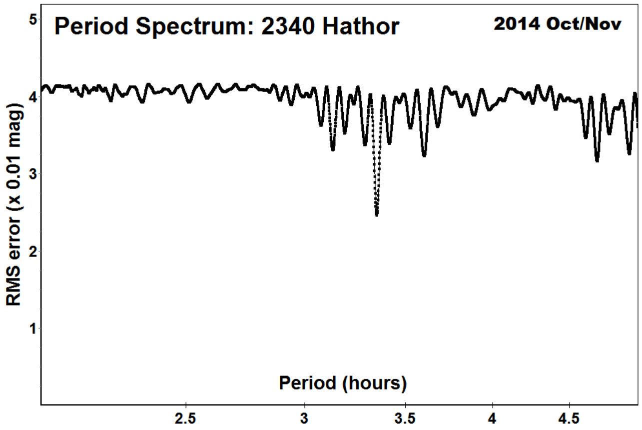


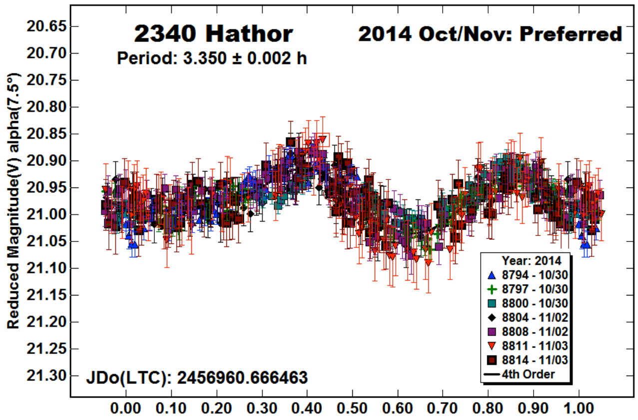




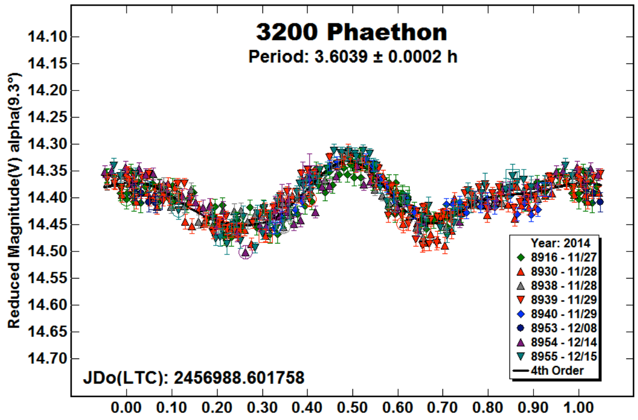
The bimodal lightcurve had a period of 2.239 h while a lightcurve with a complex asymmetric trimodal shape had a period of 3.358 h. Pravec *et al.* (private communications) had a more extensive data set that confirmed the longer period. The large phase angle of more the 60° likely lead to shadowing that produced the more complex lightcurve.

Additional observations at CS3-PDS in 2014 late October and early November, at a phase angle of only 7°, firmly established the longer period as seen in the second period spectrum. It's interesting to note that the shape of bimodal lightcurve, with the incorrect period, resembles the shape of the lightcurve obtained at lower phase angles and with the longer period.

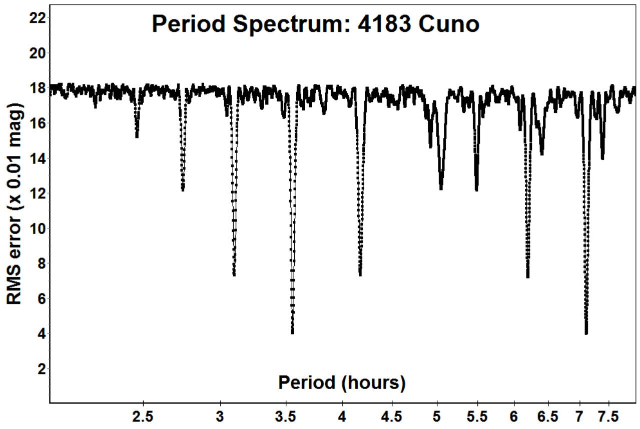


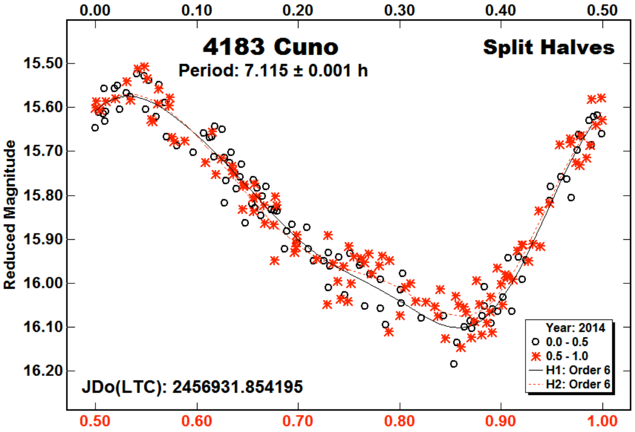


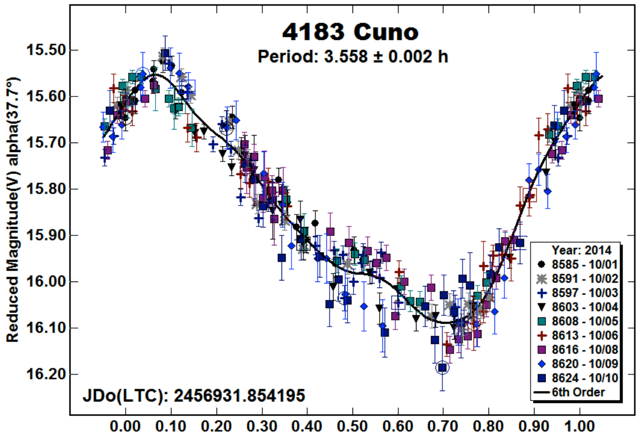
3200 Phaethon. Most results found in the LCDB have a period of about 3.6 h, the same that was found using CS3-PDS data from 2014 November and December.



4183 Cuno. An extensive data set from 2000 (Pravec *et al*., 2000) found a period of 3.559 h with slight variations in the period and significant changes in the amplitude over almost 6 weeks.

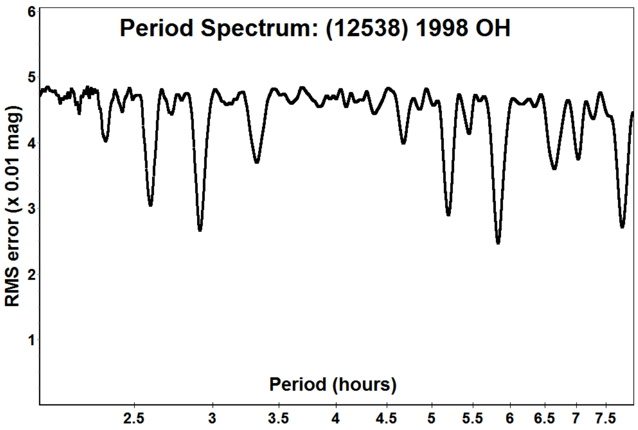


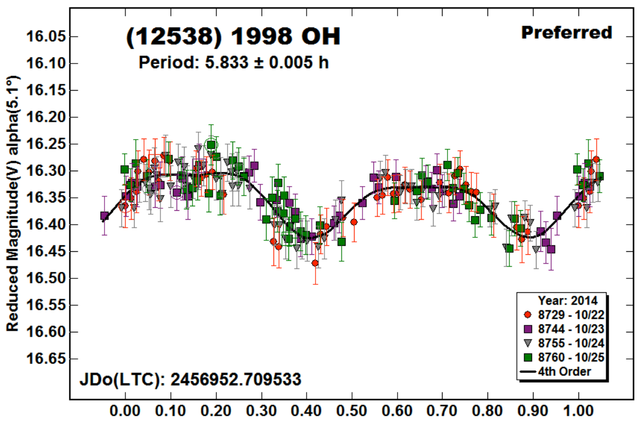


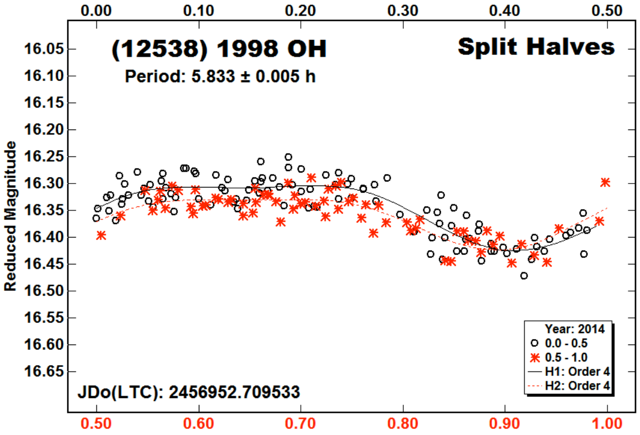


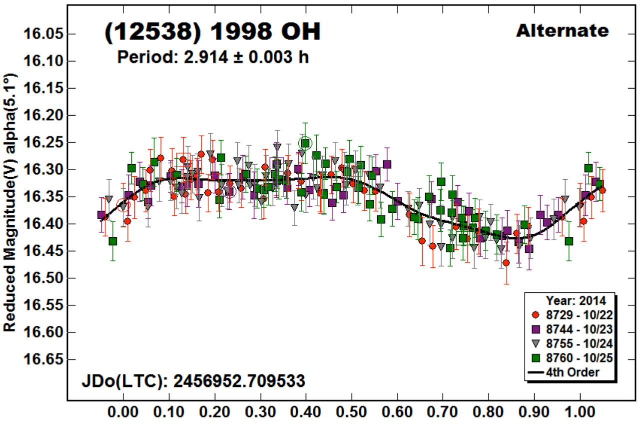
The period spectrum based on the CS3-PDS data from 2014 October showed two nearly equal solutions. The "split halves" plot (see Harris *et al.*, 2014, for a discussion) shows that the lightcurve is nearly symmetrical over the two halves of the longer period, making the half-period a possibility. Usually an amplitude of more than 0.4 mag favors a bimodal solution. At the given the phase angle, that rule doesn't always hold but, in this case, the short period monomodal lightcurve is considered correct.

(12538) 1998 OH. This asteroid also showed a period spectrum that favored two solutions. There is just enough asymmetry in the split halves plot such to adopt the longer period as the more likely choice but the shorter period cannot be formally excluded.

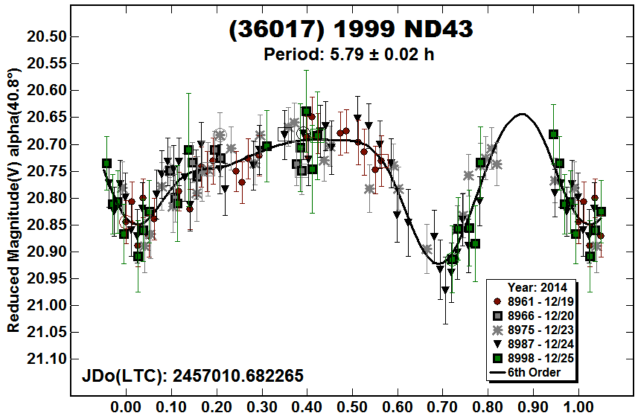




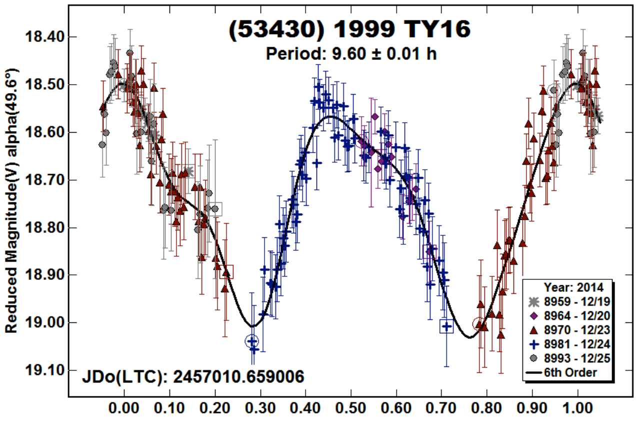




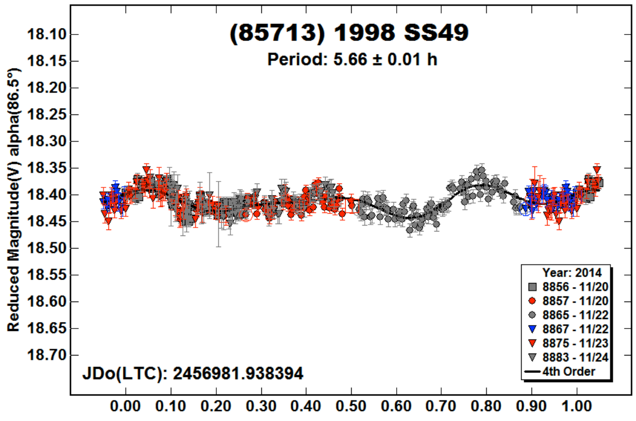
(36017) 1999 ND43. Pravec *et al.* (1999) found a period of 11.4 h for this NEA. However, it has a rating of U = 1 in the LCDB, making it "likely wrong." The data from 2014 December lead to a more likely period of 5.79 h, but it is not definitive.



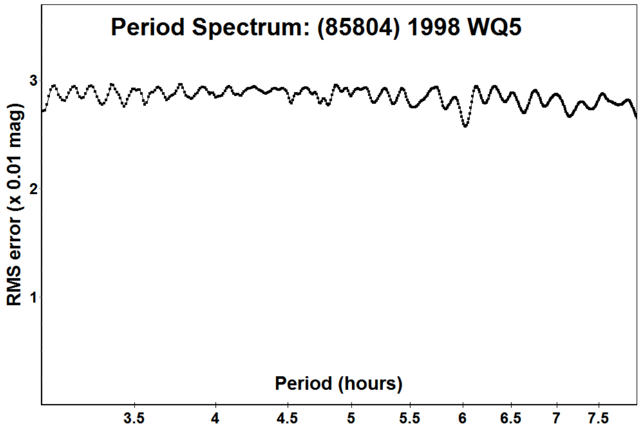
(53430) 1999 TY16. Ye (2009) found a period of 9.582 h and Skiff (2012) found 9.58 h. The period of 9.60 h reported here is in good agreement with those earlier results.

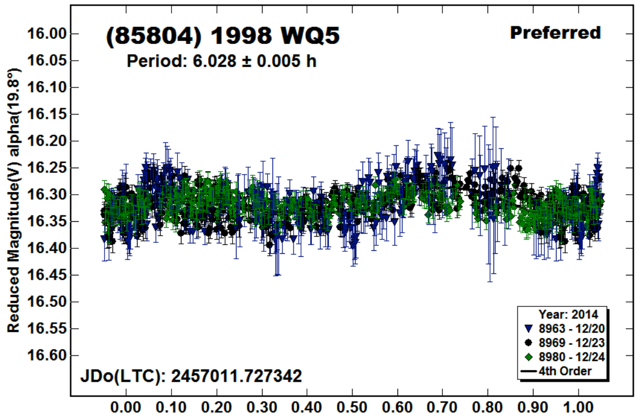


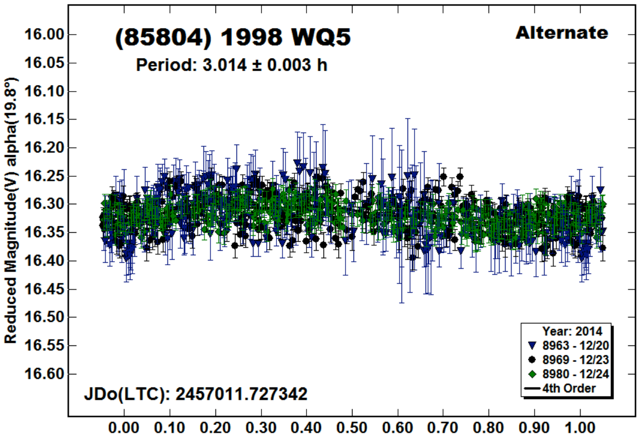
(85713) 1998 SS49. This NEA was observed by the author in 2014 September (Warner, 2015). At that time, the solution was ambiguous, being 5.370 h or 2.686 h. The additional data from November did not fully resolve the ambiguity, mostly due to the low amplitude (0.06 mag). Even so, the asymmetry in the lightcurve tends to favor the longer period.



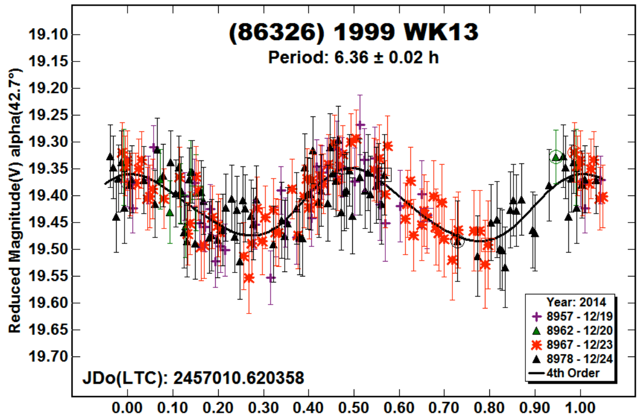
(85804) 1998 WQ5. Oey (2006) found a period of 3.0089. Using data obtained about two months earlier, Higgins (2011) found a period of 3.71 h. The period spectrum from the CS3-PDS 2014 December data is not much help. The “preferred” lightcurve is forced to the favored period of 6.028 h. The “alternate” lightcurve was forced a period near the one found by Oey.



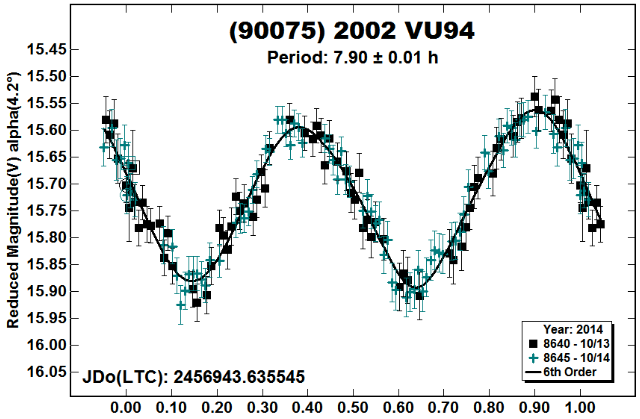




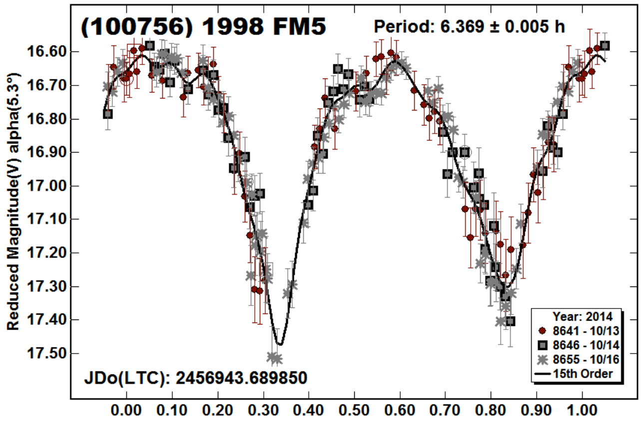
(86326) 1999 WK13. There were no previous results in the LCDB for 1999 WK13. The period spectrum showed several periods of nearly equal strength. Given the large phase angle and low amplitude, it is not possible to exclude a monomodal solution of 3.18 ± 0.01 h and amplitude 0.10 mag.



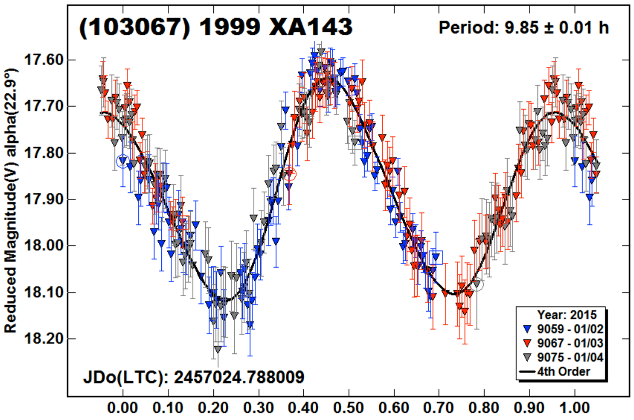
(90075) 2002 VU94. This NEA was first observed by the author in 2014 August (Warner, 2015). The period was 7.88 h and amplitude 0.63 mag at phase angle (α) 40°. Observations about two months later found P = 7.90 h and amplitude of 0.31 mag. Since the amplitude of a lightcurve decreases with phase angle, the smaller amplitude at α = 4° is expected.



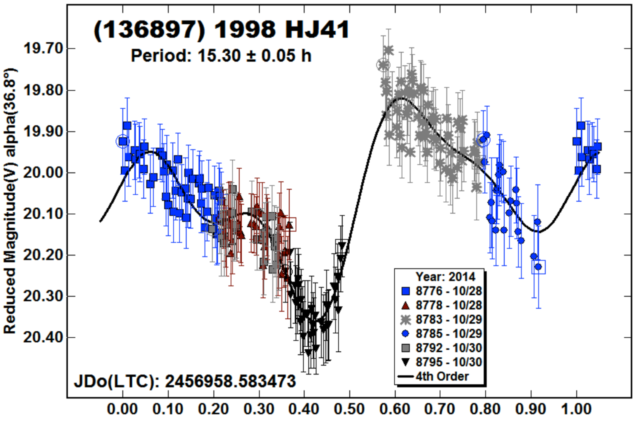
(100756) 1998 FM5. Previous results include Krugly *et al.* (2002a, 6.364 h, A = 1.14 mag) and Pravec *et al.* (1998; 6.35 h, A = 1.0 mag). The period found here is in good agreement. The amplitude, A = 0.80 mag, is significantly lower, probably because the data were obtained at much lower phase angles than in the other two cases.



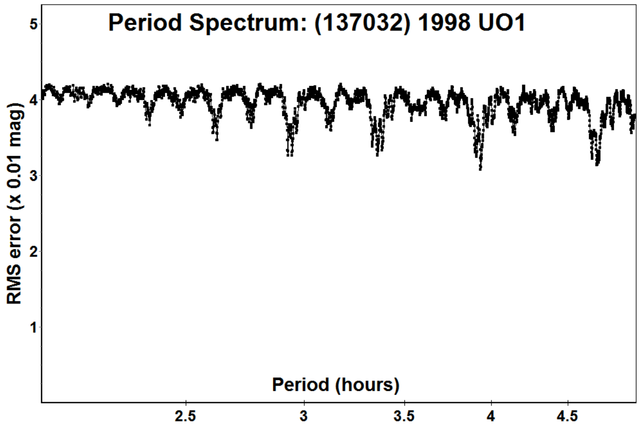
(103067) 1999 XA143. Galad *et al.* (2005) found a period of 9.8490 h for 1999 XA143. The period found using CS3-PDS data is in near perfect agreement. The amplitudes from the two data sets were the same, which is not unexpected since the viewing aspects were also nearly identical.

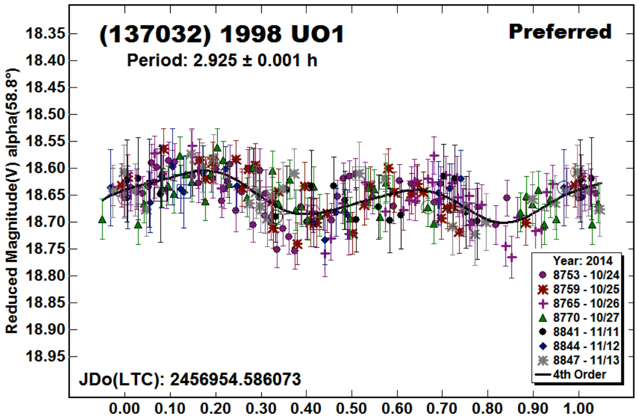


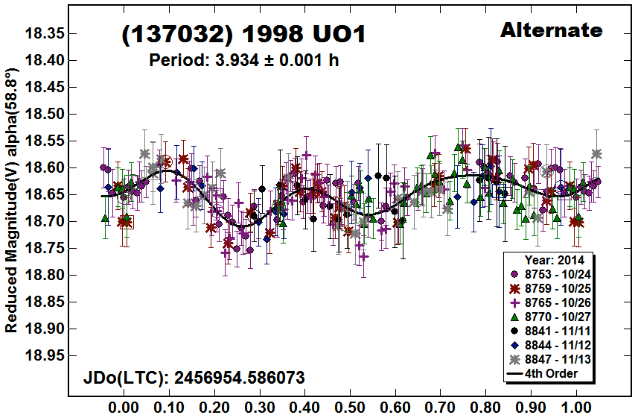
(136897) 1998 HJ41. The period of 15.30 h is close to being commensurate with an Earth day (3:2). The period spectrum strongly favored the period, but it is adopted with some caution.



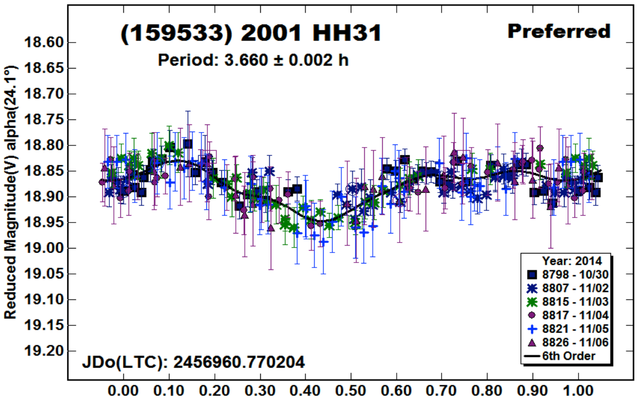
(137032) 1998 UO1. A definitive period for this asteroid has been elusive over the years. Wolters *et al.* (2008) found 3.0 h; Skiff (2012) found 4.42 h; and Pravec *et al.* (2014a) found 2.916 h. The period spectrum from CS3-PDS data in 2014 October-November shows several possibilities. A period of 2.925 h is adopted here but one of 3.934 h cannot be formally excluded given the high phase angle and low amplitude.

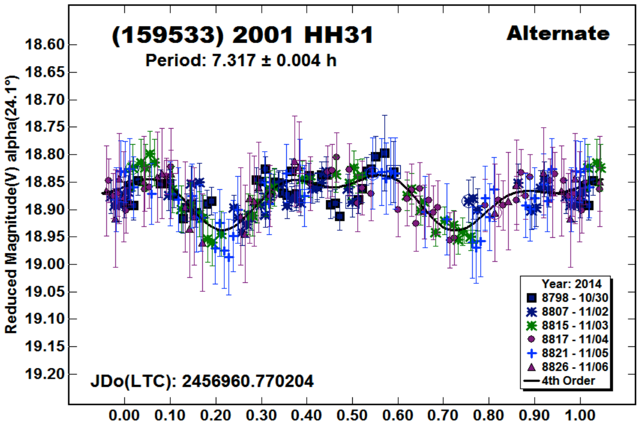




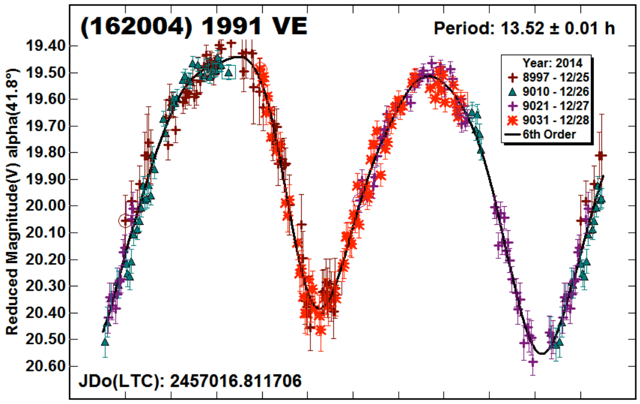


(159533) 2001 HH31. A period is 3.660 h is adopted here but the double period of 7.318 h cannot be formally excluded.

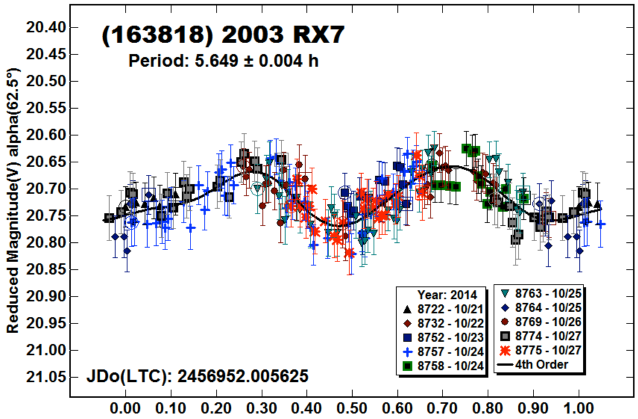




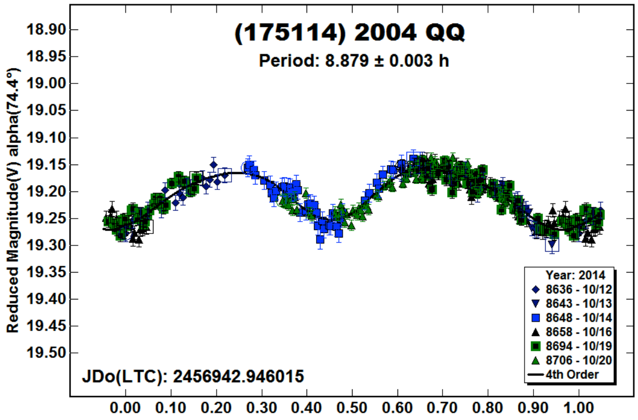
(162004) 1991 VE. Pravec *et al.* (2012) reported this to be a tumbling asteroid with periods of 13.4802 h and 17.316 h. The CS3-PDS data from 2014 December lead to a period of 13.52 h but did not show obvious signs of tumbling.



(163818) 2003 RX7. Torppa *et al.* (2005) reported a period of 2.6 h (U = 1 in the LCDB). The period of 5.649 h reported here is considered secure.

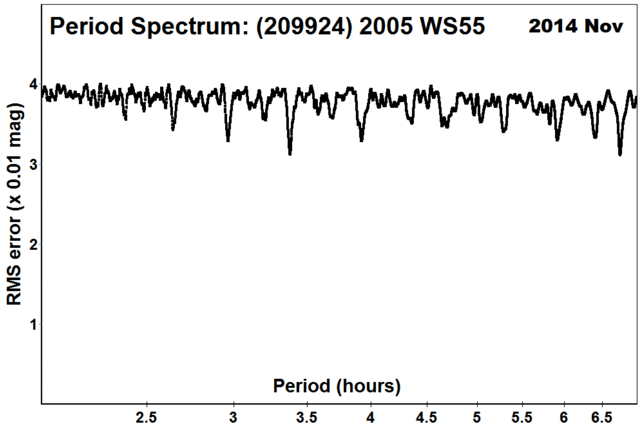


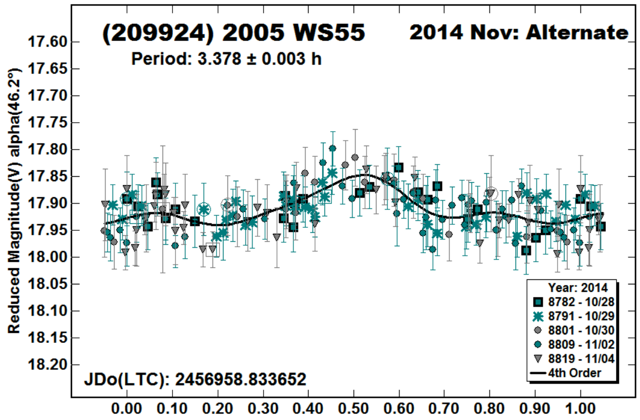
(175114) 2004 QQ. There were no previous entries in the LCDB for 2004 QQ.



(209924) 2005 WS55. This is a case where two distinct solutions were found using data sets obtained only two months apart. If the two differed by 0.5 rotations per Earth day, this could be attributed to a *rotational alias*, i.e., a miscount of the number of rotations over the span of the observations. That was not the case here.

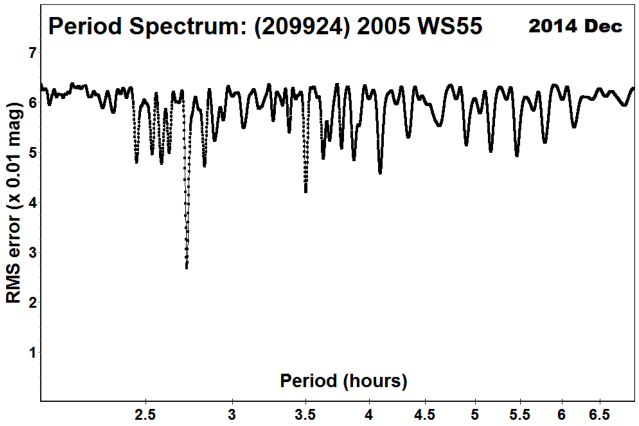
The period spectrum using data from 2014 November only does not show a clear-cut solution. The lightcurve is forced to the best fit period of 3.378 h.

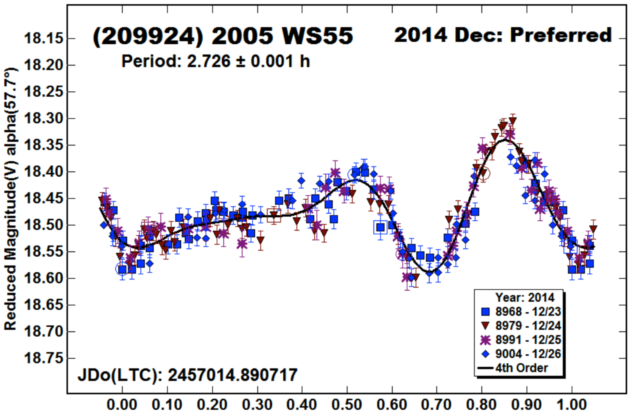




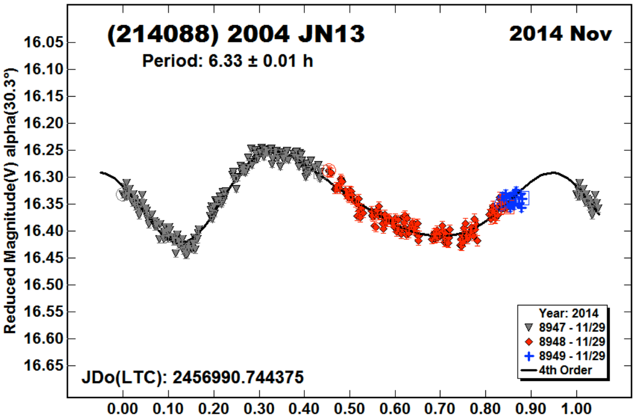
On the other hand, the period spectrum based on data from 2014 December shows a sharply defined solution with a period of 2.726 h. The two are close to a 5:4 ratio. Given that both data sets had at least three back-to-back nights and the runs on each night were longer than either period, a *rotational alias* seems unlikely.

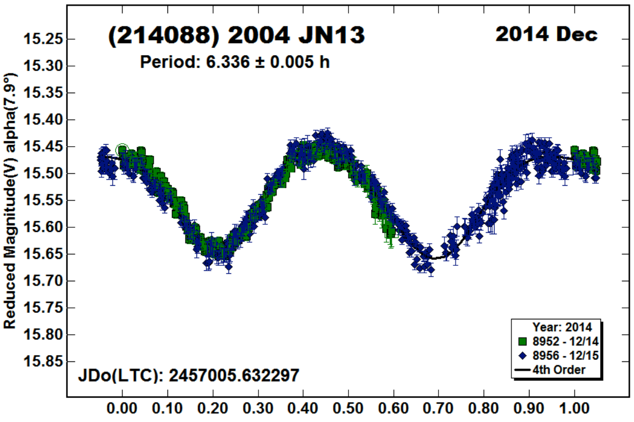
Both solutions cannot be right. The best conclusion is that the lower amplitude lightcurve leads to an ambiguous set of solutions and that the period favored by the period spectrum is spurious. The shorter period of 2.726 h is adopted for this paper.



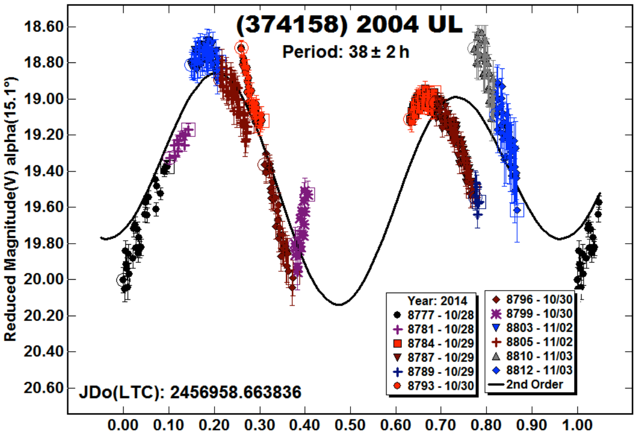


(214088) 2004 JN13. Pravec *et al.* (2014a) reported $P = 6.342$ h, $A = 0.40$ mag from data in early 2014 Nov. The CS3-PDS data from late 2014 November lead to $P = 6.33$ h, $A = 0.20$ mag while those from mid-December produced $P = 6.336$ h, $A = 0.17$ mag. The decrease in amplitude followed the decrease in phase angle over the apparition, i.e., from 100° down to 8°.

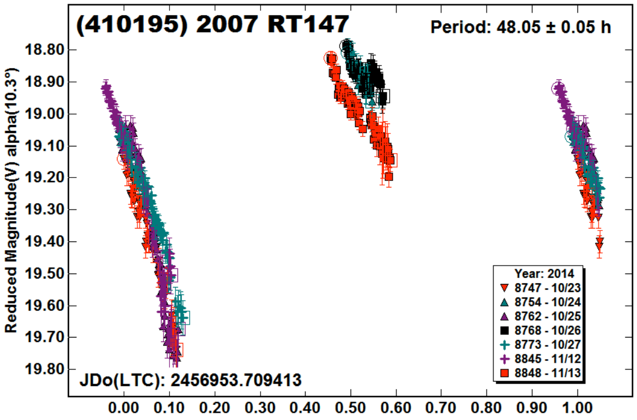




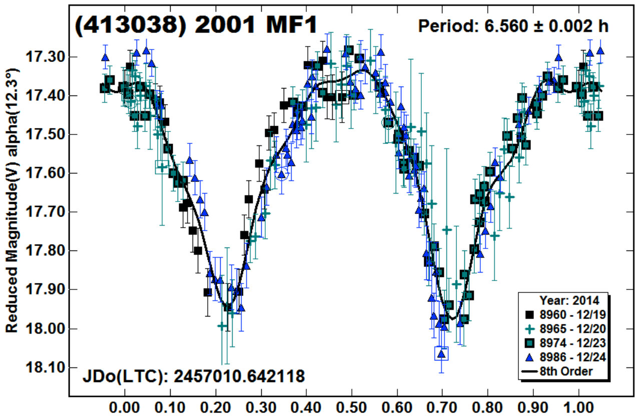
(374158) 2004 UL. Data for this NEA were obtained from 2014 Oct 28 through Nov 3. No single period could be found to fit the data, even when manipulating zero points far more than the usual tolerances. This strongly suggests that the asteroid is "tumbling" (see Pravec *et al.*, 2005, 2014b). The lightcurve shows the data forced to fit the most dominant period found by *MPO Canopus*, which is not designed to use the complex algorithms required to handle tumbling asteroids. Using a rule of thumb from Pravec *et al.* (2014b), the damping time for tumbling for this asteroid is about 1 Gyr.



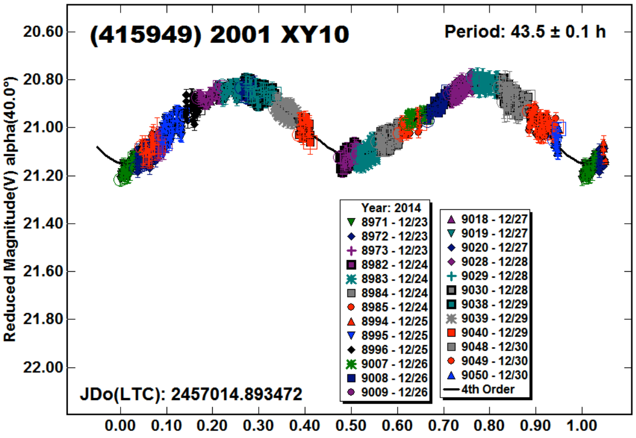
(410195) 2007 RT147. There were no previous entries in the LCDB for this asteroid. The period appears to be nearly commensurate with an Earth day, making it very difficult to complete the lightcurve from a single station. Furthermore, there are indications (the mismatch at 0.5 rotation phase) of tumbling. The rule of thumb damping time for the asteroid exceeds the age of the Solar System. More important is that the collisional lifetime is much less, and so tumbling is even more likely.



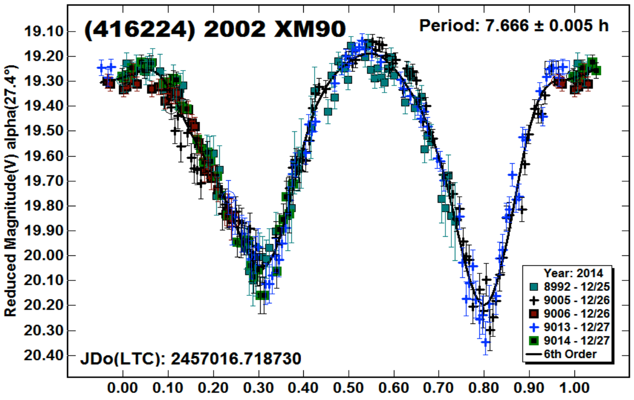
(413038) 2001 MF1. Previous results for 2001 MF1 include Krugly *et al.* (2002b, 6.572 h), Pravec *et al.* (2001, 6.569 h), and Warner (2015, 6.568 h). The Warner observations were in 2014 July and showed an amplitude of 1.22 mag at α = 51°. The December data, at α = 11°, have amplitude of 0.64 mag and more equal minimums in the lightcurve.



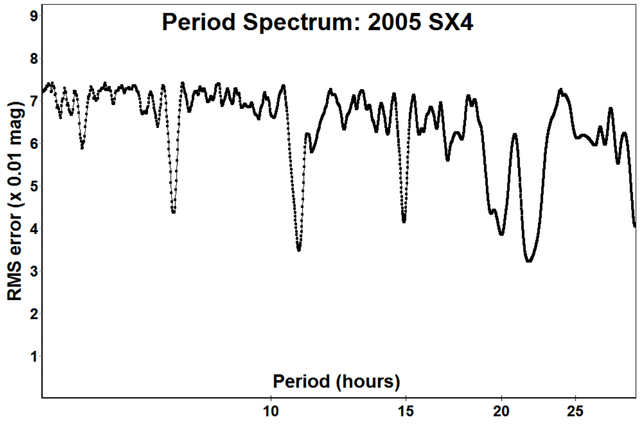
(415949) 2001 XY10. There were no previous entries in the LCDB for (415949) 2001 XY10. The size and period both favor the possibility of tumbling but there were no indications of such although it’s possible that a more extensive data set, one covering more than one cycle, would prove otherwise.

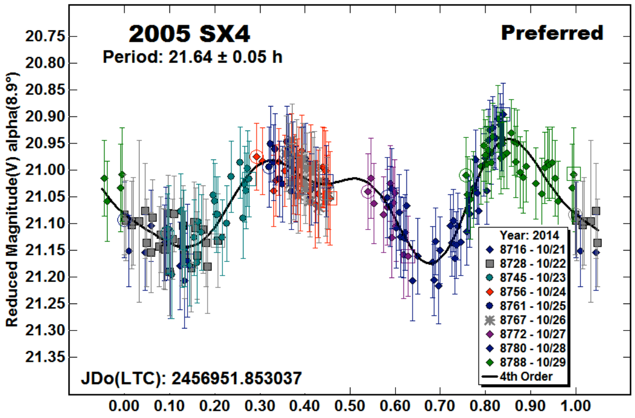


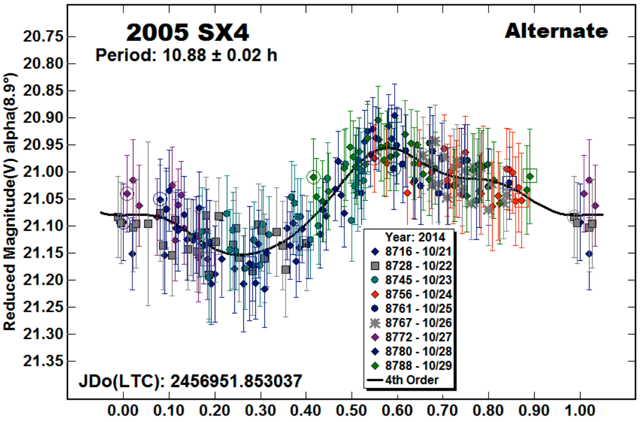
(416224) 2002 XM90. This appears to be the first reported lightcurve for (416224) 2002 XM90.

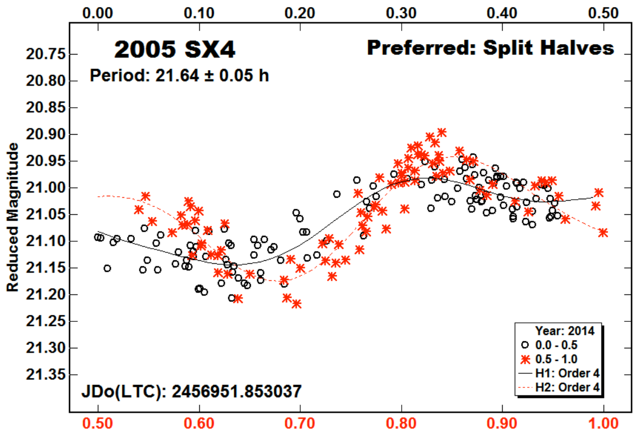


2005 SX4. The period spectrum based on data from 2014 October shows several solutions that are related to one another as being P and 2*P. The two favored solutions were about 10 h or 20 h. Using the split halves plot for the longer period shows a marked asymmetry between the two halves, making the half-period unlikely, despite the good fit seen in the lightcurve forced to the shorter solution. A period of 21.64 h is adopted for this paper but the period of 10.88 h cannot be formally excluded.

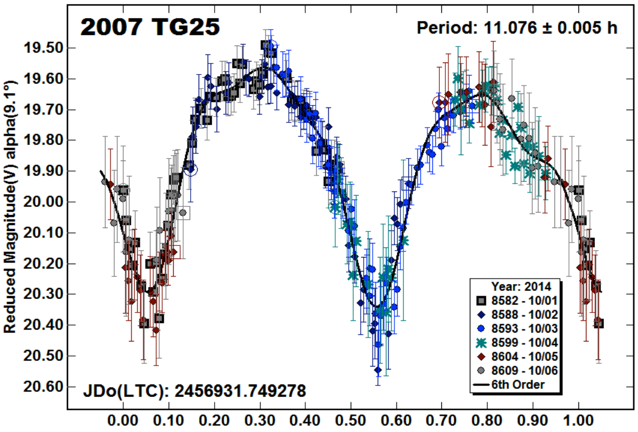




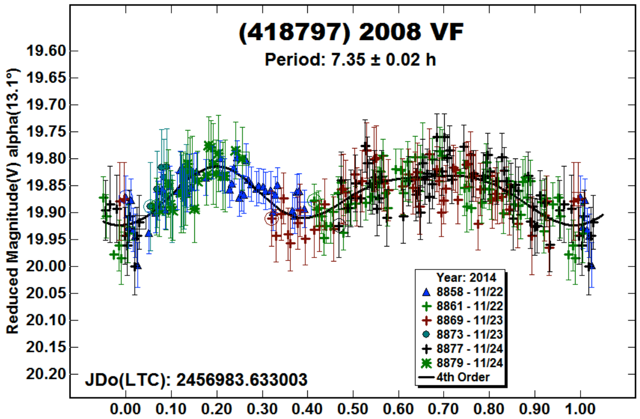


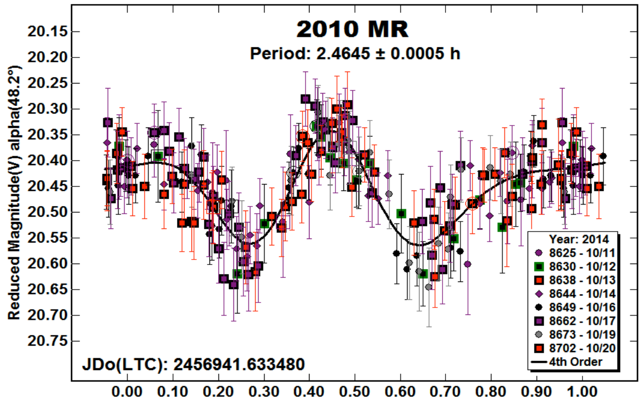


2007 TG25. No previous results were found in the literature.

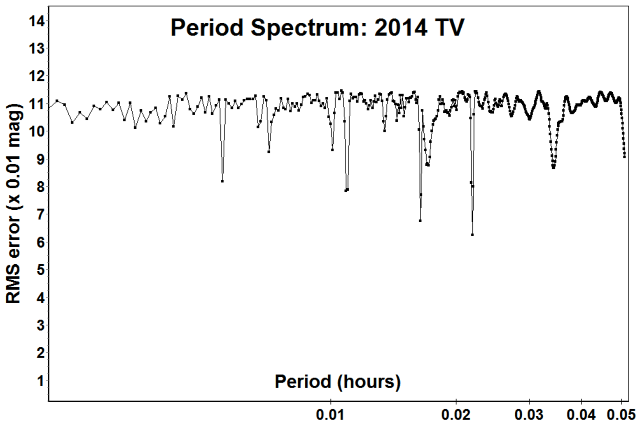


(418797) 2008 VF, 2010 MR. There were no previous entries in the LCDB for these two asteroids.

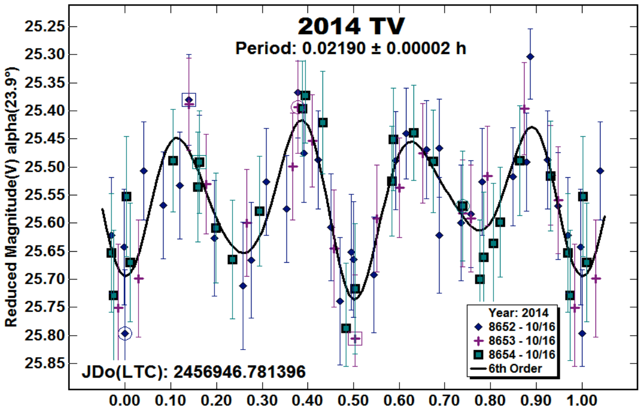


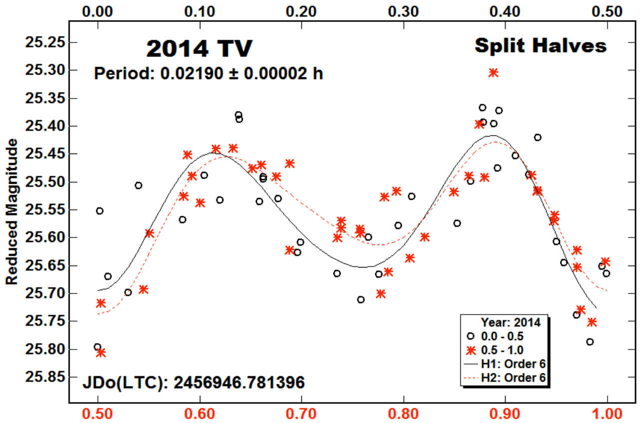


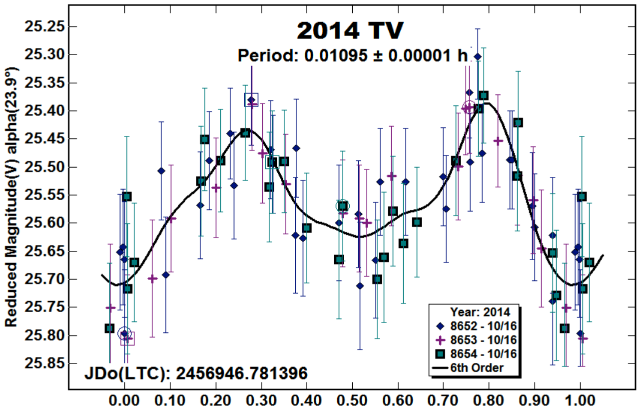
2014 TV. Initial observations in 2014 October used exposures of 2 minutes and showed what appeared to be a period of about 44 hours. Radar observations (Patrick Taylor, private communications) showed the period was likely between 30 and 90 *seconds*. If so, the long exposures would lead to *rotational smearing* and the results would be meaningless (see Pravec *et al.*, 2000b). Ten seconds were used for the run on October 16.



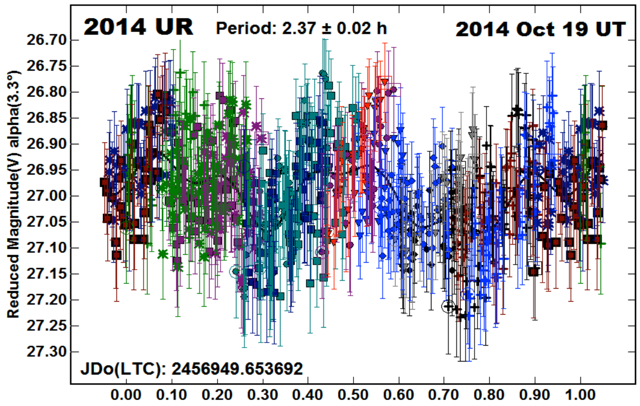
The period spectrum covering 0.001 to 0.05 hours (3.6 to 180 seconds) shows several possibilities, the most likely being 0.02190 h (78.8 sec). The corresponding lightcurve has a complex quadramodal shape. The split halves plot confirms the strong asymmetry of that solution, making the half-period (~39 sec) less likely. However, the shorter period cannot be formally excluded, especially if considering the possibility of *rotational smearing*.



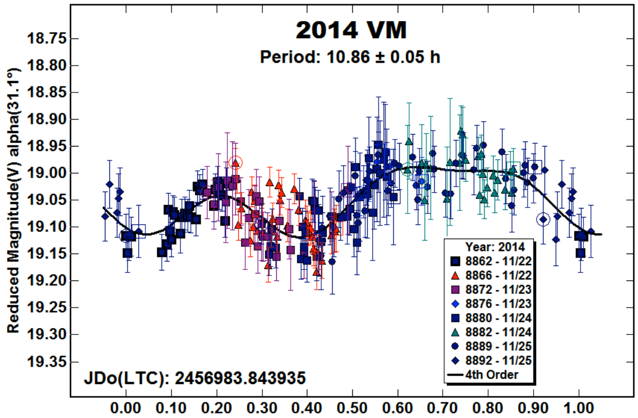


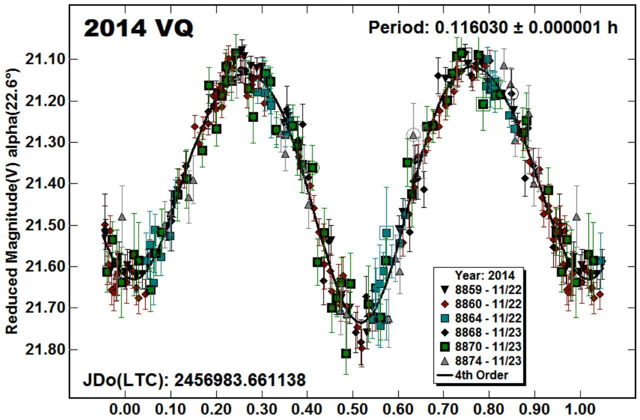


2014 UR. The period of 2.37 h shown here is just one of several possibilities. It should be considered doubtful, at best.

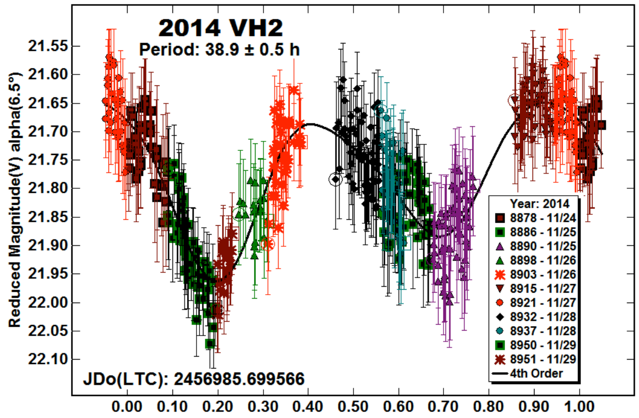


2014 VM, 2014 VQ. There were no previous entries in the LCDB for 2014 VM and 2014 VQ.

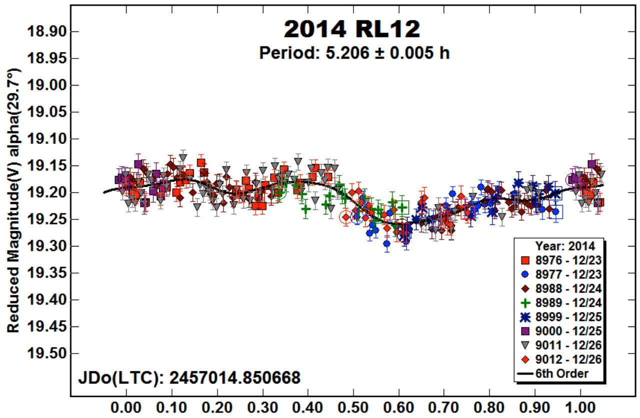


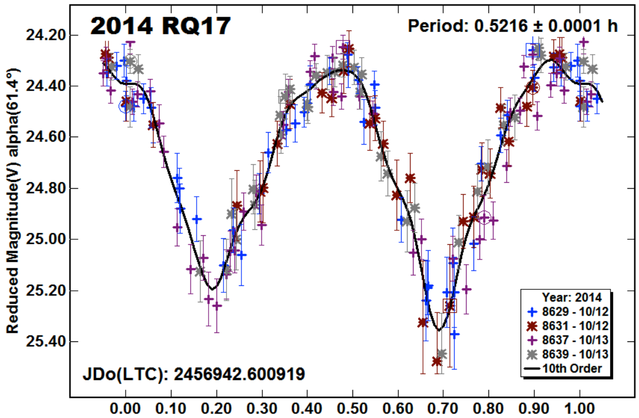


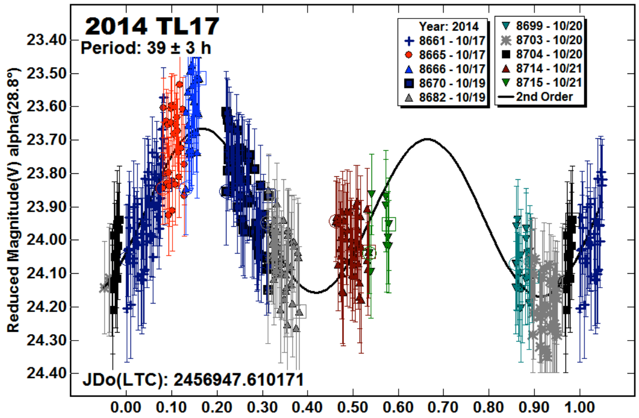
2014 VH2. Assuming the period of 38.9 h is correct, it is much greater than the rule of thumb for a damping time equal to the age of the Solar System (see Pravec *et al.*, 2005, 2014b). However, the collisional lifetime is much less, so tumbling may be possible. It's possible that the asymmetry in the lightcurve is due to low-level tumbling. A more extensive data set from multiple longitudes and with less scatter would be required to confirm whether or not the asteroid tumbling.

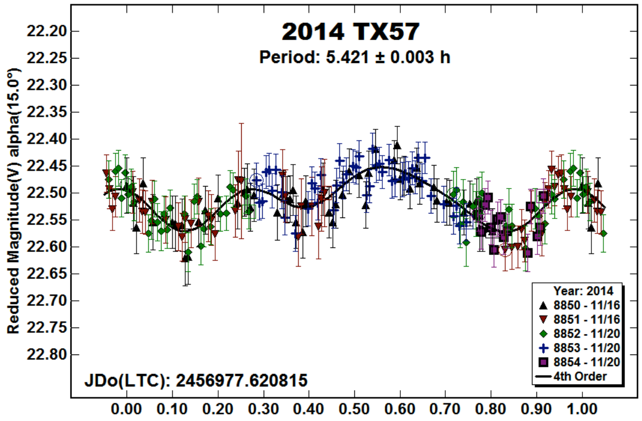


2014 RL12, 2014 RQ17, 2014 TL17, 2014 TX57. There were no previous entries in the LCDB for these four asteroids. Radar observations were made of 2014 RQ17. The results from those observations are pending. The incomplete coverage of the lightcurve for 2014 TL17 makes the solution somewhat uncertain. This is another case where the long period would suggest the possibility of tumbling.

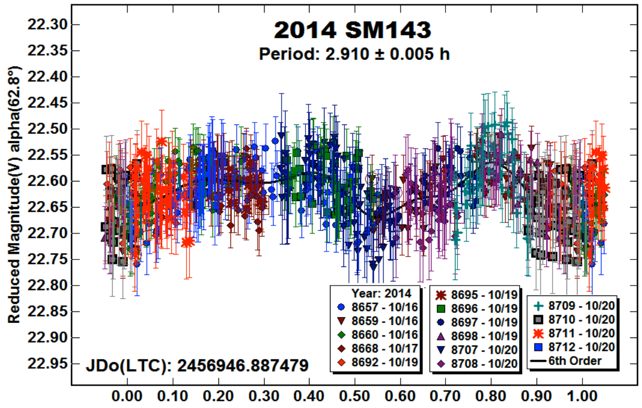




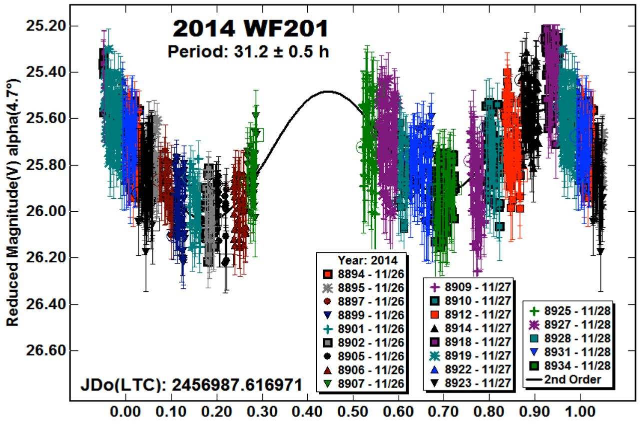




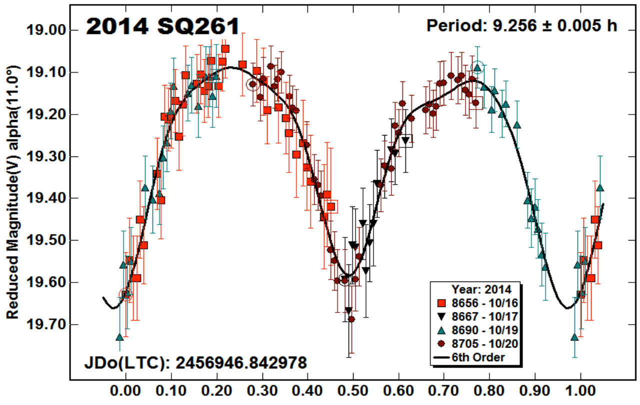
2014 SM143. The photometry data for this radar target were noisy. Partly because of this, the period spectrum showed a number of solutions that were marginally below the average flat line. The period of 2.910 h is adopted for this paper on the presumption of a bimodal lightcurve. Given the low amplitude and high phase angle, this may not be valid, but a half-period of 1.45 h for an asteroid with an estimated size of 260 meters would make it an extraordinary object.



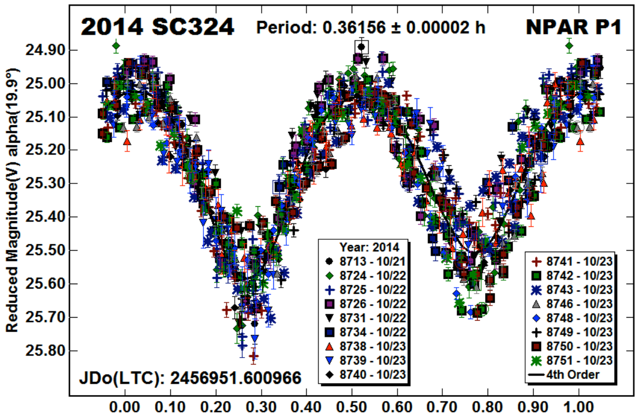
2014 WF201. The estimated size of this object is about 20 meters, making it possible that the rotation period was << 1 hour, possibly on the order of minutes if not seconds. For this reason and its rapid sky motion, exposures were kept to 30 seconds. While the solution of 31.2 h seems valid, there is some doubt since about 90% of objects in this size range have very short periods, which makes this an unusual asteroid.



2014 SQ261. There were no previous entries in the LCDB for this asteroid.



2014 SC324. This is a confirmed tumbler (Petr Pravec, private communications). The lightcurve shows the dominant period. The second period is ambiguous, the most likely one being 0.6003 ± 0.0002 h (Pravec, private communications). The ratio of the amplitudes of the second order harmonics for the two periods is only 0.21, indicating low-amplitude tumbling as seen as slight mismatches over the span of the lightcurve.



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-1210099.

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

References

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

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

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

Krugly, Yu.N., Belskaya, 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.

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

Pravec, P., Wolf, M., Sarounova, L. (1998, 1999, 2000a, 2001, 2012, 2014a). *http://www.asu.cas.cz/~ppravec/neo.htm*

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

Number	Name	2014 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
2340	Hathor	10/21-10/22	353	63.0,54.2	60	1	3.358[A]	0.002	0.18	0.02	NEA
2340	Hathor	10/30-11/03	598	7.4,13.5	36	-5	3.35	0.002	0.11	0.02	NEA
3200	Phaethon	11/27-12/15	469	9.3,21.5	62	12	3.6039	0.0002	0.12	0.01	NEA
4183	Cuno	10/01-10/10	218	37.7,39.6	77	7	3.558[A]	0.002	0.53	0.03	NEA
12538	1998 OH	10/22-10/25	176	5.1,3.8	33	6	5.833[A]	0.005	0.12	0.02	NEA
36017	1999 ND43	12/19-12/25	122	40.8,39.5	64	15	5.79	0.02	0.28	0.02	NEA
53430	1999 TY16	12/19-12/25	185	49.6,49.7	35	6	9.6	0.01	0.53	0.03	NEA
85713	1998 SS49	11/20-11/24	368	86.4,96.8	115	23	5.66[A]	0.01	0.06	0.01	NEA
85804	1998 WQ5	12/20-12/24	909	19.9,17.1	111	4	6.028[A]	0.005	0.05	0.01	NEA
86326	1999 WK13	12/19-12/24	194	42.7,42.6	52	-8	6.36[A]	0.02	0.14	0.02	NEA
90075	2002 VU94	10/13-10/14	151	4.2,4.3	18	6	7.9	0.01	0.31	0.02	NEA
100756	1998 FM5	10/13-10/14	181	5.3,5.4	21	-7	6.369	0.005	0.8	0.03	NEA
103067	1999 XA143	01/02-01/04	265	23.0,21.7	126	-3	9.85	0.01	0.49	0.03	NEA
136897	1998 HJ41	10/28-10/30	214	36.8,37.0	8	14	15.3	0.05	0.54	0.03	NEA
137032	1998 UO1	10/24-10/27	165	58.5,54.6	346	15	2.935[A]	0.003	0.1	0.01	NEA
137032	1998 UO1	10/24-11/13	230	58.5,43.0	300	16	2.943	0.001	0.08	0.01	NEA
159533	2001 HH31	10/30-11/06	214	24.1,17.8	49	-15	3.66[A]	0.002	0.11	0.01	NEA
162004	1991 VE	12/25-12/28	255	41.8,42.2	124	14	13.52	0.01	1.11	0.03	NEA
163818	2003 RX7	10/21-10/27	219	62.3,70.5	72	15	5.649	0.004	0.11	0.02	NEA
175114	2004 QQ	10/12-10/20	302	74.5,57.6	67	17	8.879	0.003	0.11	0.01	NEA
209924	2005 WS55	10/28-11/04	157	46.2,47.5	89	24	3.378[A]	0.003	0.11	0.02	NEA
209924	2005 WS55	12/23-12/26	178	57.7,58.3	139	-7	2.726	0.001	0.25	0.02	NEA
214088	2004 JN13	11/29-11/29	335	0.0,0.0	0	0	6.33	0.01	0.17	0.02	NEA
214088	2004 JN13	12/14-12/15	756	7.9,7.9	78	-5	6.336	0.005	0.20	0.02	NEA
374158	2004 UL	10/28-11/03	421	15.2,30.8	22	-9	38	2	1.2	0.1	NEA
410195	2007 RT147	10/23-11/13	385	10.3,9.4,14.4	37	-8	48.05	0.05	1.08	0.05	NEA
413038	2001 MF1	12/19-12/24	198	12.3,9.5	94	13	6.56	0.002	0.64	0.03	NEA
415949	2001 XY10	12/23-12/30	1155	40.0,31.2	110	14	43.5	0.1	0.35	0.03	NEA
416224	2002 XM90	12/25-12/27	288	27.4,27.8	111	17	7.666	0.005	1.02	0.03	NEA
418797	2008 VF	11/22-11/24	274	13.4,17.6	51	-5	7.35	0.02	0.11	0.02	NEA
	2005 SX4	10/21-10/29	222	8.9,11.4	32	-7	21.64[A]	0.05	0.25	0.03	NEA
	2007 TG25	10/01-10/06	255	9.2,5.4	16	-4	11.076	0.005	0.78	0.05	NEA
	2010 MR	10/11-10/20	218	48.2,46.6	347	9	2.4645	0.0005	0.22	0.03	NEA
	2014 TV	10/16-10/16	80	25.5,25.5	30	-11	0.02190[A]	0.00002	0.32	0.03	NEA
	2014 UR	10/19-10/19	792	6.7,6.7	24	3	2.37	0.02	0.13	0.05	NEA
	2014 VM	11/24-11/25	210	29.4,28.6	87	-3	10.86	0.05	0.13	0.02	NEA
	2014 VQ	12/31-12/31	276	29.4,28.6	0	0	0.11603	0.00005	0.62	0.04	NEA
	2014 VH2	11/24-11/29	434	6.6,9.7	60	1	38.9	0.5	0.31	0.04	NEA
	2014 RL12	12/23-12/26	251	29.7,25.0	113	-2	5.206	0.005	0.08	0.01	NEA
	2014 RQ17	10/12-10/13	154	61.7,63.6	348	14	0.5216	0.0001	0.99	0.05	NEA
	2014 TL17	10/17-10/21	339	29.0,36.5	10	11	39	3	0.53	0.05	NEA
	2014 TX57	11/16-11/20	202	14.9,15.2	47	1	5.421	0.003	0.12	0.02	NEA
	2014 WZ120	11/25-11/29	977	0.0,36.2	39	4	3.363	0.002	0.06	0.01	NEA
	2014 SM143	10/16-10/20	15	62.8,98.4	62	-15	2.91	0.005	0.09	0.02	NEA
	2014 WF201	11/26-11/28	1151	0.0,17.6	42	5	16.9	0.5	0.45	0.1	NEA
	2014 SQ261	10/16-10/20	122	11.0,7.8	33	-3	9.256	0.005	0.57	0.03	NEA
	2014 SC324	10/21-10/23	856	18.7,7.3	22	2	0.36156[D]	0.00002	0.69	0.03	NEA

Table II. Observing circumstances. [A] preferred period for an ambiguous solution. [D] dominant period of a tumbling asteroid. 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).

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

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

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 Bul.* **39**, 111-130.

Torppa, J., Aksnes, K., Dai, Z., Grav, T., Hahn, G., Laakso, T., Lagerkvist, C.-I., Muinonen, K., Niemelaa, J., Naaraanen, J., Rickman, H., Virtanen, J. (2005). "Spins and Shapes of Potentially Hazardous Asteroids." *Bul. Amer. Astron. Soc.* **37**, 643.

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.

Warner, B.D. (2015). “Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 June-October.” *Minor Planet Bul.* **42**, 41-53.

Wolters, S.D., Green, S.F., McBride, N., Davies, J.K. (2008). “Thermal infrared and optical observations of four near-Earth asteroids.” *Icarus* **193**, 535-552.

Ye, Q., Shi. L., Lin, H.-C. (2009). “CCD Lightcurve Analysis of (53430) 1999 TY16.” *Minor Planet Bul*. **36**, 126.

VOIDS AND QUESTION MARKS IN THE PRESENT-DAY DATA CONCERNING THE ROTATION PERIOD OF THE FIRST 1000 NUMBERED ASTEROIDS

Eduardo Manuel Álvarez
OLASU (I38)
Costanera Sur 559, Salto 50.000, URUGUAY
olasu@adinet.com.uy

(Received: 11 January)

Currently, there are only 19 three-digit numbered asteroids – none of them within the first 500 – for which their rotation period is unknown. Chances are that all of the first 1000 asteroids will have a known period in just a few years. However, not all of the 981 present-day published rotation period data for asteroids numbered below 1000 are secure. Ongoing investigations to verify, refine, or revise existing periods remains an important endeavor, especially for the 17 asteroids for which the period is currently uncertain.

The more complete the sampling of asteroid rotation periods, the better astronomers can develop theories concerning the origin and dynamics of the minor planet system. No matter how large the database on asteroid rotation periods, which has being steadily growing at an accelerated pace, mostly due to the contribution from amateurs. A lot of hard work still awaits.

In the last issue of the *Minor Planet Bulletin*, Alan W. Harris (2015) properly put into perspective how far the field of asteroid photometry has come in the past forty years, i.e., since the first asteroid lightcurve observations were published in 1974 in the *MPB*. He remarked that, while prior to that year, there were known rotation periods for only 64 asteroids – some of them even wrong – “today we have fairly reliable periods for more than 5000 asteroids.” Taking into account that there are more than 650,000 asteroids with well-defined orbits, this means that we currently know the rotation period for less than 0.8% of that number.

This paper focuses on what we now know about the rotation period of the first 1000 numbered asteroids – as these are generally speaking the brightest ones and, therefore, generally the easiest asteroids to observe. At the time of this study (early 2015), there remain 19 asteroids for which no rotation period has been found in the literature (Table I).

Just one year ago, of all the 3-digit numbered asteroids there were 31 with no reported rotation period (Alvarez and Pilcher, 2014). Since then, a period has been reported for 12 (~ 40%) of those, including the only four asteroids numbered below 500 that remained without a reported rotation period. Considering how rapidly such data voids have been filled, it is almost certain that by the end of the decade a reliable period will be found for all of the first 1000 numbered asteroids. However, the goal of determining the period for all 3-digit numbered asteroids will not be fully accomplished just by finding periods for the 19 remaining objects. Any measured rotation period value should also be – to put in Alan W. Harris’ own words – “fairly reliable.” Currently, 17 of the first 1000 numbered asteroids have only preliminary periods, i.e., not “fairly reliable.”

The asteroid lightcurve database (LCDB; Warner *et al.*, 2009) assigns a U code, which provides an assessment of the quality of the period solution. A quality code U = 3 means that the corresponding rotation period is basically correct; U = 2 means that the found rotation period is likely correct, although it may be wrong by 30% or it is ambiguous (e.g., the half or double period may be correct); U = 1 means that the established rotation period may be completely wrong. According to the latest public release of the LCDB (2014 December 13), of the 981 asteroids numbered below 1000 that have a published rotation period, there are 17 that have been assigned U = 1 (Table II), 146 have U = 2 (Table III), and the remaining 818 asteroids are rated U = 3.

The 17 asteroids that been assigned U = 1 should be given higher priority when selecting new targets to work. Their respective period values need to be verified or refined. Figure 1 shows how their corresponding rotation periods are distributed. The median value is 18 hours, so that there are 8 asteroids with relatively short periods (from 4 up to 15 hours) and another 8 with relatively long periods (from 24 up to 150 hours). Of the second group, it will be particularly harder to resolve those asteroids that appear to have period values commensurable to the Earth’s rotation (318 Magdalena, 467 Laura, 837 Schwarzschilda, and 957 Camelia). In order to obtain full lightcurve coverage, it will likely require the collaboration of several observers who are widely distributed in longitude. Such endeavors have become a growing practice.

The median period of the 146 asteroids assigned U = 2 is 16.5 hours, or similar to the median value corresponding to the U = 1 group. There are 73 3-digit numbered asteroids with rotation periods shorter than 16.5 hours but that are not yet completely reliable. Given the relatively short periods, a single observer’s time and resources might be best invested by first focusing on the periods that may be solidified from a single location.

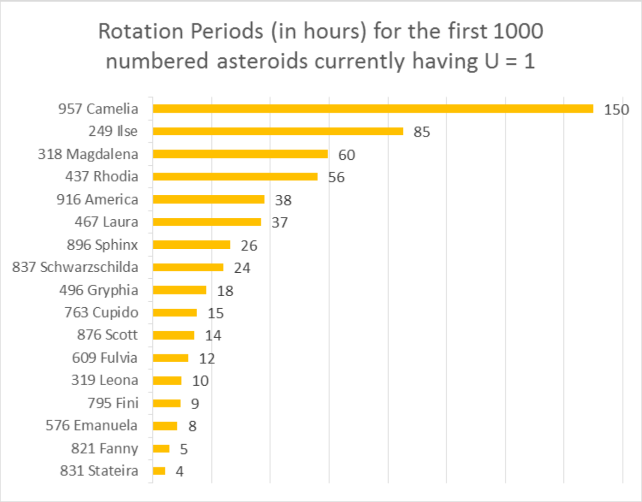


Figure 1. The 17 3-digit asteroids which periods have been rated U = 1. The periods are in hours, rounded to integer numbers.

Number	Name	Number	Name
515	Athalia	843	Nicolaia
637	Chrysothemis	848	Inna
646	Kastalia	871	Amneris
703	Noemi	910	Anneliese
717	Wisibada	930	Westphalia
722	Frieda	941	Murray
767	Bondia	961	Gunnie
820	Adriana	991	McDonalda
835	Olivia	993	Moultona
842	Kerstin		

Table I. The 19 asteroids numbered below 1000 for which no rotation parameters were known at the beginning of 2015.

Number	Name	U	Period (h)
249	Ilse	1	85.24
318	Magdalena	1	59.5
319	Leona	1	9.6
437	Rhodia	1	56
467	Laura	1	36.8
496	Gryphia	1	18.0
576	Emanuela	1-	8.192
609	Fulvia	1+	12
763	Cupido	1	14.88
795	Fini	1+	9.292
821	Fanny	1	5.44
831	Stateira	1	4
837	Schwarzschilda	1	24
876	Scott	1	14
896	Sphinx	1	26.270
916	America	1	38
957	Camelia	1+	150

Table II. The 17 asteroids numbered below 1000 for which the quality of the found rotation period appeared to be U = 1 at the beginning of 2015. The rotation periods are expressed in hours and each shows as many significant digits as are currently known.

Number	Name	U	Period (h)
227	Philosophia	2	52.98
248	Lameia	2	12.00
254	Augusta	2	6.0
269	Justitia	2	16.545
279	Thule	2+	15.962
299	Thora	2+	274
305	Gordonia	2	16.2
314	Rosalia	2	20.43
329	Svea	2+	22.77
331	Etheridgea	2	13.092
341	California	2+	317
346	Hermentaria	2	28.43
357	Ninina	2+	36.0105
375	Ursula	2	16.83
384	Burdigala	2-	21.1
392	Wilhelmina	2	17.96
393	Lampetia	2-	38.7
395	Delia	2	19.71
396	Aeolia	2-	22.2
398	Admete	2	11.208
407	Arachne	2	22.62
421	Zahringia	2	6.42
422	Berolina	2	12.79
425	Cornelia	2	17.56
426	Hippo	2	34.3
431	Nephele	2	18.821
439	Ohio	2	19.2
445	Edna	2	19.97
449	Hamburga	2+	18.263
450	Brigitta	2	10.75
455	Bruchsalia	2+	11.838
458	Hercynia	2	22.3
460	Scania	2	9.56
464	Megaira	2	12.726
470	Kilia	2	290
477	Italia	2	19.42
478	Tergeste	2+	16.104
481	Emita	2	14.35
491	Carina	2+	15.153
494	Virtus	2+	5.57
503	Evelyn	2	38.7
507	Laodica	2	6.737
521	Brixia	2-	9.78
527	Euryanthe	2-	26.06
529	Preziosa	2	27
537	Pauly	2+	14.15
548	Kressida	2	11.9404
551	Ortrud	2	13.05
555	Norma	2+	19.55
569	Misa	2	13.52
570	Kythera	2	8.120
581	Tauntonia	2	16.54
583	Klotilde	2	9.2116
589	Croatia	2+	24.821
597	Bandusia	2	15.340
605	Juvisia	2	15.93
613	Ginevra	2	13.024
618	Elfriede	2	14.801
619	Triberga	2	29.412
622	Esther	2	47.5
625	Xenia	2	21.101
630	Euphemia	2	350
645	Agrippina	2	32.6
662	Newtonia	2	16.46
664	Judith	2+	10.9829
666	Desdemona	2+	14.607
673	Edda	2	14.92
676	Melitta	2	7.87
684	Hildburg	2	15.89
691	Lehigh	2+	12.891
705	Erminia	2	53.96
707	Steina	2+	414
716	Berkeley	2+	15.55
730	Athanasia	2+	5.7345
738	Alagasta	2	17.83
739	Mandeville	2	11.931
741	Botolphia	2-	23.93
746	Marlu	2	7.787
748	Simeisa	2	11.919
761	Brendelia	2+	57.96
764	Gedania	2	24.9751
768	Struveana	2+	8.76
774	Armor	2	25.107
777	Gutemberga	2	12.88
783	Nora	2-	34.4
784	Pickeringia	2	13.17
786	Bredichina	2+	18.61
788	Hohensteina	2	29.94
791	Ani	2	16.72
807	Ceraskia	2	7.4
814	Tauris	2	35.8
819	Barnardiana	2+	66.70
823	Sisigambis	2	146
828	Lindemannia	2	20.52
830	Petropolitana	2	39.0
838	Seraphina	2	15.67
845	Naema	2	20.892
846	Lipperta	2	1641
850	Altona	2+	11.197
856	Backlunda	2	12.08
857	Glasenappia	2	8.23
858	El Djezair	2	22.31
859	Bouzareah	2-	23.2
862	Franzia	2	7.52
863	Benkoela	2+	7.03
866	Fatme	2	20.03
868	Lova	2	41.3
873	Mechthild	2	10.6

Number	Name	U	Period (h)
874	Rotraut	2	14.586
879	Ricarda	2	82.9
882	Swetlana	2-	20
887	Alinda	2	73.97
891	Gunhild	2	7.93
892	Seeligeria	2	41.40
895	Helio	2	9.3959
897	Lysistrata	2	11.26
900	Rosalinde	2	16.5
902	Probitas	2+	10.117
903	Nealley	2	21.60
904	Rockefellia	2	5.82
917	Lyka	2	7.92
920	Rogeria	2-	8.09
923	Herluga	2	19.746
926	Imhilde	2	26.8
927	Ratisbona	2	12.994
931	Whittemora	2	19.20
932	Hooveria	2+	39.1
936	Kunigunde	2	8.80
938	Chlosinde	2	19.204
946	Poesia	2+	108.5
949	Hel	2	10.862
952	Caia	2	7.51
953	Painleva	2-	7.389
958	Asplinda	2	25.3
960	Birgit	2+	8.85
965	Angelica	2	17.772
969	Leocadia	2	6.87
973	Aralia	2+	7.29
981	Martina	2	11.267
982	Franklina	2-	16
983	Gunila	2	8.37
988	Appella	2	120
992	Swasey	2	13.308
994	Otthild	2+	5.95
997	Priska	2	16.22
999	Zachia	2	22.77

Table III. The 146 asteroids numbered below 1000 for which the quality of the found rotation period appeared to be U = 2 at the beginning of 2015. The rotation periods are expressed in hours and each shows as many significant digits as are currently known.

References

Alvarez, E. M., Pilcher, F. (2014). "Period Determination for 330 Adalberta: A Low Numbered Asteroid with a Previously Unknown Period." *Minor Planet Bulletin* **41**, 23-24.

Harris, A.W. (2015). "A Perspective on How Far Asteroid Photometry Has Come in the Past Forty Years." *Minor Planet Bulletin* **42**, 10-11.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 Dec 13. *http://www.minorplanet.info/lightcurvedatabase.html*

ASTEROIDAL OCCULTATION BY 82 ALKMENE AND THE INVERSION MODEL MATCH

Brad Timerson
International Occultation Timing Association (IOTA)
623 Bell Rd., Newark, NY, USA
btimerson@rochester.rr.com

J. Durech
Astronomical Institute, Faculty of Mathematics and Physics,
Charles University in Prague, CZECH REPUBLIC

T. Beard, C. McPartlin, W. Morgan
IOTA

K. Schindler, J. Wolf
SOFIA Science Center, NASA Ames Research Center
and
Deutsches SOFIA Institut, Universität Stuttgart
Stuttgart, GERMANY

J. Bardecker, W. Anderson, C. Arrowsmith, B. Gimple
RECON

C. Coburn, H. Hill, T. Smoot
Cameron Park Rotary Community Observatory

(Received: 12 January Revised: 16 February)

On 2014 September 18, the asteroid 82 Alkmene occulted HIP 99229 for observers in the western United States. Four well-spaced chords allowed matching these observations with one of the two convex shape models available for this asteroid. Results of this event can be found on the North American Asteroidal Occultation Results webpage.

The history of asteroidal occultation observations has been reviewed before (Timerson *et al*., 2009). Successful predictions (Preston, 2009) and observations have increased dramatically, especially since 1997, aided by high-accuracy star catalogs and asteroid ephemerides (Dunham *et al*., 2002). Other prediction information is available in Timerson *et al*., 2009.

The techniques and equipment needed to make these observations are outlined in the IOTA manual (Nugent, 2007). Observations are reported to a regional coordinator who gathers these observations and uses a program called *Occult4* (Herald, 2015) to produce a profile of the asteroid at the time of the event. The asteroidal occultation data are officially deposited and archived and made available to the astronomical community through the NASA Planetary Data System (Dunham *et. al*., 2014). Additional tools such as asteroid lightcurves (Warner, 2011) and asteroid models derived from inversion techniques (Durech et al., 2010) can be combined with occultation results to yield high resolution profiles.

Names	Telescope	Imager	Time Inserter	Integration
C. Arrowsmith, W. Anderson	28 cm SCT	Mallincam	IOTA-VTI	2 frames
J. Bardecker	30 cm SCT	Mallincam	IOTA-VTI	No
T. Beard	20 cm SCT	PC165DNR	IOTA-VTI	2 frames
C. Coburn, T. Smoot, H. Hill	36 cm SCT	Mallincam	IOTA-VTI	No
H. Gimple	28 cm SCT	Mallincam	IOTA-VTI	4 frames
C. McPartlin	13 cm Refr	Stellacam II	IOTA-VTI	No
W. Morgan	20 cm SCT	PC164C	IOTA-VTI	No
K. Schindler, J. Wolf	60cm R-C	Andor DU-888	Other GPS	No

Table 1. Observers and the equipment used. SCT = Schmidt-Cassegrain, Refr = Refractor, R-C = Richey-Chrétien

The asteroid lightcurve inversion method was developed by Kaasalainen and Torppa (2001) and Kaasalainen *et al*. (2001). It enables one to derive asteroid shape, spin axis direction, and rotation period from its lightcurves observed over several apparitions. The shape is usually modeled as a convex polyhedron. When the shape model and its spin state are known, its orientation with respect to an observer (sky plane projection) can be easily computed. Such a predicted silhouette can then be compared with the occultation chords and scaled to give the best fit. Planning software called *OccultWatcher* allows observers to space themselves across the predicted path of the occultation to gather as many unique chords as conditions allow (Pavlov, 2008).

Occultation Results

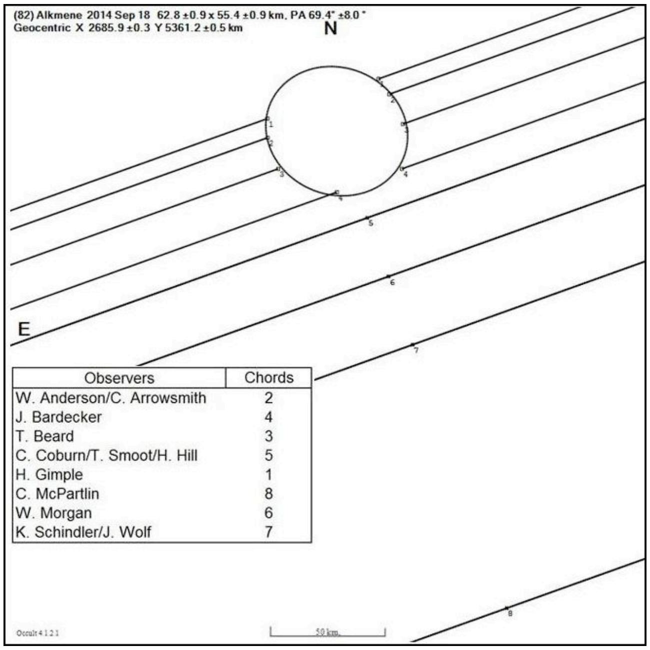
On 2014 September 18 at 6:35 UT, asteroid 82 Alkmene occulted the V magnitude 7.7 star HIP 99229 (SAO 188948) in Capricornus over a path which passed from northern California to southern Nevada, Utah, and Kansas (Dunham *et al*., 2013). The maximum duration was predicted to be 23.5 seconds. Eleven observers observed the event from 8 sites. Four of these sites recorded occultation chords while recordings at the other 4 sites showed no occultation. Seven observing sites used video recordings while Schindler and Wolf used an Andor iXon DU-888 EMCCD camera. The observers and their equipment are summarized in Table 1.

Using the *Occult4* software, the 4 chords yield a least squares ellipse with dimensions of 62.8 x 55.4 km with an error estimate of ± 0.9 km in each dimension, as shown in Figure 1. The maximum occultation duration of 19.05 seconds, which is 19% shorter than the expected maximum, occurred at station 3. The observed path was 29 km north of the predicted path on the Earth's surface and occurred 24 seconds late.

Two inversion models of Alkmene were derived by Hanus et al. (2011) from lightcurves and are available in DAMIT (http://astro.troja.mff.cuni.cz/projects/asteroids3D). Their orientation at the time of the event is shown in Figure 2. The models differ in shape and pole direction. Model #146 has pole direction lambda = 164 deg, beta = -28 deg in ecliptic coordinates, while model #147 has lambda = 349 deg, beta = -33 deg. The two models fit the light curves equally well. The occultation profile presented in this article has successfully identified Model #146 to be the correct one.

Occult4 has a provision in which inversion models can be pasted to the profile image of the asteroid so that observed chords can be matched to the model. In most cases, this also allows one to determine which model most likely provides the correct orientation. In Figure 3 the four positive chords have been matched to DAMIT Model #146.

Apart from deciding which pole orientation is correct, the occultation chords provide direct information about asteroid size. By scaling the convex model to give the best match with the chords, we determine the volume-equivalent size of Alkmene to be 61±2 km.



Observers	Chords
W. Anderson/C. Arrowsmith	2
J. Bardecker	4
T. Beard	3
C. Coburn/T. Smoot/H. Hill	5
H. Gimple	1
C. McPartlin	8
W. Morgan	6
K. Schindler/J. Wolf	7

Figure 1. Observed occultation outline for 82 Alkmene on 2014 September 18 with least squares ellipse fit.

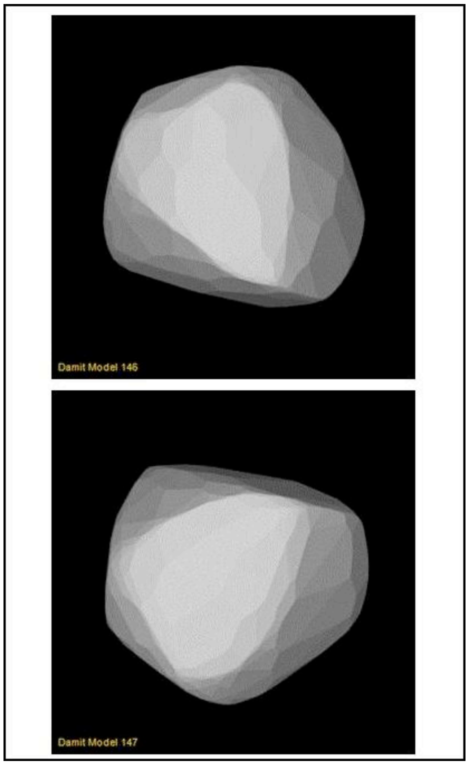


Figure 2. DAMIT models for poles (Model #146: 164 deg, -28 deg; top) and (Model #147: 349 deg, -33 deg; bottom) for 82 Alkmene at the time of the occultation.

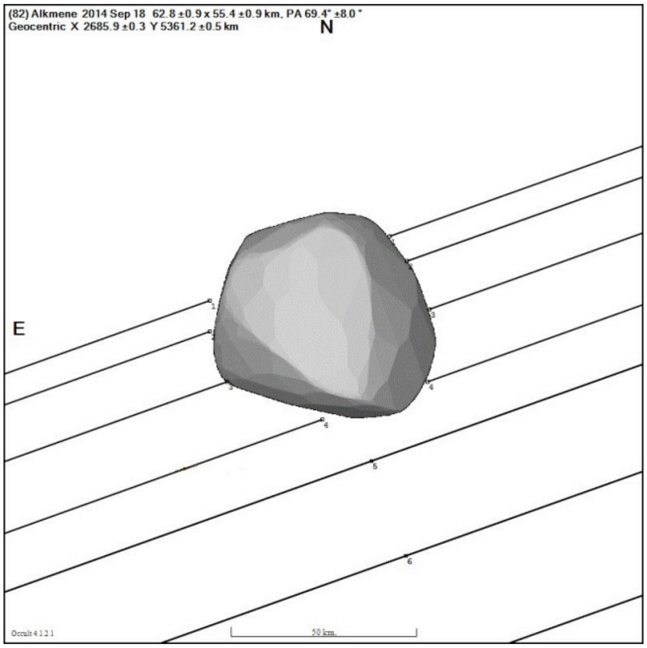


Figure 3. DAMIT Model #146 matched to the observed chords

Conclusions

Asteroidal shape models derived from inversion of light curves may result in more than one possible shape. Combining occultation profiles and light curve inversion shapes can resolve the chiral possibilities that light curve data alone cannot differentiate. This can be seen in the excellent agreement between the occultation results and one of the inversion models for 82 Alkmene. Future articles will continue to include occultation results in which multiple chords are observed. Preference will be given to those events for which lightcurves and/or inversion models are available.

Acknowledgements

The work of J. Durech was supported by the grant 15-04816S of the Czech Science Foundation. IOTA, the International Occultation Timing Association, is a volunteer science and research organization born in 1983 to gather data from timings of astronomical occultations and provide a variety of educational resources to promote and encourage observations of astronomical occultations. The 0.6 m telescope near Auberry, CA, is a joint venture between the University of Stuttgart, Germany and the German SOFIA Institute (DSI). Its primary objectives are to support teaching at the Institute of Space Systems and to provide a test platform for new hardware and software for the Stratospheric Observatory for Infrared Astronomy (SOFIA). The Research and Education Cooperative Occultation Network (RECON, 2015), is a citizen science research project aimed at exploring the outer solar system. This project, led by Dr. Marc Buie and Dr. John Keller, involves teachers, students, amateur astronomers, and community members from across the Western United States to conduct coordinated telescope observations to measure the sizes of objects from a region called the Kuiper Belt.

References

Dunham D.W., Stamm J., Maley P., Preston S., Breit D. (2013). "Planetary Occulations", in *Royal Astronomical Society of Canada Observer's Handbook 2014*, Chapman E.M.F. ed. (Webcom, Toronto), 247-251.

Dunham D.W., Goffin E., Manek J., Federspiel, M., Stone, R., Owen, W. (2002). "Asteroidal Occultation Results Multiply Helped by HIPPARCOS", *Journal of the Italian Astronomical Society* **73**, 662-665.

Dunham, D.W., Herald, D., Neese, C. (2014). Asteroid Occultations V12.0. EAR-A-3-RDR-OCCULTATIONS-V12.0. NASA Planetary Data System, 2014.
http://sbn.psi.edu/pds/resource/occ.html

Durech, J., Sidorin, V., Kaasalainen, M. (2010). "DAMIT: a database of asteroid models." *Astron. Astrophys.* **513**, A46.

Hanus, J., Durech, J., Broz, M., Warner, B.D., Pilcher, F., Stephens, R., Oey, J., Bernasconi, L., Casulli, S., Behrend, R., Polishook, D., Henych, T., Lehký, M., Yoshida, F., Ito, T. (2011). "A Study of Asteroid Pole Latitude Distribution based on an Extended Set of Shape Models derived by Lightcurve Inversion Method." *Astron. Astrophys.* **530**, A134.

Herald, D. *Occult4* software, (2015)
http://www.lunar-occultations.com/iota/occult4.htm
Unpublished profile routine using a least squares fit of an ellipse to the observed occultation chords as projected onto a moving reference frame on the fundamental plane.

Kaasalainen, M., Torppa, J. (2001). "Optimization methods for asteroid light curve inversion. I. Shape determination." *Icarus* **153**, 24-36.

Kaasalainen, M., Torppa, J., Muinonen, K. (2001). "Optimization methods for asteroid light curve inversion. II. The complete inverse problem." *Icarus* **153**, 37-51.

Nugent, R., Ed. (2007). "*Chasing the Shadow: The IOTA Occultation Observer's Manual.*" International Occultation Timing Association, Houston, TX. ISBN 9780615291246

Pavlov, H. (2008) OccultWatcher software.
http://www.hristopavlov.net/OccultWatcher/publish.htm

Preston, S. (2009). *Asteroid Occultation Updates*
http://www.asteroidoccultation.com

RECON (2015). Research and Education Cooperative Occultation Network, M. Buie, SwRI, and J. Keller, Cal Poly San Luis Obisbo, *http://tnorecon.net/about-us/*

Timerson, B., Durech, J., Aguirre, S., Benner, L., Blanchette, D., Breit, D., Campbell, S., Campbell, R., Carlisle, R., Castro, E., and 36 coauthors. (2009). "A Trio of Well-Observed Asteroidal Occultations in 2008." *Minor Planet Bulletin* **36**, 98-100.

Timerson, B., (2015) Asteroid Occultation Results for North America.
http://www.asteroidoccultation.com/observations/Results/

Warner, B.D. (2011). Minor Planet Lightcurve Data.
http://www.minorplanetobserver.com/PDO/PDOLightcurves.htm

TWO NEW BINARIES AND CONTINUING OBSERVATIONS OF HUNGARIA GROUP ASTEROIDS

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

(Received: 10 January)

Analysis of CCD photometry for five asteroids lead to the discovery of two new binary objects. (190208) 2006 AQ, is a rare "wide binary" example with a primary period of 182 h and secondary period of 2.62002 h. 2014 WZ120 is a near-Earth asteroid with a primary period of 3.361 h and orbital period of 13.665 h. The estimated effective diameter ratio for the pair is Ds/Dp ³ 0.32. The other three asteroids, 1103 Sequoia, 2083 Smither, and 3880 Kaiserman, all members of the Hungaria group, show varying signs of a secondary period but no mutual events that would confirm the existence of a satellite.

CCD photometric observations of were made of five asteroids between 2014 October through December: 1103 Sequoia, 2083 Smither, 3880 Kaiserman, (190208) 2006 AQ, and 2014 WZ120. The first three, all members of the Hungaria group, were found to have secondary periods that possibly indicate the existence of a satellite. The other two, both near-Earth asteroids, are considered to be confirmed binary objects.

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

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

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

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

Measurements were done 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 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 (2007b). When possible, magnitudes are taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag. This consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

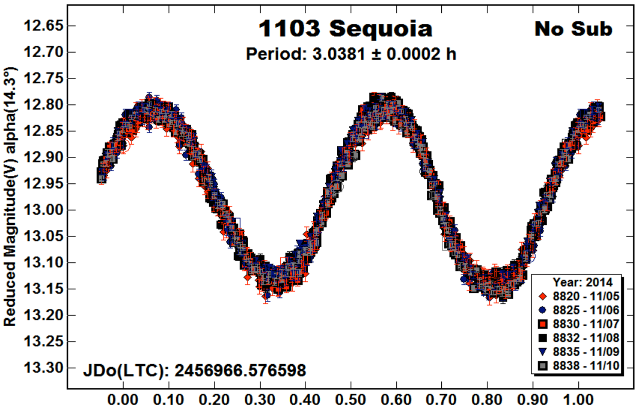
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances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

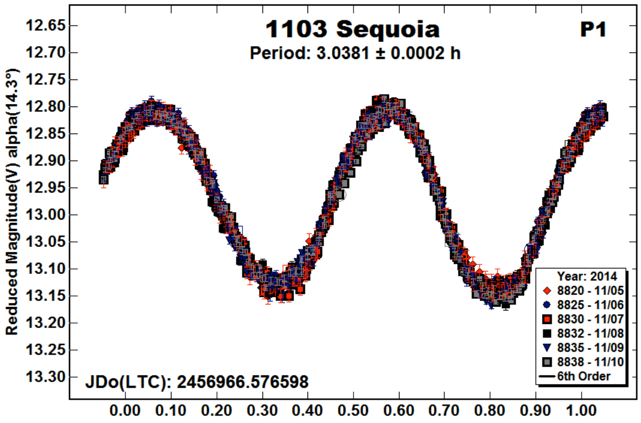
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

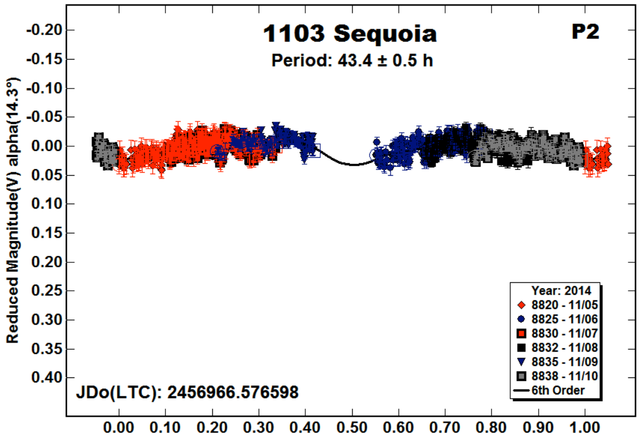
In general, the dual period search feature in *MPO Canopus* was used to determine if there was a second period present in the data for each asteroid. The process started by finding a best fit period of all data without subtraction that covered the dominant period. The resulting Fourier model curve was subtracted from the data when conducting a search for a second period. The resulting Fourier model for the secondary period was subtracted from the data in another search near the dominant period. The process of going back-and-forth was repeated until both periods stabilized. Additional details are given in the discussion for each asteroid.

1103 Sequoia (Hungaria). The period for Sequoia has been measured on numerous occasions with no reports of a suspected satellite. This is the third time the author has studied Sequoia (Warner 2012a; 2015a). Even though worked in 2014 August, additional observations were made in November to see how the lightcurve evolved with changing viewing aspect and phase angle.

The *No Sub* lightcurve based on the 2014 November data only and without subtracting a second period does not show any obvious signs of a satellite. However, the larger scatter at the minimums prompted a dual period search. The results are shown in the P_1 and P_2 plots.







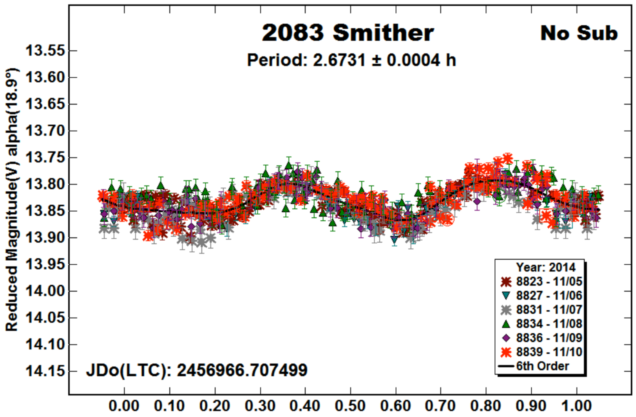
It is worth noting that if a secondary period exists, and it is a sum of intensities of the primary period and the secondary period, the amplitude, in magnitudes, of the secondary will be much greater at minimum light, simply because it is not diluted by so much light from the primary.

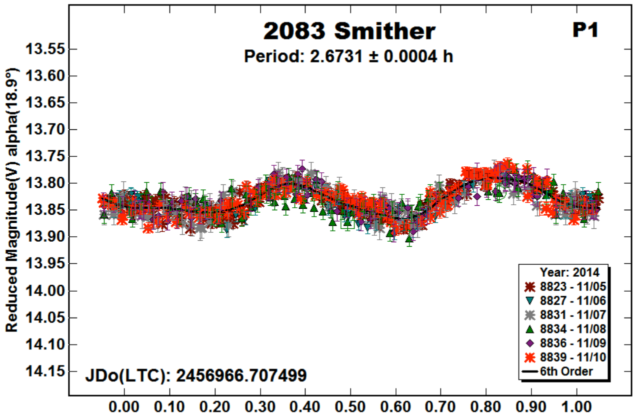
The P_1 plot is almost indistinguishable from the *No Sub* plot but, given the 0.04 mag amplitude of P_2, that's understandable. The period of P_2 = 43.4 h seems long for a typical binary with P_1 of 3.038 h. A search for a "more reasonable" period found P_2 = 21.7 h with a monomodal shape. The periods of 3.0381 h and 43.4 h (and 21.7 h) do not have an integral ratio, which helps eliminate the possibility of a *harmonic alias*, which is when the Fourier analysis locks onto noise in the data and finds a period other than the dominant one that has an integral ratio with the dominant period.

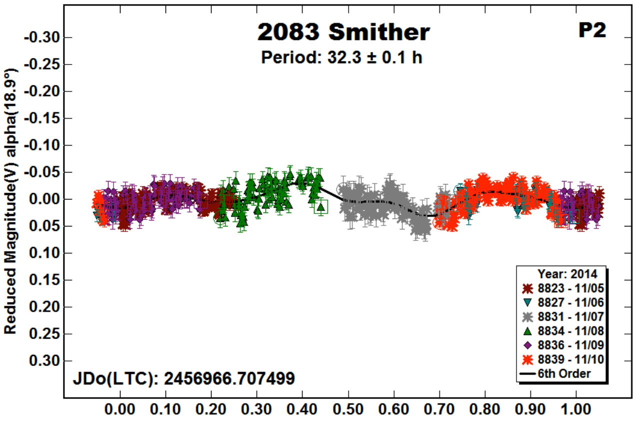
In summary, there are weak indications of a second period in this system but not so much as to suggest that this is a binary system with certainty. Observations are strongly encouraged at future apparitions.

<u>2083 Smither (Hungaria)</u>. This is the fourth apparition that Smither was observed by the author (Warner, 2007a; 2010; 2012a). Weak indications of a satellite were seen during the 2009 apparition (Warner, 2010) when a second period of 30.09 h was found (presumed also to be the orbital period). The viewing aspect, i.e., the phase angle bisector longitude, at that time and for the 2014 November observations were similar, making for a good opportunity to try to verify the earlier results.

As with 1103 Sequoia, the *No Sub* plot does not show overt signs of a satellite, just larger scatter than expected, particularly at the minimums, which fits with the idea of the satellite being more noticeable at the minimums of the primary lightcurve.

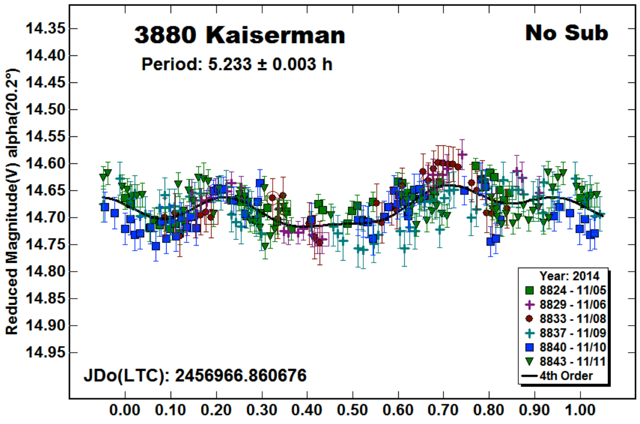


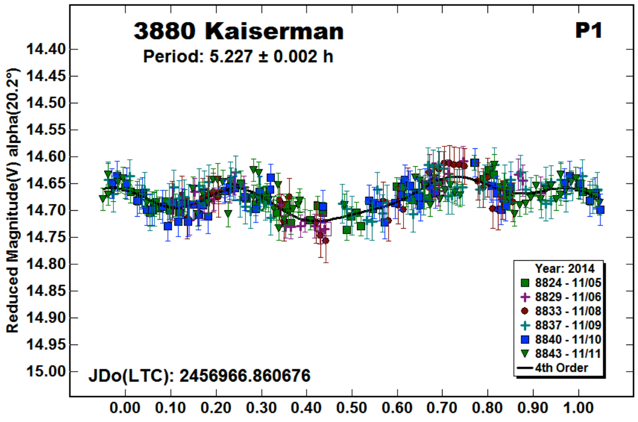


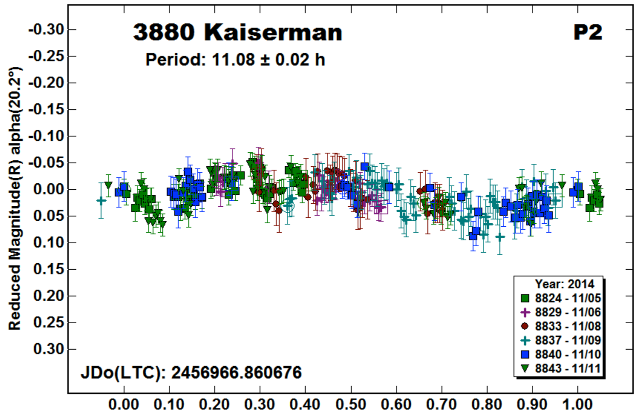


After the dual period search, the P_1 lightcurve is noticeably improved. The P_2 lightcurve at 32.3 h is similar to the results from 2009 but is hardly conclusive. This asteroid might be a binary but it will take stronger evidence to make a convincing case. The next apparition is 2016 July (V ~ 15.5, Dec +7°).

<u>3880 Kaiserman (Hungaria)</u>. Kaiserman was first observed by the author in 2011 (Warner, 2012b), when a period of 5.270 h was reported and no indications of a satellite seen. The phase angle bisector longitude in 2014 November was about 70° from the 2011 observations, which can lead to significantly different results. For example, as in this case, the amplitude of the main lightcurve changes dramatically. In 2011, the amplitude was 0.23 mag. In 2014, it was only 0.08 mag. If nothing else, this gives some indications of the orientation of the of the primary's spin axis.

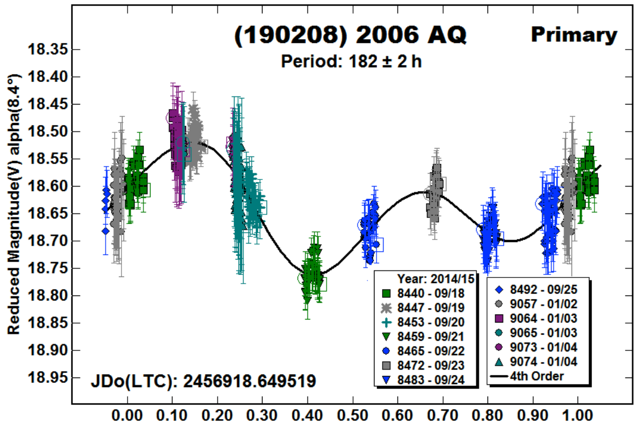


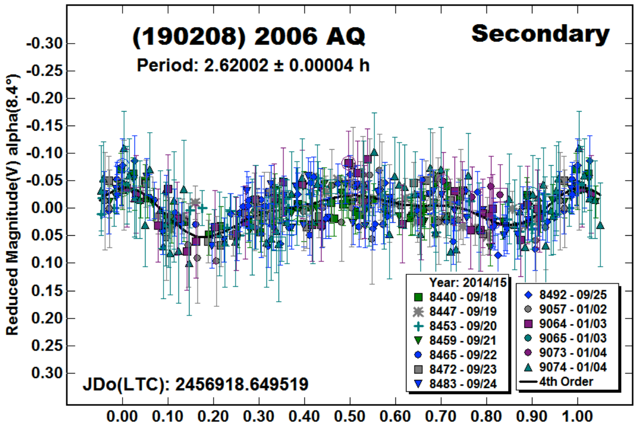




The *No Sub* lightcurve is fairly noisy, but this could easily be attributed to the low amplitude, the asteroid being V ~ 16.0, and a nearly full moon in the sky. The P_1 lightcurve is better but still somewhat noisy. On the other hand, the P_2 lightcurve appears to show a distinct shape with amplitude of 0.07 mag. The double period of 22.14 h should not be ruled out and, in fact, would be more appropriate given the 5.2 h period of the primary. Of the three Hungaria asteroids this is the most convincing case for a binary, but it is still not conclusive; all three rate as *possible*.

(190208) 2006 AQ (NEA). This NEA adds to the growing evidence for the existence of so-called *wide binaries* (see Warner *et al.*, 2015, and references therein). In these fully asynchronous systems, the primary has a long period, usually on the order of hundreds of hours, and the satellite has a short period, low amplitude lightcurve. The two are separated by many primary radii, meaning that the orbital period is very long. The chances of seeing *mutual events* (occultation and/or eclipses) are very small.



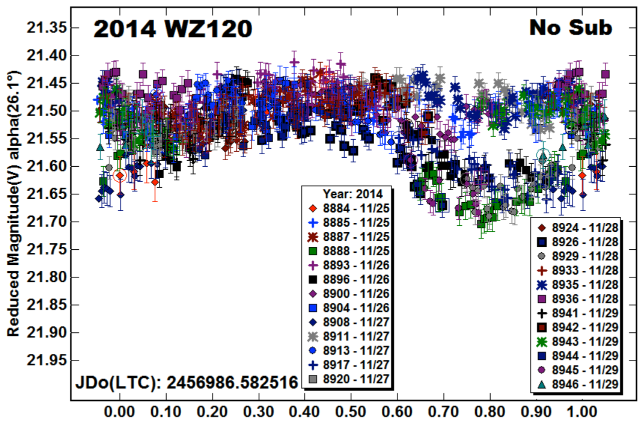


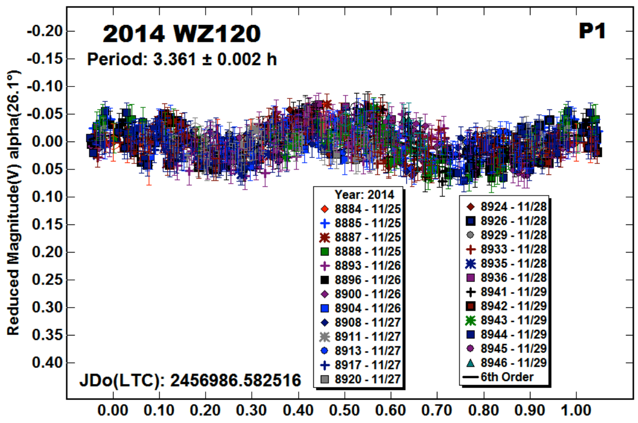
For these objects, it is nearly impossible to start with finding the short period first since the primary lightcurve amplitude dominates and the short period appears to be merely noise. The only reason a dual period search is conducted is because a visual inspection of the individual nights shows a distinct short period that is consistent in period and amplitude from night to night.

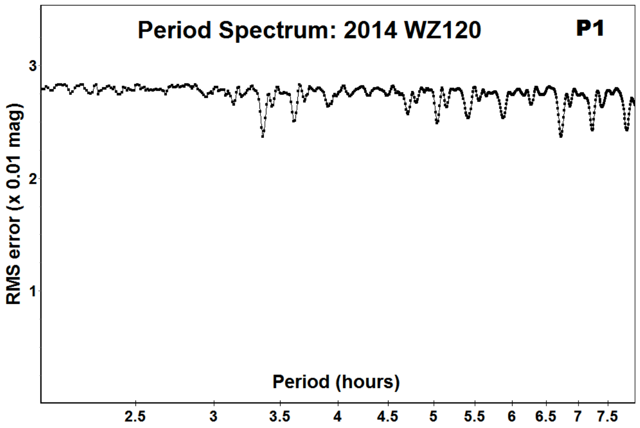
Initial results for this asteroid were first reported after observations in 2014 September (Warner, 2015b). Additional observations were made in 2015 January to fill in the long period lightcurve (which confirmed the initial result) and see if evidence of the satellite was still present. The result of subtracting P_1 from the extended data set is shown in the P_2 plot, which is in line with previous examples of this unusual binary type.

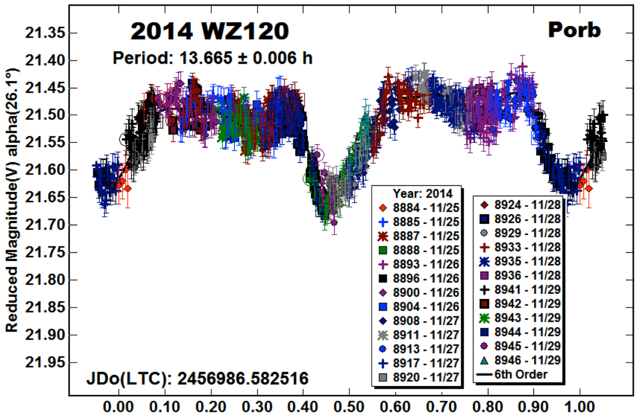
2014 WZ120 (NEA). This is the only candidate reported here that can be considered a confirmed binary by the usual standard of seeing mutual events in the secondary lightcurve. The *No Sub* plot shows obvious signs of a satellite, i.e., the attenuations on several nights at about 0.8 rotation phase of the primary period. In this case, the attenuations were so deep that it was easier to find the long (orbital) period first and then extract the low amplitude primary lightcurve.

The P_1 plot shows the rotation due to the primary body. The low amplitude (0.05 mag) indicates a nearly spheroidal body, which is typical of many small binary systems. The P_2 plot clearly shows the mutual events due to occultations and/or eclipses involving the satellite. The lesser attention at about 0.0 orbital phase is used to estimate the effective diameter ratio of the two bodies. In this case, this gives Ds/Dp ≥ 0.32 ± 0.02. Since the events do not appear to total (neither is flat-bottomed), this is a minimum value.









The period spectrum shows that the period of 3.361 h is not unique. However, referring to the plot from Pravec *et al.* (2010) that shows the relation between the primary period to the size ratio of the two bodies, the adopted period and size ratio are almost on the model's central line and very near three other data points. Adopting a longer period for the primary would make this an unusual binary. That is not impossible but a more definitive period for the primary would be required to make that claim.

Conclusions

The usual photometric evidence required to make a claim that an asteroid has a satellite is the presence of mutual events in the secondary period lightcurve. In this regard, there is no doubt that 2014 WZ120 is a binary asteroid. Such evidence will almost certainly not be found for the *wide binaries* such as (190208) 2006 AQ because the orbital period is so long. Theory says such systems exist. The hope of confirming the theory probably lies with techniques such as adaptive optics (AO) observations. However, most of the objects in this class found to date are too faint for the current technology. For now, to accept that the evidence for these types of binaries exists requires accepting that the short-period, low-amplitude lightcurves found for a handful of candidates so far are proof enough.

On the other hand, for more typical binaries, the simple presence of a second period is not sufficient evidence to make a certain claim of a satellite, especially when the secondary period is marginally established. The evidence for a binary among three Hungaria asteroids presented here, save possibly 3880 Kaiserman, should be treated with some skepticism. The justification for drawing attention to them is to encourage high-precision campaigns in the future that are designed to capture evidence, if any, of a satellite rather than "quick and dirty" confirmation of the presumed period of the asteroid. This means several nights and, preferably, coordinated efforts involving stations from well-separated 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-1210099. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

References

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

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

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

Pravec, P., Wolf, M., Sarounova, L. (1998, 1999, 2000a, 2001, 2012, 2014a). *http://www.asu.cas.cz/~ppravec/neo.htm*

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.

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

Warner, B.D. (2007b). "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.

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

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

Warner, B.D (2012b). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 September – December." *Minor Planet Bul.* **39**, 69-80.

Warner, B.D. (2015a). "Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2014 June-October." *Minor Planet Bul.* **42**, 54-60.

Warner, B.D. (2015b). "A Quartet of Near-Earth Asteroid Binary Canidates." *Minor Planet Bul.* **42**, 79-83.

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

THE ROTATION PERIOD OF 2043 ORTUTAY

Kim Lang
Klokkerholm Observatory
Blomstervaenget 15, DK-9320 Klokkerholm, DENMARK
kim_lang@kila-astro.dk

(Received: 13 January)

A lightcurve of 2043 Ortutay was generated using images recorded on seven nights of 2013 November and December. The analysis yielded a synodic rotation period P = 7.7475 ± 0.0005 h and amplitude A = 0.47 mag.

2043 Ortutay was discovered 1936 November 12 by G. Kulin at Budapest. Gyula Ortutay, a professor of ethnography, patronized the popularization of astronomy in his country and the asteroid was named in his honor. This asteroid appeared on the *Lightcurve Opportunities* list in the *Minor Planet Bulletin* (Warner *et al.*, 2013) as not having a previously published period. At the start of this campaign, other asteroids were in the field of 2043 Ortutay and this object was thus selected.

A 203-mm Newtonian telescope with a Baader Multipurpose coma corrector was used, giving an effective focal length of 890-mm. The camera was an Atik 383L+ with a Kodak KAF-8300 chip and pixel size of 5.4x5.4 µm. The image scale was 1.25 arc second per pixel at 1x1 binning. The observations of 2043 Ortutay were executed with different filter and binning configurations (Table I). All images were calibrated with master darks and flats corresponding to different filters and binning configurations using the Batch Imaging Process utility of *MPO Canopus*. Master darks and flats were generated by median filtering large sets of raw darks and flats using IRIS 5.59 software (Buil, 2011).

Using IRIS 5.59, photometry for pairs of equally bright field stars of approximately the same magnitude as the asteroid was made to determine the photometric noise in the time series for a large number of different sets of three apertures.

The one set of apertures with the least photometric noise was used in *MPO Canopus* to measure the lightcurve. 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. On several occasions, faint field stars was near the track of the asteroid and so were removed using the Star-B-Gone functionality of *MPO Canopus*. The beginning of the lightcurve of Dec 28 was impaired by clouds. These data were not excluded since this session is the longest of all and was hoped to help with suppressing aliases in the period solution. Since this was the first

Date [UT]	Canopus Session ID	Filter	Binning	Exposure time [s]	Number Obs	Session Duration [h]	Solar Phase Angle [°]	Note
2013 Nov 23	3	V	1x1	360	32	3.3	2.5	
2013 Nov 24	4	C	1x1	360	34	4.8	2.2	a)
2013 Nov 25	5	C	2x2	180	55	3.1	1.9	
2013 Nov 28	6	C	2x2	180	89	4.6	1.6	e)
2013 Dec 01	7	C	2x2	180	82	5.0	2.2	b)
2013 Dec 07	8	C	2x2	180	76	4.0	4.2	c)
2013 Dec 28	9	C	2x2	180	104	6.9	11.7	d)

Table I. Observations of 2043 Ortutay. a) Photometry interrupted 1.4 h by clouds near maximum brightness. b) Photometry interrupted 0.6 hours near first brightness. c) Photometry may be affected by two nearby field stars for about 1.9 hours. d) The first 13 data points degraded by clouds and interrupted by 0.9 h. e) Opposition occurred on Nov 26.9 at phase angle 1.6°

time this equipment setup was used, there was some doubt about which filter and binning mode would yield the most accurate lightcurve. The sessions went from V-filter unbinned to a clear filter binned 2x2. To investigate the possible implications of the different combinations of filters and binning modes, the period search was first limited to sessions 5 through 8, all in C-filter binned 2x2. Though session 9 was in C-filter binned 2x2, it was initially excluded for two reasons: the weather was unstable and 2043 Ortutay was moving through the Pleiades near Alcyone and its reflection nebula.

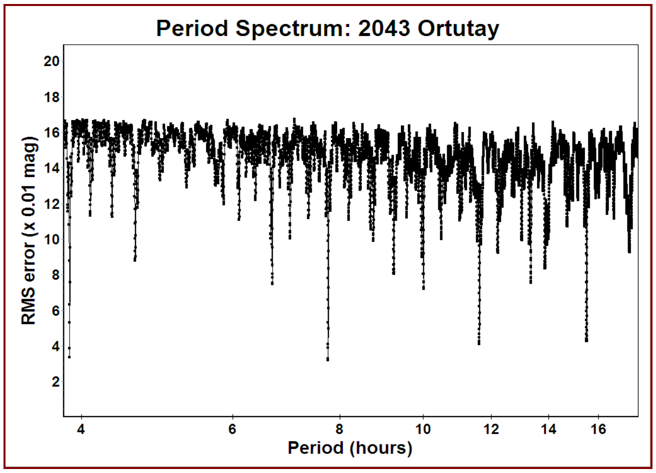


Figure 1. Period Spectrum shows multiple solutions that are a multiple of 3.87 h.

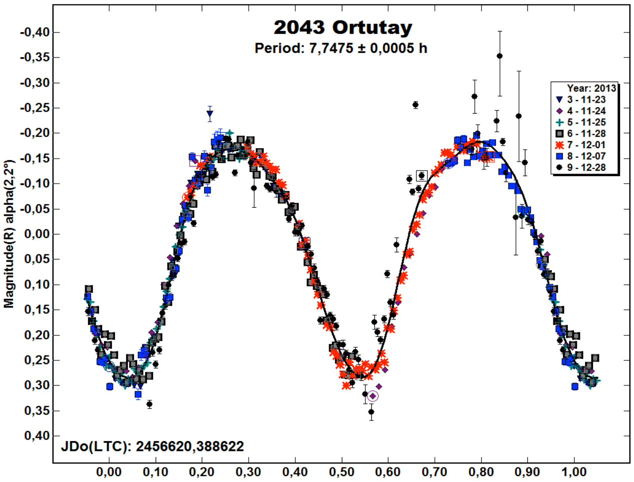


Figure 2. The lightcurve of 2043 Ortutay with a period of 7.7475 ± 0.0005 h and amplitude of 0.47 mag.

The lightcurve of 2043 Ortutay was found to be very symmetric and the period spectrum from *MPO Canopus* (Fig. 1) shows good fits at 3.87, 7.75 and 11.6 h, corresponding to one, two, or three maxima per rotation, respectively.

Period searches using 4, 6 and 8 harmonic orders in turns and a step size of down to 0.0001h found that the solution at 3.87 h is marginally better than the one at 7.7 h in all three cases. All RMS values were between 0.02 to 0.03 mag. Including sessions 4, 3, and 9 one at a time and then repeating the period searches using 4, 6 and 8 harmonic orders in turns, did not improve the results. The solutions all showed the same pattern.

Not being able to get a definitive distinction between the different solutions, the conclusion of this analysis is a period of $P = 7.7475 \pm 0.0005$ h and an amplitude of 0.47 mag with a RMS = 0.03 mag when using 8 harmonic orders (Fig. 2).

References

Buil, C. (2011). Software *IRIS* version 5.59 *http://www.astrosurf.com/buil/us/iris/iris.htm*

Warner, B.D. (2013). Bdw Publishing MPO Software, *MPO Canopus* version 10.4.3.21

Warner, B.D., Harris, A.W., Pravec, P., Durech, J., Benner, L.A.M. (2013). "Lightcurve Photometry opportunities: 2013 October-December." *Minor Planet Bulletin* **40,** 236-240.

ROTATION PERIOD AND H-G PARAMETERS DETERMINATION FOR 248 LAMEIA

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

Vladimir Benishek
Belgrade Astronomical Observatory
Volgina 7, 11060 Belgrade 38, SERBIA

Kevin Hills
Riverland Dingo Observatory (RDO)
Moorook, 5343, South Australia
AUSTRALIA

(Received: 14 January)

For 248 Lameia, which has a rotation period nearly commensurate with an Earth day, lightcurves from three observers at widely different longitudes are needed for full phase coverage. These were obtained and provide a good fit to a lightcurve phased to 11.912 ± 0.001 hours with an amplitude of 0.17 ± 0.01 mag. A color index V-R = 0.40 ± 0.03 was found. The R- and V-band absolute magnitudes H_R and H_V were determined to be 9.91 ± 0.02 and 10.31 ± 0.04 mag, respectively. The slope parameter of $G = 0.05 \pm 0.03$ was found. These led to an estimated size of $D = 47 \pm 3$ km.

The only previous published period for 248 Lameia is by Binzel (1987), who found an Earth commensurate period of 12.0 hours based on very sparse data. Recognizing that observations widely spaced in longitude were necessary for full phase coverage, Pilcher in North America requested collaboration from Benishek in Europe and Hills in Australia. Both of these observers kindly accepted the invitation and provided useful data.

Benishek used a 0.35-m Meade LX-200 GPS Schmidt-Cassegrain, SBIG ST-8 XME CCD camera, and R filter. Hills used a 0.41-m *f*/9 Richey-Chretien telescope, SBIG STL-1001E CCD, and V filter. Pilcher used a 0.35-m Meade LX-200 GPS Schmidt-Cassegrain, SBIG STL-1001E CCD, and clear filter.

Analysis of photometric data from a total of 15 sessions 2014 Aug 29 - Nov 1 provides a good fit to a synodic rotation period of 11.912 ± 0.001 hours, amplitude 0.17 ± 0.01 mag with a somewhat irregular lightcurve. In our lightcurve in Figure 1, data points are binned in sets of three separated by no more than five minutes to make the lightcurve easier to read. Our data have about 90% phase coverage when plotted to the double period of 23.823 hours. The available segments of the two halves of this lightcurve are identical within reasonable photometric error. For the double-period to be the correct one, the shape of the target would have to be both highly irregular and symmetric over a 180 degree rotation to produce the observed lightcurve. The probability of such symmetry is sufficiently small that the double period may be safely rejected. Hence we claim that the 11.912 hour period is secure.

On 2014 Nov 13, FP obtained 35 images of 90 second exposure time each with V and R filters, obtained alternately, to determine the color index V-R. On 2014 Nov 26, VB obtained 29 images of 180 second exposure with V and R filters, obtained alternately, as a second determination of the color index V-R. Four of the V filter images were defective and not used. The r´, J, and K magnitudes of each calibration star were obtained from the CMC15 catalog as posted on the VizieR web site (2014). Cousins R filter magnitudes were computed from R = r´ – 0.22 and used to measure the R filter images. Johnson V filter magnitudes were computed from V = 0.9947r´ + 0.6278(J-K) and used to measure the V filter images from the same calibration stars. Both procedures are from Dymock (2009). The magnitudes in R and V bands, respectively, thus obtained, are shown for the Nov 13 observations in Fig. 2 and for the Nov 26 observations in Fig. 3. For the Nov 13 observations adjustment of the V magnitudes upward by 0.41 produced the lowest residual fit, and for the Nov 26 observations adjustment of the V magnitudes upward by 0.39 produced the lowest residual fit. Hence we state a color index V-R = 0.40 ± 0.03.

The following table summarizes the individual sessions. The sessions are listed in time sequence in which the data were obtained.

Obs	Session	Date 2014	UT	Phase Angle	Num Obs
FP	1102	08/29	06:31-11:50	10.6	225
FP	1105	08/31	03:48-11:38	9.8	365
KH	1111	09/01	13:23-17:44	9.2	56
FP	1109	09/03	03:39-11:53	8.5	367
KH	1112	09/06	12:36-17:38	7.0	74
KH	1113	09/07	12:27-18:14	6.6	139
VB	1118	09/17-18	23:37-02:18	2.8	50
VB	1119	09/18-19	19:13-02:05	2.6	124
FP	1117	09/20	03:01-10:32	2.6	162
FP	1124	09/24	07:59-10:51	3.3	70
FP	1141	09/27	03:49-10:38	4.3	355
VB	1143	09/27	18:51-23:09	4.5	81
VB	1179	10/09-10	18:49-00:07	9.5	161
VB	1195	10/20	16:53-23:22	13.7	106
VB	1215	11/01	18:28-22:37	17.4	52

Table I. Observer code VB, Vladimir Benishek; KH, Kevin Hills; FP, Frederick Pilcher.

Photometric data obtained by Pilcher and Benishek (with the exception of the Benishek's September 27 data set) were used also to determine the R-band absolute magnitude (H_R) and slope parameter (G_R). These values were found by employing the H-G calculator tool of *MPO Canopus*, based upon the FAZ algorithm developed by Alan Harris (1989). A total of 13 data points (representing the lightcurve *average* for each observing session) are included in the phase curve, of which 3 represent pre-opposition and 10 are post-opposition data. Analysis of the data found $H_R = 9.91 \pm 0.02$, $G_R = 0.05 \pm 0.03$ (Fig. 4).

It should be noted that although the pre-opposition sparse data points show a significant deviation from the post-opposition data, the post-opposition data show a remarkable consistency in the obtained results for the H_R and G_R parameters.

Using the adopted V-R color index value of 0.40 ± 0.03 and assuming $G_V = G_R$, it follows that $H_V = 10.31 \pm 0.04$. Assuming a geometric albedo of $p_V = 0.062 \pm 0.007$ (JPL, 2015) and using the formula by Pravec and Harris (2007) for the asteroid diameter (D) in kilometers

$$D = \frac{1329}{\sqrt{pv}}\, 10^{-0.2Hv}$$

the estimated diameter of 248 Lameia is $D = 47 \pm 3$ km, which is perfect agreement with the value of 48.66 km (JPL, 2015) found from the IRAS Minor Planet Survey observations and by Masiero *et al.* (2012; 48.51 km).

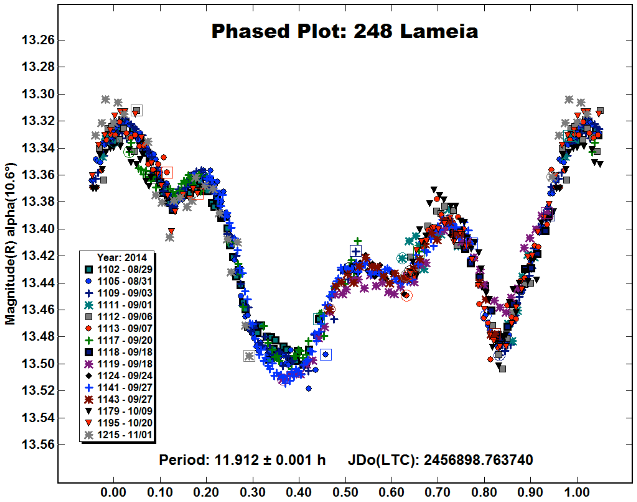


Figure 1. Lightcurve of 248 Lameia phased to 11.912 hours.

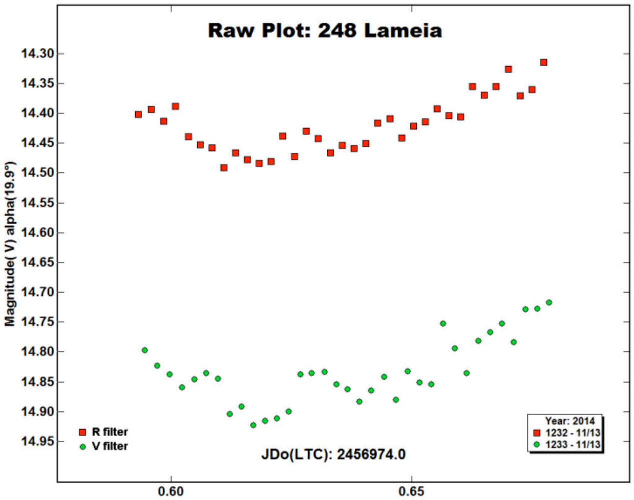


Figure 2. R and V magnitudes of 248 Lameia on 2014 Nov 13

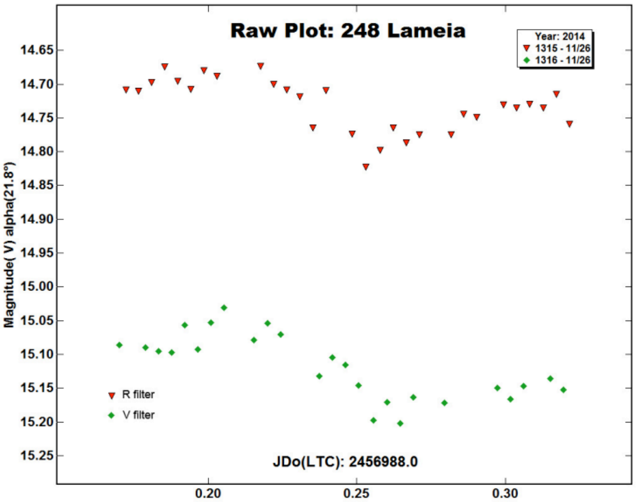


Figure 3. R and V magnitudes of 248 Lameia on 2014 Nov 26

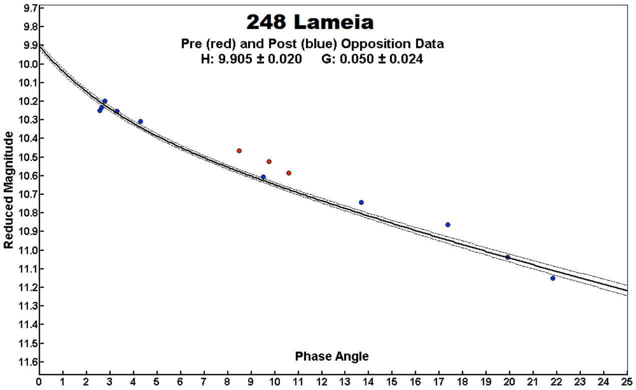


Figure 4. H-G plot of 248 Lameia in the Cousins R magnitude system.

References

Binzel, R.P. (1987). "A Photoelectric Survey of 130 Asteroids." *Icarus* **72**, 135-208.

Dymock, R., Miles, R. (2009). "A method for determining the V magnitudes of asteroids from CCD images." *J. Brit. Astron. Assoc.* **119**, 149-156.

Harris, A.W. (1989). "The H-G Asteroid Magnitude System: Mean Slope Parameters." Abstracts of the Lunar and Planetary Science Conference **20**, 375.

JPL (2015). Small-Body Database Browser - JPL Solar System Dynamics web site. *http://ssd.jpl.nasa.gov/sbdb.cgi*

Masiero, J., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Nugent, C., Cabrera, M.S. (2012). "Preliminary Analysis of WISE/NEOWISE 3-Band Cryogenic and Post-cryogenic Observations of Main Belt Asteroids." *Astrophys. J. Letters* **759**, L8.

Pravec, P., Harris, A.W. (2007). "Binary Asteroid Population I. Angular Momentum Content." *Icarus* **158**, 106-145.

VizieR (2014). *http://vizier.u-strasbg.fr/viz-bin/VizieR*

LIGHTCURVE ANALYSIS FOR SEVEN MAIN-BELT ASTEROIDS

Giovanni Battista Casalnuovo
Eurac Observatory C62 Bolzano, ITALY
studioarchigraph@virgilio.it

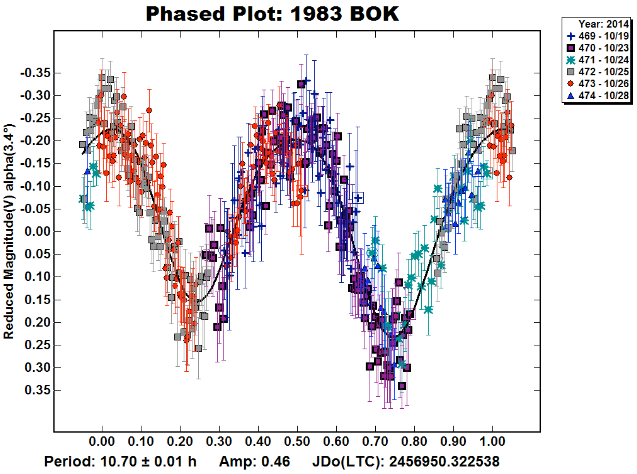
(Received: 16 December)

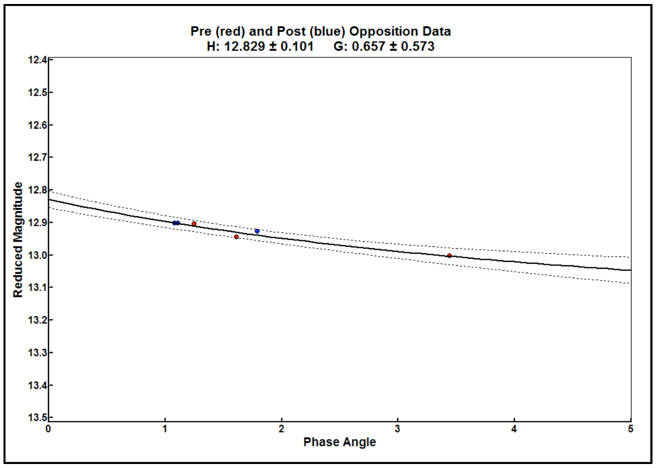
Photometric observations of seven main-belt asteroids were made at the Eurac Observatory (C62 in Bolzano-Italy) in 2014: 1983 Bok, 2634 James Bradley, 4252 Godwin, 5116 Korsor, 10597 (1996 TR10), 52505 (1996 FD4), and 53247 (1999 DE2).

CCD photometric observations were made of seven main-belt asteroid during 2014 at the Eurac Observatory in Bolzano, Italy. The images were obtained using a 0.30-m reflector telescope reduced to *f*/4.0 and a QHY9 CCD camera. All filtered images (V Johnson and R Cousins) were calibrated with dark and flat-field frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2014). The imaging computer clock was synchronized to an Internet time server before each observing run.

1983 Bok. The main-belt asteroid 1983 Bok was reported as a lightcurve photometry opportunity for October 2014 (CALL, 2014). The derived synodic period is $P = 10.70 \pm 0.01$ h with an amplitude of $A = 0.46 \pm 0.05$ mag. A color index of V-R = 0.39 ± 0.09 mag was found from the mean of 28 values. This value possibly indicates a C-type asteroid (Shevchenko and Lupishko, 1998). Assuming C-type, the geometric albedo is $p_V = 0.06 \pm 0.02$ (Shevchenko and Lupishko, 1998). The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. Six post-opposition values were obtained, using the maximum values of the lightcurve. These led to $H = 12.82 \pm 0.10$ and $G = 0.657 \pm 0.573$. From H and the assumed albedo, a diameter of $D = 15 \pm 3$ km is estimated using the expression (Pravec and Harris, 2007):

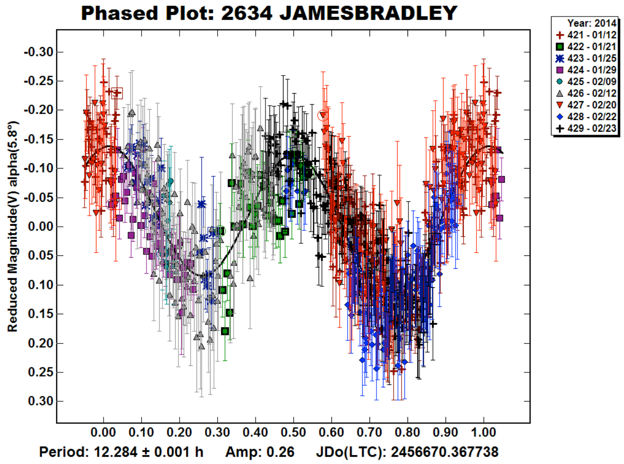
$$D_{(km)} = (1329/\sqrt{Pv})10^{-0.2Hv}$$

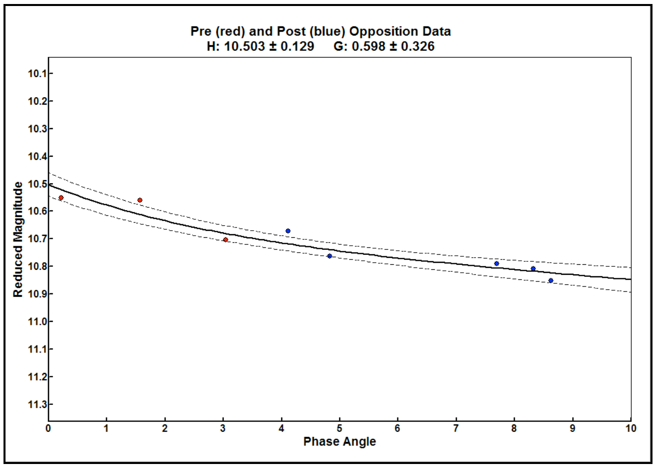




All the data were at small phase angles and so the solution for *G* is not well constrained. In fact, it is not consistent with the typical value for C-type asteroids, *G* = 0.12 ± 0.08 (Warner *et al*., 2009). This shows the importance of obtained data at both low and high phase angles.

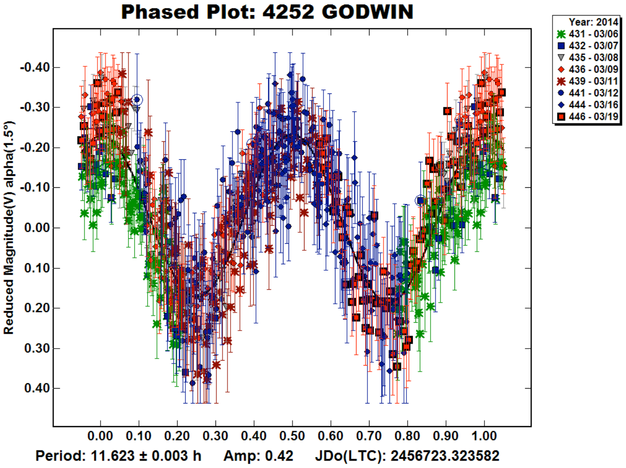
2634 James Bradley. 2634 James Bradley was reported as a lightcurve photometry opportunity for January 2014 (CALL, 2014). The derived synodic period is *P* = 12.284 ± 0.001 h with an amplitude of *A* = 0.26 ± 0.05 mag.

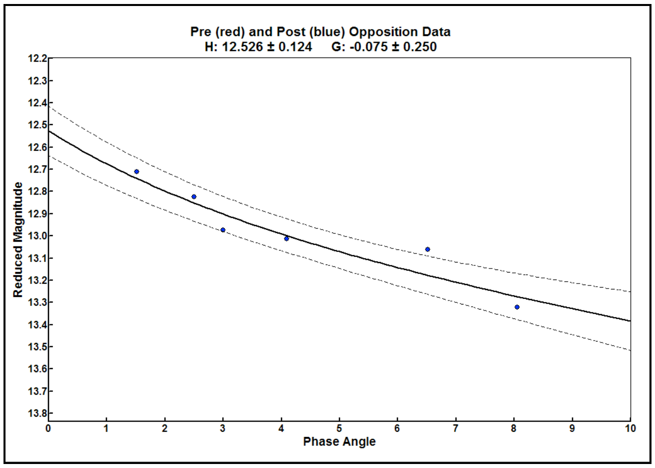




V and R band frames were acquired in sequence changing alternatively the filters (VR VR VR). This allowed finding the color index of V-R = 0.39 ± 0.06 mag (mean of 45 values). This value falls within the range of a C-type asteroid (Shevchenko and Lupishko, 1998). Assuming a C-type, the geometric albedo is *pv* = 0.06 ± 0.04 (Shevchenko and Lupishko, 1998). The absolute magnitude (*H*) and slope parameter (*G*) were found using the H-G Calculator function of *MPO Canopus*. Eight values were obtained pre- and post-opposition of the asteroid, using the maximum values of the lightcurve. The results were *H* = 10.503 ± 0.129 and the slope parameter *G* = 0.598 ± 0.326; a value that is not well constrained over the phase angle range being under 10 degrees. From *H* and the assumed albedo, a diameter of *D* = 37 ± 3 km was found.

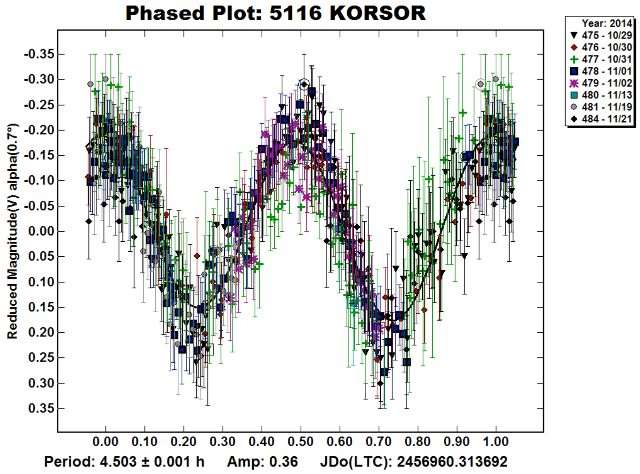
4252 Godwin. This main-belt asteroid was reported as a lightcurve photometry opportunity for March 2014 (CALL, 2014). The derived synodic period is *P* = 11.623 ± 0.003 h with an amplitude of *A* = 0.42 ± 0.07 mag.

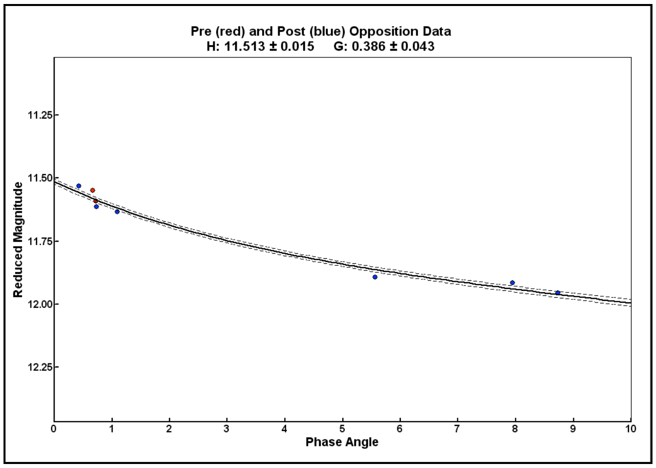




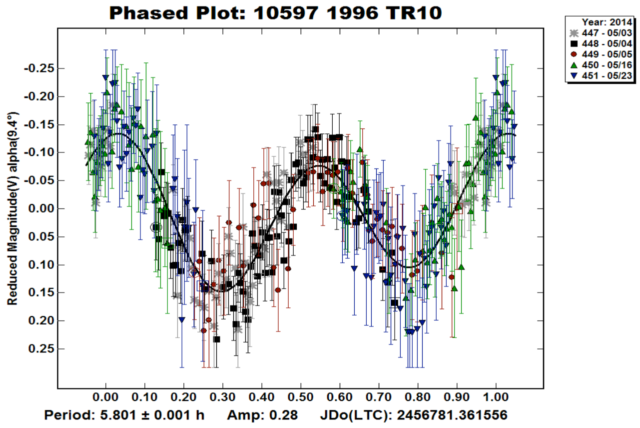
A color index of V-R = 0.41 ± 0.08 mag was found from the mean of 30 values. This value is broadly within the range of an M- or C-type asteroid (Shevchenko and Lupishko, 1998). The absolute magnitude (*H*) and slope parameter (*G*) were found using the H-G Calculator function of *MPO Canopus* with six values, all at low phase angles. The result was *H* = 12.526 ± 0.124. Using *H* and p_V = 0.06, this gives *D* = 17 ± 3 km.

5116 Korsor. The main-belt asteroid 5116 Korsor was reported as a lightcurve photometry opportunity for October 2014 (CALL, 2014). The derived synodic period is *P* = 4.503± 0.001 h with an amplitude of *A* = 0.36 ± 0.07 mag. The mean of 30 values gives V-R = 0.40 ± 0.05. This value possibly indicates a C- or M- type asteroid (Shevchenko and Lupishko, 1998). Assuming M-type, the geometric albedo is p_V = 0.17 ± 0.04 (Shevchenko and Lupishko, 1998). The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. Eight values were obtained, using the maximum values of the lightcurve and, again, all at small phase angles. The results were H = 11.513 ± 0.015 and G = 0.385 ± 0.043. The estimated diameter is D = 16 ± 3 km.

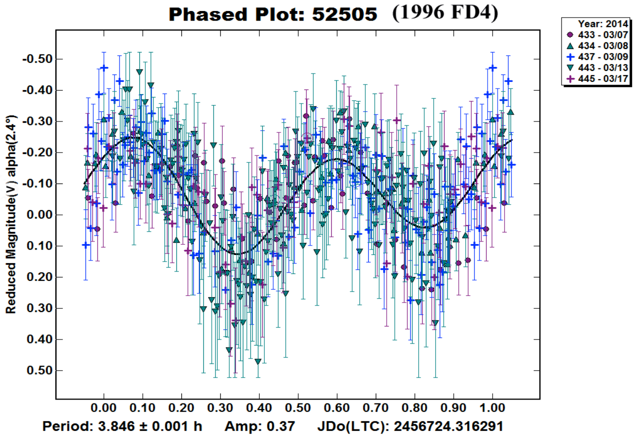




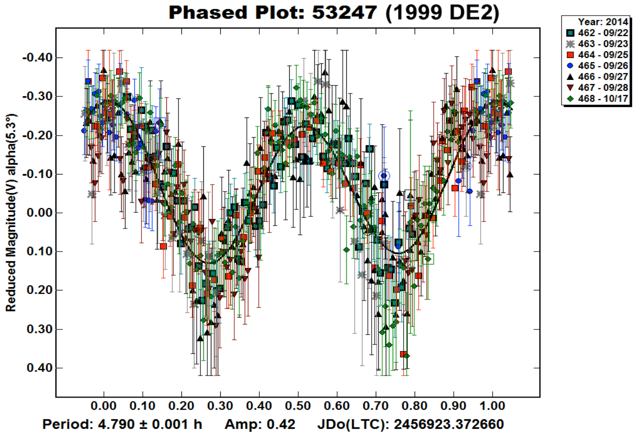
(10597) 1996 TR10. The main-belt asteroid 10597 (1996 TR10) was reported as a lightcurve photometry opportunity for May 2014 (CALL, 2014) and observed on five nights from 2014 May 5-23. The derived synodic period is P = 5.801 ± 0.001 h with an amplitude of A = 0.28 ± 0.05 mag.



(52505) 1996 FD4. 1996 FD4 was reported as a lightcurve photometry opportunity for March 2014 (CALL, 2014). The asteroid was observed on six nights from 2014 March 7-17. The derived synodic period is P = 3.846 ± 0.001 h with an amplitude of A = 0.37 ± 0.08 mag.



(53247) 1999 DE2. This main-belt asteroid was reported as a lightcurve photometry opportunity for September 2014 (CALL, 2014). It was observed on seven nights from 2014 Sep 22 – Oct 17. The derived synodic period is P = 4.790 ± 0.001 h with an amplitude of A = 0.42 ± 0.06 mag.



References

CALL web site (2014). Oppositions browser page. *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*

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

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146.

Warner, B.D. (2014). MPO Software, *MPO Canopus* version 10.4.3.17. Bdw Publishing. *http://www.minorplanetobserver.com/*

LIGHTCURVE ANALYSIS FOR ASTEROIDS 4880 TOVSTONOGOV AND 5750 KANDATAI

Isabel O. Taylor, Caroline E. Odden
Phillips Academy Observatory (I12)
180 Main Street
Andover, MA 01810 USA
ceodden@andover.edu

(Received: 14 January)

Observations for asteroids 4880 Tovstonogov and 5750 Kandatai were obtained at the Phillips Academy Observatory between 2014 September and November.

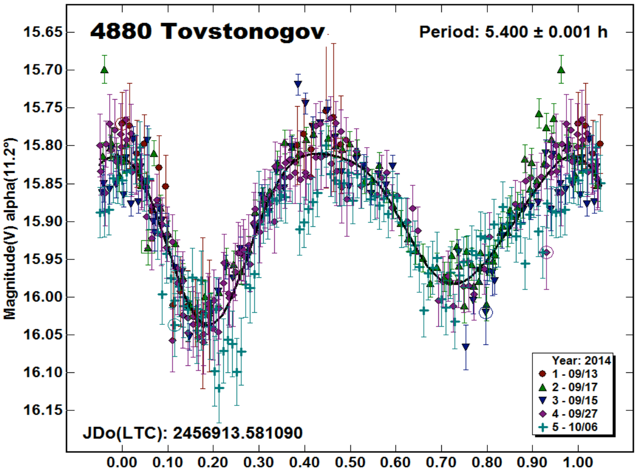
Lightcurves for asteroids 4880 Tovstonogov and 5750 Kandatai were obtained from Phillips Academy Observatory between 2014 September and November. All observations were made with a 0.40-m *f*/8 Ritchey-Chrétien by DFM Engineering. Phillips Academy Observatory was in the process of transitioning from an old camera to a new camera this fall. Thus, photometric observations of the asteroids were taken using both an SBIG STL-1301E with a 1280x1024 array of 16-micron pixels and an Andor Tech iKon DW436 with a 2048x2048 array of 13.5-micron pixels. The resulting image scale was 1.02 arcseconds per pixel for the SBIG and 0.86 arcseconds per pixel for the Andor. In order to test the new camera, the authors experimented with binning, exposure length, filter type, and CCD temperature during the months in which observations of the asteroids were collected. Table I describe the various permutations. All images were dark and flat-field corrected and guided.

Images were measured using *MPO Canopus* (Bdw Publishing) using a differential photometry technique. All comparison stars were selected to near solar color by using the “comp star selector” tool of *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 from both observatories were analyzed by Taylor, a student in an astronomy research class taught by Odden at Phillips Academy. A search of the asteroid lightcurve database (LCDB; Warner *et al.,* 2009) and other sources did not reveal previously reported lightcurve results for either asteroid.

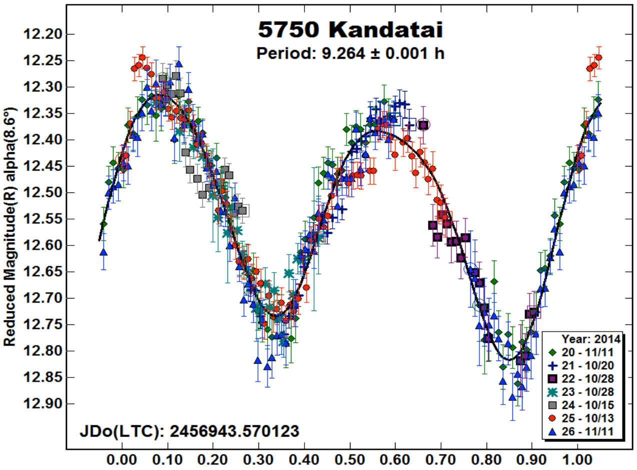
Asteroid	UT yyyymmdd	Exp Sec	Bin	Temp °C	Cam	Filter
4880	20140913	300	1x1	-25	SBIG	None
4880	20140915	300	1x1	-25	SBIG	None
4880	20140917	300	1x1	-30	SBIG	None
4880	20140927	180	2x2	-55	Andor	Lum
4880	20141006	180	2x2	-65	Andor	Lum
5750	20141013	300	2x2	-30	SBIG	None
5750	20141015	300	2x2	-30	SBIG	None
5750	20141020	300	1x1	-30	SBIG	None
5750	20141028	300	2x2	-50	Andor	Lum
5750	20141028	300	1x1	-30	SBIG	None
5750	20141111	300	1x1	-50	Andor	Lum
5750	20141111	300	1x1	-50	Andor	Lum

Table I. Camera settings for each observing run

<u>4880 Tovstonogov</u>. Astronomer L. I. Chernykh discovered this main-belt asteroid on 1975 October 14 at Nauchnyj (Schmadel, 2003). Images were taken from 2014 September to October. The resulting plot consists of 397 data points derived from images taken on five separate nights. The amplitude of the lightcurve is 0.23 mag; the period spectrum strongly favors a synodic period of 5.400 ± 0.001 hours.



<u>5750 Kandatai.</u> Takahashi and Watanabe discovered this main-belt asteroid on 1991 April 11 at Kitami (Schmadel, 2003). The resulting lightcurve consists of nine different sessions on eight nights from 2014 October to November. The resulting lightcurve contains 330 data points. The amplitude of the lightcurve is 0.50 mag, sufficient to ensure a bimodal solution. The period spectrum favors the period of 9.264 ± 0.001 hours.



Acknowledgments

Research at the Phillips Academy Observatory is supported by the Israel Family Foundation. Many thanks to the Abbot Academy Association for the generous grant used to purchase the new Andor Tech camera.

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.

Schmadel, L.D. (2003). *Dictionary of Minor Planet Names.* (5th ed., p. 146). Springer, New York, NY.

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The asteroid lightcurve database.” *Icarus* **202**, 134-146. Updated 2014 December 13.
http://www.minorplanet.info/lightcurvedatabase.html

ROTATION PERIOD DETERMINATIONS FOR 1724 VLADIMIR, 3965 KONOPLEVA, AND 9222 CHUBEY

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

(Received: 15 January)

Analysis of observations made from 2014 June-December found the synodic rotation periods and lightcurve amplitudes for three main-belt asteroids: 1724 Vladimir, 3965 Konopleva, and 9222 Chubey.

Photometric observations of three main-belt asteroids were carried out from 2014 June through December at the Sopot Astronomical Observatory (SAO) using a 0.35-m *f*/6.3 Schmidt-Cassegrain (SCT) equipped with a SBIG ST-8XME CCD camera. The exposures were unfiltered and unguided. The camera was operated in 2x2 binning mode, which produced an image scale of 1.66 arcsec/pixel. All images were corrected with dark and flat field frames.

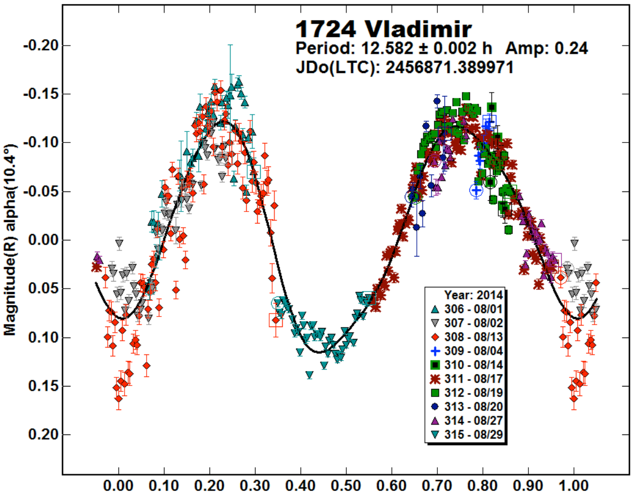
Photometric reduction, lightcurve construction, and period analysis were conducted using *MPO Canopus* software (Warner, 2013). The Comparison Star Selector (CSS) utility was employed for differential photometry. This allowed using up to five comparison stars of near solar color. The V-band (for the asteroid 9222) and R-band (for the asteroids 1724 and 3965) magnitudes were taken from the hybrid MPOSC3 catalog, where BVRI magnitudes were derived from J and K 2MASS catalog magnitudes by applying formulae developed by Warner (2007). As a result, the magnitude zero-points for individual data sets are generally consistent within a few hundredths of a magnitude. However, in some cases, more significant misfits between the individual data sets of the order of a few tenths of a magnitude have been noticed. Most likely such discrepancies could be a consequence of catalog magnitude errors. To produce best lightcurve fit, the zero-point of each individual data set was adjusted until a minimum Fourier residual was reached. All targets have been selected using the CALL website maintained by Warner (2014).

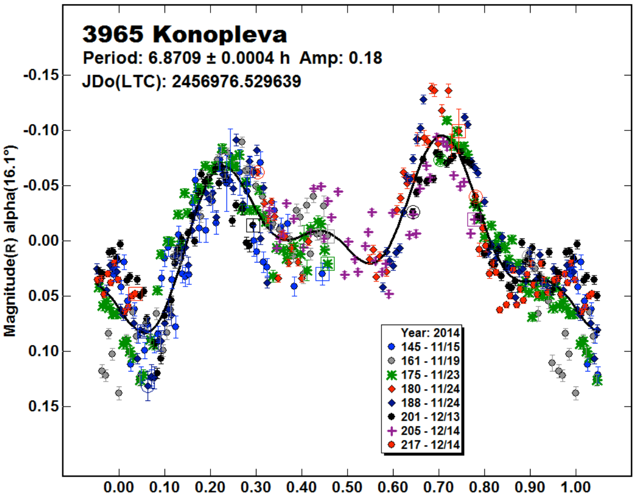
<u>1724 Vladimir</u>. This asteroid was observed by Benishek (2009) where a period of 12.57 hours based on an incomplete bimodal lightcurve was found. Due to the relatively low lightcurve amplitude at that apparition (0.14 mag), there was a possibility of a monomodal solution of 6.29 hours.

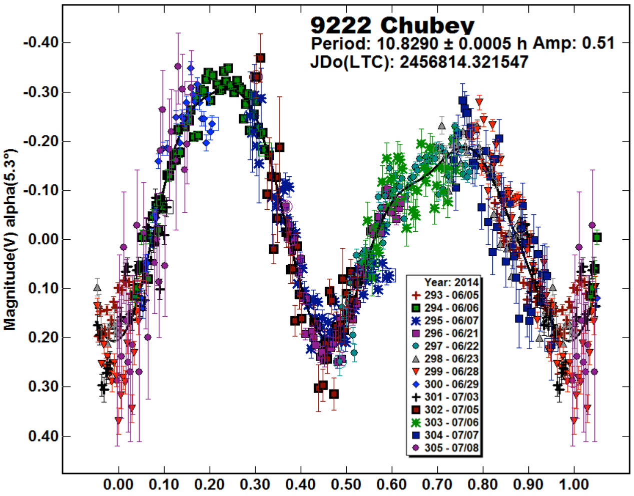
The observations from 2014 August 1-29 resulted in 10 data sets with 427 data points. A bimodal lightcurve phased to 12.582 hours emerged as the most favorable solution based on the lowest RMS residual. Since the lightcurve amplitude calculated from the 2014 data (0.24 ± 0.02 mag.) is significantly higher than it was in 2008 and the asteroid was observed in the range of rather low phase angles, the bimodal solution can be favored over the monomodal with a high degree of reliability. Therefore, the adopted solution for rotation period is $P = 12.582 \pm 0.002$ hours.

<u>3965 Konopleva</u>. No previously reported period for Konopleva was found in the literature. It was observed from 2014 November 15 to December 14, which resulted in eight observing sessions and a total of 451 data points. Analysis found an unambiguous synodic period of $P = 6.8709 \pm 0.0004$ h. The lightcurve amplitude is 0.18 ± 0.03 mag.

<u>9222 Chubey</u>. No previous rotation period determinations were found for Chubey. The observations were made from 2014 June 5 through July 8 and produced 13 data sets with a total of 575 data points. The period analysis found a unique period of $P = 10.8290 \pm 0.0005$ h. The lightcurve amplitude was 0.51 ± 0.03 mag.







References

Benishek, V., Protitch-Benishek, V. (2009). "CCD Photometry of Asteroids at the Belgrade Astronomical Observatory: 2008 January-September." *Minor Planet Bull.* **36**, 35-37.

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

Warner, B.D. (2013). MPO Software, *MPO Canopus* version 10.4.3.17. Bdw Publishing. *http://www.minorplanetobserver.com/*

Warner, B.D. (2014). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

TARGET ASTEROIDS! OBSERVING CAMPAIGNS FOR APRIL THROUGH JUNE 2015

Carl Hergenrother and Dolores Hill
Lunar & Planetary Laboratory
University of Arizona
1629 E. University Blvd.
Tucson, AZ 85721 USA
chergen@lpl.arizona.edu

(Received: 15 January)

Asteroid observation campaigns to be conducted by the *Target Asteroids!* program during the period of April through June 2015 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, the target asteroid of the OSIRIS-REx sample return mission.

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) 1999 JU3, 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! plans 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 = 18.0 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	19.8	late Jun
(68278)	2001 FC7	17.8	late Jun
(164221)	2004 QE20	18.9	late Jun
(163000)	2001 SW169	19.7	late Jun
(350713)	2001 XP88	19.1	late Jun
(416186)	2002 TD60	17.9	late Apr

The campaign targets are split up into two sections: 1) carbonaceous MBAs that are analogous to Bennu and 1999 JU3 and 2) NEAs analogous to the Bennu and 1999 JU3 or provide an opportunity to fill some of the gaps in our knowledge of these spacecraft targets (examples include very low and high phase angle observations, phase functions in different filters and color changes with phase angle).

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

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

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

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

Analog Carbonaceous Main Belt Asteroid Campaigns

(19) Fortuna (a=2.44 AU, e=0.16, i=1.6°, H = 7.1)
Fortuna is one of the larger asteroids in the Main Belt with a diameter of ~220 km. Taxonomically it is classified as a Ch-type or hydrated carbonaceous asteroid. It rotates once every 7.44 hours with a lightcurve amplitude of 0.2-0.3 magnitudes. Though an inner Main Belt carbonaceous asteroid, it does not appear to belong to any obvious collisional family. Such 'background' objects may still be related to objects like Bennu.

On April 23 Fortuna reaches an extremely low phase angle of 0.02°. The phase angle increases to ~20° by the end of the quarter. We request lightcurve and phase function photometry of this object as well as color photometry and low-resolution spectroscopy.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	14 19	-14 05	1.90	2.83	11.4	9	153
04/11	14 12	-13 20	1.85	2.83	11.2	5	165
04/21	14 03	-12 28	1.83	2.83	10.9	1	177
05/01	13 54	-11 34	1.83	2.83	11.1	3	171
05/11	13 43	-10 42	1.87	2.83	11.3	8	159
05/21	13 38	-09 59	1.92	2.83	11.5	11	147
05/31	13 34	-09 29	2.01	2.83	11.8	14	136
06/10	13 31	-09 12	2.10	2.82	12.0	17	126
06/20	13 32	-09 09	2.22	2.82	12.1	19	117
06/30	13 34	-09 20	2.34	2.82	12.3	20	108

(3064) Zimmer (a=2.45 AU, e=0.12, i=2.9°, H = 13.4)

Many of the Main Belt asteroids observed by *Target Asteroids!* have been large bodies with diameters on the order of 50 to hundreds of kilometers. Zimmer is only on the order of 10 km or so in diameter. It is a member of either the carbonaceous Eulalia or 'Old' Polana families (Walsh et al. 2013) Surprisingly, no lightcurve parameters have been published for this object. Lightcurve photometry is especially requested in addition to color and phase function photometry. Phase function photometry can be obtained over a range of 27° to 1.3°. Minimum phase angle was reached in late March.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	12 31	-00 18	1.19	2.18	15.7	2	176
04/11	12 23	+00 46	1.21	2.19	16.0	7	164
04/21	12 17	+01 36	1.26	2.20	16.3	12	153
05/01	12 13	+02 07	1.32	2.21	16.6	16	142
05/11	12 11	+02 16	1.41	2.21	16.9	20	132
05/21	12 13	+02 04	1.51	2.22	17.1	23	123
05/31	12 17	+01 33	1.61	2.23	17.3	25	114
06/10	12 23	+00 47	1.73	2.24	17.5	26	107
06/20	12 32	-00 12	1.85	2.25	17.7	27	99
06/30	12 42	-01 22	1.98	2.26	17.9	27	93

Near-Earth Asteroid Campaign Targets

(1566) Icarus (a=1.08 AU, e=0.83, i=22.8°, H = 16.9)

Icarus is one of the best-known near-Earth asteroids. It is also one of the better characterized. This June Icarus passes within 0.05 AU of Earth and brightens to V=13.5. The flyby gives a wonderful opportunity to confirm previous phase function studies of Icarus as it will be observable from phase angles of ~147° down to 39°. It is a S or Q-type asteroid with an albedo of 0.14. Its short rotation period of 2.27 hr and small lightcurve amplitude of <0.2 magnitudes will make it easier than usual to remove rotational variations from its phase function.

DATE	RA	DEC	Δ	r	V	PH	Elong
06/11	04 55	+52 42	0.11	0.92	19.8	147	30
06/12	05 21	+56 08	0.10	0.94	19.1	144	33
06/13	06 02	+60 02	0.08	0.95	18.2	139	38
06/14	07 13	+63 39	0.07	0.97	17.1	133	44
06/15	09 08	+64 08	0.06	0.98	15.9	123	54
06/16	11 10	+57 13	0.06	1.00	14.7	110	67
06/17	12 31	+43 53	0.05	1.01	13.9	94	83
06/18	13 18	+29 25	0.06	1.03	13.6	80	97
06/19	13 46	+17 20	0.07	1.04	13.5	68	108
06/20	14 04	+08 16	0.08	1.05	13.7	60	116
06/21	14 17	+01 39	0.09	1.07	13.9	55	121
06/24	14 39	-09 47	0.14	1.11	14.6	46	128
06/27	14 51	-15 25	0.19	1.15	15.2	43	130
06/30	14 59	-18 42	0.24	1.19	15.8	41	130

(1580) Betulia (a=2.19 AU, e=0.48, i=52.1°, H = 14.5)

Near-Earth asteroid Betulia has been selected as a *Target Asteroids!* campaign object due to its low albedo (0.077) and taxonomy (C-type). During the current quarter it brightens from V = 16.8 to a maximum of 14.7 as its phase angle increases from 51° to a maximum of 63°.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	19 25	+72 42	0.95	1.27	16.8	51	81
04/11	19 00	+74 44	0.86	1.22	16.6	54	82
04/21	18 15	+76 50	0.75	1.18	16.3	57	83
05/01	16 33	+77 13	0.64	1.16	16.0	61	86
05/11	14 02	+72 03	0.52	1.14	15.6	63	90
05/21	13 23	+58 24	0.42	1.13	15.1	64	95
05/31	12 44	+35 14	0.36	1.13	14.7	62	100
06/10	12 46	+07 42	0.37	1.14	14.8	61	101
06/20	12 09	-14 13	0.45	1.17	15.2	60	98
06/30	11 59	-28 35	0.57	1.20	15.8	58	94

(85989) 1999 JD6 (a=0.88 AU, e=0.63, i=17.1°, H = 17.1)

1999 JD6 is really an object for the next quarter. It comes within 0.016 AU of Earth on July 20. During this flyby the asteroid peaks at magnitude V=14.6 and covers a range of phase angles from 109° to 16°. This asteroid is rather faint until June when it rapidly brightens within range of small aperture telescopes.

Taxonomic classification is all over the place with K, L and Cg types being assigned to it. Its albedo is on the dark side at 0.075. Lightcurve observations show a 7.7 hr rotation period and large amplitude of up to 1.2 magnitudes.

DATE	RA	DEC	Δ	r	V	PH	Elong
06/10	21 15	+07 42	0.54	1.32	18.1	45	113
06/20	21 22	+10 36	0.42	1.27	17.5	45	118
06/30	21 26	+14 29	0.30	1.21	16.6	45	123

2011 UW158 (a=1.62 AU, e=0.37, i=4.6°, H = 19.4)

This is yet another target that is better during the next quarter when it will brighten to magnitude 14.6 in mid-July. Before that it will be bright enough for small aperture observers in May and June. Little is known of about this object so phase function, lightcurve and color photometry is welcome.

DATE	RA	DEC	Δ	r	V	PH	Elong
05/01	13 43	-32 06	0.28	1.27	18.0	16	160
05/11	13 25	-32 18	0.23	1.22	17.7	22	152
05/21	13 07	-31 37	0.19	1.17	17.5	32	142
05/31	12 51	-30 09	0.16	1.13	17.4	43	131
06/10	12 41	-28 03	0.13	1.09	17.1	54	120
06/20	12 36	-25 06	0.10	1.05	16.8	66	109
06/30	12 36	-20 12	0.07	1.03	16.4	78	99

References

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

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.

Walsh, K., Delbo, M., Bottke, W., Vokrouhlicky, D., Lauretta, D. (2013). "Introducing the Eulalia and New Polana Asteroid Families: Re-assessing Primitive Asteroid Families in the Inner Main Belt." *Icarus* **225**, 283-297.

CCD PHOTOMETRY LIGHTCURVES OF THREE MAIN BELT ASTEROIDS

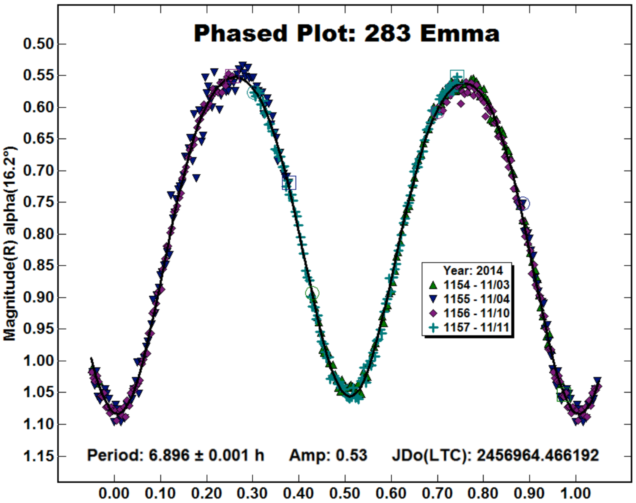
Kevin B. Alton
UnderOak Observatory
70 Summit Ave.
Cedar Knolls, NJ 07927

(Received: 28 November)

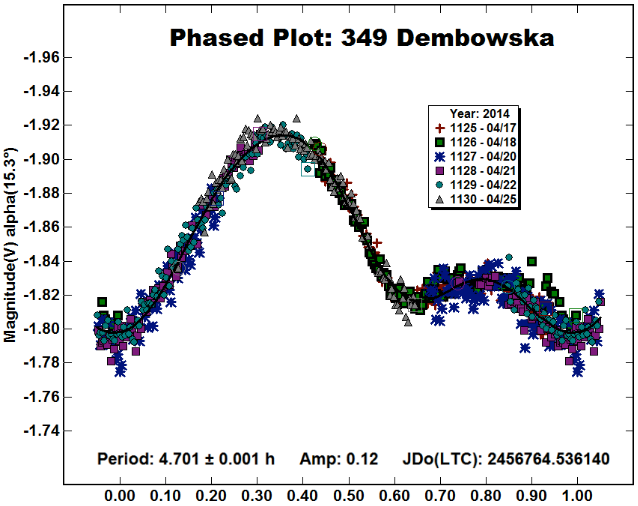
Fourier analyses of new CCD-derived lightcurves produced synodic period solutions for 283 Emma (6.896 ± 0 .001 h), 349 Dembowska (4.701 ± 0.001 h), and 409 Aspasia (9.023 ± 0.001 h).

The photometric instrument used at UnderOak Observatory (UO) for these studies was a 0.28-m SCT equipped with an SBIG ST-8XME thermoelectrically-cooled CCD. This combination produced a 10.4×15.6 arcmin field-of-view (FOV). Image calibration and registration procedures typically used at UO have been published elsewhere (Alton, 2013). Data reduction with *MPO Canopus* (Warner, 2013) used at least three non-varying comparison stars in the same 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 each folded dataset and then independently verified with *Peranso* (Vannmunster, 2006) using ANOVA (Schwarzenberg-Czerny, 1996). Phased lightcurve data are available upon written request. Relevant aspect parameters for each of these main belt asteroids taken at the mid-point from each observing session are shown in Table I.

283 Emma. Discovered in 1889 by Auguste Charlois, this fairly dark (p_V = 0.0262) main belt asteroid (D = 148.1 ± 4.6 km) was found by Merline *et al.* (2003) to have a satellite (9 ± 5 km) which orbits every 3.364 d at a distance of 370 km. The first photometric study that determined the primary's synodic period was published by Stanzel (1978; 6.89 h). Additional photometric (Strabla, 2011) and shape modeling studies (Michalowski *et al.*, 2006; Marchis *et al.*, 2008) point to an asteroid with a nearly perfect ellipsoid shape. At UO, a total of 524 images (R_c bandpass for 90 s) were taken over four nights (2014 Nov 3-11). Fourier analysis of the lightcurves produced the best fit at 6.896 h, identical to the value presently posted at the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). The sinusoidal nature of the lightcurve and peak-to-peak amplitude (0.53 mag) observed during this most recent apparition were consistent with the shape and range (0.14-0.57 mag) published for this object by Stanzel (1978), Michalowski *et al.* (2006), and Strabla (2011).



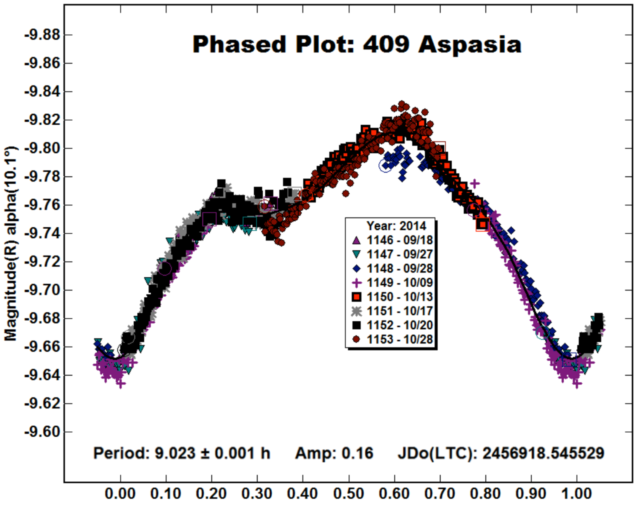
349 Dembowska. This main belt asteroid (D ≈ 140 km) was discovered by Auguste Charlois in 1892. Chang and Chang (1963) published the earliest lightcurve followed by similar studies from other investigators (Zappalà *et al.*, 1979; Di Martino *et al.,* 1987; Weidenschilling *et al.*, 1987; Lagerkvist *et al.*, 1988; and Majaess *et al.*, 2008). The most remarkable features of this object are its very high albedo (p_V = 0.384) and unique composition; it is the first of only a few asteroids thus far classified as R-type (Abell and Gaffey, 2000; Bus and Binzel, 2002). Shape and spin-axis modeling for this object has been reported by Torppa *et al.* (2003) and Majaess *et al.* (2008). A total of 785 images (clear filter for 60 s) were acquired at UO on six nights between 2014 Apr 17-25. The synodic period (4.701 h) estimated from the resulting lightcurve is identical to the value presently reported by the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). The folded lightcurve exhibited a peak-to-peak amplitude (0.12 mag) which was within the published range (0.08-0.47 mag) for this object.



Object	Range Over Observation Period			
	UT Date mm/dd	Phase	L_{PAB}	B_{PAB}
283 Emma	2014 11/03-11/11	16.2,18.1	2,3	+9,+9
349 Dembowska	2014 04/17-04/25	15.3,16.6	159,160	+7,+6
409 Aspasia	2014 09/18-10/28	10.1,19.7	338,341	+14,+12

Table I. Observing circumstances. Phase is the solar phase angle. PAB is the phase angle bisector.

<u>409 Aspasia.</u> This large CX-type asteroid ($D \approx 162$ km) was also discovered by Auguste Charlois, in 1895. A partial lightcurve was first reported by Lagerkvist (1981). Complete lightcurves were subsequently published by Di Martino and Cacciatori (1984), Hainaut-Rouelle *et al*. (1995), Piironen *et al*. (1998), and López-González and Rodríguez (2005). Shape and spin-axis models for this minor planet have been developed by Warner *et al*. (2008) and Ďurech *et al*. (2011). During the photometric study at UO, 1129 images (R_c bandpass for 75 s) were acquired on eight nights between 2014 Sep 18 and Oct 28. The synodic period solution (9.023 h) was very similar to the value (9.022 h) presently reported on the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov/sbdb.cgi*). This lightcurve exhibited a peak-to-peak amplitude (0.16 mag), which was within the range (0.09-0.16 mag) estimated from all the lightcurves referenced herein.



Acknowledgements

Many thanks to the SAO/NASA Astrophysics Data System and the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009), both of which proved indispensable for locating relevant literature references.

References

Abell, P.A., Gaffey, M.J. (2000). "Probable Geologic Composition, Thermal History, and Meteorite Affinities for Mainbelt Asteroid 349 Dembowska." *Lunar and Planetary Institute Conference Abstracts* **31**, #1291.

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

Bus, S.J., Binzel, R.P. (2002). "Phase II of the Small Main-Belt Asteroid Spectroscopic Survey - A Feature-Based Taxonomy." *Icarus* **158**, 146-177.

Chang, Y.C., Chang, C-S. (1963). *Acta Astron. Sin.* **11**, 139-149.

Di Martino, M., Cacciatori, S. (1984). "Rotation periods and light curves of the large asteroids 409 Aspasia and 423 Diotima." *Astron. Astrophys.* **130**, 206-207.

Di Martino, M., Zappalà, G, De Sanctis, G., Cacciatori, S. (1987). "Photoelectric photometry of 17 asteroids." *Icarus* **69**, 338-353.

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

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

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.

Lagerkvist, C-I. (1981). "Physical Studies of Asteroids II: Photoelectric Observations of the Asteroids 63, 93, 135 and 409." *Astron. Astrophys. Suppl. Ser.* **44**, 345-347.

Lagerkvist, C-I., Magnusson, P., Williams, I.P., Buontempo, M.E., Gibbs, P., Morrison, L.V. (1988). "Physical studies of asteroids XVIII. Phase relations and composite lightcurves obtained with the Carlsberg Meridian Circle." *Astron. Astrophys. Suppl. Ser.* **73**, 395-405.

López-González, M.J., Rodríguez, E. (2005). "Lightcurves and poles of seven asteroids." *Planetary and Space Sci.* **53**, 1147-1165.

Majaess, D.J., Tanner, J., Savoy, J., Sampson, B. (2008). "349 Dembowska: A minor study of its shape and parameters." *Minor Planet Bulletin* **35**, 88-91.

Marchis, F, Descamps, P., Berthier, J. Hestroffer, D., Vachier, F., Baek, M., Harris, A.W., Nesvorný (2008). "Main belt binary asteroidal systems with eccentric mutual orbits." *Icarus* **195**, 295-316.

Merline, W.J., Dumas, C., Siegler, N., Close, L.M, Chapman, C.R., Tamblyn, P.M., Terrell, D., Conrad, A., Menard, F., Duver, G. (2003). *IAU Circ.* **8165**.

Michałowski, T., Kaasalainen, M., Polińska, M., Marciniak, A., Kwiatkowski, T., Kryszczyńska, A., Velichko, F.P. (2006). "Photometry and models of selected main belt asteroids: III. 283 Emma, 665 Sabine, and 690 Wratislavia." *Astron. Astrophys.* **459**, 663-668.

Piironen, J., Lagerkvist, C-I., Erikson, A., Oja, T., Magnusson, P., Festin, L. Nathues, A., Gaul, M., Velichko, F. (1998). "Physical studies of asteroids XXXII. Rotation periods and UBVRI-colours for selected asteroids." *Astron. Astrophys. Suppl. Ser.* **128**, 525-540.

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

Stanzel, R. (1978). "Lightcurves and Rotation Period of Minor Planet 283 Emma." *Astron. Astrophys. Suppl.* **34**, 373-376.

Strabla, L. (2011). "Minor Planet Lightcurve Analysis at Bassano Research Observatory 2010 October – 2011 March." *Minor Planet Bulletin* **38**, 169-172.

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

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.

Weidenschilling, S.J., Chapman, C.R., Davis, D.R., Greenberg, R., Levy, D.H., Vail, S. (1987). "Photometric geodesy of main-belt asteroids. I – Lightcurves of 26 large, rapid rotators." *Icarus* **70**, 191-245.

Warner, B.D., Ďurech, J., Fauerbach, M., Marks, S. (2008). "Shape and Spin Axis Models for Four Asteroids." *Minor Planet Bulletin* **35**, 167-170.

Warner, B.D. (2013). MPO Software, *MPO Canopus* v10.4.3.17. Bdw Publishing, Eaton, CO.

Zappalà, V., van Houten-Groeneveld, I., van Houten, C.J. (1979). "Rotation Period and Phase Curve of the Asteroids 349 Dembowska and 354 Eleonora." *Astron. Astrophys. Suppl.* **35**, 213-221.

THE ROTATION PERIOD OF 4528 BERG

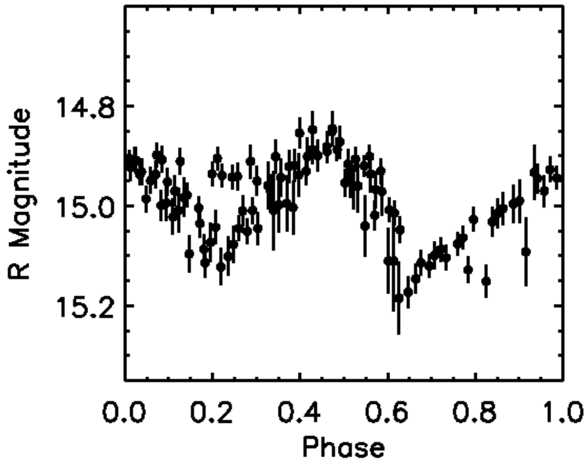
George Stecher, Lyle Ford, Jesse Bluem,
Blake Smith, Samuel Fahey
Department of Physics and Astronomy
University of Wisconsin-Eau Claire
Eau Claire, WI 54702-4004
gstecher@uwec.edu

(Received: 20 January)

We observed 4528 Berg for 5.6 hours on 2014 March 30 and obtained R and V standard magnitudes. The period was determined to be 3.47 ± 0.44 h, which is consistent with the period of 3.5163 ± 0.0004 h previously reported by Behrend (2006).

On 2014 March 30 we made photometric measurements of 4528 Berg in the R and V bands using the 0.35-m Schmidt-Cassegrain (SCT) at Hobbs Observatory near Fall Creek, Wisconsin (MPC code 750). Sixty-second exposures were taken using an SBIG STL-1001E camera. The images were dark-subtracted and flat-fielded before measuring and analysis. Photometric transforms were found using standard stars from the LONEOS catalog and first order extinction coefficients were determined using the modified Hardie method as described in Warner (2006). The image analysis was carried out with *MPO Canopus* version 10.4.3.7 (Warner, 2013). A Lomb periodogram (Press *et al.*, 1992) was performed on the lightcurve data to find the most likely rotation period of the asteroid. Our data have been submitted to the Minor Planet Center's Light Curve Database.

The R and V data were analyzed independently of each other and the period for both lightcurves was found to be 3.47 ± 0.44 h, where the uncertainly was determined from the full-width at half-maximum of the periodogram's power spectrum. This period is consistent with the value of 3.5163 ± 0.0004 h reported by Behrend (2006). R magnitudes varied from about 14.85 to 15.2. The range for V magnitudes was about to 15.25 to 15.7. A phased plot of the R data is shown here; the V data show a similar shape.



References

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

Minor Planet Center Light Curve Database
http://minorplanetcenter.net/light_curve

Press, W.H., Teukolsky, S.A., Vetterling, W.T., Flannery, B.P. (1992). *Numerical Recipes in FORTRAN (2nd edition)*. pp 569–573. Cambridge University Press.

Warner, B.D. (2006). *A Practical Guide to Lightcurve Photometry and Analysis (2nd edition)*. pp 59–61. Springer, New York.

Warner, B.D. (2013). MPO Software, *MPO Canopus* version 10.4.3.7, Bdw Publishing. *http://www.minorplanetobserver.com/*

ROTATIONAL PERIOD OF 10042 BUDSTEWART

Johan Warell
Lindby Observatory (K60)
Lindby 229, SE-274 93 Skurup, SWEDEN
johan.warell@gmail.com

Daniel A. Klinglesmith III, Austin DeHart
Etscorn Campus Observatory
Socorro, New Mexico, USA

(Received: 27 December)

We report photometric observations of the main-belt asteroid 10042 Budstewart made on five nights in 2014 September and October. We obtain a well-determined synodic rotation period of 3.695 ± 0.002 h and amplitude of 0.33 ± 0.02 mag.

The main-belt asteroid 10042 Budstewart was discovered by E. Bowell at Lowell Observatory, Flagstaff, on 1985 August 14. The orbit has a semi-major axis of 2.57 AU, eccentricity 0.22 and period 4.13 years (JPL, 2014). The diameter is unknown but based on an absolute magnitude $H = 13.0$, the likely diameter is in the range 5-15 km (Minor Planet Center, 2013).

Observations were made on five nights between 2014 September 16 and October 5 from our two sites. At Lindby Observatory (K60) in southernmost Sweden, data were obtained with a 0.25-m *f*/10 Schmidt-Cassegrain telescope (SCT) operating at *f*/4.6, Starlight Xpress SXV-H9 CCD camera and clear filter. The pixel scale was 2.3 arcsec and the exposure time 45 seconds. At the Etscorn Campus Observatory (ECO, 2014), data were obtained with a 0.35-m SCT with an SBIG STL-1001E CCD camera. The pixel scale was 1.25 arcsec and the exposure time 6 minutes through a clear filter. Budstewart culminated at an altitude of 45° at Lindby and 69° at ECO.

Images were calibrated with bias, flats, and darks according to standard procedure using *Maxim DL* and *MPO Canopus* (Warner, 2014). Photometric reduction to the R filter band was made with *MPO Canopus* using the MPOSC3 star catalogue and the Photometry Magnitude Method. The multi-night data sets were combined with the FALC routine (Harris *et. al.*, 1989). In the analysis, 415 observations were used, all reduced to 7.1° phase angle using a value of $G = 0.15$.

The resulting phased light curve is very well-constrained, double peaked, and quite symmetric. The lightcurve period is 3.695 ± 0.002 h and the amplitude is 0.33 ± 0.02 mag. We found no previous photometric observations of this asteroid in the CALL (2014) and the LCDB (Warner *et al.*, 2009) databases.

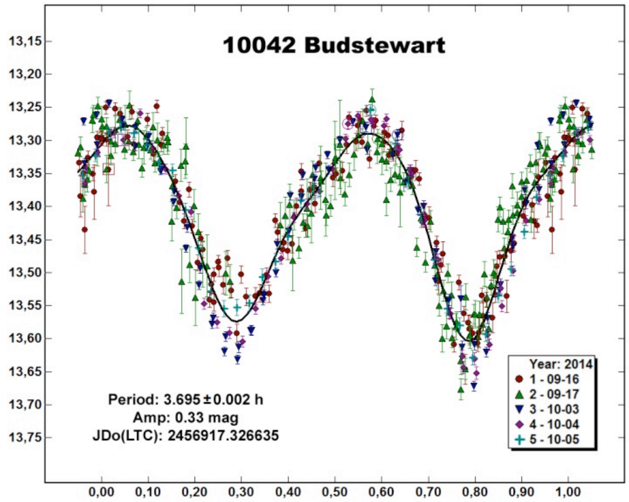


Fig. 1. Phased plot of the reduced R magnitude for 10042 Budstewart (phase angle 7.1 degrees) with a 6th order polynomial fit. The observations were obtained on 2014 September 16 (session 1) and 17 (session 2) at Lindby, and October 3 (session 3), 4 (session 4) and 5 (session 5) at ECO.

Acknowledgments

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of the New Mexico Institute of Mining and Technology (NMIMT). Student support at NMIMT is given by NASA EPSCoR grant NNX11AQ35A, the Department of Physics, and the Title IV of the Higher Education Act from the Department of Education.

References

CALL (2014). Collaborative Asteroids Lightcurve Link
http://www.minorplanet.info/call/

ECO (2014). Etscorn Campus Observatory
http://www.mro.nmt.edu/education-outreach/etscorn-campus-observatory

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

JPL (2014). JPL Small Body Database Browser
http://ssd.jpl.nasa.gov/sbdb.cgi

Minor Planet Center (2013). "Conversion of Absolute Magnitude to Diameter." *http://minorplanetcenter.net/iau/lists/Sizes.html*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. On-line database accessed 2014 July 22.
http://www.minorplanet.info/lightcurvedatabase.html

Warner, B.D. (2014). MPO Software, *MPO Canopus* version 10.4.4.0. Bdw Publishing, *http://www.minorplanetobserver.com/*

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2015 APRIL-JUNE

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

Alan W. Harris
MoreData!
La Cañada, CA 91011-3364 USA

Josef Ďurech
Astronomical Institute
Charles University in Prague
18000 Prague, CZECH REPUBLIC
durech@sirrah.troja.mff.cuni.cz

Lance A.M. Benner
Jet Propulsion Laboratory
Pasadena, CA 91109-8099 USA
lance.benner@jpl.nasa.gov

We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and have no or poorly-defined lightcurve parameters. Additional data on these objects will help with shape and spin axis modeling via lightcurve inversion. We also include lists of objects that will 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 2015 April-June.

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

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

The ephemeris generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.0 during any month in the current year, e.g., limiting the results by magnitude and declination.

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

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

Once you've obtained and analyzed your data, it's important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It's also important to make the data available at least on a personal website or upon request. We urge you to consider submitting your raw data to the ALCDEF 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 1.5 million observations for more than 2300 objects.

Lightcurve/Photometry Opportunities

Objects with U = 1 should be given higher priority over those rated U = 2 or 2+ but not necessarily over those with no period. On the other hand, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide

An asterisk (*) follows the name if the asteroid is reaching a particularly favorable apparition. A hashtag (#) indicates a near-Earth asteroid (NEA).

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
2248	Kanda*	04 03.8	14.7	-4			
2641	Lipschutz*	04 09.2	14.6	-5			
5392	Parker*	04 14.7	14.0	+17	45.	0.2	1
4590	Dimashchegolev*	04 15.7	15.0	+5	25.4	0.23	2+
2692	Chkalov*	04 19.1	14.3	-19			
1492	Oppolzer*	04 27.1	14.6	-2			
3865	Lindbloom*	04 30.5	14.9	-14			
1637	Swings*	05 01.4	14.5	-22			
949	Hel*	05 01.6	13.0	-32	10.862	0.12-0.14	2
4027	Mitton*	05 01.6	14.7	-13			
1365	Henyey*	05 03.0	13.5	-21	18.986	0.23	2+
5633	1978 UL7*	05 04.1	14.8	-18			
1905	Ambartsumian*	05 04.2	14.1	-14			
4185	Phystech*	05 04.6	14.9	-19			
910	Anneliese*	05 08.2	13.4	-16			
5222	Ioffe*	05 13.3	14.6	-4	19.4	0.27	2
873	Mechthild*	05 17.9	14.1	-10	10.6	0.33	2
3470	Yaronika*	05 22.5	15.0	-20			
2081	Sazava*	05 25.9	14.1	-21			
2019	van Albada*	05 28.6	13.5	-22	2.72	0.13-0.20	2+
1795	Woltjer*	06 01.7	14.6	-11			
3494	Purple Mountain*	06 03.9	14.7	-19	5.86	0.5	2
8257	Andycheng*	06 05.2	14.8	-26			
13832	1999 XR13*	06 05.7	14.8	-18			
16446	1989 MH*	06 06.3	15.0	-19			
396	Aeolia*	06 11.6	12.5	-22	22.2	0.30	2-
3614	Tumilty*	06 11.9	14.1	-36	26.8	0.10	2-
1516	Henry*	06 12.0	14.5	-12	17.37	0.54	2
3891	Werner*	06 13.6	15.9	-23			
858	El Djezair*	06 18.3	13.5	-28	22.31	0.06- 0.1	2
1780	Kippes*	06 18.9	14.5	-29	18.	0.23	2
897	Lysistrata*	06 20.3	13.0	-19	11.26	0.11	2
2433	Sootiyo*	06 21.8	13.7	-3	7.2298	0.4-0.54	2+
48900	1998 MP22*	06 22.3	14.8	-26			
7293	Kazuyuki*	06 23.7	14.8	-30			
1397	Umtata*	06 24.0	13.1	-25	30.	0.13	1
2270	Yazhi*	06 26.9	14.8	-24	7.78	0.09-0.45	2
3029	Sanders*	06 27.6	14.7	-27			
2804	Yrjo*	06 27.8	14.9	-19	8.12	0.26	2+
3985	Raybatson*	06 28.1	14.7	-29	4.298	0.10	2
14829	Povalyaeva*	06 29.0	14.8	-11	>12.	0.2	1
1517	Beograd*	06 30.1	14.4	-28	6.943	0.18-0.23	2

Low Phase Angle Opportunities

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

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 have to 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 tricky. Refer to Harris, *et al.* ("Phase Relations of High Albedo Asteroids." *Icarus* **81**, p365 ff) 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.

#	Name	Date	α	V	Dec	Period	Amp	U
359	Georgia	04 03.2	0.39	13.0	-06	5.537	0.15-0.54	3
50	Virginia	04 03.4	0.40	13.9	-04	14.315	0.07-0.20	3
673	Edda	04 15.2	0.60	13.9	-11	14.92	0.12	2
20	Massalia	04 20.3	0.17	9.3	-11	8.098	0.15-0.27	3
64	Angelina	04 22.6	0.82	10.9	-14	8.752	0.04-0.42	3
19	Fortuna	04 23.1	0.07	10.7	-12	7.4432	0.14-0.35	3
377	Campania	04 29.0	0.50	12.7	-13	11.664	0.14-0.27	3
110	Lydia	05 01.9	0.91	11.5	-13	10.927	0.10-0.26	3
910	Anneliese	05 08.2	0.32	13.4	-16			
184	Dejopeja	05 09.4	0.56	12.4	-19	6.455	0.25-0.3	3
789	Lena	05 12.2	0.25	13.8	-19	5.848	0.40-0.50	3
122	Gerda	05 12.5	0.60	12.3	-16	10.685	0.10-0.26	3
438	Zeuxo	05 15.0	0.43	12.5	-20	8.831	0.13-0.14	3
208	Lacrimosa	05 16.7	0.72	12.8	-21	14.085	0.15-0.33	3
2019	van Albada	05 28.5	0.48	13.5	-22	2.72	0.20	2+
310	Margarita	06 02.2	0.77	13.1	-20	12.070	0.14-0.37	3
211	Isolda	06 10.7	0.15	12.7	-23	18.365	0.09-0.14	3
396	Aeolia	06 11.6	0.38	12.5	-22	22.2	0.30	2-
24	Themis	06 11.9	0.24	11.5	-24	8.374	0.09-0.14	3
954	Li	06 12.0	0.67	13.5	-21	7.207	0.11-0.25	3
1137	Raissa	06 17.1	0.39	13.3	-24	37.	0.11-0.34	1
142	Polana	06 19.1	0.81	12.4	-25	9.764	0.11	3
451	Patientia	06 19.2	0.24	11.1	-23	9.727	0.05-0.10	3
1397	Umtata	06 23.9	0.90	13.1	-25	30.	0.13	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

Below is a list of objects reaching brightest this quarter with well-determined periods and for which there is no pole solution in the LCDB. They are further limited to those reaching a favorable apparition. Since they have a high U rating, this means there is at least one dense lightcurve of high quality. 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.

Note that you can compare and combine the results of searches using the ephemeris generator and LCDB query (limited to with or without a pole solution) at the sites listed above to create your own customized list of objects.

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
454	Mathesis	04 02.5	11.9	-1	8.378	0.20-0.37	3
1617	Alschmitt	04 09.6	14.8	+6	7.062	0.39-0.52	3
151	Abundantia	04 11.8	12.2	-5	9.864	0.03-0.20	3
1484	Postrema	04 21.8	13.6	+9	12.1923	0.22-0.23	3-
3541	Graham	05 11.7	15.0	-13	3.5277	0.12-0.13	3
789	Lena	05 12.2	13.8	-19	5.848	0.40-0.50	3
438	Zeuxo	05 15.0	12.5	-20	8.831	0.13-0.14	3
5381	Sekhmet	05 18.8	14.2	-45	2.8233	0.1 -0.36	3
405	Thia	05 28.0	10.4	-25	10.08	0.15-0.23	3
914	Palisana	06 01.5	10.9	-28	15.922	0.04-0.18	3
1848	Delvaux	06 10.1	14.5	-25	3.637	0.57-0.68	3
1625	The NORC	06 10.7	13.8	-46	13.959	0.08-0.16	3-
1059	Mussorgskia	06 18.0	13.4	-6	5.636	0.2 -0.21	3
1598	Paloque	06 18.4	15.0	-31	5.949	0.30-0.33	3-
1321	Majuba	06 21.1	13.6	-36	5.207	0.24-0.43	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 if you get data (through Dr. Benner's email listed above). They may not always be observing the target but, in some cases, 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" in the header 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.

(141527) 2002 FG7 (Mar-Apr, H = 18.9, PHA)
There are no known lightcurve parameters for this 0.5 km NEA. It's better placed for southerly observers when at brightest in mid-March. However, it should still be a relatively easy target by the time it moves north enough for those above the equator.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/10	00 03.7	-64 08	0.06	0.97	17.2	116.7	60	101	-0.84	-52
03/13	09 40.9	-79 57	0.04	1.00	15.0	81.7	96	75	-0.58	-20
03/16	11 10.0	-42 00	0.05	1.03	14.2	42.5	135	104	-0.26	+17
03/19	11 19.6	-20 22	0.08	1.07	14.5	21.1	157	152	-0.03	+38
03/22	11 23.3	-09 38	0.10	1.10	14.9	12.3	166	149	+0.04	+47
03/25	11 25.5	-03 40	0.14	1.13	15.5	10.8	168	107	+0.27	+53
03/28	11 27.1	+00 01	0.17	1.16	16.1	12.6	165	67	+0.57	+56
03/31	11 28.4	+02 28	0.20	1.19	16.7	15.0	162	31	+0.83	+58
04/03	11 29.7	+04 11	0.24	1.23	17.1	17.3	159	6	+0.98	+60
04/06	11 31.0	+05 24	0.28	1.26	17.6	19.3	155	41	-0.98	+61

1685 Toro (Jun-Jul, H = 14.2)

The rotation period for this near-Earth asteroid is well established at 10.20 h. The amplitude of the lightcurve ranges from 0.47 to 1.80 mag. With the phase angle changing significantly during the apparition, it would be a good idea to get blocks of lightcurves separated by a week or so and then analyze each block independently. This can reveal not only a changing synodic period but changes in the shape and amplitude of the lightcurve from block to block. See Warner (2013; *MPB* **40**, 26-29) for an example of this approach.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/15	16 16.0	-28 12	0.73	1.72	15.4	10.3	162	169	-0.03	+16
06/20	16 05.1	-27 02	0.72	1.70	15.5	14.3	156	114	+0.13	+19
06/25	15 55.3	-25 48	0.73	1.68	15.6	18.4	149	52	+0.56	+21
06/30	15 46.8	-24 34	0.73	1.66	15.7	22.2	142	16	+0.95	+23
07/05	15 39.8	-23 22	0.74	1.63	15.8	25.9	135	85	-0.88	+25
07/10	15 34.3	-22 15	0.76	1.61	15.9	29.3	129	156	-0.36	+27
07/15	15 30.5	-21 13	0.78	1.58	16.0	32.4	123	134	-0.01	+28
07/20	15 28.2	-20 19	0.80	1.56	16.1	35.2	118	72	+0.15	+29

(285331) 1999 FN53 (Apr-Jul, H = 18.3)

Accurate astrometry will be needed shortly before the closest approach by 1999 FN53 in mid-May. The rotation period is not known. The estimated diameter is about 600 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	12 44.2	+72 05	0.32	1.12	18.2	60.3	104	69	+0.90	+45
04/16	11 17.0	+74 42	0.23	1.04	17.8	74.7	93	108	-0.10	+41
05/01	08 05.8	+69 08	0.13	0.98	17.3	99.0	74	84	+0.91	+32
05/16	05 01.7	+09 01	0.07	0.95	21.6	153.8	24	49	-0.06	-19
05/31	03 48.6	-38 15	0.15	0.95	18.3	111.3	61	126	+0.93	-52
06/15	03 23.0	-46 35	0.25	0.98	18.5	89.9	76	64	-0.03	-54
06/30	03 12.2	-49 14	0.34	1.05	18.7	75.7	85	110	+0.95	-55
07/15	03 01.5	-51 14	0.41	1.13	18.9	64.2	94	85	-0.01	-56

2011 UW158 (Apr-May/Jun-Jul, H = 19.4, PHA)

The absolute magnitude of 19.4 suggests a diameter of roughly 450 m, but otherwise this asteroid's physical properties are unknown. It will approach within 0.0164 AU on 2015 July 19 and it will be one of the strongest radar targets of 2015. The radar SNRs should be high enough to support imaging at the highest resolutions available at Goldstone and Arecibo.

2011 UW158 is on NASA's NHATS list of potential human mission targets.

The asteroid will be visible in small telescopes for weeks before the close approach so it's hoped that that rotation period will be known before the Goldstone observations start. However, that may be difficult since the asteroid is not very bright for very long before it slips into superior conjunction starting in mid-May. Given the estimated size, the rotation period is not going to be on the order of minutes but hours and, hopefully, not days.

Note that the ephemeris breaks in early May and restarts in mid-June. This is because the asteroid is too near the Sun for photometry purposes.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	12 44.2	+72 05	0.32	1.12	18.2	60.3	104	69	+0.90	+45
04/16	11 17.0	+74 42	0.23	1.04	17.8	74.7	93	108	-0.10	+41
05/01	08 05.8	+69 08	0.13	0.98	17.3	99.0	74	84	+0.91	+32
...										
06/15	03 23.0	-46 35	0.25	0.98	18.5	89.9	76	64	-0.03	-54
06/30	03 12.2	-49 14	0.34	1.05	18.7	75.7	85	110	+0.95	-55
07/15	03 01.5	-51 14	0.41	1.13	18.9	64.2	94	85	-0.01	-56

(385186) 1994 AW1 (Jun-Aug, H = 17.5, PHA, Binary)

1994 AW1 is a binary system that has not yet been observed by radar. This was the first candidate binary NEA identified by possible mutual events in lightcurves (Mottola *et al.*, 1995; Pravec and Hahn, 1997). The effective diameter of the system, based on the absolute magnitude, is roughly 1 km. The primary has a low lightcurve amplitude of 0.12 mag, suggesting a shape with low elongation. The secondary has an orbital period of 22.3 h. Pravec *et al.* (2006) estimate a secondary/primary diameter ratio of 0.49; if correct, then the secondary could be about 0.5 km in diameter. The lightcurve observations suggest a low elongation for the secondary as well.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/01	06 01.3	-72 10	0.30	1.08	17.5	68.7	95	89	+0.97	-30
06/11	06 38.0	-72 43	0.24	1.07	17.0	70.2	97	94	-0.34	-27
06/21	07 51.7	-73 43	0.18	1.06	16.4	71.2	99	86	+0.20	-22
07/01	10 29.0	-71 36	0.12	1.05	15.5	70.9	103	78	+0.99	-12
07/11	13 27.2	-47 28	0.07	1.04	14.3	68.7	107	141	-0.26	+15
07/21	14 56.9	+06 50	0.08	1.03	14.6	75.0	101	50	+0.23	+54
07/31	15 40.8	+33 52	0.13	1.03	15.9	81.0	92	82	+1.00	+53
08/10	16 06.5	+43 57	0.19	1.02	16.8	81.8	88	114	-0.20	+48

(294739) 2008 CM (Jun-Jul, H = 17.3, PHA)

Warner (2014) found a rotation period of 3.054 hr. The amplitude of 0.48 mag at the time suggests a somewhat elongated shape. The estimated diameter is about 1 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/20	20 39.3	-07 53	0.78	1.67	19.0	24.4	137	174	+0.13	-28
06/25	20 32.9	-04 51	0.73	1.65	18.8	22.6	142	118	+0.56	-25
06/30	20 24.7	-01 29	0.68	1.62	18.5	20.8	145	56	+0.95	-21
07/05	20 14.6	+02 10	0.64	1.59	18.3	19.6	148	24	-0.88	-17
07/10	20 02.4	+06 03	0.60	1.57	18.2	19.3	149	90	-0.36	-13
07/15	19 48.5	+10 05	0.58	1.54	18.1	20.4	148	148	-0.01	-8
07/20	19 32.9	+14 05	0.56	1.51	18.0	22.9	145	127	+0.15	-3
07/25	19 16.3	+17 55	0.55	1.48	18.1	26.4	140	74	+0.59	+3

(66391) 1999 KW4 (Jun-Jul, H = 16.5, PHA, Binary)

This is the famous "top-shapped" binary asteroid first announced by Ostro *et al*. (2006) based on radar images. The last lightcurve reported in the LCDB is from that same year. This will mark a rare opportunity to get more photometry on the NEA. Even if its shape and system dynamics are well-determined, it's a chance to see if you can independently determine binary nature of 1999 KW4.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	20 55.1	-25 03	0.77	0.93	18.3	71.3	62	153	+0.90	-37
04/11	21 00.9	-20 16	0.71	1.00	18.2	69.6	69	36	-0.62	-37
04/21	21 07.7	-14 25	0.63	1.04	18.0	68.6	75	106	+0.07	-37
05/01	21 14.7	-06 58	0.55	1.07	17.8	68.1	81	132	+0.91	-35
05/11	21 21.7	+03 01	0.47	1.08	17.4	68.3	86	16	-0.54	-31
05/21	21 28.7	+16 54	0.39	1.08	17.1	69.8	89	123	+0.10	-24
05/31	21 36.8	+35 51	0.34	1.05	16.8	73.8	87	111	+0.93	-12
06/10	21 51.0	+58 32	0.33	1.01	16.9	81.2	80	63	-0.45	+4
06/20	22 55.5	+79 52	0.35	0.95	17.3	90.2	69	85	+0.13	+18
06/30	07 30.0	+80 37	0.41	0.87	17.8	98.5	58	115	+0.95	+28

(85989) 1999 JD6 (Jun-Jul, H = 17.1, PHA)

1999 JD6 has been studied extensively and many of its physical properties are well known. It has a rotation period of 7.68 h and a lightcurve amplitude of 1.2 mag that suggests a very elongated shape. This object was observed by NASA's Wide-Field Infrared Survey Explorer (WISE) spacecraft. Mainzer *et al.* (2011) used WISE data to estimate a diameter of 1.8 km and an optical albedo of 0.075, which indicates that this is a relatively dark object. Spectroscopic results have been ambiguous and this object has received multiple classifications from dark to relatively bright.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/01	21 07.7	+05 31	0.65	1.36	18.6	45.2	108	89	+0.97	-27
06/09	21 14.6	+07 28	0.55	1.33	18.2	45.0	112	26	-0.57	-27
06/17	21 20.4	+09 41	0.46	1.29	17.7	44.8	117	125	+0.00	-27
06/25	21 24.8	+12 24	0.36	1.24	17.1	44.6	121	132	+0.56	-26
07/03	21 27.5	+16 08	0.26	1.19	16.3	44.9	124	42	-0.99	-24
07/11	21 27.8	+22 40	0.17	1.13	15.3	47.5	125	79	-0.26	-20
07/19	21 20.5	+40 53	0.09	1.06	14.1	60.9	115	129	+0.09	-6
07/27	10 07.8	+57 57	0.05	0.98	16.9	134.8	43	107	+0.78	+48

IN THIS ISSUE

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

Number	Name	EP	Page
1	Ceres	6	94
12	Victoria	6	94
82	Alkmene	41	129
248	Lameia	49	137
254	Augusta	3	91
283	Emma	58	146
349	Dembowska	58	146
409	Aspasia	58	146
453	Tea	16	104
465	Alekto	3	91
475	Ocllo	16	104
477	Italia	3	91
515	Athalia	3	91
549	Jessonda	16	104
746	Marlu	13	101
757	Portlandia	16	104
802	Epyaxa	16	104
1061	Paeonia	3	91
1103	Sequoia	44	132
1110	Jaroslawa	2	90
1334	Lundmarka	1	89
1463	Nordenmarkia	13	101
1724	Vladimir	55	143
1904	Massevitch	1	89
1920	Sarmiento	20	108
1983	Bok	51	139
2043	Ortutay	48	136
2083	Smither	44	132
2340	Hathor	27	115
2390	Nezarka	13	101
2554	Skiff	12	100
2571	Geisei	1	89
2634	James Bradley	51	139
2649	Oongaq	13	101
2693	Yan'an	13	101
2699	Kalinin	1	89
2824	Franke	26	114
3107	Weaver	12	100
3197	Weissman	1	89
3200	Phaethon	27	115
3483	Svetlov	20	108
3730	Hurban	13	101
3880	Kaiserman	44	132
3883	Verbano	26	114
3965	Konopleva	55	143
4125	Lew Allen	20	108
4183	Cuno	27	115
4252	Godwin	51	139
4271	Novosibirsk	19	107
4528	Berg	60	148
4531	Asaro	20	108
4713	Steel	20	108
4765	Wasserburg	20	108
4880	Tovstonogov	54	142
4909	Couteau	13	101
5116	Korsor	51	139
5750	Kandatai	54	142
5841	Stone	20	108
6335	Nicolerappaport	19	107
6500	Kodaira	16	104
6509	1983 CQ3	13	101
7837	Mutsumi	1	89
9222	Chubey	55	143
9387	Tweedledee	20	108
10042	Budstewart	61	149
10597	1996 TR10	51	139
10645	Brac	13	101
12538	1998 OH	27	115
14927	Satoshi	1	89
15786	1993 RS	20	108
18899	2000 JQ2	16	104
20392	Mikeshepard	20	108
21028	1989 TO	8	96
24654	Fossett	20	108
25076	1998 QM98	20	108
29769	1999 CE28	1	89
31723	1999 JT61	13	101
31832	2000 AP59	16	104
32814	1990 XZ	8	96
36017	1999 ND43	27	115
40229	1998 TO3	20	108
52505	1996 FD4	51	139
53247	1999 DE2	51	139
53430	1999 TY16	27	115
54234	2000 JD16	20	108
68553	2001 XF68	20	108
70030	Margaretmiller	20	108
85713	1998 SS49	27	115
85804	1998 WQ5	27	115
86326	1999 WK13	27	115
90075	2002 VU94	27	115
96518	1998 RO3	20	108
99395	2002 AB19	20	108
100756	1998 FM5	27	115
103067	1999 XA143	27	115
136897	1998 HJ41	27	115
137032	1998 UO1	27	115
159533	2001 HH31	27	115
162004	1991 VE	27	115
163818	2003 RX7	27	115
175114	2004 QQ	27	115
190208	2006 AQ	44	132
209924	2005 WS55	27	115
214088	2004 JN13	27	115
374158	2004 UL	27	115
410195	2007 RT147	27	115
413038	2001 MF1	27	115
415949	2001 XY10	27	115
416224	2002 XM90	27	115
418797	2008 VF	27	115
	2005 SX4	27	115
	2007 TG25	27	115
	2010 MR	27	115
	2014 RL12	27	115
	2014 RQ17	27	115
	2014 SC324	27	115
	2014 SM143	27	115
	2014 SQ261	27	115
	2014 TL17	27	115
	2014 TV	27	115
	2014 TX57	27	115
	2014 UR	27	115
	2014 VH2	27	115
	2014 VM	27	115
	2014 VQ	27	115
	2014 WF201	27	115
	2014 WZ120	27	115
	2014 WZ120	44	132

THE MINOR PLANET BULLETIN (ISSN 1052-8091) is the quarterly journal of the Minor Planets Section of the Association of Lunar and Planetary Observers (ALPO). Current and most recent issues of the *MPB* are available on line, free of charge from:

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

Nonmembers are invited to join ALPO by communicating with: Matthew L. Will, A.L.P.O. Membership Secretary, P.O. Box 13456, Springfield, IL 62791-3456 (will008@attglobal.net). The Minor Planets Section is directed by its Coordinator, Prof. Frederick Pilcher, 4438 Organ Mesa Loop, Las Cruces, NM 88011 USA (fpilcher35@gmail.com), assisted by Lawrence Garrett, 206 River Rd., Fairfax, VT 05454 USA (LSGasteroid@msn.com). Dr. Alan W. Harris (Space Science Institute; awharris@spacescience.org), and Dr. Petr Pravec (Ondrejov Observatory; ppravec@asu.cas.cz) serve as Scientific Advisors. The Asteroid Photometry Coordinator is Brian D. Warner, Palmer Divide Observatory, 446 Sycamore Ave., Eaton, CO 80615 USA (brian@MinorPlanetObserver.com).

The Minor Planet Bulletin is edited by Professor Richard P. Binzel, MIT 54-410, Cambridge, MA 02139 USA (rpb@mit.edu). Brian D. Warner (address above) is Assistant Editor. The *MPB* is produced by Dr. Robert A. Werner, 3937 Blanche St., Pasadena, CA 91107 USA (bwernerca1@att.net) and distributed by Derald D. Nye. Direct all subscriptions, contributions, address changes, etc. to:

Mr. Derald D. Nye - Minor Planet Bulletin
10385 East Observatory Drive
Corona de Tucson, AZ 85641-2309 USA
(nye@kw-obsv.org) (Telephone: 520-762-5504)

Effective with Volume 38, the *Minor Planet Bulletin* is a limited print journal, where print subscriptions are available only to libraries and major institutions for long-term archival purposes. In addition to the free electronic download of the *MPB* noted above, electronic retrieval of all *Minor Planet Bulletin* articles (back to Volume 1, Issue Number 1) is available through the Astrophysical Data System

http://www.adsabs.harvard.edu/.

Authors should submit their manuscripts by electronic mail (rpb@mit.edu). Author instructions and a Microsoft Word template document are available at the web page given above. All materials must arrive by the deadline for each issue. Visual photometry observations, positional observations, any type of observation not covered above, and general information requests should be sent to the Coordinator.

* * * * *

The deadline for the next issue (42-3) is April 15, 2015. The deadline for issue 42-4 is July 15, 2015.