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SOMETHING OLD, SOMETHINGS NEW: THREE BINARY DISCOVERIES FROM THE PALMER DIVIDE OBSERVATORY

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Analysis of new CCD photometric observations in early 2013 of the Vestoid asteroid 4383 Suruga and Hungaria asteroid (53432) 1999 UT55 showed that the two are binary systems. A review of data from 2005 for the Hungaria asteroid 4440 Tchantches indicates that the original analysis probably overlooked a satellite.

The Palmer Divide Observatory (PDO) observing program concentrates on the Hungaria asteroids. As such, CCD photometric observations of (53432) 1999 UT55 were made in early 2013. If a Hungaria asteroid is not available, then one of the five telescopes at PDO is used to observe other targets, either near-Earth asteroids (NEAs) or objects in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) that have poorly-defined rotation periods. The latter was the case for 4383 Suruga, a Vestoid member, which was observed in 2013 February. Email discussions prompted a review of the original 2005 data set from PDO for the Hungaria asteroid 4440 Tchantches. As detailed below, all three objects were found to be binary systems.

All exposures in 2013 were guided, unfiltered, and 240 seconds. The images were measured in *MPO Canopus*. The dual-period feature in that program, based on the FALC algorithm developed by Harris *et al.* (1989) was used to subtract one of the periods from the data set in an iterative process until both periods remained stable. For the 2013 data sets, night-to-night calibration was accomplished using the Comp Star Selector feature in *MPO Canopus*. Catalog magnitudes for the comparison stars were derived from J-K to BVRI formulae developed by Warner (2007) using stars from the 2MASS catalog (Skrutskie *et al.*, 2006). A description of this method was described by Stephens (2008).

Three figures are presented for each asteroid. The first shows the *unsubtracted* data set, meaning that the effects of the satellite have not been removed. The second figure shows the lightcurve of the primary, i.e., after removing the effects of the satellite. The third figure shows the lightcurve after removing the rotation of the primary, thus revealing the mutual events and other features due to the satellite. The latter often includes an upward bowing between the events, indicating an elongated satellite that is tidally-locked to its orbital period.

<u>4383 Suruga</u>. Observations of 4383 Suruga were made from 2013 Feb 2-13. Initial observations were made with a 0.35-m Schmidt-Cassegrain and Finger Lakes FLI-1001E CCD camera. When indications of a satellite were seen in those first data sets, the target was moved to a 0.5-m Ritchey-Chretien with FLI-1001E to improve the signal-to-noise ratio. Data on the order of 0.01-0.02 mag are usually required for reliable detections of mutual events (occultations and/or eclipses) caused by a satellite.

The results of the analysis are shown in Figures 1-3. The period of the primary is 3.4068 ± 0.0003 h with an amplitude of 0.14 ± 0.01 mag, indicating a nearly spheroidal shape. The orbital period of the satellite is 16.386 ± 0.001 h. The depths of the events are 0.1 and 0.05 mag. The shallower of the two is used to estimate the secondary-primary size ratio. In this case, the result is Ds/Dp ≥ 0.21 ± 0.02. Hasegawa *et al.* (2012) reported a period of 3.811 h and no indication of the object being binary.

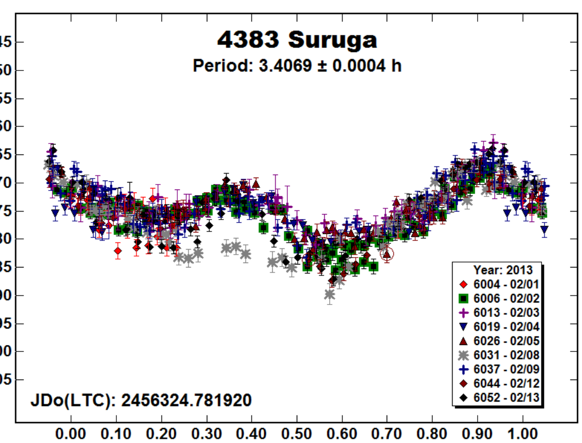

Figure 1. The unsubtracted lightcurve of 4383 Suruga.

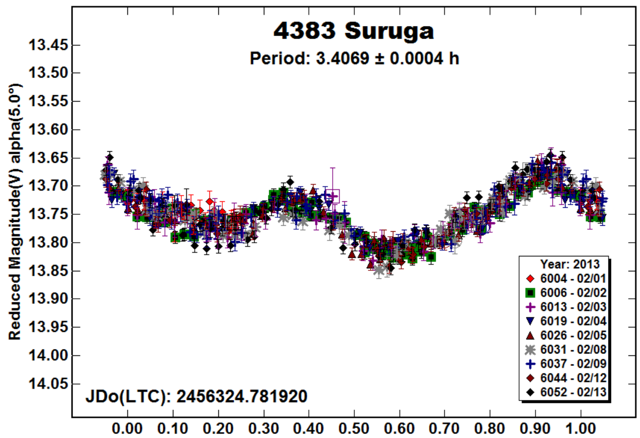

Figure 2. The lightcurve for the primary of 4383 Suruga.

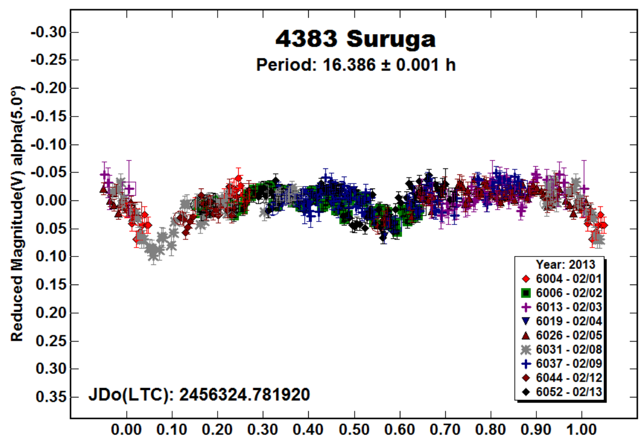

Figure 3. The lightcurve of 4383 Suruga showing the mutual events due to the presumed satellite.

4440 Tchantches. This Hungaria asteroid had been observed several times before at PDO (Warner 2006, 2009, 2011) and by Behrend *et al*. (2002). In those cases, a period of about 2.78 h was reported. In Warner *et al*. (2006), the possibility that the asteroid was binary was discussed and, based on an extensive observing campaign, the results were considered inconclusive.

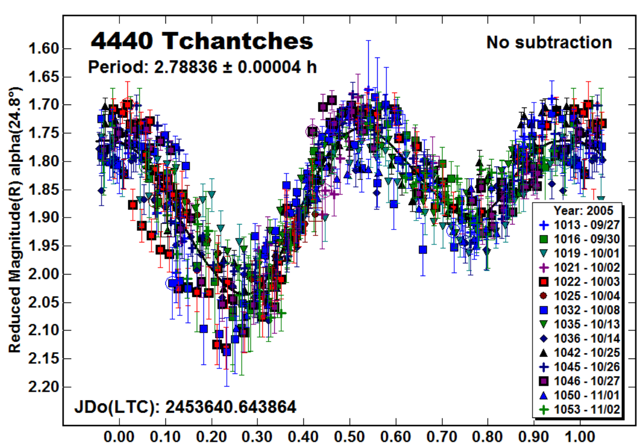

Figure 4. The unsubtracted lightcurve for 4440 Tchantches.

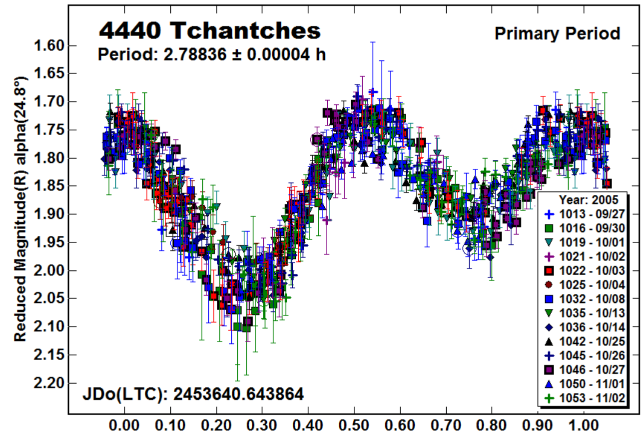

Figure 5. The primary lightcurve for 4440 Tchantches.

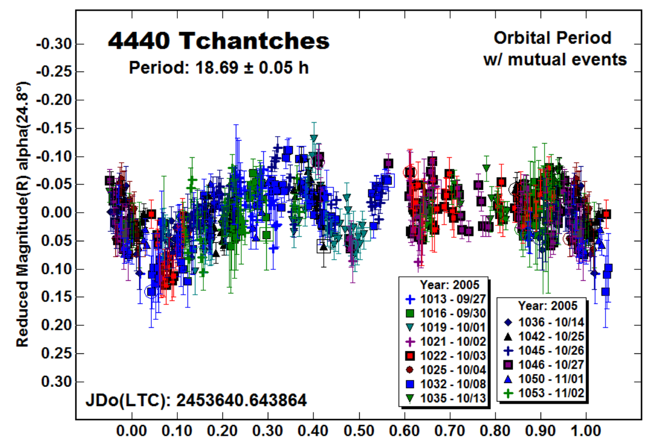

Figure 6. The lightcurve for 4440 Tchantches showing the effects of the satellite: an upward bowing indicating an elongated body and "dips" due to occultations and/or eclipses.

Email discussions on an unrelated matter in 2013 put the original 2005 data set from PDO under review. In 2005, the observations were not calibrated from night-to-night but strictly relative, meaning that the assignment of zero points was arbitrary. The original plot using only PDO data seemed "suspicious" and so a new analysis was done whereby the zero points were shifted until a minimum RMS value from the Fourier analysis was found. This improved the fit from the original analysis significantly. Figure 4 shows the revised lightcurve. While relatively noisy, it did show signs similar to those caused by a satellite, i.e., somewhat prolonged and subtle deviations from the average curve.

Figure 6 shows a typical upward bowing with some "dips" spaced about 0.5 rotation phase apart. While the data are somewhat noisy, the result is considered sufficient to say that this is a binary asteroid. Assuming this is the case, the orbital period is 18.69 ± 0.05 h and the secondary-primary size ratio is $D_s/D_p \geq 0.25 \pm 0.03$. The primary rotation period was refined to 2.78836 ± 0.00004 h with an amplitude of 0.29 mag. This would make it among the more elongated primaries within the small binary population. Assuming an equatorial view and simple triaxial ellipsoid, the a/b ratio is about 1.3:1.

(53432) 1999 UT55. This Hungaria was observed for the first time from PDO from 2013 Jan 1-12. The 0.5-m Ritchey-Chretien with FLI-1001E CCD camera was used for all observations. Figure 7 shows what appeared to be a very noisy lightcurve, but still with some of the usual signs of a satellite. Part of the problem was that the asteroid was fainter than predicted and so the data are noisier than usually preferred.

The primary rotation period is $P = 3.330 \pm 0.002$ h and amplitude $A = 0.10 \pm 0.01$ mag. The orbital period of the satellite is 14.10 ± 0.01 h. The estimated secondary-primary size ratio is $D_s/D_p \geq 0.23 \pm 0.02$.

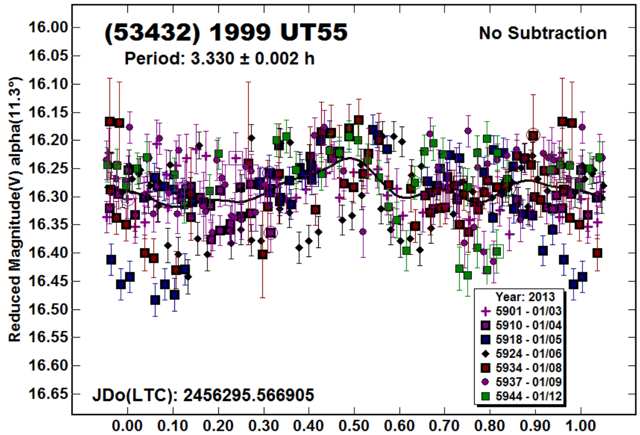

Figure 7. The unsubtracted lightcurve for (53432) 1999 UT55.

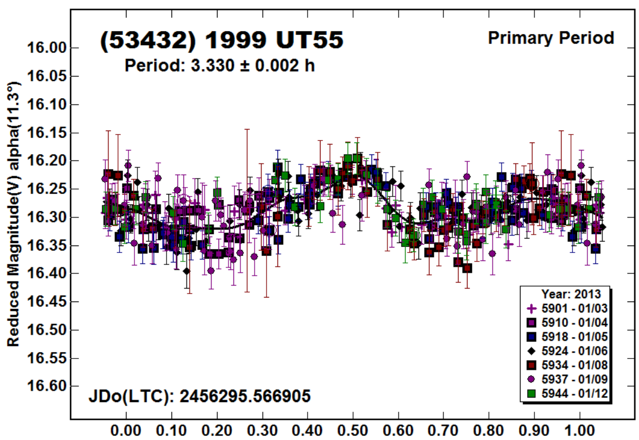

Figure 8. The lightcurve of (53432) 1999 UT55 showing the rotation of the primary.

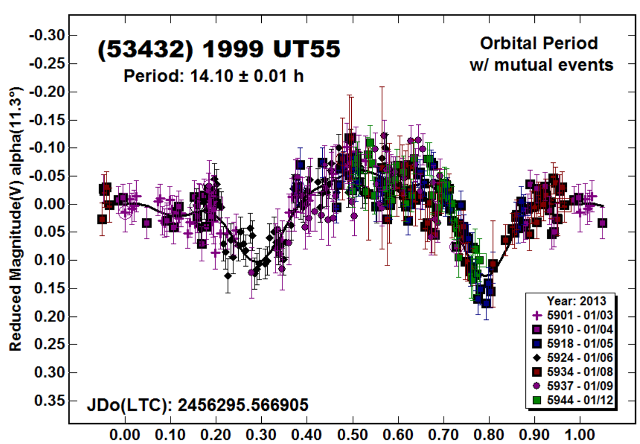

Figure 9. The lightcurve for (53432) 1999 UT55 showing mutual events due to the presumed satellite.

Acknowledgements

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LIGHTCURVE PHOTOMETRY, H-G PARAMETERS AND ESTIMATE DIAMETER FOR 4613 MAMORU

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Photometric observations of main-belt asteroid 4613 Mamoru, were made over eight nights during 2012 November and December, with a filtered system. The resulting synodic period is P = 5.388 ± 0.001 h with an amplitude A = 0.26 ± 0.03 mag. The color index is V-R = 0.41 ± 0.03 mag. The measured absolute visual magnitude, H = 11.48 ± 0.06 mag, and the slope parameter, G = 0.20 ± 0.08, are consistent with a medium albedo object, e.g., type M. The diameter is estimated to be D = 16 ± 3 km.

The main-belt asteroid 4613 Mamoru was reported as a lightcurve photometry opportunity, for 2012 November, in Minor Planet Call *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*. All the observations were carried out from C62 Eurac Observatory in Bolzano (Italy), during eight observing nights, using a 0.20-m reflector telescope, reduced to f/4.0 and a QHY9 CCD camera. Before each session, the observers synchronized the computer's clock with atomic clock time, via Internet NTP servers. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2012). The derived synodic period was P = 5.388 ± 0.001h (Fig.1) with an amplitude of A = 0.26 ± 0.01 mag.

All filtered images (V Johnson, R Cousins) were calibrated with dark and flat-field frames. The V and R band frames were acquired in sequence changing alternatively the filters (VR VR VR). This allowed us to find the color index of V-R = 0.41 ± 0.03 mag (mean of 40 values). This value is typical of an M-type asteroid (Shevchenko and Lupishko, 1998). Assuming M-type, the geometric albedo is Pv = 0.17 ± 0.04 (Shevchenko and Lupishko, 1998). The absolute magnitude (H) and slope parameter (G) ware found using the H-G Calculator function of *MPO Canopus* (Warner, 2012). Six values obtained pre and post opposition of the asteroid, using the maximum values of the lightcurve. Unfortunately, there are no V values at small phase angles, near 0 deg, which are necessary for an optimal fit. We obtained H = 11.48 ± 0.06 mag, and the slope parameter G = 0.20 ± 0.08 (Fig. 2). From this, we can estimate a diameter of D = 16 ± 3 km, using the expression (Pravec and Harris, 2007):

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

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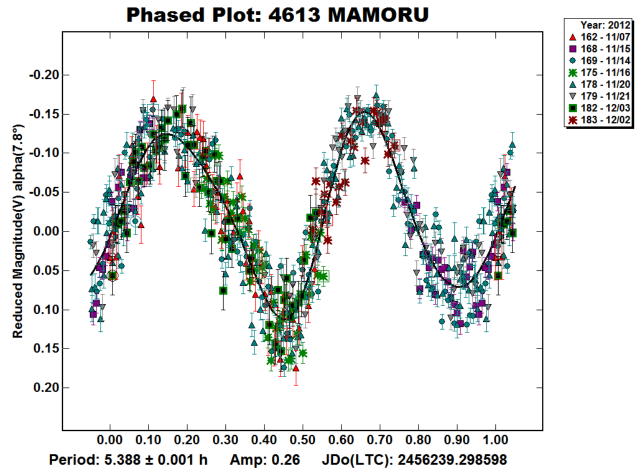

Figure 1. The lightcurve of 4613 Mamoru with a period of 5.388 ± 0.001 h and an amplitude of 0.26 ± 0.01 mag.

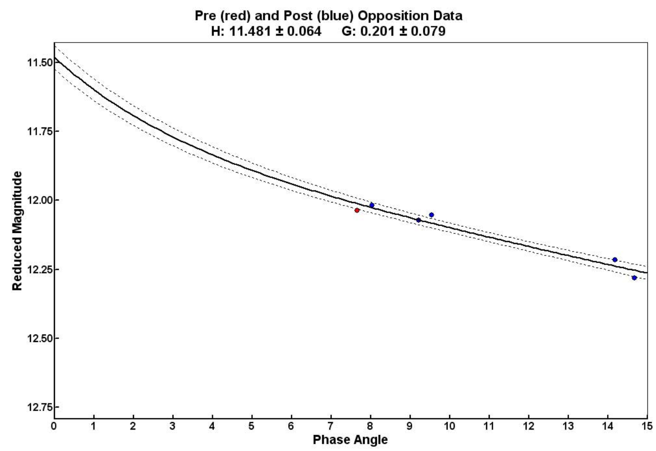

Figure 2. Visual reduced magnitude vs. phase angle for Hv = 11.48 ± 0.06 mag. and the slope parameter, G = 0.20 ± 0.08.

ASTEROID 2012 DA14 ROTATION LIGHT CURVE

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Near-Earth object 2012 DA14 was observed for 10 hours during its outbound leg on 2013 February 16. This lightcurve shows a rotation period of 9.1 ± 0.5 hours. The shape and length of the minima and maxima are very different, suggesting a complicated asteroid shape or perhaps a complex, non-periodic rotation.

The Near-Earth object 2012 DA14 (hereafter referred to as "D14") passed close to Earth on 2013 Feb 15, at ~ 19.5 UT, and was visible for Northern Hemisphere observers starting 6.6 hours later. Because of DA14's closeness it moved at high speed through the sky, which presented a challenge for producing a lightcurve (LC) for the purpose of determining rotation period. A large aperture was needed because the ephemeris for D14 showed that it would fade to ~ 15th mag during the first opportunity observing session.

However, large aperture telescopes typically have a small field-of-view (FOV), requiring many FOV position changes, at frequent intervals, in order to follow DA14's motion. Another challenge for D14 is related to the fact that it could only be observed when it was at high declinations, where there are few calibrated stars. The CMC14 catalog of stars with r'-band calibrations does not extend north of +50º, and this necessitated developing a method for deriving r' mags from others that are available. These observing challenges were overcome and lessons learned may be useful for future NEO observations.

Hardware and Observing Procedure

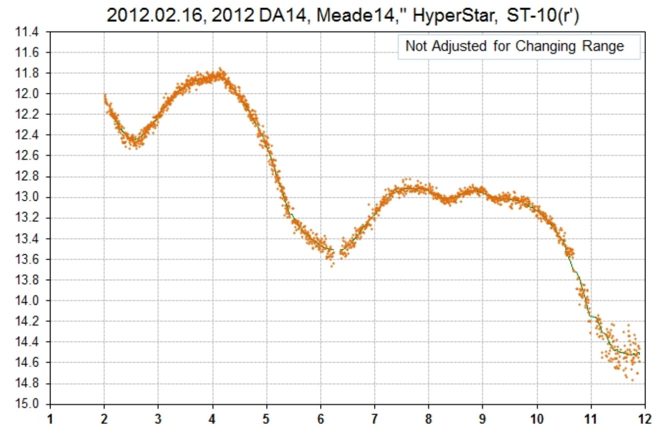
A 14-inch Meade LX-200 GPS was reconfigured for prime focus observing using a Starizona HyperStar lens. An SBIG ST-10XME CCD with a 10-slot filter wheel was attached to the HyperStar, affording an f-ratio of 2.04, image scale of 1.95 arcsec/pixel and FOV of 71 x 48 arcmin. The telescope is in an 8-foot diameter dome (Explora-Dome), and all equipment is controlled using MaxIm DL from a control room using signal lines in a buried conduit. An r'-band filter was used, mostly because it has a higher throughput than any of the other filters. After HyperStar collimation sharp images were achieved across the entire FOV, with point-spread-functions ~ 2.0 pixels (4.0 arcsec) when seeing and tracking were good. Since D14 was moving at ~160 arcsec/min at the beginning of the observing session exposure times of 3 s were used; this changed to 10 s when D14's rate of motion had decreased to ~70 arcsec/min.

The large FOV was important as it allowed only 19 position changes for tracking DA14's motion during the 12 hours of observing. A Cassegrain configuration would have required ~ 50 FOV changes, and this would have reduced the time available for exposing images in addition to being exhausting. Another essential procedure was MaxIm DL's "Move telescope here" tool, which enabled fast FOV moves.

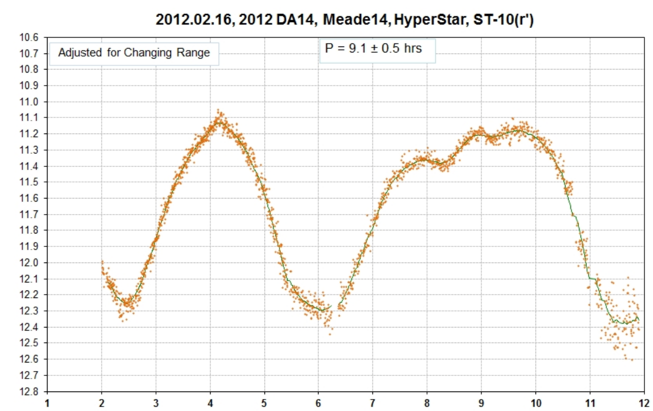
Image Analysis and Lightcurve Creation

MaxIm DL was used for image calibration (bias, dark and flat – all taken the evening before observations), star alignment and aperture photometry. Since none of the stars in the 19 FOVs had known r'-mags (as far as I could determine), an artificial star was inserted in a corner of every image and used as the only reference for aperture photometry of the DA14 moving target. Nearby stars were included as "check stars" in the photometry measurements and were thus included in the recorded data file. This is an unusual procedure, but the "check stars" are actually candidates for "reference stars" in the next stage of spreadsheet analysis. This is a flexible way of evaluating the suitability of candidate reference stars, because within a spreadsheet their variability can be assessed, magnitudes can be assigned to them, and internal consistency of catalog-assigned magnitudes can be used for identifying stars that should not be used for reference due to either poor quality catalog mags or star variability.

Before calculating r'-mags for candidate reference stars a crude LC was derived using only the artificial star for reference. Such a LC can be distorted by atmospheric extinction changes, as well as changes in air mass during an observing session. Since air mass changed by a small amount during the 12 hours of observing (from 2.51 to 1.93) due to DA14's high declination (80 to 86º), and since the skies were clear the entire 12 hours, this "instrumental magnitude LC" was considered a worthwhile check on a later version using reference stars. The first figure shows this "instrumental magnitude LC."

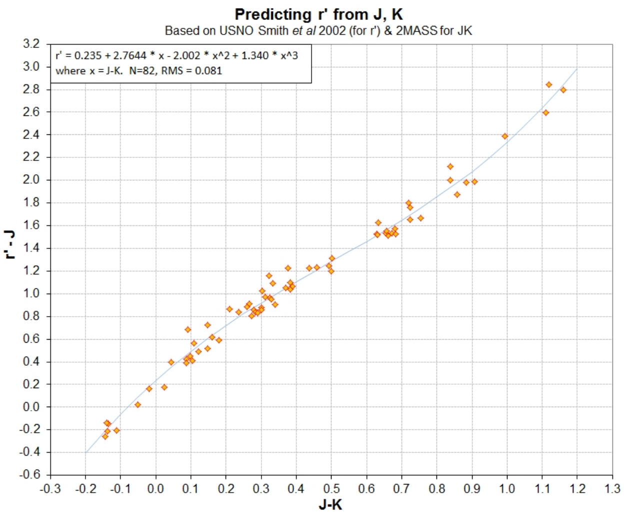


There's an overall fade caused by a fast increasing range from the observer to DA14. The ephemeris calls for a 2.2 mag fade during this 10-hour interval. A 3[rd] order polynomial fit to the fade versus UT during this interval was used to adjust all mags to a 2.0 UT referenced time, shown in the next figure.



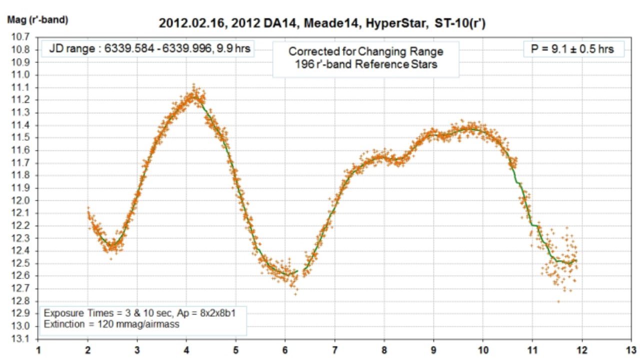
Adjusting for changing range produces a rotation LC with approximately equal secondary minima. The "dips" at 8.2 and 9.2 UT could be produced by temporary increases in atmospheric extinction, given that these two graphs are plots of instrumental magnitude, not differential photometry using nearby reference stars.

In order to perform a differential photometry LC a method was devised for assigning approximate r'-band mags to all of the stars in the 19 FOVs that were measured photometrically using MaxIm DL and assigned "check star" status for possible use as reference in a spreadsheet. Star colors with various definitions correlate with each other, as shown by color-color scatter diagrams. Warner and Harris (2007) determined useful conversion equations allowing for the estimate of BVRcIc mags from the 2MASS catalog of J and K mags, which has coverage of the entire sky for stars as faint as r' ~ 17. For example, Rc–J is correlated with J-K that enables Rc to be determined with an accuracy of ~0.040 mag. I used the well-calibrated list of 158 stars in Smith *et al* (2002) for the SDSS bands u'g'r'i'z' to determine an equation relating r'-J to J-K. This is shown in the next graph.



The 19 FOVs produced a total of 196 "check stars" that were assigned r'-mag values using the J-K method. If the SE for each r'-mag is 0.081 mag, then the SE for an average of 10 stars, typical for each FOV, should be ~0.027 mag. An internal consistency of this amount, or better, was indeed achieved; as a bonus it was possible to identify a few stars that must have been variable based on their inconsistency with others.

With ~10 reference stars per FOV it was possible to produce a differential photometry LC, shown below.



This LC should have an accurate r'-band mag calibration. Note that all plotted values are adjusted for changing range to correspond to the range at the beginning of observations, at 2.0 UT (range = 0.0010685 a.u.).

More information about these observations can be found at the following web site: *www.brucegary.net/2012DA14/*, where a link allows downloading of a data file with 1768 individual measurements.

Concluding Thoughts

The "instrument mag" and "differential photometry" LCs exhibit essentially identical structure; the "dips" at 8.2 and 9.2 UT must therefore be real. Also, the asymmetry of intervals between primary/secondary and secondary/primary minima must also be real. The two peak brightness shapes are distinctly different; one is pointed and the other is broad and bumpy. Since the sun-target-observer angle varied from 75 to 81° during the 10-hour observing period the viewing geometry is favorable for emphasizing the effects of shadows produced by surface irregularities. Photometric observations by other observers can be combined with this LC to refine the LC shape and its change with viewing geometry.

Perhaps the most useful information from this LC is that a rotation period can be estimated (9.1 ± 0.5 h), but because it does not repeat, single axis rotation cannot be determined. Asteroids this small are thought to rotate faster (e.g., 2 h), so this asteroid rotates slower than expected. It is important to refine histograms of rotation period versus size (or mass), so we can thank 2012 DA14 for providing an important datum at the very small end of the asteroid size range.

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16525 SHUMARINAIKO: A NEW NYSA BINARY

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Analysis of CCD photometric observations of the Nysa group asteroid 16525 Shumarinaiko made in 2013 January shows that the asteroid is a binary system. A bimodal lightcurve for the primary has a period 2.5932 ± 0.0003 h with an amplitude of 0.08 ± 0.01 mag. The orbital period of the presumed satellite is 14.409 ± 0.005 h. Based on the depth of the mutual events, the satellite-primary diameter ratio is estimated to be $D_s/D_p \geq 0.16 \pm 0.02$. Indications are that the satellite is elongated and tidally-locked to its orbital period.

16525 Shumarinaiko is a member of the Nysa group with an estimated diameter of 6 km (LCDB; Warner *et al.*, 2009). Its rotation period had been determined twice before: Behrend *et al.* (2006, 2.6425 h) and Higgins (2011, 8.8 h). Both lightcurves were rated U = 1 in the LCDB, meaning that the solution was "likely wrong." Normally, the observing program at the Palmer Divide Observatory (PDO) concentrates on Hungaria asteroids. However, when there are no Hungarias available, e.g., too far south or too faint, a brighter target with no or an uncertain period is chosen with the intent of improving its status in the LCDB. Such was the case for 16525 Shumarinaiko.

The observations at PDO were started on 2013 January 9 using a 0.35-m Schmidt-Cassegrain and SBIG STL-1001E CCD camera. Exposures were 240 seconds and unfiltered. After the first two nights (Jan 9 and 12) some initial indications of deviations from the overall curve similar to those caused by a satellite were seen. Help from Coley at the Center for Solar System Studies (CS3) was requested since bad weather prevented observations at PDO. The

CS3 observations on Jan 13 and 14 were made with a 0.35-m Schmidt-Cassegrain and SBIG ST-9XE. Exposures there were also unfiltered and 240 seconds. All images were measured in *MPO Canopus*. The dual-period feature in that program, based on the FALC algorithm developed by Harris (Harris *et al.*, 1989) was used to subtract one of the periods from the data set in an iterative process until both periods remained stable. Night-to-night calibration of the data was done using the Comp Star Selector feature in *MPO Canopus*. Catalog magnitudes for the comparison stars were derived from J-K to BVRI formulae developed by Warner (2007) using stars from the 2MASS catalog (Skrutskie *et al.*, 2006). A description of this method was described by Stephens (2008).

The results of the analysis are shown Figures 1-3. Figure 1 shows the full data set before subtracting the effects of the occultation and/or eclipses caused by the satellite. This shows the nature of the deviations that prompted the additional analysis. Figure 2 shows the lightcurve after subtracting the mutual events and so represents the rotation of the primary body. Figure 3 shows the mutual events by subtracting the rotation of the primary from the overall data set. The "dips" at 0.45 and 0.95 rotation phase represent an occultation or eclipse. Using the magnitude drop of the shallower of the two, the estimated secondary-primary size ratio is $D_s/D_p \geq 0.16 \pm 0.02$. The event at 0.95 may be total, so this could be the actual ratio and not a minimum.

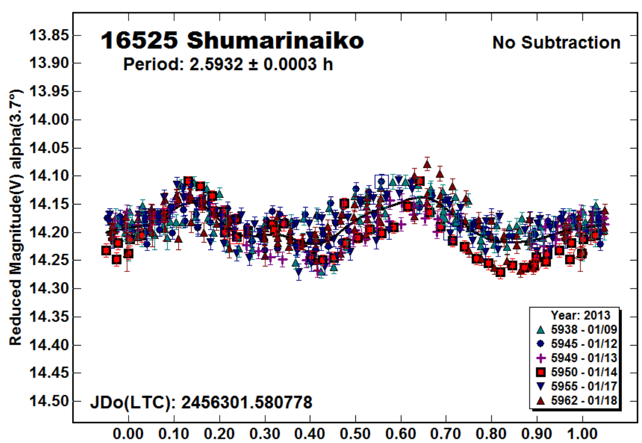

Figure 1. The lightcurve of 16525 Shumarinaiko without subtracting the effects of the satellite. The period was forced to that found for the primary after final analysis.

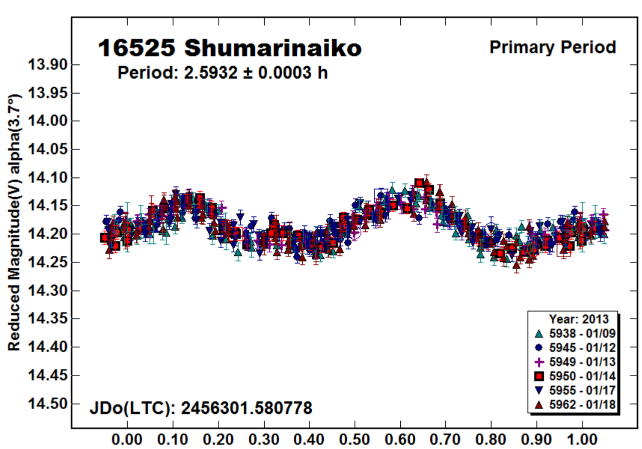

Figure 2. The lightcurve for 16525 Shumarinaiko showing only the rotation of the primary.

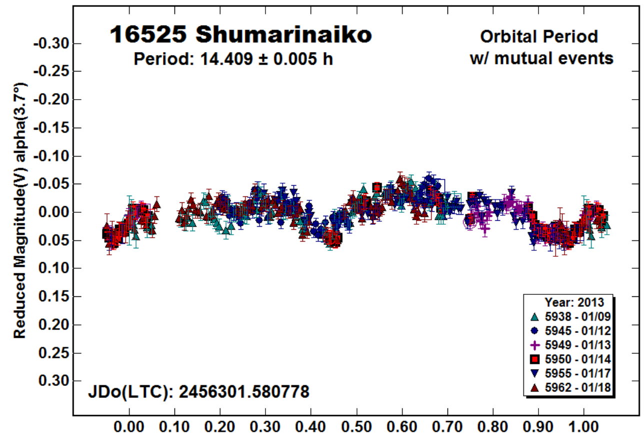

Figure 3. The lightcurve of 16525 Shumarinaiko after subtracting the primary lightcurve. The "dips" at about 0.45 and 0.95 rotation phase are due to occultations or eclipses involving the satellite. The bowing between events indicates the satellite is somewhat elongated and tidally-locked to its orbital period.

Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G and by National Science Foundation grant AST-1032896.

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NEW PHOTOMETRY OF 1473 OUNAS

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Semi-calibrated lightcurves were obtained of 1473 Ounas in 2012 August – October which indicate a long synodic rotation period of 139.1 ± 0.1 hours, amplitude 0.6 ± 0.1 magnitudes. Some sessions provide data which do not fit for any derived period and are an indicator of tumbling. But errors of calibration are sufficiently large to hamper finding the tumbling period.

The Asteroid Lightcurve Data Base (Warner et al. 2012) shows no previous observations of 1473 Ounas. Vladimir Benishek, Andrea Ferrero, and Daniel Klinglesmith III began observing 1473 Ounas independently. When they learned of each other's work through the CALL website they agreed to share their data. Later Frederick Pilcher contributed additional observations. Also Rene Roy had posted his results on R. Behrend's web site (2012) and accepted the invitation to share data and join the collaboration.

A total of 55 sessions were obtained by the five observers in the interval 2012 Aug. 2 – Oct. 23. Almost all are by direct comparison to catalog magnitudes of stars in the CCD field. As a consequence of their having started observations independently, different filters R, V, and Clear were used by the different observers and in different sessions. Details of the separate sessions are provided in a table below.

Data Analysis. *MPO Canopus* software was used by all observers except Roy to measure the images photometrically. R. Behrend used CoubRot software (Behrend, 2001) to measure the images by Roy. Only stars with near solar colors were used, and in each of the several different sessions 2 to 5 comparison stars were used. The Comparison Star Selector (CSS) procedure in *MPO Canopus* computes and displays a separate value for the magnitude of the asteroid as compared with the catalog magnitude of each comparison star. Errors of calibration arise from errors in the catalog magnitudes, intrinsic color differences V-R between star and asteroid, and instrumental effects arising from the filters. For each session the range in asteroid magnitudes as compared with each comparison star was often in the range 0.05 – 0.10 magnitudes, but occasionally as high as 0.25 magnitudes. This provides an order of magnitude of the calibration errors. The asteroid magnitude used for a single session in the subsequent steps of analysis is the mean obtained from these 2 to 5 catalog based magnitudes. When several sessions are combined into a single lightcurve *MPO Canopus* software adjusts the measured magnitudes on the different nights for changes caused by variations in geocentric and heliocentric distances and phase angle with a default G = 0.15. A further calibration error systematic with phase angle arises if G is considerably different from 0.15. Figure 1 is a raw plot of all observations adjusted as described above. A scatter considerably beyond rotational variations, for some sessions as high as 0.3 to 0.4 magnitudes, is likely due to both errors in calibration and the effects of tumbling of a slowly rotating target. Minor planet 1473 Ounas has diameter near 15 km and this investigation finds a rotation period near 6 days, as is described below. Tumbling behavior is common among objects of this size and rotation period. However there is no overall trend with phase angle which implies the real value of G for 1473 Ounas is not greatly different from 0.15.

MPO Canopus contains the FALC algorithm (Harris et al. 1989) which searches the data for many possible periods and plots a lightcurve for the period with the best (lowest rms residual) fit. A period near 140 hours is found and shown in Figure 2. Symbols on this figure are shown for successive cycle numbers of the approximately 140 hour period. Next the magnitudes of the separate sessions are adjusted, one at a time, up and down through several hundred separate steps until a best fit is obtained. This is shown in Figure 3, in which symbols are again shown for successive cycle numbers. In principle this removes errors of calibration, but it also removes variations caused by tumbling which have periods longer than a single session. The lightcurve in Figure 3 is unrealistically smooth. At a given phase slope variations, especially those in which rising sessions overlap falling sessions, are still readable, but all night magnitude differences caused by tumbling have been removed. The first order period due to principal axis rotation of 139.22 hours should however be reliable. Inspection of a lightcurve with this period shows that some sessions at nearly the same phase in different rotational cycles have inconsistent slopes. We illustrate in Figures 4 and 5 two spectacular cases in which rising segments overlap falling segments. These are small parts of the complete lightcurve produced by Pilcher with *MPO Canopus* software in which the magnitudes (mean for entire lightcurve = 0) and phase have been carefully preserved. In Figure 4 the misfit session with blue + sign symbols near phase 0.03 is for the interval Aug. 2 21:30 UT – Aug. 3 02:34 UT. In Figure 5 the misfit session with black triangle symbols near phase 0.23 is for the interval Oct. 1 2:57 – 6:59 UT. A careful inspection of Fig. 3 finds several much smaller but probably significant slope misfits. This behavior we can only explain by tumbling behavior in the target. Unfortunately the errors of calibration are sufficiently large to hamper determination of a second period.

The lightcurve presented here (Figure 3) with period 139.22 ± 0.01 hours was prepared with a single period search with *EXELIS IDL* (Interactive Data Language, www.exelisvis.com) software by author Klinglesmith. Other authors have independently prepared lightcurves which we do not present here. The periods they find are: Raoul Behrend 139.01 ± 0.07 hours with *CourbRot* software (Behrend, 2001); Andrea Ferrero 139.12 ± 0.02 hours with *MPO Canopus*; Frederick Pilcher 139.14 ± 0.02 hours also with *MPO Canopus*. These quoted errors are all one sigma errors which are likely unrealistically small. If we assign equal weight to the four periods stated above, a least squares solution provides a period 139.12 ± 0.06 hours. With some caution we should claim an error not smaller than ± 0.1 hours.

It is significant that all four independent period determinations all converged to a value very near 139.1 hours. The period spectrum between 130 and 150 hours (Figure 6) also shows that there is no viable period other than one near 139.1 hours. The removal of magnitude ordinate variations by the procedure of adjusting all sessions to best fit does not invalidate the period of 139.1 hours thus obtained, but does make the amplitude of principal variation somewhat uncertain. The amplitude we find here, about 0.6 magnitudes, is sufficiently large that despite a likely considerable error the only possible period is the one which produces our bimodal lightcurve. We claim that the reliability of this period is secure.

We conclude that this study indicates that 1473 Ounas has a rotation period of 139.1± 0.1 hours with amplitude 0.6 ± 0.1 magnitudes and a very strong suggestion of tumbling.

Future studies. The next favorable opposition of 1473 Ounas occurs in 2016 July near +4 degrees declination and brightest magnitude 14.4. This is comparably observable from both northern and southern hemispheres. We recommend that a consortium of observers from a wide range of terrestrial longitudes be assembled. Prior to the beginning of observation, probably 2016 May, procedures for improving the calibration magnitudes should be refined and adopted uniformly by all participating observers.

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Observer equipment: VB, Vladimir Benishek; AF, Andrea Ferrero; DK, Daniel Klinglesmith III; FP, Frederick Pilcher; RR, Rene Roy.

VB	40 cm S-C	SBIG ST-10 XME
AF	30 cm R-C	SBIG ST9XE
DK	35 cm S-C	SBIG ST10
FP	35 cm S-C	SBIG STL-1001E
RR	40 cm f/5.1	1603ME Binnig Platinum 2x2 Audine

Session Data: Cy, cycle number; Obs, observer; Date 2012 of session; UT of first and final data points of session; Filter, C clear, R red, V visual; RA and Dec in J2000 coordinates of mid time of session; Phase angle in degrees.

Cy	Obs	Date 2012	UT	Filter	RA	Dec	Phase
01	VB	Aug 02-03	21:30-02:34	C	21 36.6	+12 42	15.6
01	VB	Aug 04-05	21:22-02:37	C	21 35.4	+12 40	15.0
01	VB	Aug 06-07	20:51-02:28	C	21 34.1	+12 37	14.5
01	VB	Aug 07-08	20:55-02:24	C	21 33.4	+12 35	14.3
02	VB	Aug 08-09	20:46-02:07	C	21 32.8	+12 32	14.2
02	VB	Aug 09	20:59-23:35	C	21 32.1	+12 30	14.1
04	VB	Aug 21-22	20:06-01:19	V	21 23.8	+11 23	12.6
04	VB	Aug 24-25	20:31-01:05	C	21 21.8	+10 58	12.7
05	AF	Aug 26-27	19:42-02:27	R	21 20.6	+10 40	12.9
05	AF	Aug 27-28	20:09-02:25	R	21 20.0	+10 30	13.0
05	DK	Aug 28	03:20-04:11	C	21 19.8	+10 28	13.0
05	DK	Aug 28	04:14-05:59	C	21 19.8	+10 28	13.0
05	DK	Aug 28	06:11-09:27	C	21 19.7	+10 27	13.0
05	AF	Aug 28-29	19:13-02:26	R	21 19.4	+10 20	13.1
05	DK	Aug 29	03:50-08:36	C	21 19.2	+10 18	13.1
05	DK	Aug 30	03:39-09:30	C	21 18.7	+10 08	13.3
05	DK	Aug 31	03:02-09:48	C	21 18.2	+09 58	13.5
06	DK	Sep 01	02:33-03:53	C	21 17.7	+09 48	13.7
06	DK	Sep 02	04:26-09:33	C	21 17.2	+09 36	13.9
06	DK	Sep 03	03:01-05:32	C	21 16.7	+09 26	14.1
07	AF	Sep 06-07	19:16-01:41	R	21 15.2	+08 42	15.1
07	AF	Sep 09-10	18:40-01:29	R	21 14.2	+08 06	15.9
07	AF	Sep 11	18:47-22:14	R	21 13.7	+07 43	16.5
08	AF	Sep 12-13	21:27-00:53	R	21 13.5	+07 30	16.8
08	AF	Sep 13-14	18:46-01:10	R	21 13.4	+07 18	17.1
08	AF	Sep 14	18:49-20:39	R	21 13.2	+07 05	17.5
08	DK	Sep 15	02:37-05:33	C	21 13.2	+07 02	17.5
08	AF	Sep 15-16	18:39-00:48	R	21 13.1	+06 53	17.8
08	DK	Sep 16	02:15-04:38	C	21 13.1	+06 50	17.8
08	AF	Sep 16-17	18:26-01:03	R	21 13.1	+06 40	18.1
08	AF	Sep 17-18	21:54-00:52	R	21 13.0	+06 27	18.4
09	AF	Sep 19-20	18:57-00:42	R	21 13.0	+06 02	19.0
09	DK	Sep 20	02:00-06:13	C	21 13.0	+06 00	19.1
09	AF	Sep 20	18:40-23:20	R	21 13.1	+05 50	19.3
10	AF	Sep 24	18:14-20:44	R	21 13.7	+05 02	20.6
10	VB	Sep 25	18:59-23:01	R	21 13.7	+04 50	20.9
11	FP	Sep 30	01:36-07:37	C	21 15.2	+03 59	22.0
11	FP	Oct 01	02:57-06:59	C	21 15.7	+03 47	22.3
11	AF	Oct 01	19:34-23:28	R	21 16.0	+03 39	22.6
11	RR	Oct 01-02	18:35-00:57	C	21 16.0	+03 39	22.6
11	FP	Oct 02	01:40-06:39	C	21 16.2	+03 36	22.7
11	AF	Oct 02	18:13-23:12	R	21 16.5	+03 28	22.9
11	DK	Oct 03	02:17-05:39	C	21 16.6	+03 24	23.0
11	DK	Oct 04	02:15-06:11	C	21 17.1	+03 13	23.2
11	FP	Oct 05	01:31-07:37	C	21 17.7	+03 02	23.4
12	FP	Oct 08	01:31-07:23	C	21 19.5	+02 31	24.2
12	FP	Oct 09	01:31-07:18	C	21 20.1	+02 21	24.4
12	FP	Oct 11	01:44-05:51	C	21 21.5	+02 01	24.9
13	AF	Oct 12	18:07-22:59	R	21 22.8	+01 45	25.3
13	FP	Oct 14	01:19-06:12	C	21 23.9	+01 32	25.6
13	AF	Oct 16	17:48-22:47	R	21 26.2	+01 09	26.2
14	FP	Oct 18	01:32-06:32	C	21 27.4	+00 58	26.4
14	FP	Oct 19	01:22-05:09	C	21 28.3	+00 50	26.6
14	FP	Oct 20	01:12-05:05	C	21 29.3	+00 42	26.7
14	FP	Oct 23	01:18-04:51	C	21 32.4	+00 20	27.2

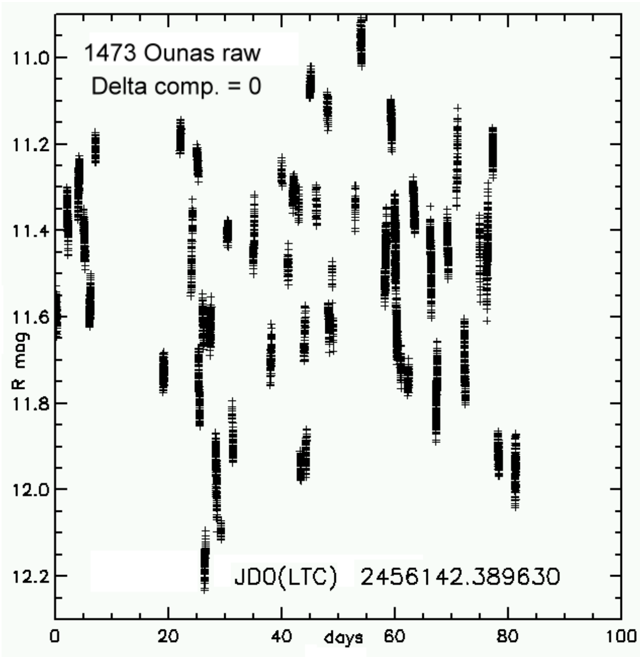

Figure 1. Raw plot of all CSS observations of 1473 Ounas adjusted for changes in Sun and Earth distances and assumed G = 0.15.

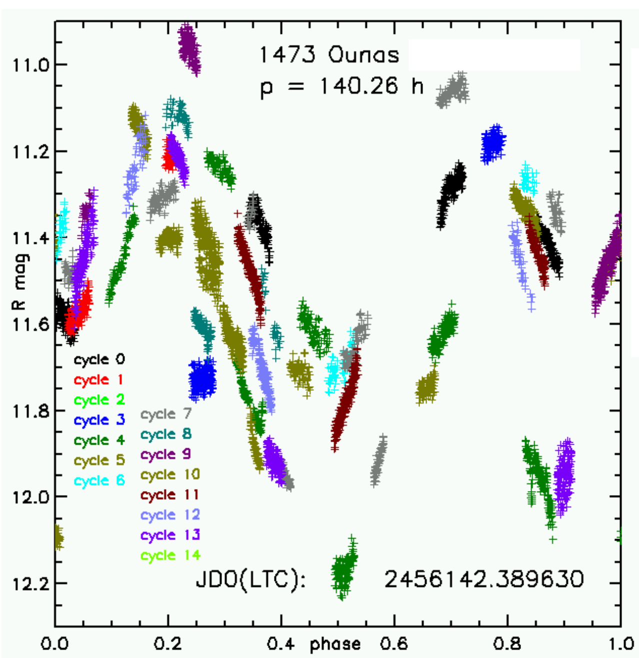

Figure 2. Phased plot of all CSS observations of 1473 Ounas coded by cycle number and adjusted for changes in Sun and Earth distances and assumed G = 0.15.

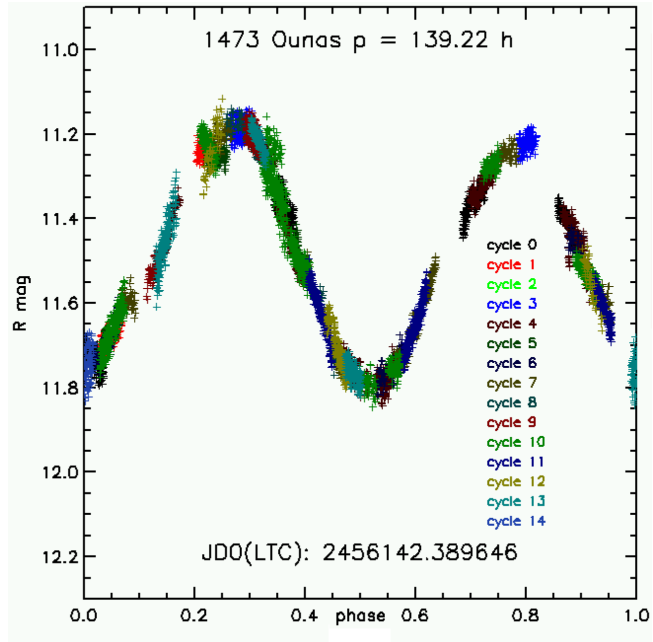

Figure 3. Phased plot of all observations of 1473 Ounas coded by cycle number with magnitudes of separate sessions adjusted for best fit.

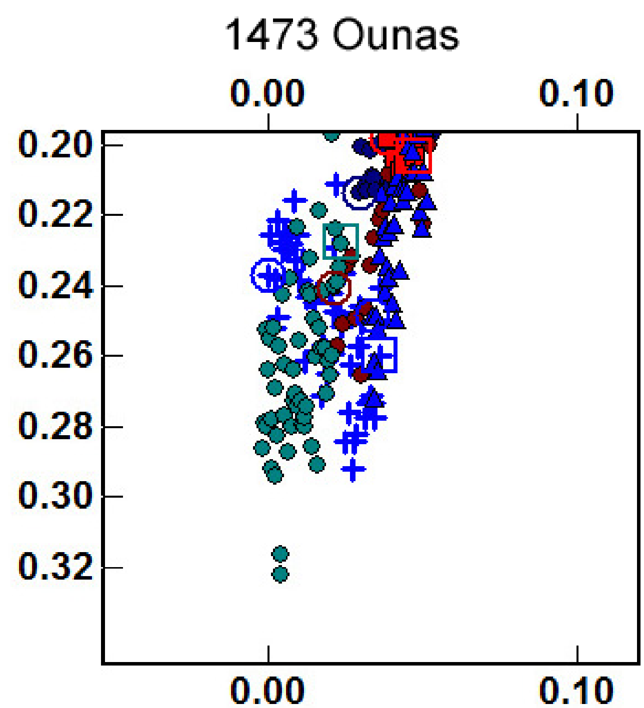

Figure 4. Enlargement of a small section of the lightcurve showing the session of Aug. 2 21:30 UT - Aug. 3 02:34 UT (blue + signs) with a slope misfit.

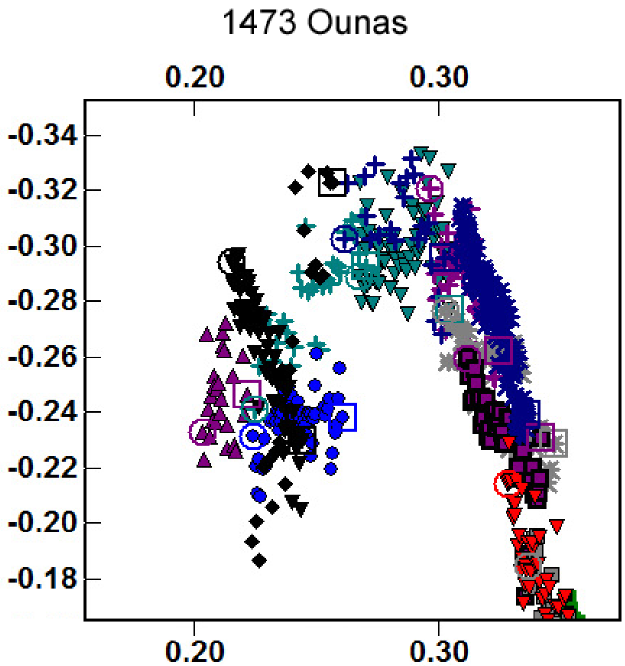

Figure 5. Enlargement of a small section of the lightcurve showing the session of Oct. 1 02:57 UT - 06:59 UT (black triangles) with a slope misfit.

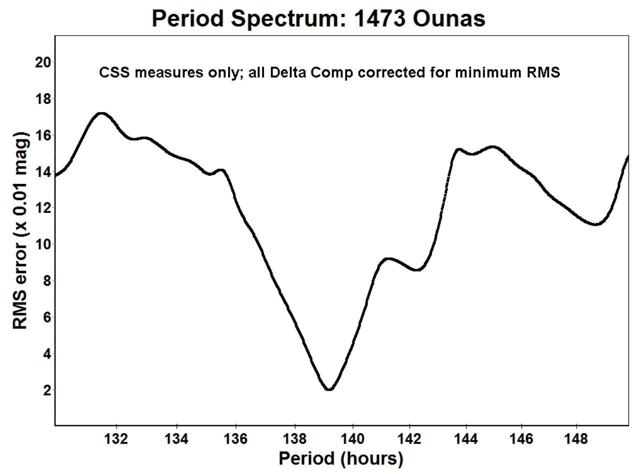

Figure 6. Period spectrum of 1473 Ounas between 130 and 150 hours with magnitudes adjusted as in Fig. 3.

1727 METTE: A NEW HUNGARIA BINARY

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Analysis of CCD photometric observations of the Hungaria asteroid 1727 Mette made in 2013 January shows that the asteroid is a binary system. A bimodal lightcurve for the primary has a period 2.98109 ± 0.00007 h with an amplitude of 0.33 ± 0.01 mag. This makes the primary one of the more elongated objects in the small binary population. The orbital period of the satellite is 20.99 ± 0.02 h. Based on the depth of the mutual events, the satellite-primary diameter ratio is estimated to be $D_s/D_p = 0.21 \pm 0.02$.

The rotation period of the (now known to be) primary of the Hungaria asteroid 1727 Mette had been determined on several previous occasions, e.g., Wisiniewski (1987, 2.63 h), Behrend *et al.* (2003, 2.981 h), Gandolfi (2009), and Warner (2011, 2.981 h). Other observers have reported periods of 2.4-2.6 h over the years. See the references in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). None of the previous results seemed to indicate signs of the asteroid having a satellite.

As part of the regular observations of the Hungaria asteroids conducted at the Palmer Divide Observatory since 2005, CCD photometric observations of 1727 Mette were started in 2013 January. In this case, the intent was to provide additional dense lightcurves for modeling the asteroid's spin axis and shape. Initial observations showed what appeared to be deviations from a 2.98 hour lightcurve (Figure 1). This prompted additional observations so that the primary curve could be well-determined and then subtracted from the overall data set to determine the period of the satellite events (occultations and/or eclipses), i.e., the orbital period.

The observations at the Palmer Divide Observatory (PDO) were made using a 0.30-m Schmidt-Cassegrain and SBIG ST-9XE CCD camera. Exposures were 120 seconds and unfiltered. Observations at the Center for Solar System Studies (CS3) were made with a 0.35-m Schmidt-Cassegrain and SBIG STL-1001E. Exposures were also unfiltered and 120 seconds. All images were measured in *MPO Canopus*. The dual-period feature in that program, based on the FALC algorithm developed by Harris (Harris *et al.*, 1989) was used to subtract one of the periods from the data set in an iterative process until both periods remained stable. Night-to-night calibration of the data was done using the Comp Star Selector feature in *MPO Canopus*. Catalog magnitudes for the comparison stars were derived from J-K to BVRI formulae developed by Warner (2007) using stars from the 2MASS catalog (Skrutskie *et al.*, 2006). A description of this method was described by Stephens (2008).

The results of the analysis are shown Figures 1-3. Figure 1 shows the full data set before subtracting the effects of the occultation and/or eclipses caused by the satellite. This shows the nature of the deviations that prompted the additional analysis. Figure 1 also demonstrates the usual nature of these events in *unprocessed* lightcurves: they are not sharp, short-lived, and deep. Instead they extend over a period of an hour or more and somewhat subtle. There are, of course, exceptions, but if an “event” consists of a few data points dropping several tenths of a magnitude and recovering very quickly, it should be viewed with some suspicion and, as always, confirmed with additional observations.

Figure 2 shows the lightcurve after subtracting the mutual events and so represents the rotation of the primary body. The amplitude of 0.33 mag implies a minimum a/b ratio of about 1.4:1 for a simple triaxial ellipsoid, assuming an equatorial view. This makes it one of the more elongated primaries among the small binary population. Usually, primaries tend to be more spheroidal, showing amplitudes in the range of 0.05 to 0.20 mag.

Figure 3 shows the mutual events by subtracting the rotation of the primary from the overall data set. The “dips” at 0.05 and 0.55 rotation phase represent an occultation or eclipse. Using the magnitude drop of the shallower of the two, the estimated secondary-primary size ratio is $D_s/D_p = 0.21 \pm 0.02$. The event at 0.05 appears to be total, so this is probably the actual ratio and not a minimum.

Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G and by National Science Foundation grant AST-1032896.

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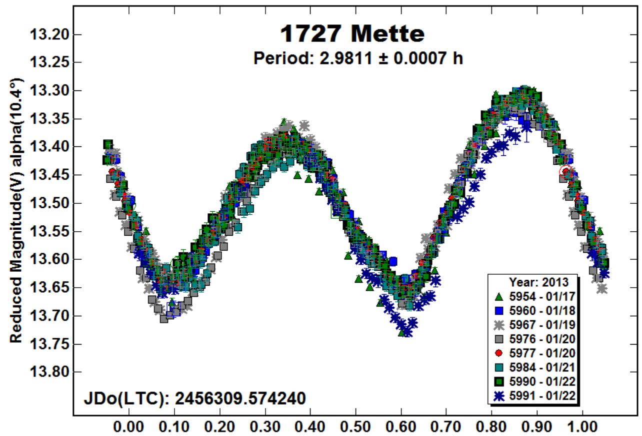

Figure 1. The lightcurve of 1727 Mette without subtracting the effects of the satellite. The deviations from the overall curve are what lead to additional analysis and discovery of the satellite.

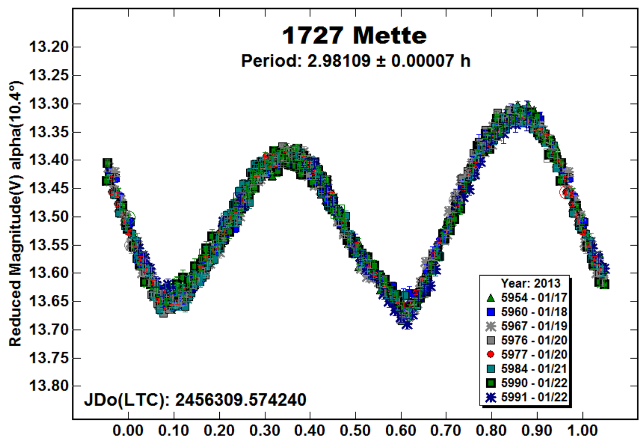

Figure 2. The lightcurve for 1727 Mette showing only the rotation of the primary. The somewhat large amplitude is unusual for the primary of a small binary system. Most primaries have amplitudes in the range of 0.05-0.20 mag.

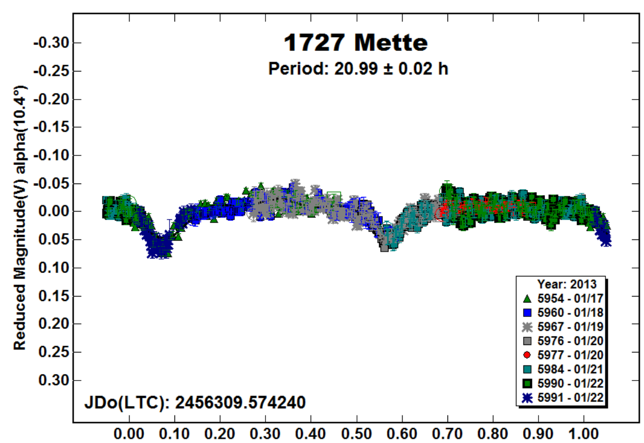

Figure 3. The lightcurve of 1727 Mette after subtracting the primary lightcurve. The “dips” at about 0.05 and 0.55 rotation phase are due to occultations or eclipses involving the satellite. The small upward bowing between the events indicates the satellite is slightly elongated.

ASTEROID PHOTOMETRY FROM THE PRESTON GOTT OBSERVATORY

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Asteroid period and amplitude results obtained at the Preston Gott Observatory are presented for six asteroids observed in 2012: 271 Penthesilea, 3872 Akirafujii, 5953 Shelton, 8077 Hoyle, 8417 Lancetaylor, and (46436) 2002 LH5.

The Preston Gott Observatory is the main astronomical facility of the Texas Tech University. Located about 20km north of Lubbock, the main instrument is a 20" f/6.8 Dall-Kirkam cassegrain. An SBIG STL-1001E CCD, was used with this telescope. All images were unfiltered and were reduced with dark frames and sky flats. Several of the asteroids observed on this occasion were asteroids I had observed on a previous opposition. The reason for the repeat observations was for use in shape modeling. Measurements were also made of any other asteroids that happened to be in the field of view. Other asteroids were chosen from "CALL" website maintained by Warner. (2011)

Image analysis was accomplished using differential aperture photometry with MPO Canopus. Period analysis was also done in Canopus, which implements the algorithm developed by Alan Harris (Harris et al. 1989). Differential magnitudes were calculated using reference stars from the USNO-A 2.0 catalog and the UCAC2 catalog. Results are summarized in the table below, and the lightcurve plots are presented at the end of the paper. The data and curves are presented without additional comment except were circumstances warrant. Column 3 gives the range of dates of observations and column 4 gives the number of nights on which observations were undertaken.

3872 Akirafuji. Observations of this asteroid previously were made in July and August 2005 (Clark 2007). At that time, despite observations being made on 7 nights, any period was very poorly determined. A solution using a double peak and a period of 10.635 hours was suggested, but was questionable. This time, observations were made on 5 nights, and still the result is poor. The current observations rule out a 10.6 hour period, and instead suggest a 22.289 hour period. However, once again the result is open to question as the observations did not completely cover the whole lightcurve. This is an asteroid that will require more work!

5953 Shelton. Observations of this asteroid were only possible on 3 nights due to equipment problems. The resulting lightcurve was very noisy with only a few hints of variation. The indicated period is only a suggestion from these limited data.

8077 Hoyle. Observations of this asteroid indicated a very asymmetrical lightcurve. The derived period was 8.136 h with an amplitude of 0.25 mag. However one peak was substantially greater than the other. The minima were also unequal.

8417 Lancetaylor. This asteroid was observed in 2002 and a period of 6.538h and an amplitude of 1.71 mag was derived from the data (Clark 2003). However, as noted at the time, the asteroid was in a fairly rich region of the Milky Way and field stars contamination was a considerable problem. The current observations rule that result out completely. The current observations result in a period of 3.5862 h with an amplitude of about 0.55 mag. Unfortunately, data from only 2 of the nights in 2002 are still available, the rest having been lost when a CD malfunctioned. Re-analyzing those two nights showed that they would fit with the current result as shown in the second 8417 lightcurve below. The 2002 result was most likely an alias caused by the interfering background stars.

46436 2002 LH5. This asteroid was observed in 2007 and a period of 3.8836h and an amplitude of 0.65 mag was derived from the data (Clark 2008). The current observations are in complete agreement with that result, with the period being derived being 3.8832 h and the amplitude of about 0.65 mag. Also in agreement with the previous result are the unequal minima. Combining the data from both years gave a result for the period of 3.88355 h as shown in the second 46436 lightcurve below.

Acknowledgments

I would like to thank Brian Warner for all of his work with the program *MPO Canopus* and for his efforts in maintaining the "CALL" website.

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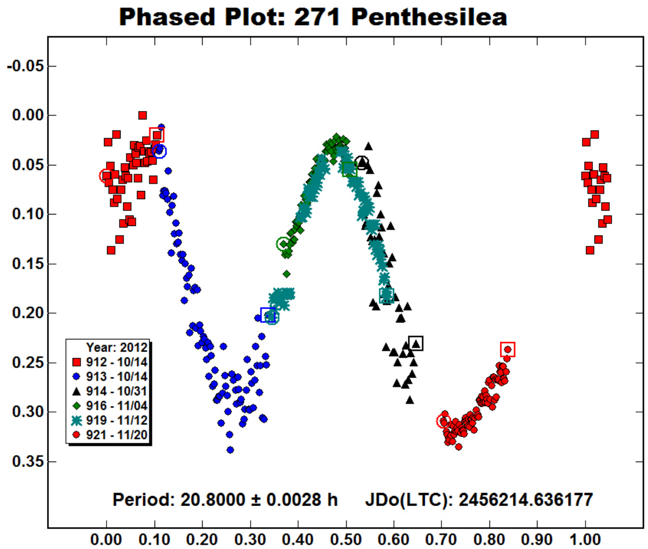
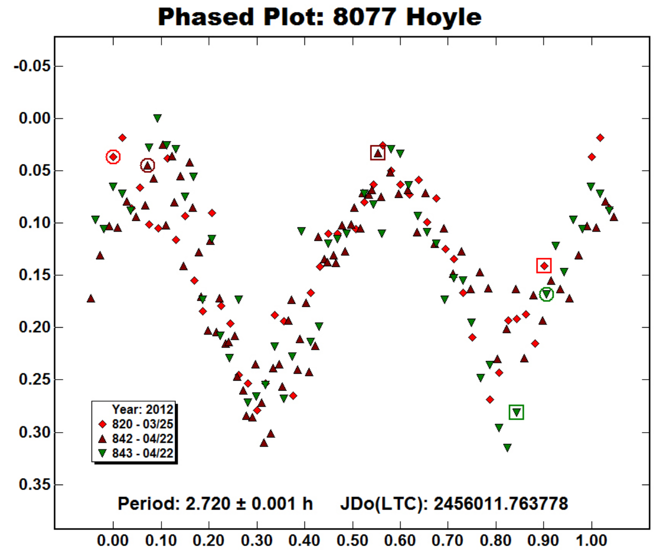
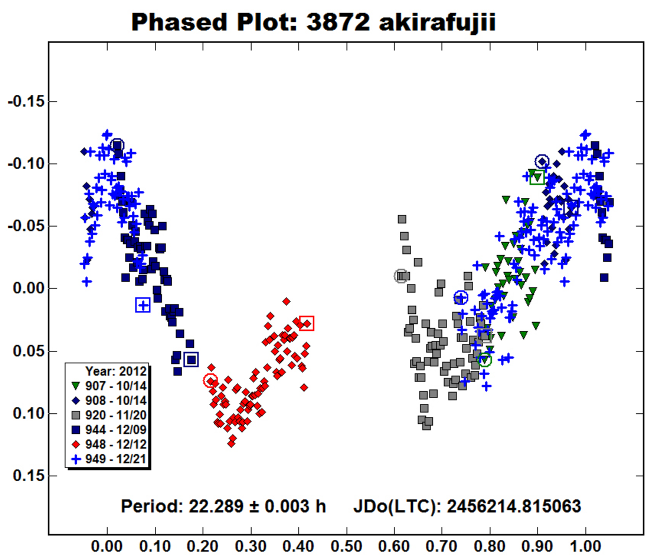
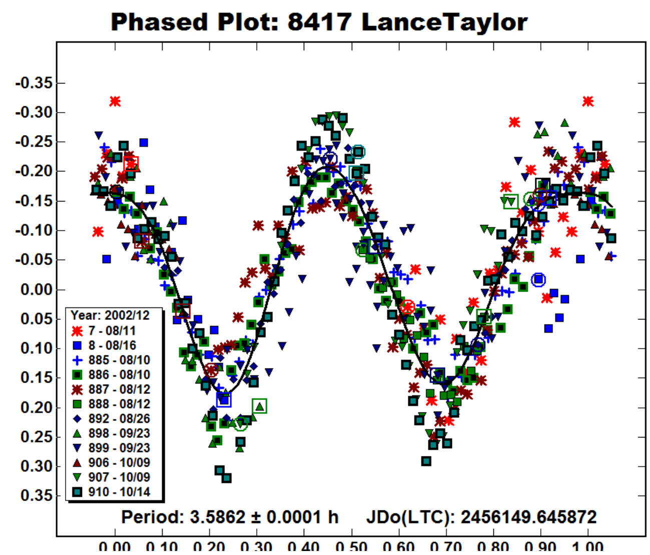
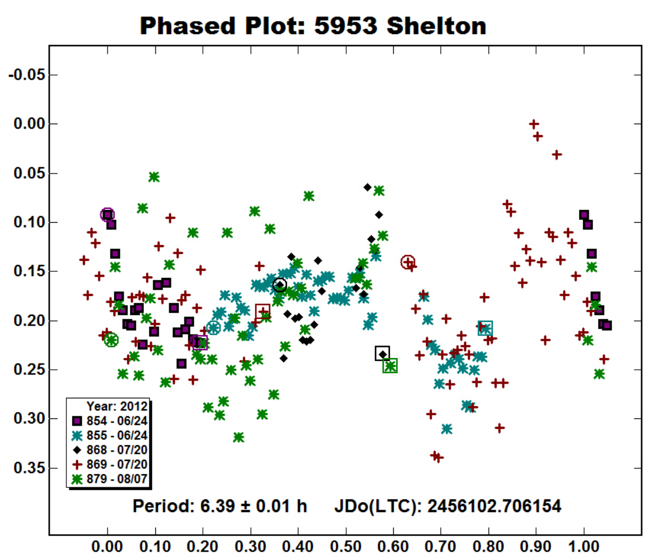
#	Name	Date Range	Sessions	Per (h)	Error (h)	Amplitude	Error
271	Penthesilea	Oct 14, - Nov 20, 2012	5	20.800	0.003	0.32	0.02
3872	Akirafujii	Oct 14, - Dec 2, 2012	5	22.289	0.003	0.23	0.04
5953	Shelton	June 24 - Aug 7, 2012	3	6.39	0.01	0.25	0.1
8077	Hoyle	Mar 24, - Apr 22, 2012	2	2.720	0.001	0.3	0.02
8417	Lancetaylor	Aug 10 - Oct 14, 2012	6	3.5862	0.0001	0.55	0.02
46436	2002 LH5	Sept 10, - Oct 8, 2012	4	3.8832	0.0001	0.65	0.02

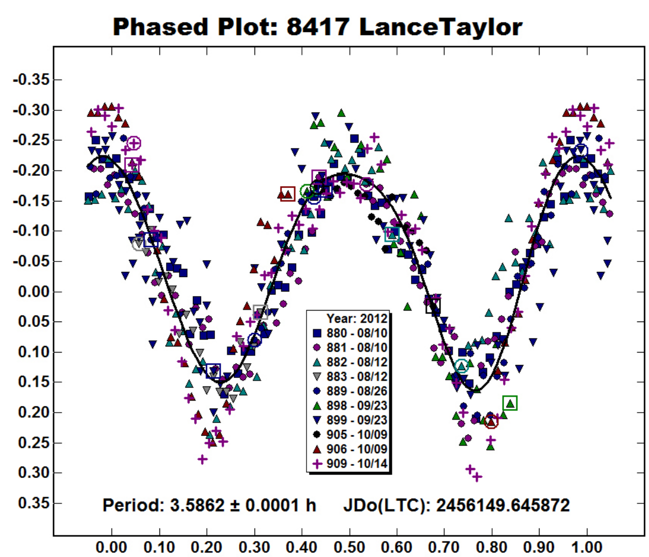

Phased Plot: 271 Penthesilea
Year: 2012
912 - 10/14
913 - 10/14
914 - 10/31
916 - 11/04
919 - 11/12
921 - 11/20
Period: 20.8000 ± 0.0028 h JDo(LTC): 2456214.636177

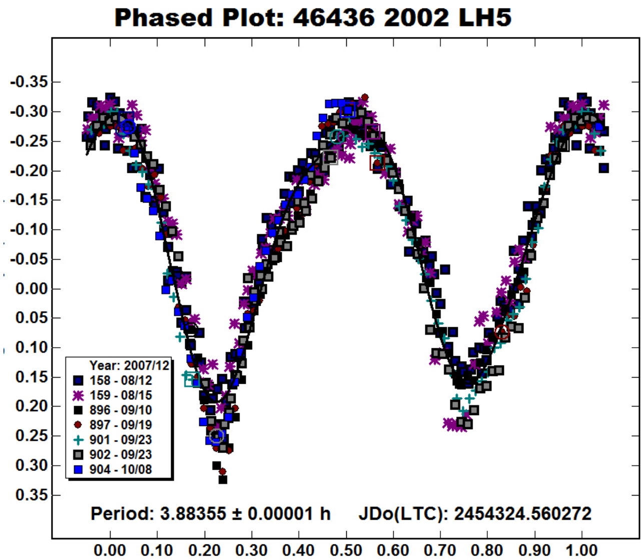

Phased Plot: 8077 Hoyle
Year: 2012
820 - 03/25
842 - 04/22
843 - 04/22
Period: 2.720 ± 0.001 h JDo(LTC): 2456011.763778

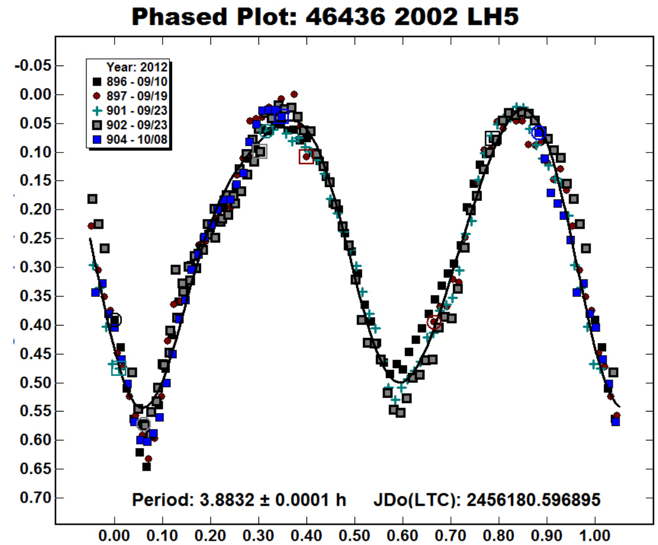

Phased Plot: 3872 akirafujii
Year: 2012
907 - 10/14
908 - 10/14
920 - 11/20
944 - 12/09
948 - 12/12
949 - 12/21
Period: 22.289 ± 0.003 h JDo(LTC): 2456214.815063


Phased Plot: 8417 LanceTaylor
Year: 2002/12
7 - 08/11
8 - 08/16
885 - 08/10
886 - 08/10
887 - 08/12
888 - 08/12
892 - 08/26
898 - 09/23
899 - 09/23
906 - 10/09
907 - 10/09
910 - 10/14
Period: 3.5862 ± 0.0001 h JDo(LTC): 2456149.645872


Phased Plot: 5953 Shelton
Year: 2012
854 - 06/24
855 - 06/24
868 - 07/20
869 - 07/20
879 - 08/07
Period: 6.39 ± 0.01 h JDo(LTC): 2456102.706154


Phased Plot: 8417 LanceTaylor
Year: 2012
880 - 08/10
881 - 08/10
882 - 08/12
883 - 08/12
889 - 08/26
898 - 09/23
899 - 09/23
905 - 10/09
906 - 10/09
909 - 10/14
Period: 3.5862 ± 0.0001 h JDo(LTC): 2456149.645872





ASTEROID LIGHTCURVE ANALYSIS AT ELEPHANT HEAD OBSERVATORY: 2012 NOVEMBER – 2013 APRIL

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Thirteen asteroids were observed from Elephant Head Observatory from 2012 November to 2013 April: the main-belt asteroids 227 Philosophia, 331 Etheridgea, 577 Rhea, 644 Cosima, 850 Altona, 906 Repsolda, 964 Subamara, 973 Aralia, 1016 Anitra, 1024 Hale, 2034 Bernoulli, 2556 Louise, and Jupiter Trojan 3063 Makhaon.

The synodic rotation rates for each of the asteroids reported here were determined from the analysis of CCD photometric observations. Observations were conducted with a 0.25-m Schmidt-Cassegrain Telescope on a German Equatorial Mount (GEM) using an SBIG STT-8300M CCD camera with 5.4 micron pixels binned at 4x4 with an image scale of 1.67 arcsecond per pixel. A clear filter was used for all exposures. Exposures were between 100 and 250 seconds. All images were dark and flat-field corrected. All lightcurve data were submitted to the ALCDEF website.

All images were obtained from an automated image routine using *CCDAutopilot* v5. Imaging and plate solving were done with *Maxim DL* v5 and *TheSkyX* v10. Data were reduced in *MPO Canopus* v10 using differential photometry. Comparison stars were chosen for near-solar color index with the "comp star selector" of *MPO Canopus*. Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.* 1989). These asteroids were reported as lightcurve opportunities in the *Minor Planet Bulletin*.

227 Philosophia. A search for previous period determinations of 227 Philosophia found Bembrick *et al.* (2006; 18.048 h) and Ditteon and Hawkins (2007; no period was found). New observations were obtained over eight nights from 2012 November to 2103 January. Analysis of the data found a period of 17.181 ± 0.001 h, amplitude 0.09 ± 0.02 mag. The newly determined period differs from that of Bembrick *et al.* When the new data were phased to the Bembrick *et al.* period, an RMS error of 2.2025 (units of 0.01 mag) was found compared to an RMS error of 1.8516 for the newly determined period. Both lightcurve periods are plotted below for reference. This low amplitude lightcurve asteroid requires further study.

331 Etheridgea. A search for previous period determinations of 331 Etheridgea found one reported by Warner (1999; 40 h). New observations were obtained over ten nights from 2013 March to April. Analysis of the data found a period of 13.092 ± 0.001 h, amplitude 0.13 ± 0.02 mag.

577 Rhea. Behrend (2007) reported a period of 12.2667 h for this asteroid. New observations were obtained over eight nights from 2013 February to March. Analysis of the data found a period of 12.249 ± 0.001 h, amplitude 0.25 ± 0.02 mag. The newly determined period differs from that of Behrend. When the new data were phased to the Behrend period and the nightly zero points adjusted, an RMS error of 2.2737 was found compared to an RMS error of 1.8765 for the newly determined period. Both lighcurves are plotted below for reference.

644 Cosima. A search for previous period determinations of 644 Cosima found Binzel (1987; 15.13 h). New observations were obtained over eight nights from 2013 January to February. Analysis of the data found a period of 7.556 ± 0.001 h, amplitude 0.23 ± 0.02 mag. The newly determined period differs from that of Binzel. Full phase coverage for the double-period was obtained. When the new data were phased to the double-period, the two halves of the lightcurve appeared similar. A plot of the period spectrum shows that the shorter period has a smaller RMS error. Both lighcurves are plotted below for reference.

850 Altona. A search for previous period determinations of 850 Altona found Pilcher and Benishek (2011; 11.197 h). New

Number	Name	Dates	Points	Period	P.E.	Amp	A.E.
-	-	2012-2013	-	(h)	(h)	(mag)	(mag)
227	Philosophia	11/25, 12/3-4, 8-9, 18, 1/7, 12	715	17.181	0.001	0.09	0.02
331	Etheridgea	03/13-15, 17, 23, 31, 04/01, 03, 04, 06	667	13.092	0.001	0.13	0.02
577	Rhea	2/16-18, 3/2, 7, 11-13	537	12.249	0.001	0.25	0.02
644	Cosima	2/1-2, 6-8, 10, 11, 13	570	7.556	0.001	0.23	0.02
850	Altona	12/10-11, 12/17, 12/20-21, 12/27, 1/1, 1/10	648	11.195	0.001	0.16	0.02
906	Repsolda	1/17-20, 30, 31	540	15.368	0.001	0.24	0.02
964	Subamara	1/6, 1/9, 1/13-14	438	6.868	0.001	0.21	0.02
973	Aralia	12/1-5	289	7.291	0.003	0.17	0.02
1016	Anitra	11/19, 11/22-24	499	5.929	0.001	0.32	0.04
1024	Hale	1/1, 7, 9, 10, 12, 18, 19, 20	360	16.0	0.1	0.14	0.05
2034	Bernoulli	12/11, 12/21, 12/24, 1/2-3, 1/5	644	6.248	0.001	0.20	0.03
2556	Louise	3/15, 17, 4/3-4, 7	304	3.809	0.001	0.36	0.04
3063	Makhaon	1/20-22, 2/10-11, 13, 14, 16	541	8.639	0.001	0.08	0.02

Table I. Observing circumstances and results.

observations were obtained over eight nights in 2012 December and 2013 January. Analysis of the data found a period of 11.195 ± 0.001 h, amplitude 0.16 ± 0.02 mag. The newly determined period is within experimental uncertainty with Pilcher and Benishek.

906 Repsolda. No published period was found for this asteroid. Observations over six nights in 2013 January resulted in a period determination of 15.368 ± 0.001 h, amplitude 0.24 ± 0.02 mag.

964 Subamara. A search for previous period determinations of 964 Subamara found Folbeth *et al*. (2011; 6.864 h). New observations were obtained over four nights in 2013 January. Analysis of the data found a period of 6.868 ± 0.001 h, amplitude 0.21 ± 0.02 mag. The newly determined period is within experimental uncertainty with Folbeth *et al*.

973 Aralia. A search for previous period determinations of 973 Aralia found Stephens (2002; 7.29 h). New observations were obtained over five nights in 2012 December. Analysis of the data found a period of 7.291 ± 0.003 h, amplitude 0.17 ± 0.02 mag. The newly determined period is within experimental uncertainty with Stephens.

1016 Anitra. A search for previous period determinations of 1016 Anitra found Menke (2005; 5.930 h) and Pray *et al.* (2006; 5.928 h). New observations were obtained over four nights in 2012 November and December. Analysis of the data found a period of 5.929 ± 0.001 h, amplitude 0.32 ± 0.04 mag. The newly determined period is within experimental uncertainty with both Menke and Pray *et al*.

1024 Hale. No published period was found for this asteroid. This asteroid proved to be a difficult object due to the low signal-to-noise ratio and its period being a multiple of 8 hours. Observations over eight nights in 2013 January resulted in a period determination of 16.0 ± 0.1 h, amplitude 0.14 ± 0.05 mag.

2034 Bernoulli. No published period was found for this asteroid. Observations over six nights in 2012 December and 2013 January resulted in a period determination of 6.248 ± 0.001 h, amplitude 0.20 ± 0.03 mag.

2556 Louise. No published period was found for this asteroid. Observations obtained over five nights in 2013 March and April resulted in a period determination of 3.809 ± 0.001 h, amplitude 0.36 ± 0.04 mag.

3063 Makhaon. A search for previous period determinations of 3063 Makhaon found French *et al.* (2011; 8.64 h). New observations were obtained over eight nights in 2013 January and February. Analysis of the data found a period of 8.639 ± 0.001 h, amplitude 0.08 ± 0.02 mag. The newly determined period is within experimental uncertainty of French *et al*.

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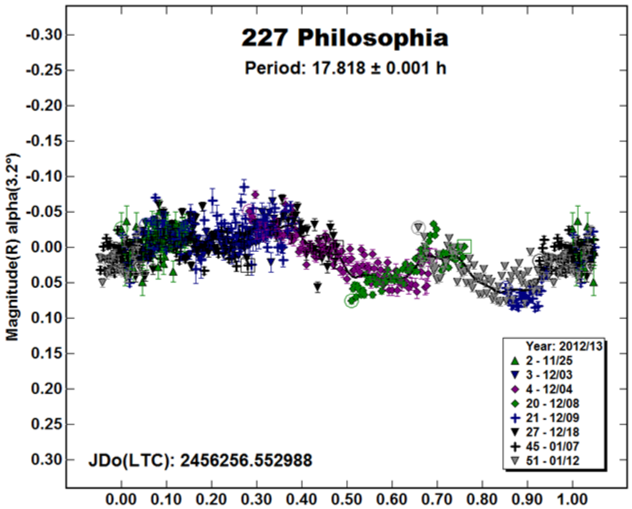
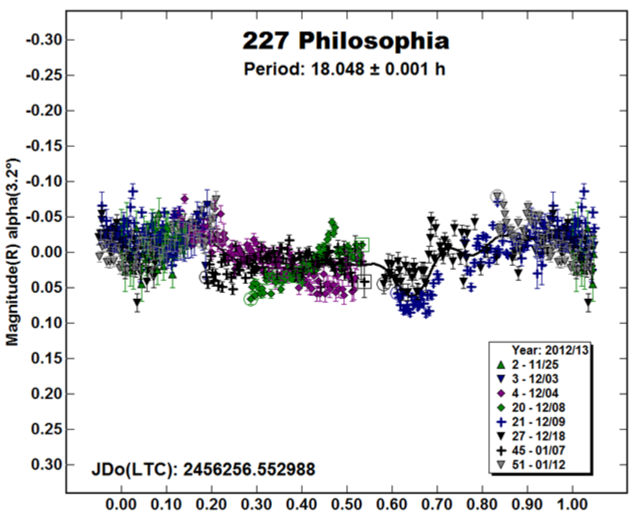
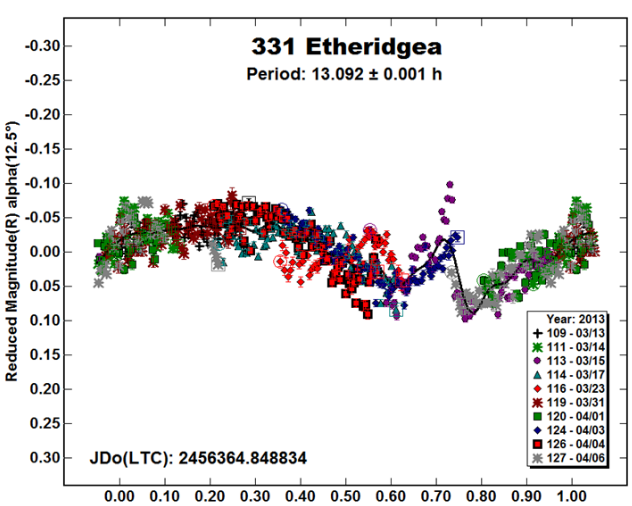
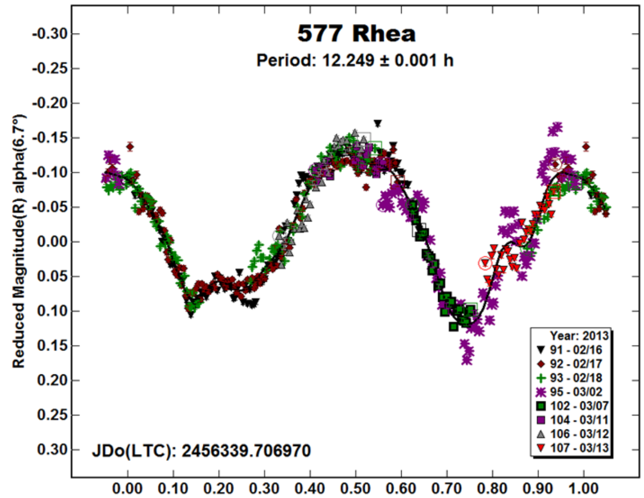
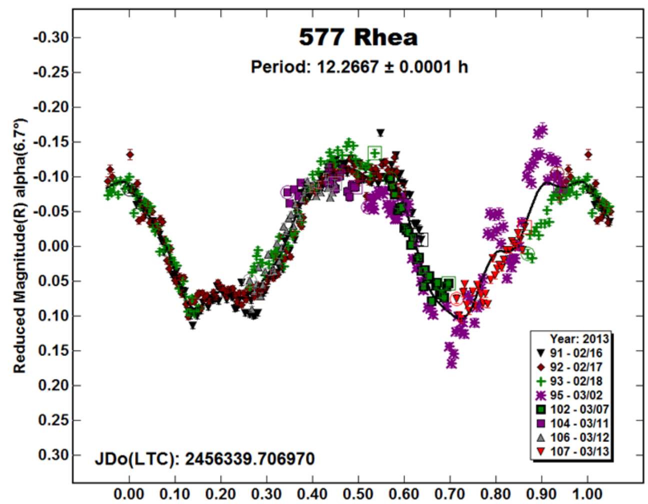
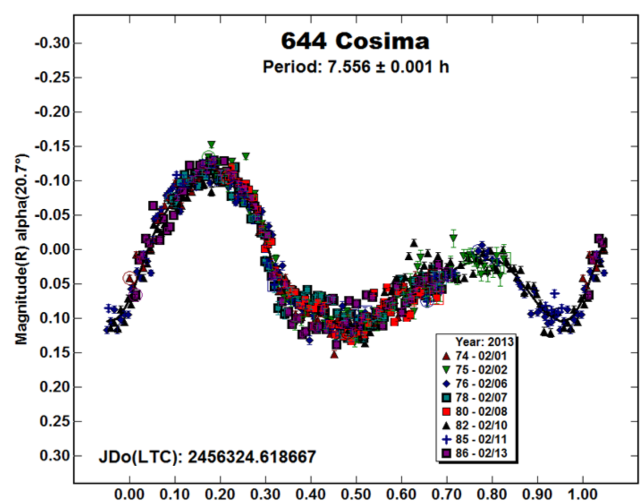


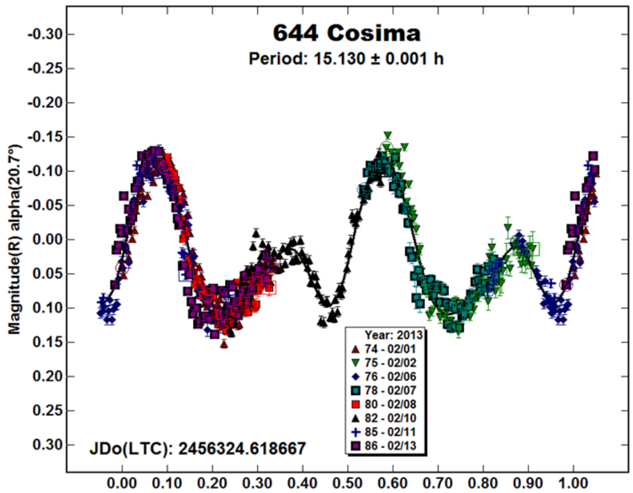


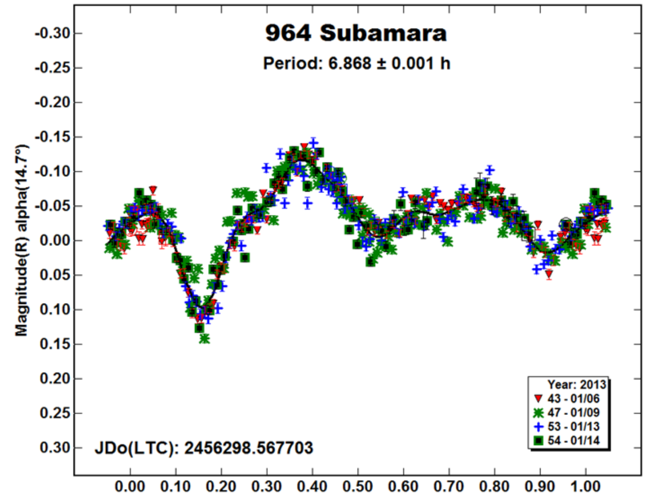


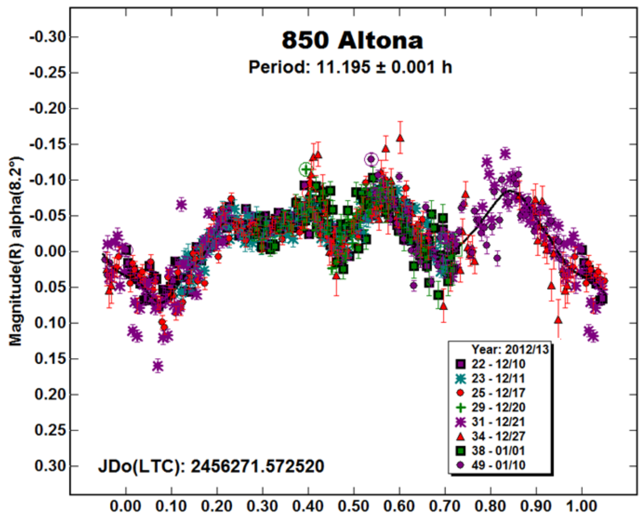


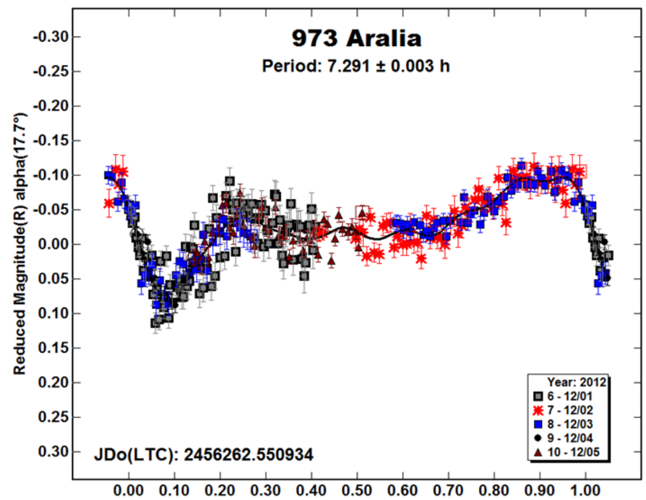


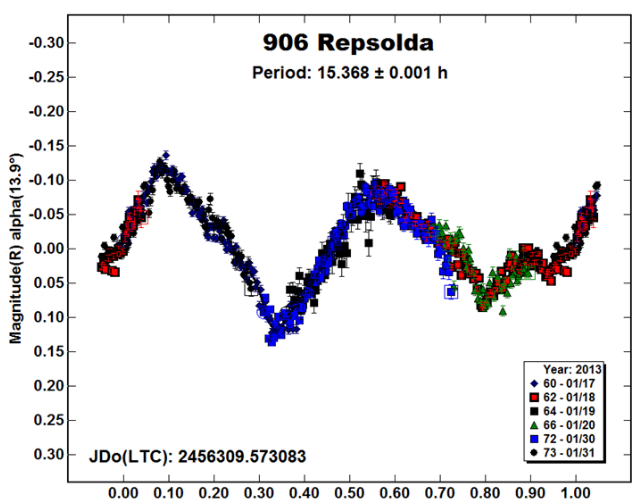


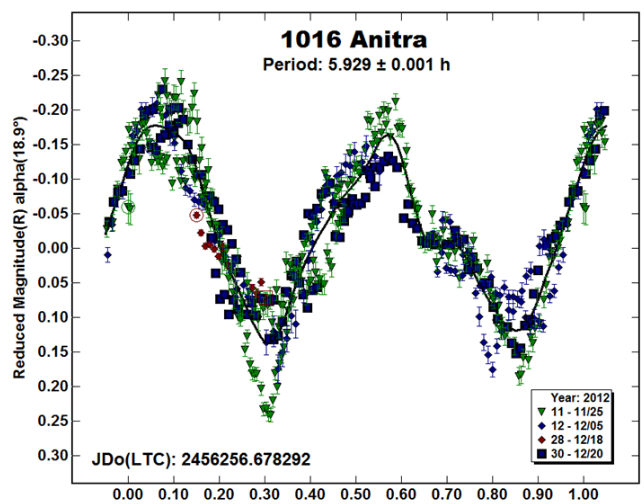

644 Cosima
Period: 15.130 ± 0.001 h
Magnitude(R) alpha(20.7°)
Year: 2013
74 - 02/01
75 - 02/02
76 - 02/06
78 - 02/07
80 - 02/08
82 - 02/10
85 - 02/11
86 - 02/13
JDo(LTC): 2456324.618667


964 Subamara
Period: 6.868 ± 0.001 h
Magnitude(R) alpha(14.7°)
Year: 2013
43 - 01/06
47 - 01/09
53 - 01/13
54 - 01/14
JDo(LTC): 2456298.567703


850 Altona
Period: 11.195 ± 0.001 h
Magnitude(R) alpha(8.2°)
Year: 2012/13
22 - 12/10
23 - 12/11
25 - 12/17
29 - 12/20
31 - 12/21
34 - 12/27
38 - 01/01
49 - 01/10
JDo(LTC): 2456271.572520


973 Aralia
Period: 7.291 ± 0.003 h
Reduced Magnitude(R) alpha(17.7°)
Year: 2012
6 - 12/01
7 - 12/02
8 - 12/03
9 - 12/04
10 - 12/05
JDo(LTC): 2456262.550934


906 Repsolda
Period: 15.368 ± 0.001 h
Magnitude(R) alpha(13.9°)
Year: 2013
60 - 01/17
62 - 01/18
64 - 01/19
66 - 01/20
72 - 01/30
73 - 01/31
JDo(LTC): 2456309.573083


1016 Anitra
Period: 5.929 ± 0.001 h
Reduced Magnitude(R) alpha(18.9°)
Year: 2012
11 - 11/25
12 - 12/05
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30 - 12/20
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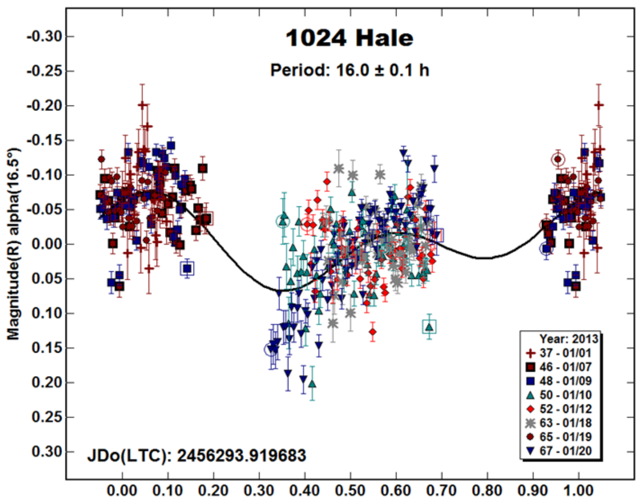

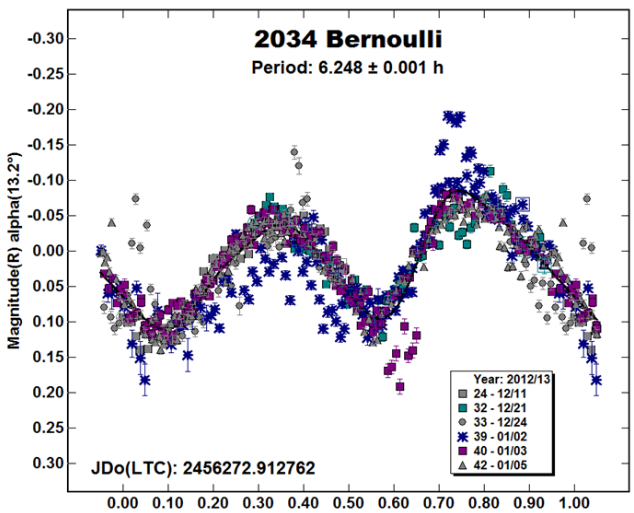

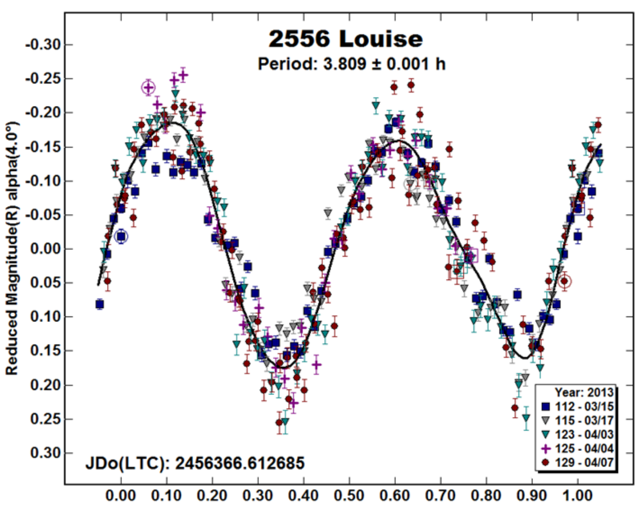

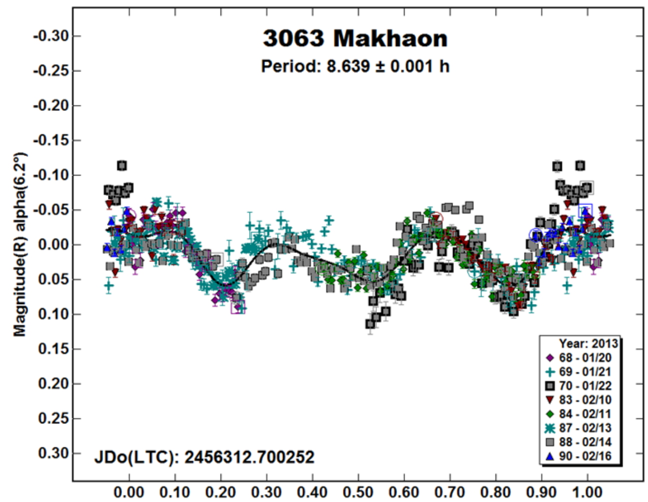

ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2013 JANUARY – MARCH

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Lightcurves for 41 asteroids were obtained at the Palmer Divide Observatory (PDO) from 2013 January through March: 785 Zwetana, 1509 Esclangona, 1599 Giomus, 1925 Franklin-Adams, 2048 Dwornik, 2491 Tvashtri, 3007 Reaves, 3720 Hokkaido, 4719 Burnaby, 4736 Johnwood, 5841 Stone, (6394) 1990 QM2, (8825) 1988 MF, 9231 Shimaken, 9387 Tweedledee, (11405) 1999 CV3, 11437 Cardalda, 16669 Rionuevo, (18486) 1996 AS2, (27713) 1989 AA, 28126 Nydegger, (29242) 1992 HB4, (29298) 1993 SA14, (29308) 1993 UF1, (31354) 1998 TR3, (32750) 1981 EG9, (32772) 1986 JL, (35340) 1997 GV18, (41044) 1999 VW6, (56318) 1999 UR3, (66092) 1998 SD, (68537) 2001 VC123, (75648) 2000 AW59, (99008) 2001 DU52, (125738) 2001 XE116, (135486) 2001 XP2, (137199) 1999 KX4, (154347) 2002 XK4, (343098) 2009 DV42, (349068) 2006 YT13, and 2013 BE19. The 2013 results for 9387 Tweedledee lead to a revised analysis of the data from 2006 for that asteroid and resolved the ambiguous solution reported at that time.

CCD photometric observations of 41 asteroids were made at the Palmer Divide Observatory (PDO) from 2013 January to March. See the introduction in Warner (2010c) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling. The "Reduced Magnitude" in the plots is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using

Number	Name	2013 (mm/dd)	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
785	Zwetana	03/02-03/07	603	10.9,11.9	156	18	8.885	0.001	0.18	0.01
1509	Esclangona (H)	01/17-01/18	191	6.7,6.8	119	-9	3.252	0.005	0.11	0.01
1599	Giomus	02/02-02/08	401	3.7,5.4	127	7	29.1	0.5	0.04	0.01
1925	Franklin-Adams	01/04-01/05	172	6.2,6.7	91	-3	2.978	0.002	0.25	0.02
2048	Dwornik (H)	01/22-02/02	176	17.0,19.5	107	-24	3.717	0.001	0.04	0.01
2491	Tvashtri (H)	03/02-03/07	141	25.8,24.4	169	18	4.084	0.001	0.08	0.01
3007	Reaves	12/29-01/03*	127	12.3,14.2	71	2	4.160	0.002	0.45	0.02
3720	Hokkaido	12/29-01/03*	183	9.3,11.3	79	8	4.79	0.01	0.20	0.02
4719	Burnaby	12/21-12/23*	236	6.4,7.0	83	10	13.01	0.03	0.07	0.01
4736	Johnwood (H)	01/06-01/08	223	11.2,10.6	109	14	6.217	0.005	0.91	0.02
5841	Stone (H)	02/16-03/07	279	7.9,1.6,5.0	159	3	2.8896	0.0006	0.04	0.01
6394	1990 QM2 (H)	01/23-02/02	132	20.9,23.0	99	-26	3.6888	0.0004	0.30	0.02
8825	1988 MF (H)	01/23-02/09	610	19.6,16.5	146	21	40.651	0.009	0.95	0.02
9231	Shimaken	02/13-02/19	233	4.2,1.4	152	2	10.917	0.005	0.55	0.02
9387	Tweedledee (H)	02/12-02/19	232	5.7,1.1	152	1	3.535	0.002	0.09	0.01
9387	Tweedledee (H)	09/16-09/19^	157	13.9,13.5	3	15	3.543	0.002	0.10	0.01
11405	1999 CV3 (N)	01/19-01/22	167	18.2,19.3	108	-19	6.504	0.002	0.72	0.02
11437	Cardalda (H)	12/29-01/01*	112	26.1,26.3	90	35	2.926	0.002	0.31	0.02
16669	Rionuevo (H)	02/03-02/05	240	20.4	139	33	4.953	0.001	0.53	0.02
18486	1996 AS2	03/02	56	1.4	159	2	3.62	0.05	0.34	0.02
27713	1989 AA (H)	12/29-01/01*	122	16.4,18.0	73	1	3.999	0.002	0.82	0.03
28126	Nydegger	02/09-02/13	206	2.2,3.0	141	-4	3.783	0.005	0.11	0.02
29242	1992 HB4 (H)	01/17-01/18	111	21.6,21.8	96	-29	3.947	0.005	0.56	0.02
29298	1993 SA14 (H)	01/05-01/12	183	25.6,27.0	81	29	7.795	0.003	0.20	0.02
29308	1993 UF1 (H)	01/02-01/04	353	17.1,17.2	103	28	9.805	0.004	0.83	0.02
31354	1998 TR3 (H)	01/23-02/09	469	19.0,16.4	143	29	35.36	0.03	0.18	0.02
32750	1981 EG9	02/12-02/13	121	2.3,2.6	140	-5	100	30	>0.6	
32772	1986 JL (H)	12/22-12/29*	209	13.7,14.6	95	19	6.047	0.005	0.69	0.02
35340	1997 VO18	01/05-01/12	192	7.9,10.5	87	-5	12.519	0.005	0.84	0.02
41044	1999 VW6	02/13-02/17	164	2.2,3.5	141	-4	2.734	0.001	0.21	0.02
56318	1999 UR3 (H)	01/04-01/05	142	10.7,11.4	91	5	3.541	0.002	0.36	0.02
66092	1998 SD (H)	02/09-03/07	569	2.4,16.7	141	-6	448	5	0.42	0.05
68537	2001 VC123 (H)	02/08-02/13	171	9.7,12.5	131	-10	2.997	0.001	0.16	0.02
75648	2000 AW59	02/12-02/13	100	2.4,2.7	141	-4	4.09	0.05	0.13	0.03
99008	2001 DU52	02/02-02/13	367	5.4,10.5	125	6	37.45	0.10	0.47	0.05
125738	2001 XE116	03/02	52	2.0	159	2	4.09	0.08	0.19	0.02
135486	2001 XP2 (H)	01/17-02/01	143	14.0,20.0	101	12	69	5	1.2	0.1
137199	1999 KX4 (N)	01/05-01/08	257	35.5,35.7	132	8	2.767	0.001	0.12	0.01
154347	2002 XK4 (N)	01/02-01/04	299	36.7,33.9	119	27	3.319	0.003	0.08	0.01
343098	2009 DV42 (N)	01/09-01/19	301	14.7,8.3	111	-5	9.658	0.006	0.06	0.01
349068	2006 YT13 (N)	01/19-01/21	308	8.6,13.9	118	8	2.433	0.001	0.11	0.01
	2013 BE19 (N)	01/21-01/23	304	41.0,36.5	138	17	115	10	0.40	0.05

*2012 December for first (and second) date ^2006

Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. Asteroids with (N) after the name are near-Earth asteroids (q < 1.3 AU). 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).

G = 0.15, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0.

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

785 Zwetana. This 50 km Eunomia asteroid was observed to support radar observations being carried out about the same time. The period of 8.888 h had been previously determined by Behrend (2005) and Shepard *et al*. (2008). Analysis of the 2013 data from PDO found the same result within error bars.

1509 Esclangona. This is a known binary asteroid (Merline 2003). Warner (2005) and Polishook (2009) reported a period for the primary of about 3.252 h. The 2013 PDO results are consistent with those. Warner *et al.* (2010b) reported a secondary period of P = 6.6422 h with A = 0.04 mag but no evidence of mutual events (occultations and/or eclipses). It's believed that the secondary period is due to the rotation of a satellite. Given the size and distance from the primary, the chances of observing mutual events are considered very unlikely. No evidence of the secondary period was seen in the 2013 data analysis.

1599 Giomus. This asteroid was observed to see if it would be possible to confirm one of two previously reported periods: 6.46 h (Clark 2010) and > 7.3 h (Garlitz 2013). Unfortunately, the low amplitude of 0.04 mag made finding a unique solution difficult, if not impossible. The period of 29.1 h reported here should not be given much weight.

1925 Franklin-Adams. This was a *target of opportunity*, i.e., an asteroid in the same field as a planned target. Behrend (2005) reported a period of 3.082 h. The PDO data analysis found a period of 2.978 h. The PDO data could not be fit to the slightly longer period.

2048 Dwornik. Schevchenko (2003), Warner (2011), and Skiff (2011) all reported a period of about 3.67 h for this Hungaria asteroid. The amplitude in 2013 was too low (0.04 mag) to find a definitive solution. The lightcurve presented here was forced to a period near the earlier results with a best fit of 3.717 h.

2491 Tvashtri. This Hungaria asteroid was observed by the author in 2008 (Warner 2008). A period of 4.0839 h was reported at that time. The results from the 2013 data analysis are in good agreement.

3007 Reaves. Pravec *et al.* (2013) found a period of 4.15554 h using data from 2007. Within error bars, the 2013 PDO results are the same.

3720 Hokkaido. This was a *target of opportunity* from the Flora group that managed to stay in the planned target field for an extended time. No previously reported period was found.

4719 Burnaby. Behrend (2009) reported a period of 8.2 h. Using the 2103 PDO data, there is a weak solution near this but the more dominant solution is at 13.01 h.

4736 Johnwood. This was the third time this Hungaria was observed at PDO (Warner 2005, 2010). All three results were consistent with one another, as were those from Behrend *et al.* (2012) who observed the asteroid in late 2012.

5841 Stone. The 2013 PDO data analysis found multiple solutions, all very weak and due to the low amplitude (0.04 mag). The solution presented here was the best fit to one near to previous results from PDO (Warner 2007a, 2010a) when the amplitude was larger and the solutions unambiguous.

(6394) 1990 QM2. The 2013 observations were follow-up to work at PDO on two previous occasions (Warner 2008, 2011). The period from 2008 was 3.768 h while in 2011 the period was found to be 3.6873 h. The 2013 results agree with the shorter period. The discrepancy is likely explained by the fact that the 2008 data set consisted of only two nights separated by 7 days. This produced a large number of alias solutions, one being near 3.68 h.

9387 Tweedledee. Warner (2007) reported an ambiguous solution of 7.05 h with the alternate being 3.54 h, it not being certain if a bimodal (longer period) or monomodal (shorter period) solution was correct. Analysis of the data from 2013 found a period of 3.535 h with a curve that was sufficiently asymmetric so as to make the double-period of about 7 h very unlikely. In that light, the data from 2007 were re-analyzed and found to give a good fit to a period of 3.543 h with an amplitude of 0.10 mag (instead of 0.15 mag as originally reported). Lightcurves for both years based on the 3.5 h solutions are presented here.

(11405) 1999 CV3. Pravec *et al.* (2013) reported a period of 6.5113 h for this near-Earth asteroid (NEA) based on data obtained in 1999. The analysis of the 2013 PDO data found a period of 6.504 h, in good agreement with the earlier results.

(11437) Cardalda. This was the first time that a period for this Hungaria had been obtained at PDO or, apparently, anywhere else.

16669 Rionuevo. Analysis of the 2013 PDO data found a period of 4.953 h, in very good agreement with earlier results from PDO (Warner 2010a).

(18486) 1996 AS2. This was a *target of opportunity*. Galad (2008) reported an ambiguous period of 3.89 h with one of 3.59 h being possible. The results from PDO 2013 data analysis found 3.62 h based only one night but with coverage over more than one rotation. All indications are that the 3.89 h solution is incorrect and that one near 3.6 is more likely.

(29242) 1992 HB4. Earlier results for the period of this Hungaria (Warner 2010, 2011) and those from 2013 are in good agreement with one another.

(29308) 1993 UF1. The period of 9.810 h (Warner 2010a) was confirmed by the analysis of the PDO data from 2013.

(31354) 1998 TR3. Warner (2007b) found a period of 35.39 h for this Hungaria. Within error bars, the results from 2013 were the same.

(32750) 1981 EG9. This *target of opportunity* is a main-belt asteroid with no previously reported period. The best that could be determined is that the period is long, likely on the order of four or more days.

(32772) 1986 JL. This is the first time this Hungaria was worked at PDO. The WISE survey (Mainzer *et al.* 2011) report an albedo of $p_V = 0.1385$. This would mean the asteroid is not a member of the Hungaria *family*, whose members have albedos on the order of $p_V = 0.4$.

(66092) 1998 SD. Long breaks due to weather prevented obtaining a more detailed lightcurve. A half-period solution of 223 h is shown, which gives a better indication of the period than the full-period plot at 448 h. It’s possible that the asteroid might be tumbling, but a much more extensive data set of well-calibrated data would be required to confirm that hypothesis.

(68537) 2001 VC123. There were no previous results found. The period and amplitude of the lightcurve make this a good candidate for being a binary. It should be given priority at future apparitions.

(75648) 2000 AW59. This member of the Eunomia group was a *target of opportunity*.

(99008) 2001 DU52. This *target of opportunity* is an inner main-belt asteroid with an estimated effective diameter of 2.5 km.

(125738) 2001 XE116. A member of the Flora group, this was also a *target of opportunity*.

(135486) 2001 XP2. The period of 69 h is a reasonable estimate because of the large amplitude and bimodal lightcurve. This is a Hungaria and, based on a high albedo from WISE (Mainzer *et al.* 2011), likely a *family* member.

(137199) 1999 KX4, (154347) 2002 XK4, (343098) 2009 DV42, (349068) 2006 YT13, and 2013 BE19. These are all near-Earth asteroids. The PDO observing program has been giving some preference to these objects as the need grows for finding the physical characteristics of the group, rotation rates being among the most readily determined traits. None of these had previously reported periods. 2013 BE19 is listed by the Minor Planet Center as a Potentially Hazardous Asteroid (PHA) although the JPL close approach tables do not show it among those with close approaches through 2200.

Acknowledgements

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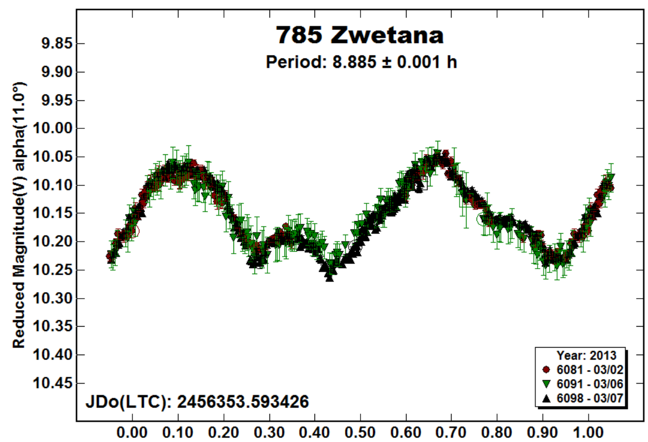

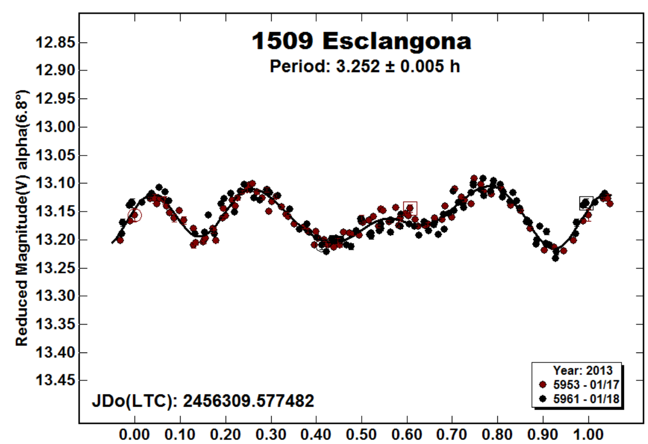

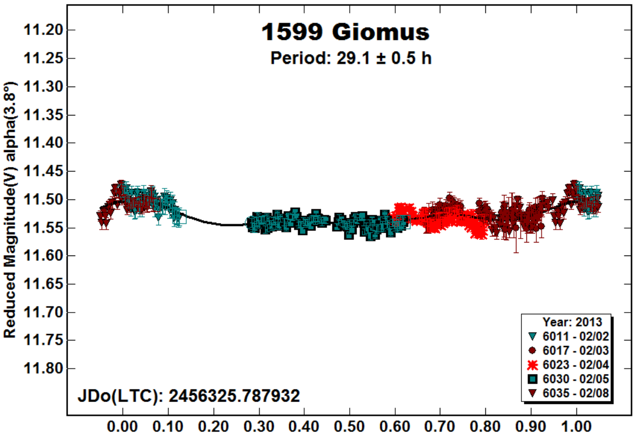
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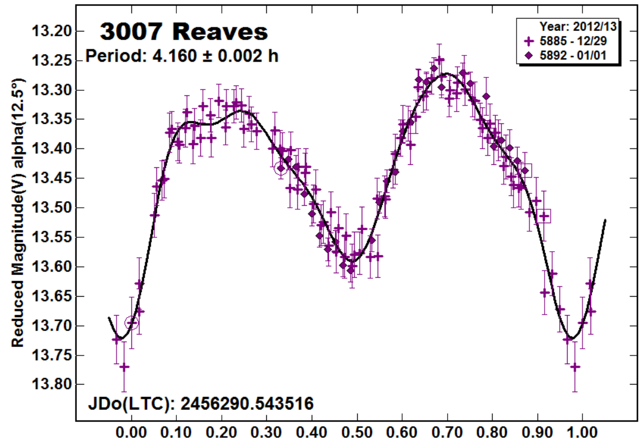
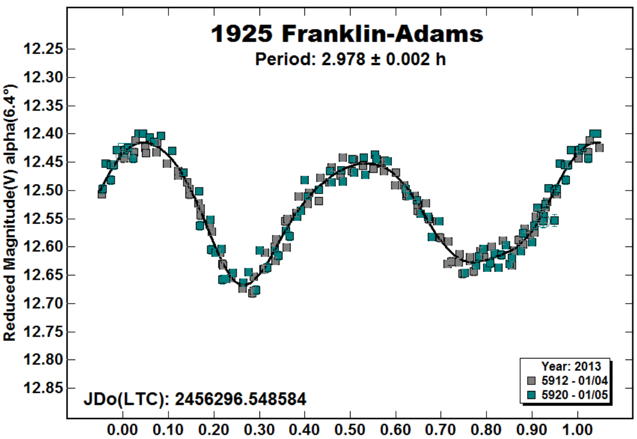
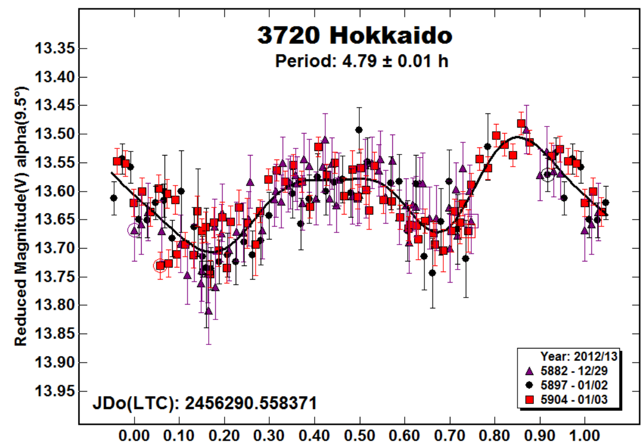
Period: 29.1 ± 0.5 h
Reduced Magnitude(V) alpha(3.8°)
Year: 2013
6011 - 02/02
6017 - 02/03
6023 - 02/04
6030 - 02/05
6035 - 02/08
JDo(LTC): 2456325.787932


3007 Reaves
Period: 4.160 ± 0.002 h
Reduced Magnitude(V) alpha(12.5°)
Year: 2012/13
5885 - 12/29
5892 - 01/01
JDo(LTC): 2456290.543516


1925 Franklin-Adams
Period: 2.978 ± 0.002 h
Reduced Magnitude(V) alpha(6.4°)
Year: 2013
5912 - 01/04
5920 - 01/05
JDo(LTC): 2456296.548584


3720 Hokkaido
Period: 4.79 ± 0.01 h
Reduced Magnitude(V) alpha(9.5°)
Year: 2012/13
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5897 - 01/02
5904 - 01/03
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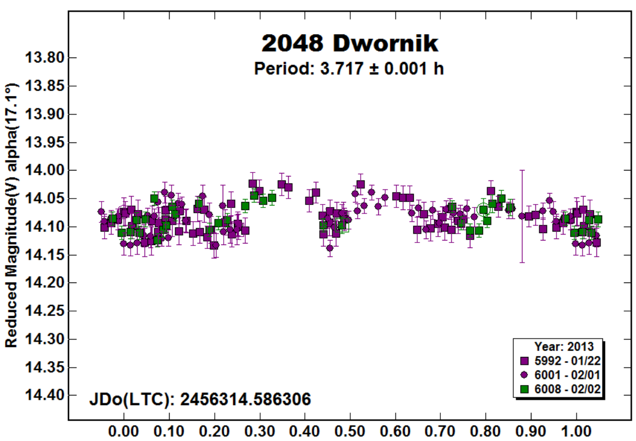
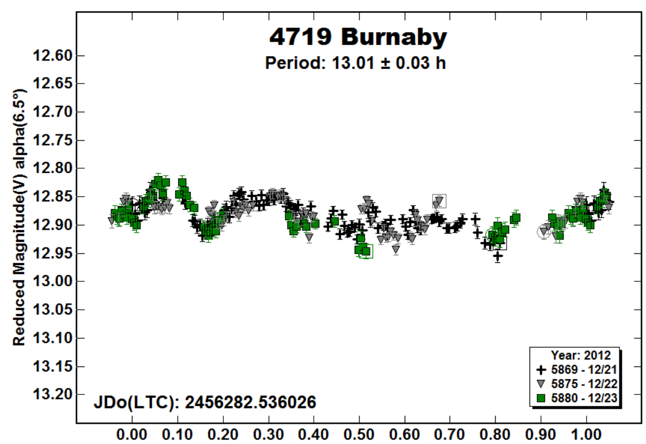
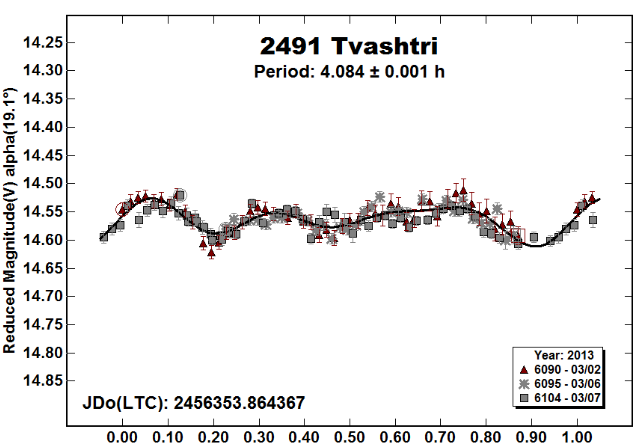
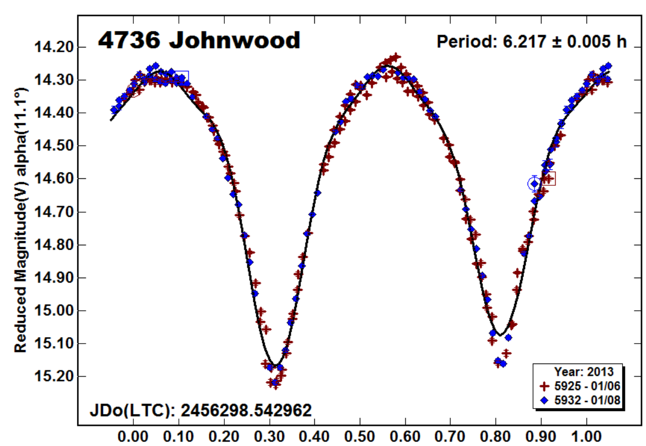
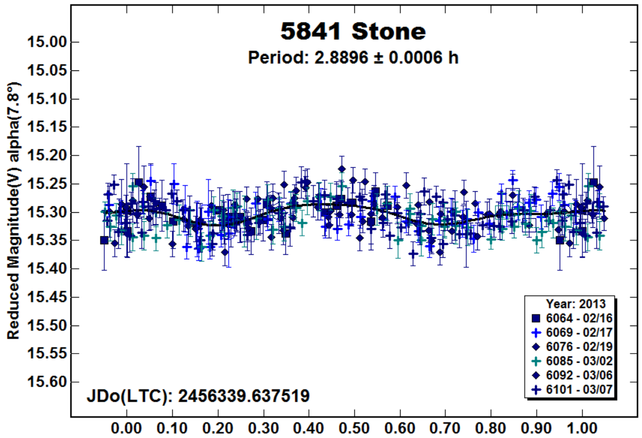

2048 Dwornik
Period: 3.717 ± 0.001 h
Reduced Magnitude(V) alpha(17.1°)
Year: 2013
5992 - 01/22
6001 - 02/01
6008 - 02/02
JDo(LTC): 2456314.586306


4719 Burnaby
Period: 13.01 ± 0.03 h
Reduced Magnitude(V) alpha(6.5°)
Year: 2012
5869 - 12/21
5875 - 12/22
5880 - 12/23
JDo(LTC): 2456282.536026


2491 Tvashtri
Period: 4.084 ± 0.001 h
Reduced Magnitude(V) alpha(19.1°)
Year: 2013
6090 - 03/02
6095 - 03/06
6104 - 03/07
JDo(LTC): 2456353.864367


4736 Johnwood
Period: 6.217 ± 0.005 h
Reduced Magnitude(V) alpha(11.1°)
Year: 2013
5925 - 01/06
5932 - 01/08
JDo(LTC): 2456298.542962


5841 Stone
Period: 2.8896 ± 0.0006 h
Reduced Magnitude(V) alpha(7.8°)
Year: 2013
6064 - 02/16
6069 - 02/17
6076 - 02/19
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6092 - 03/06
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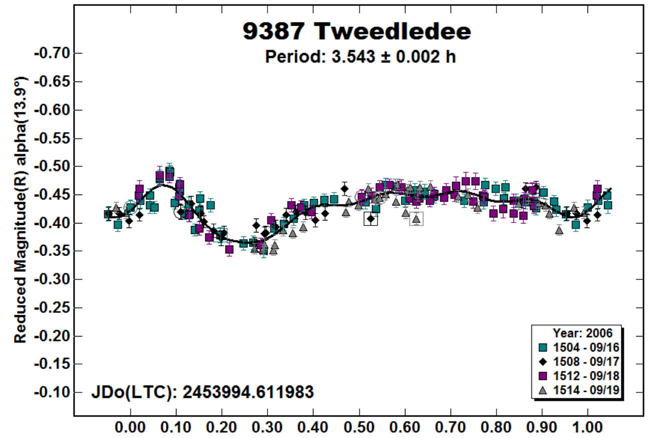
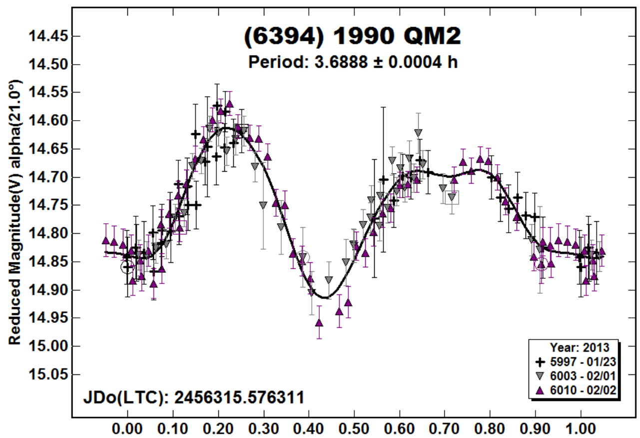
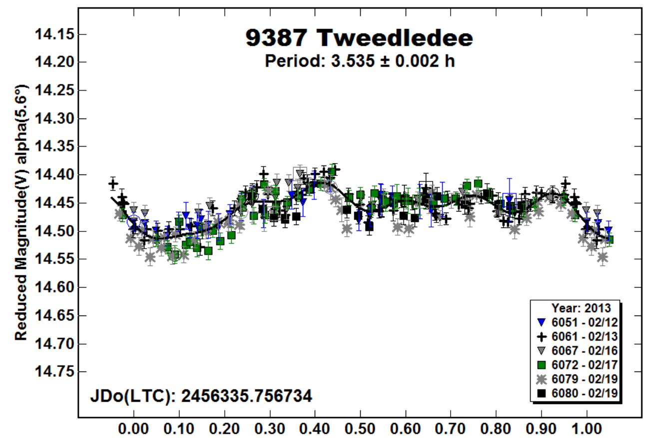
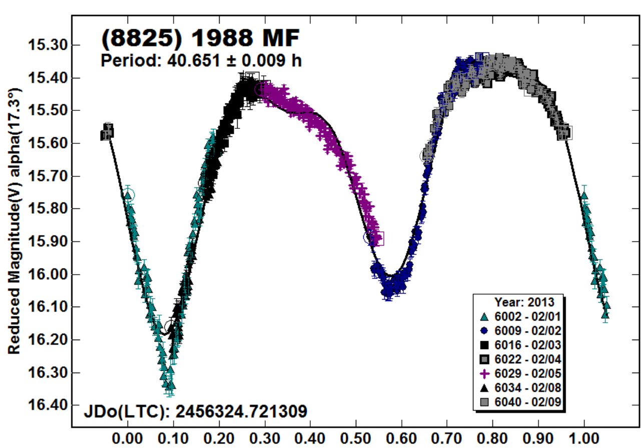
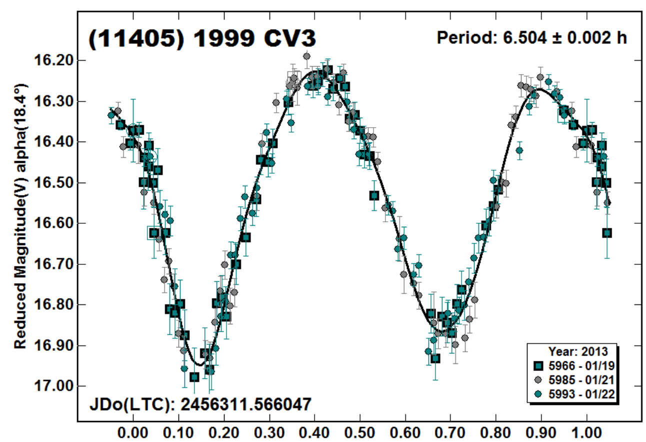
JDo(LTC): 2456339.637519

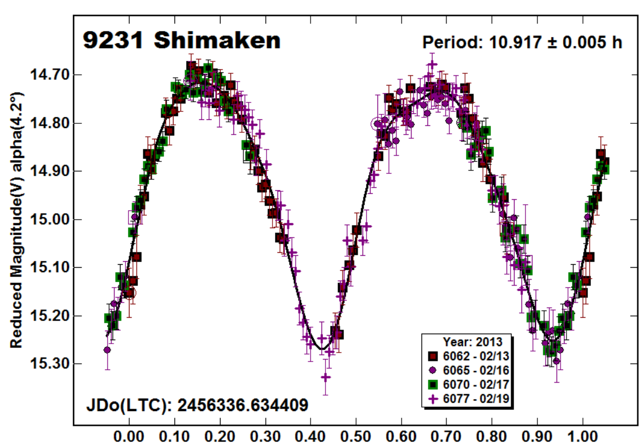

9387 Tweedledee
Period: 3.543 ± 0.002 h
Reduced Magnitude(R) alpha(13.9°)
Year: 2006
1504 - 09/16
1508 - 09/17
1512 - 09/18
1514 - 09/19
JDo(LTC): 2453994.611983

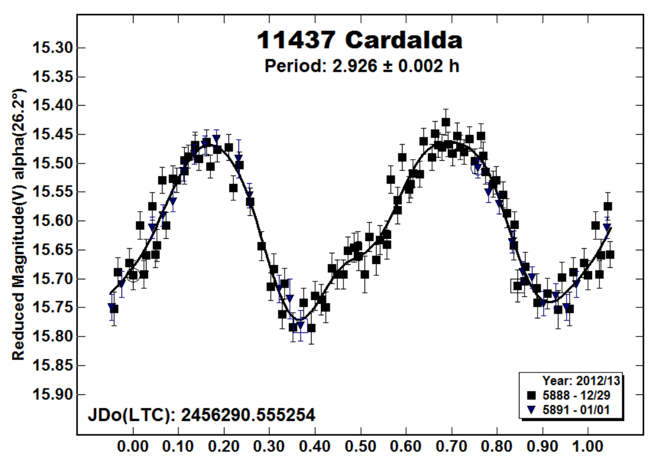

(6394) 1990 QM2
Period: 3.6888 ± 0.0004 h
Reduced Magnitude(V) alpha(21.0°)
Year: 2013
5997 - 01/23
6003 - 02/01
6010 - 02/02
JDo(LTC): 2456315.576311

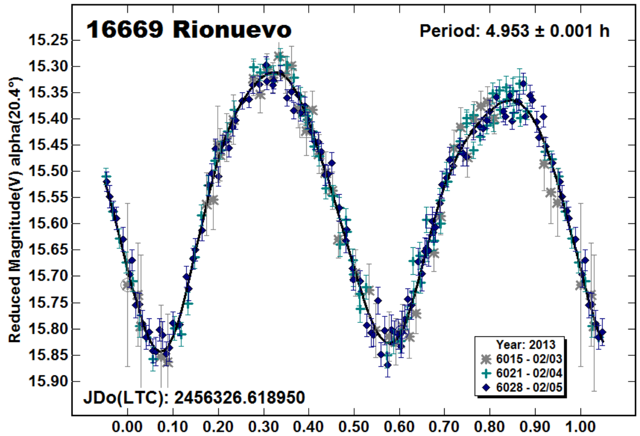

9387 Tweedledee
Period: 3.535 ± 0.002 h
Reduced Magnitude(V) alpha(5.6°)
Year: 2013
6051 - 02/12
6061 - 02/13
6067 - 02/16
6072 - 02/17
6079 - 02/19
6080 - 02/19
JDo(LTC): 2456335.756734

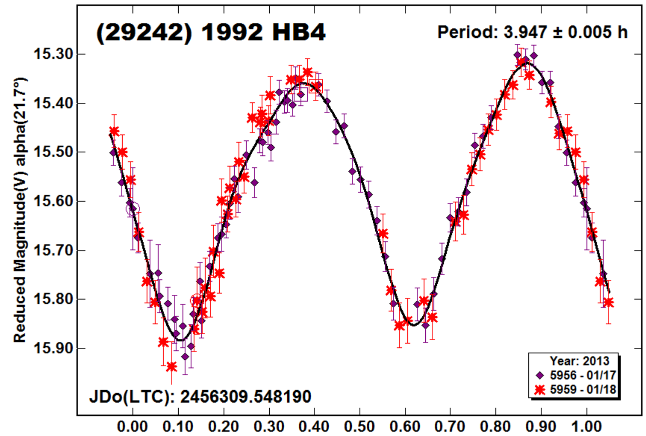

(8825) 1988 MF
Period: 40.651 ± 0.009 h
Reduced Magnitude(V) alpha(17.3°)
Year: 2013
6002 - 02/01
6009 - 02/02
6016 - 02/03
6022 - 02/04
6029 - 02/05
6034 - 02/08
6040 - 02/09
JDo(LTC): 2456324.721309

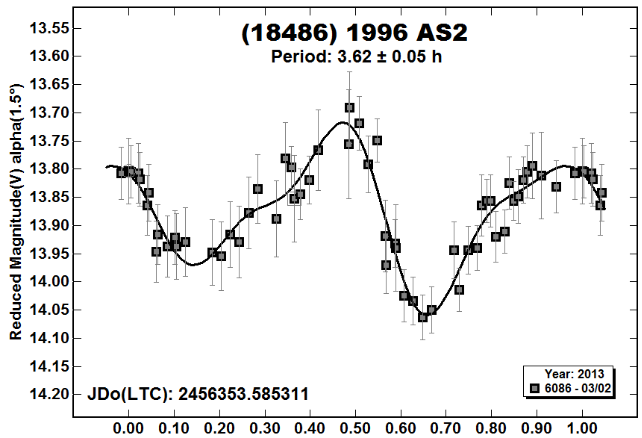

(11405) 1999 CV3
Period: 6.504 ± 0.002 h
Reduced Magnitude(V) alpha(18.4°)
Year: 2013
5966 - 01/19
5985 - 01/21
5993 - 01/22
JDo(LTC): 2456311.566047

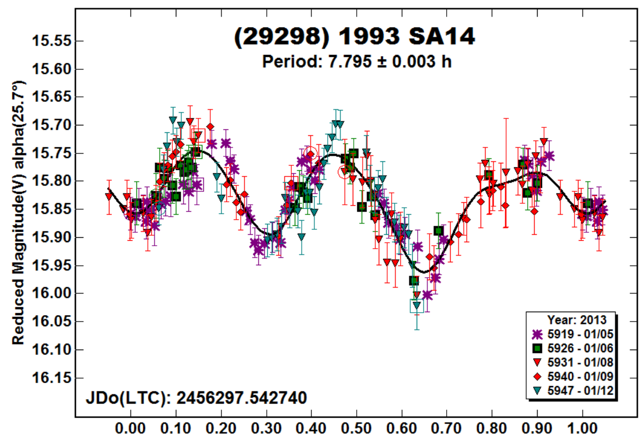

9231 Shimaken
Period: 10.917 ± 0.005 h
Reduced Magnitude(V) alpha(4.2°)
Year: 2013
6062 - 02/13
6065 - 02/16
6070 - 02/17
6077 - 02/19
JDo(LTC): 2456336.634409

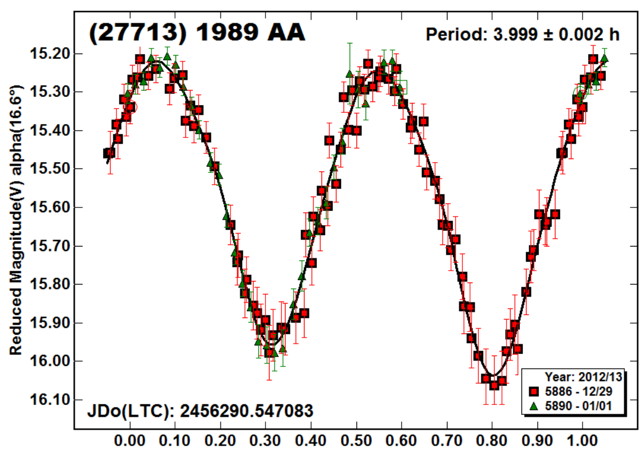

11437 Cardalda
Period: 2.926 ± 0.002 h
Reduced Magnitude(V) alpha(26.2°)
Year: 2012/13
5888 - 12/29
5891 - 01/01
JDo(LTC): 2456290.555254

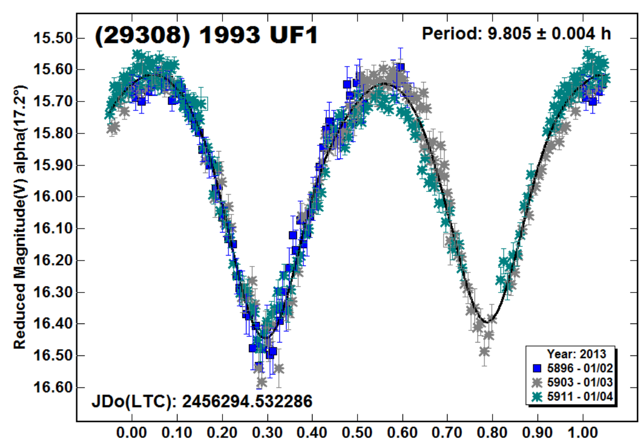

16669 Rionuevo
Period: 4.953 ± 0.001 h
Reduced Magnitude(V) alpha(20.4°)
JDo(LTC): 2456326.618950
Year: 2013
6015 - 02/03
6021 - 02/04
6028 - 02/05

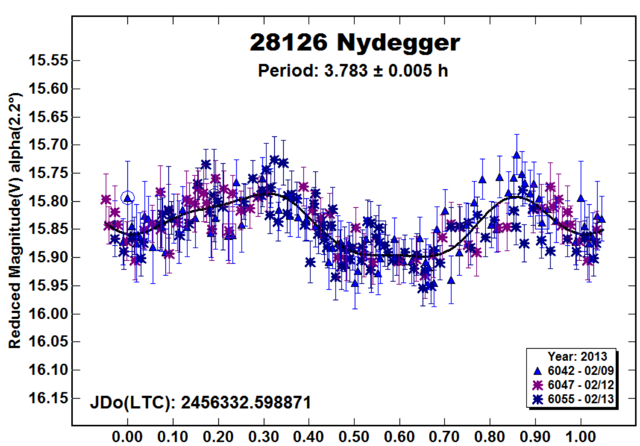

(29242) 1992 HB4
Period: 3.947 ± 0.005 h
Reduced Magnitude(V) alpha(21.7°)
JDo(LTC): 2456309.548190
Year: 2013
5956 - 01/17
5959 - 01/18

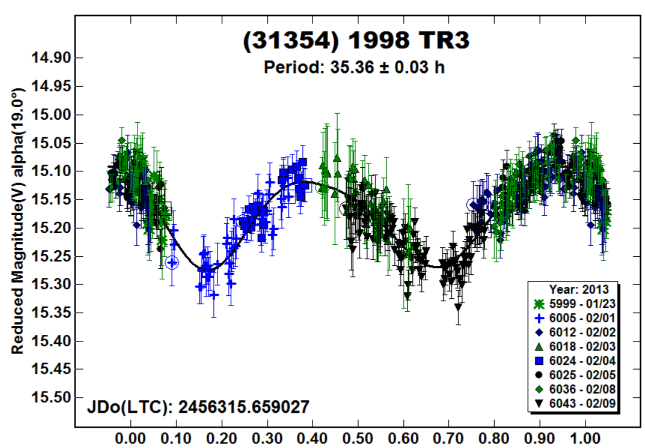

(18486) 1996 AS2
Period: 3.62 ± 0.05 h
Reduced Magnitude(V) alpha(1.5°)
JDo(LTC): 2456353.585311
Year: 2013
6086 - 03/02

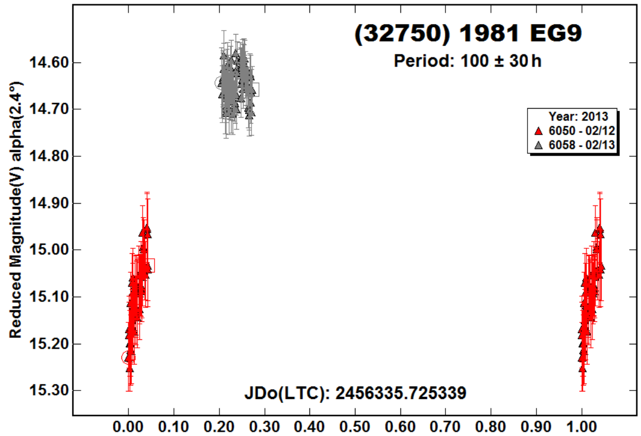

(29298) 1993 SA14
Period: 7.795 ± 0.003 h
Reduced Magnitude(V) alpha(25.7°)
JDo(LTC): 2456297.542740
Year: 2013
5919 - 01/05
5926 - 01/06
5931 - 01/08
5940 - 01/09
5947 - 01/12

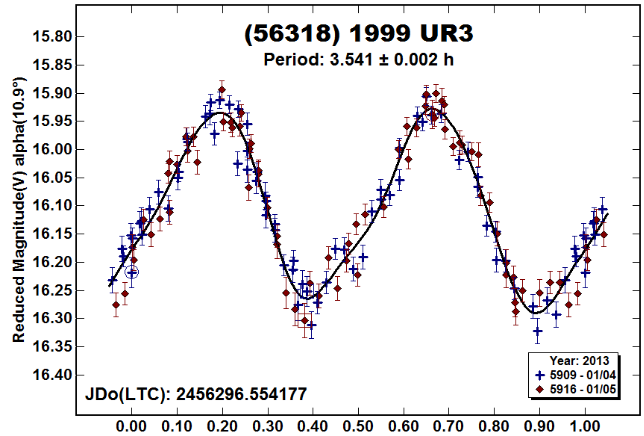

(27713) 1989 AA
Period: 3.999 ± 0.002 h
Reduced Magnitude(V) alpha(16.6°)
JDo(LTC): 2456290.547083
Year: 2012/13
5886 - 12/29
5890 - 01/01

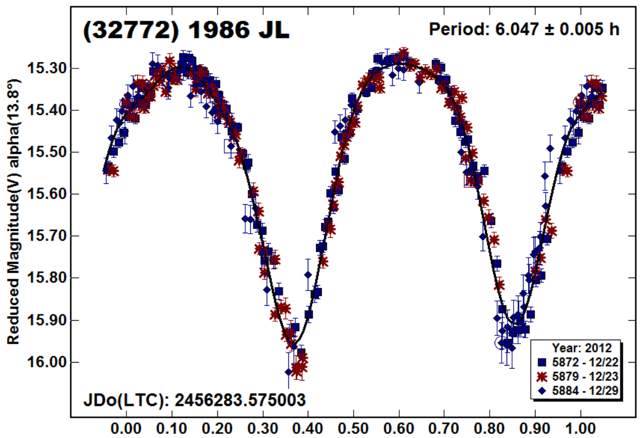

(29308) 1993 UF1
Period: 9.805 ± 0.004 h
Reduced Magnitude(V) alpha(17.2°)
JDo(LTC): 2456294.532286
Year: 2013
5896 - 01/02
5903 - 01/03
5911 - 01/04

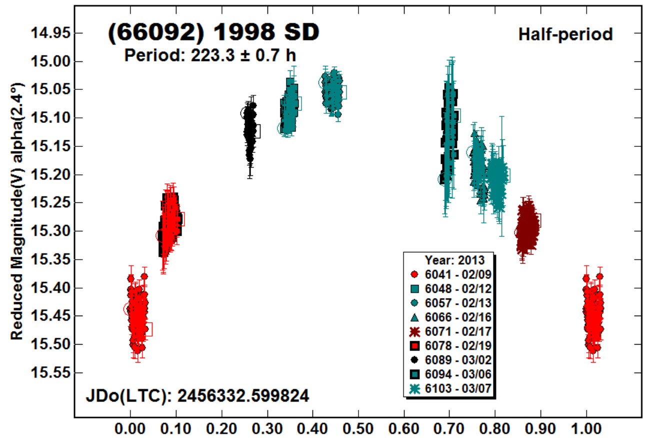

28126 Nydegger
Period: 3.783 ± 0.005 h
Reduced Magnitude(V) alpha(2.2°)
JDo(LTC): 2456332.598871
Year: 2013
6042 - 02/09
6047 - 02/12
6055 - 02/13

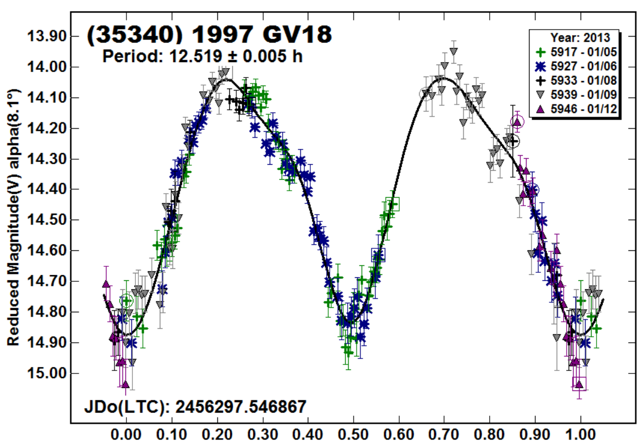

(31354) 1998 TR3
Period: 35.36 ± 0.03 h
Reduced Magnitude(V) alpha(19.0°)
JDo(LTC): 2456315.659027
Year: 2013
5999 - 01/23
6005 - 02/01
6012 - 02/02
6018 - 02/03
6024 - 02/04
6025 - 02/05
6036 - 02/08
6043 - 02/09

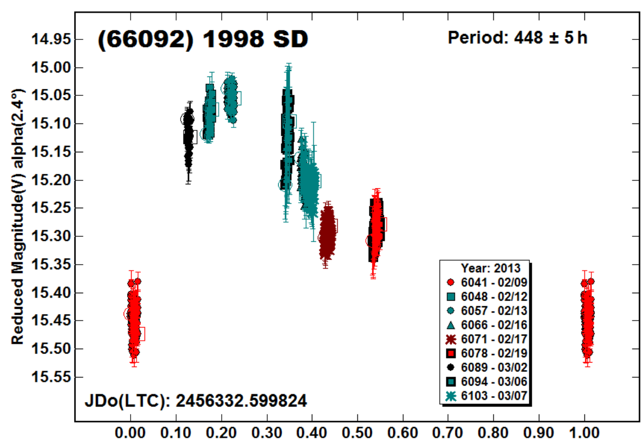

(32750) 1981 EG9
Period: 100 ± 30 h
Year: 2013
6050 - 02/12
6058 - 02/13
JDo(LTC): 2456335.725339
Reduced Magnitude(V) alpha(2.4°)

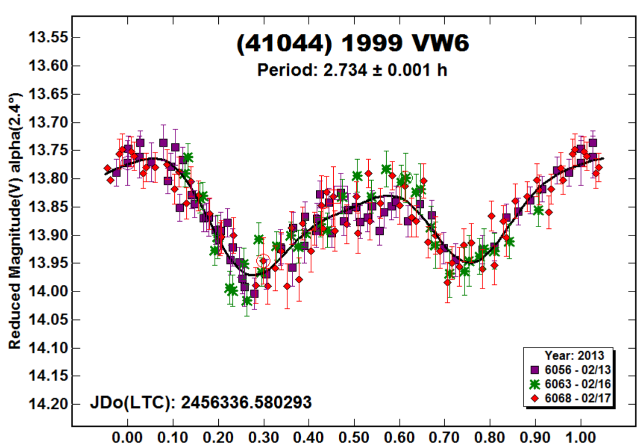

(56318) 1999 UR3
Period: 3.541 ± 0.002 h
Year: 2013
5909 - 01/04
5916 - 01/05
JDo(LTC): 2456296.554177
Reduced Magnitude(V) alpha(10.9°)

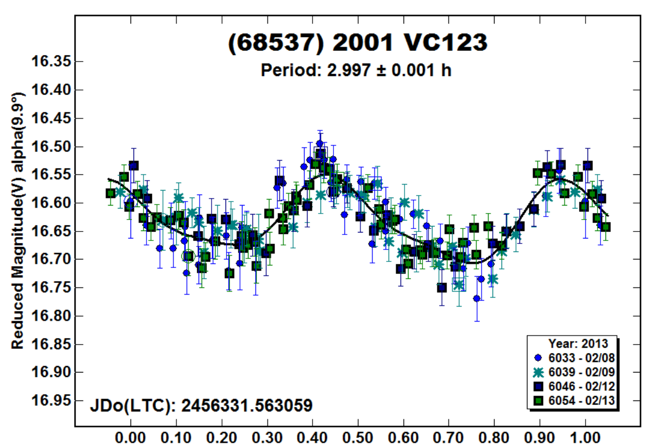

(32772) 1986 JL
Period: 6.047 ± 0.005 h
Year: 2012
5872 - 12/22
5879 - 12/23
5884 - 12/29
JDo(LTC): 2456283.575003
Reduced Magnitude(V) alpha(13.8°)

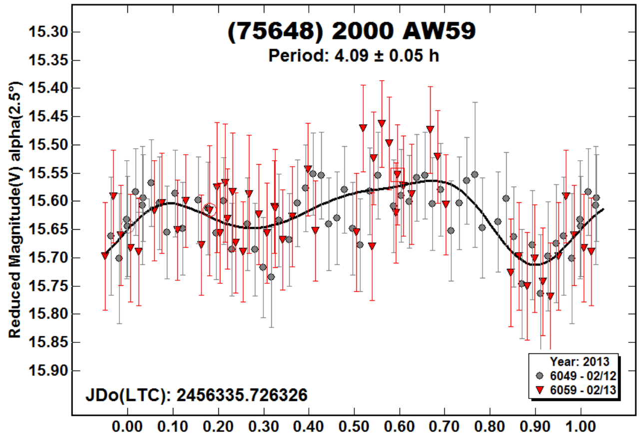

(66092) 1998 SD
Half-period
Period: 223.3 ± 0.7 h
Year: 2013
6041 - 02/09
6048 - 02/12
6057 - 02/13
6066 - 02/16
6071 - 02/17
6078 - 02/19
6089 - 03/02
6094 - 03/06
6103 - 03/07
JDo(LTC): 2456332.599824
Reduced Magnitude(V) alpha(2.4°)

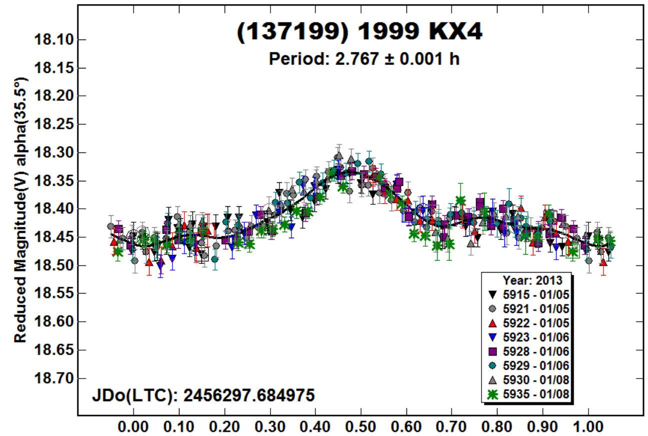

(35340) 1997 GV18
Period: 12.519 ± 0.005 h
Year: 2013
5917 - 01/05
5927 - 01/06
5933 - 01/08
5939 - 01/09
5946 - 01/12
JDo(LTC): 2456297.546867
Reduced Magnitude(V) alpha(8.1°)

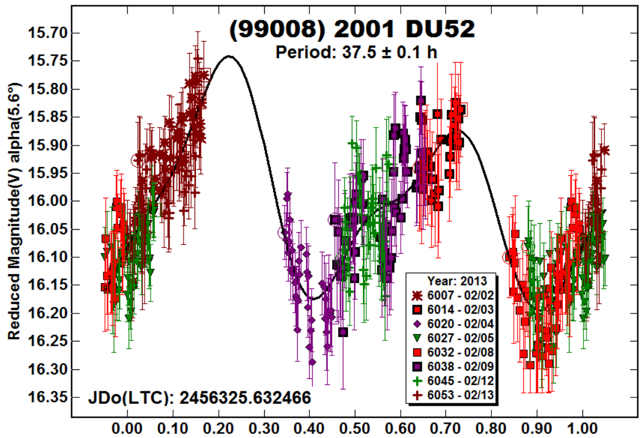

(66092) 1998 SD
Period: 448 ± 5 h
Year: 2013
6041 - 02/09
6048 - 02/12
6057 - 02/13
6066 - 02/16
6071 - 02/17
6078 - 02/19
6089 - 03/02
6094 - 03/06
6103 - 03/07
JDo(LTC): 2456332.599824
Reduced Magnitude(V) alpha(2.4°)

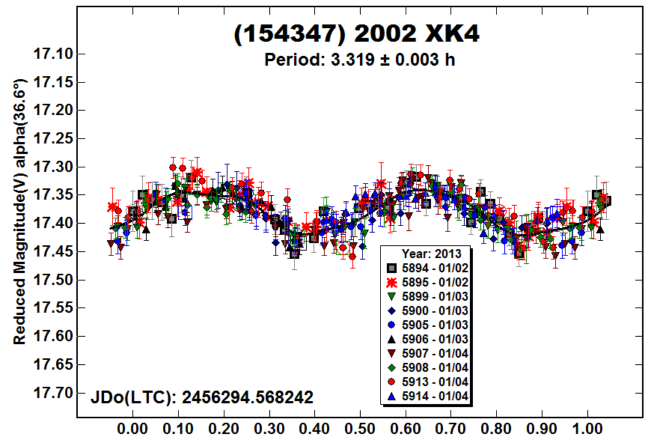

(41044) 1999 VW6
Period: 2.734 ± 0.001 h
Year: 2013
6056 - 02/13
6063 - 02/16
6068 - 02/17
JDo(LTC): 2456336.580293
Reduced Magnitude(V) alpha(2.4°)

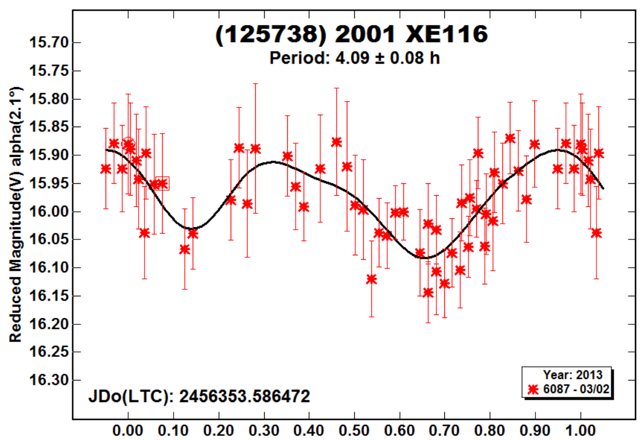

(68537) 2001 VC123
Period: 2.997 ± 0.001 h
Year: 2013
6033 - 02/08
6039 - 02/09
6046 - 02/12
6054 - 02/13
JDo(LTC): 2456331.563059
Reduced Magnitude(V) alpha(9.9°)

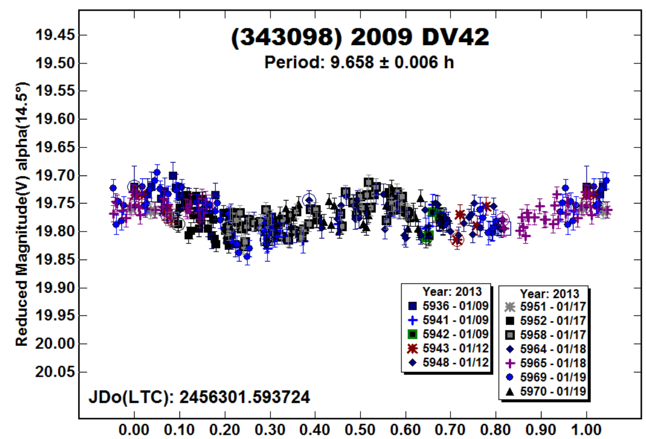

(75648) 2000 AW59
Period: 4.09 ± 0.05 h
Reduced Magnitude(V) alpha(2.5°)
JDo(LTC): 2456335.726326
Year: 2013
6049 - 02/12
6059 - 02/13

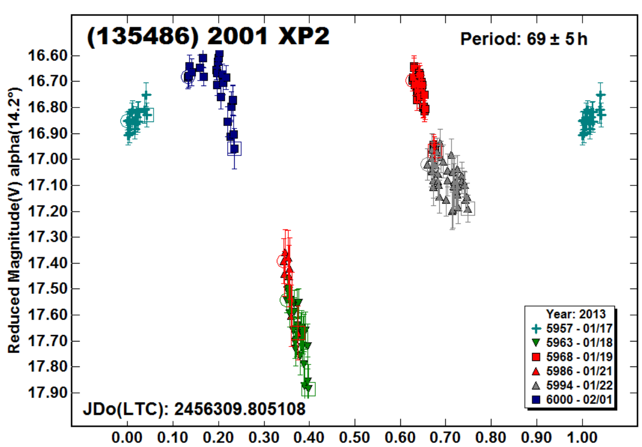

(137199) 1999 KX4
Period: 2.767 ± 0.001 h
Reduced Magnitude(V) alpha(35.5°)
JDo(LTC): 2456297.684975
Year: 2013
5915 - 01/05
5921 - 01/05
5922 - 01/05
5923 - 01/06
5928 - 01/06
5929 - 01/06
5930 - 01/08
5935 - 01/08

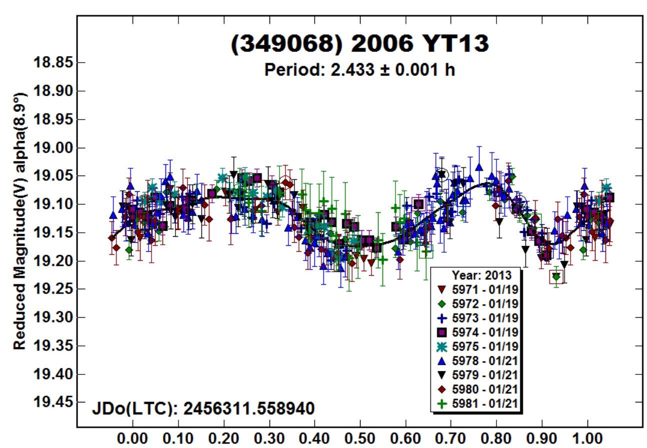

(99008) 2001 DU52
Period: 37.5 ± 0.1 h
Reduced Magnitude(V) alpha(5.6°)
JDo(LTC): 2456325.632466
Year: 2013
6007 - 02/02
6014 - 02/03
6020 - 02/04
6027 - 02/05
6032 - 02/08
6038 - 02/09
6045 - 02/12
6053 - 02/13


(154347) 2002 XK4
Period: 3.319 ± 0.003 h
Reduced Magnitude(V) alpha(36.6°)
JDo(LTC): 2456294.568242
Year: 2013
5894 - 01/02
5895 - 01/02
5899 - 01/03
5900 - 01/03
5905 - 01/03
5906 - 01/03
5907 - 01/04
5908 - 01/04
5913 - 01/04
5914 - 01/04


(125738) 2001 XE116
Period: 4.09 ± 0.08 h
Reduced Magnitude(V) alpha(2.1°)
JDo(LTC): 2456353.586472
Year: 2013
6087 - 03/02


(343098) 2009 DV42
Period: 9.658 ± 0.006 h
Reduced Magnitude(V) alpha(14.5°)
JDo(LTC): 2456301.593724
Year: 2013
5936 - 01/09
5941 - 01/09
5942 - 01/09
5943 - 01/12
5948 - 01/12
Year: 2013
5951 - 01/17
5952 - 01/17
5958 - 01/17
5964 - 01/18
5965 - 01/18
5969 - 01/19
5970 - 01/19


(135486) 2001 XP2
Period: 69 ± 5 h
Reduced Magnitude(V) alpha(14.2°)
JDo(LTC): 2456309.805108
Year: 2013
5957 - 01/17
5963 - 01/18
5968 - 01/19
5986 - 01/21
5994 - 01/22
6000 - 02/01


(349068) 2006 YT13
Period: 2.433 ± 0.001 h
Reduced Magnitude(V) alpha(8.9°)
JDo(LTC): 2456311.558940
Year: 2013
5971 - 01/19
5972 - 01/19
5973 - 01/19
5974 - 01/19
5975 - 01/19
5978 - 01/21
5979 - 01/21
5980 - 01/21
5981 - 01/21

ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2012 AUGUST - OCTOBER

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Over the course of 47 observational nights between 2012 August and 2012 October, photometric data for 42 asteroids were collected using the Oakley Southern Sky Observatory. The asteroids were: 560 Delila, 1798 Watts, 1802 Zhang Heng, 1887 Virton, 2046 Leningrad, 2239 Paracelsus, 2308 Schilt, 2353 Alva, 2512 Tavastia, 2516 Roman, 2730 Barks, 3024 Hainan, 3140 Stellafane, 3558 Shishkin, 3582 Cyrano, 3647 Dermott, 3920 Aubignan, 4100 Sumiko, 4188 Kitezh, 4460 Bihoro, 4875 Ingalls, 5418 Joyce, 6092 Johnmason, 6384 Kervin, 7140 Osaki, 7213 Conae, (7534) 1995 UA7, 7545 Smaklosa, (7569) 1989 BK, 7857 Lagerros, 7866 Sicoli, (9366) 1992 WR1, 11063 Poynting, (11705) 1998 GN7, (12499) 1998 FR47, 13234 Natashaowen, 14873 Shoyo, 20936 Nemrut Dagi, (24730) 1991 VM5, (24844) 1995 VM1, (28788) 2000 HW57, and (58148) 1987 SH4.

Forty-two asteroids were observed remotely from the Oakley Southern Sky Observatory in New South Wales, Australia, on the nights of 2012 August 6, 8, 10-14, 16-17, 19-22, September 2-4, 6-10, 11-16, 18-23, October 7-9, 11-15, 17-19, and 22-24. Lightcurves were found for 23 asteroids, 17 of which were previously unrecorded. The remaining 19 asteroids yielded no repeatable data patterns.

The Oakley Southern Sky Observatory houses a 20-inch Ritchey-Chretien optical tube assembly mounted on a Paramount ME. The telescope utilizes a Santa Barbara Instrument Group STL-1001E CCD camera with a clear filter. The image scale is 1.2 arcseconds per pixel at f/8.4. Image exposure times between 45 and 210 seconds were chosen based upon target asteroid characteristics. Target asteroids were selected based upon their position in the sky approximately 1 hour after sunset in order to maximize potential data collection. Image calibration was done in *CCDSoft* using master twilight flat, dark and bias frames. Processed images were measured in *MPO Canopus*. Note, higher priority was given to asteroids with previously unknown periods but objects with highly uncertain periods were also measured in order to potentially improve previous results.

Of the 42 asteroids measured, 19 yielded no repeatable pattern or insufficient periodic data trends. For these objects, only magnitude variations are reported. Lightcurves and measured periods were published for the remaining asteroids. With regards to objects for which light curves were generated, previously published periods were found to exist for 2308 Schilt, 3024 Hainan, 3920 Aubignan, 6384 Kervin, (7569) 1989 BK, and (11705) 1998 GN7. Comments on these findings are shown below.

2308 Schilt. The rotational period found is reasonably close to the period of 9.759 ± 0.002 h published by Mazzone (2012) but does not lie within the given range of uncertainty.

3024 Hainan. The rotational period found agrees with the published value of 11.785 ± 0.005 h given by Li, et al. (2013) to well within 1% relative error but does not agree to stated calculation uncertainty.

3920 Aubignan. The rotational period found does agree with the published value of 4.4762 ± 0.005 h given by Li, et. al (2013) within stated uncertainty.

6384 Kervin. The rotational period found agrees with the published value of 3.6203 ± 0.0003 given by Warner (2006) to stated uncertainty and agrees very closely with the value of 3.617 ± 0.001 republished by Warner (2011) although not within stated range of uncertainty.

(7569) 1989 BK. The rotational period found agrees with the published value of 3.60 ± 0.04 h given by Carbo et al. (2009) to within stated uncertainty.

(11705) 1998 GN7. The rotational period found agrees with the previously published value of 3.8 ± 0.3 h given by Polishook et al. (2012) to within stated uncertainty.

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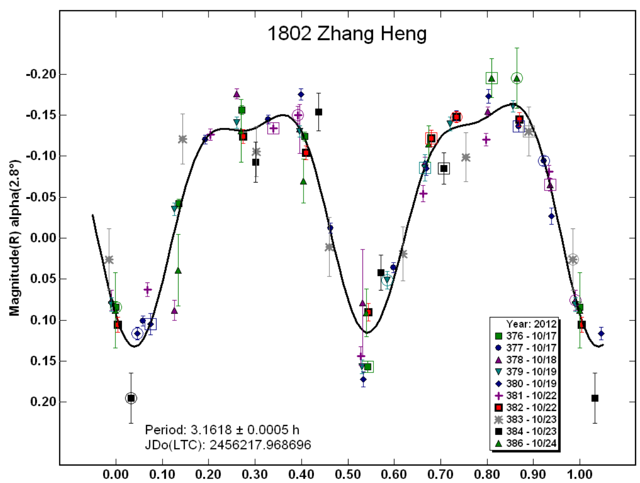
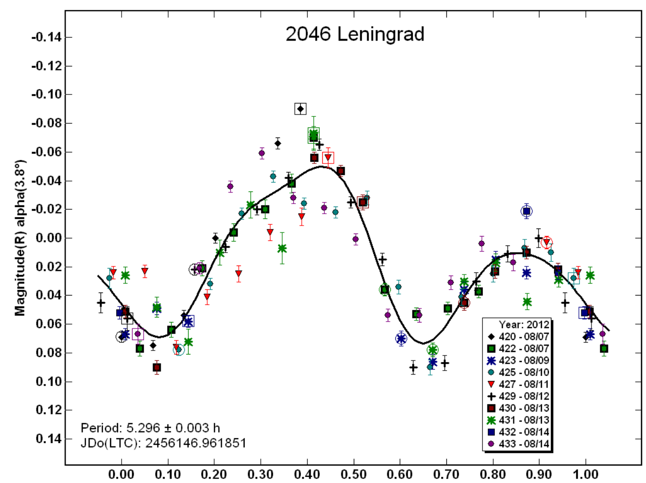
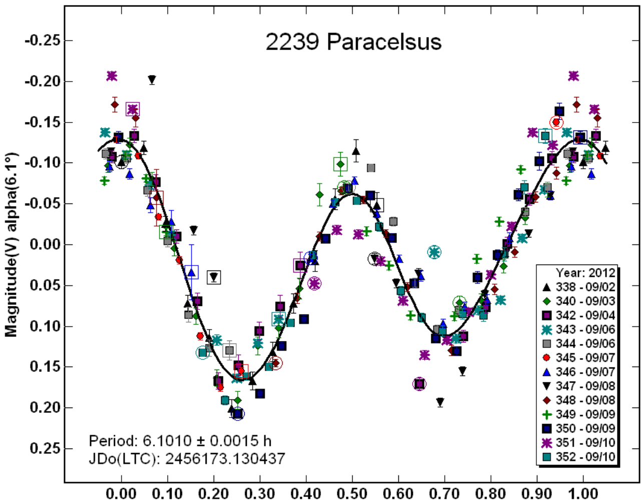
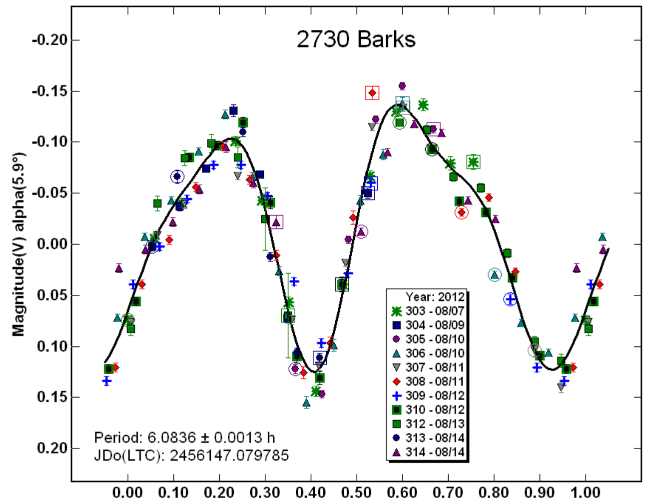
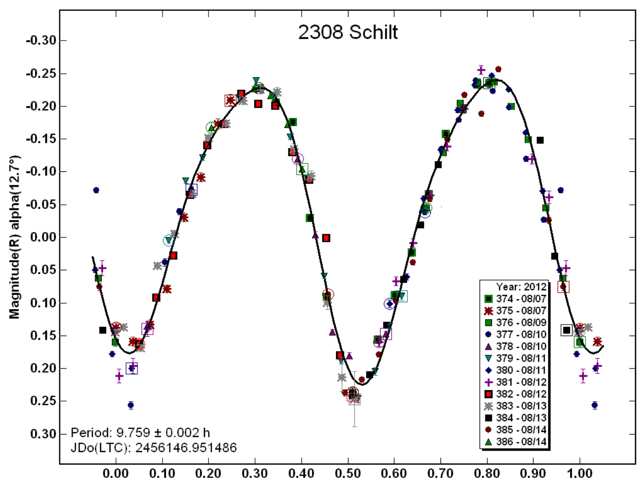
Number	Name	Dates mm/dd/2012	Data Points	Period (h)	Period Error (h)	Amplitude (mag)	Amplitude Error (mag)
560	Delila	9/2-4, 6-10	204			0.25	0.05
1798	Watts	9/11-12, 14, 15, 18, 20-23	191			0.25	0.03
1802	Zhang Heng	10/17-19, 22-24	72	3.1618	0.0005	0.30	0.04
1887	Virton	8/16-17, 19-22	86			0.10	0.05
2046	Leningrad	8/7, 9-14	98	5.296	0.003	0.11	0.08
2239	Paracelus	9/2-4, 6-10	187	6.101	0.0015	0.3	0.1
2308	Schilt	8/7, 9-14	148	9.759	0.002	0.44	0.03
2353	Alva	8/16-17, 19-22	111			0.2	0.1
2512	Tavastia	10/17-19, 22-14	76	7.296	0.003	0.30	0.02
2516	Roman	10/17-19, 22-14	75			0.42	0.06
2730	Barks	8/6, 8, 10-14	120	6.0836	0.0013	0.26	0.02
3024	Hainan	9/11-12, 14, 15, 18, 20-23	141	11.746	0.004	0.14	0.02
3140	Stellafane	9/2-4, 6-10	169	19.232	0.014	0.17	0.02
3558	Shishkin	8/7, 9-14	162	6.875	0.002	0.9	0.2
3582	Cyrano	10/7-9, 11-15	174			0.2	0.1
3647	Dermott	10/7-9, 11-15	147	21.779	0.007	0.83	0.01
3920	Aubignan	9/11-16, 18-23	199	4.4764	0.0002	0.97	0.02
4100	Sumiko	10/7-9, 11-15	153	6.2108	0.0007	0.31	0.05
4188	Kitezh	10/7-9, 11-15	153	2.5787	0.0003	0.19	0.04
4460	Bihoro	8/16-17, 19-22	105			0.13	0.05
4875	Ingalls	9/11-16, 18-23	189			0.1	0.1
5418	Joyce	10/17, 19, 22, 23, 24	83	20.96	0.02	0.4	0.1
6092	Johnmason	8/16-17, 19-22	110			0.30	0.05
6384	Kervin	10/7-9, 11-15	184	3.6205	0.0008	0.12	0.04
7140	Osaki	9/2-4, 6-10	232			0.2	0.1
7213	Conae	8/7, 9-14	107	5.3855	0.0009	0.70	0.05
7534	1995 UA7	9/2-4, 6-10	202			0.10	0.05
7545	Smaklosa	8/7, 9-14	131	14.322	0.004	0.75	0.05
7569	1989 BK	10/7-9, 11-15	174	3.5890	0.0007	0.2	0.1
7857	Lagerros	10/17-19, 22-24	97			0.25	0.05
7866	Sicoli	8/16-17, 19-22	112			0.15	0.04
9366	1992 WR1	9/11-16, 18-23	222			0.2	0.1
11063	Poynting	8/7, 9-14	131	7.926	0.002	0.53	0.05
11705	1998 GN7	8/16-17, 19-22	75	3.7187	0.0004	0.45	0.03
12499	1998 FR47	8/6, 8, 10-14	132			0.4	0.1
13234	Natashaowen	10/17-19, 22-24	84			0.2	0.1
14873	Shoyo	10/7-9, 11-15	157	3.5746	0.0003	0.49	0.03
20936	Nemrut Dagi	9/11-16, 18-23	222			0.1	0.1
24730	1991 VM5	9/2-4, 6-9	217			0.2	0.1
24844	1995 VM1	10/17, 19, 22, 24	81	5.353	0.002	0.25	0.07
28788	2000 HW57	10/17-19, 22-24	77	3.3905	0.0007	0.34	0.04
58148	1987 SH4	9/11-16, 18-23	212			0.1	0.2

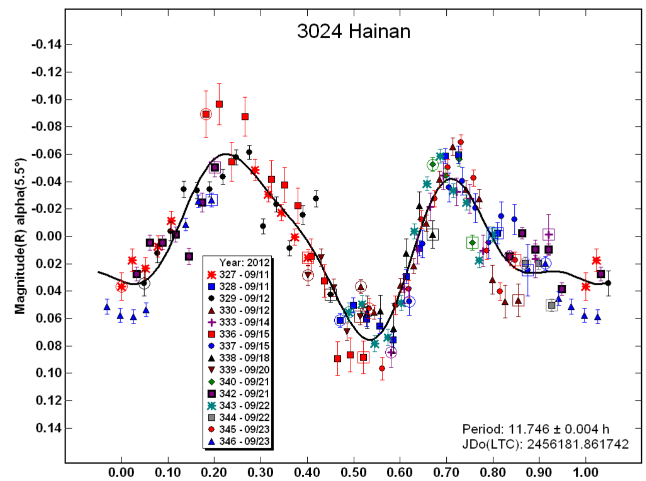


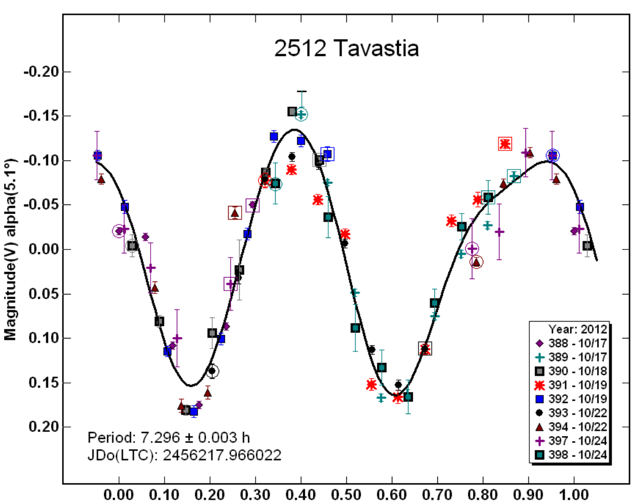


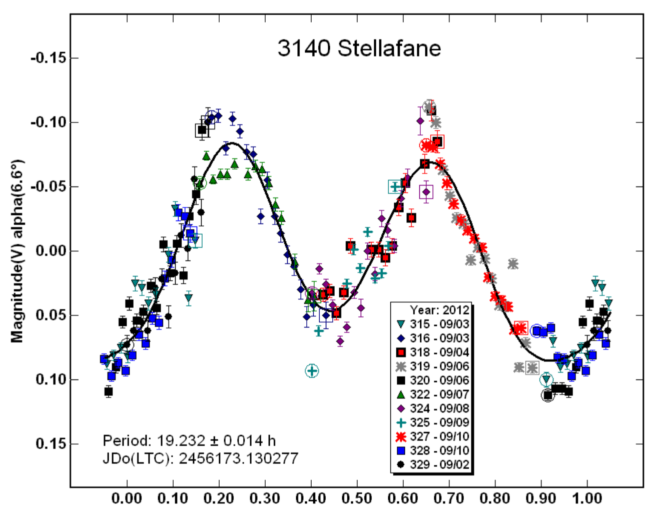

2239 Paracelsus
Magnitude(V) alpha(6.1°)
Year: 2012
338 - 09/02
340 - 09/03
342 - 09/04
343 - 09/06
344 - 09/06
345 - 09/07
346 - 09/07
347 - 09/08
348 - 09/08
349 - 09/09
350 - 09/09
351 - 09/10
352 - 09/10
Period: 6.1010 ± 0.0015 h
JDo(LTC): 2456173.130437

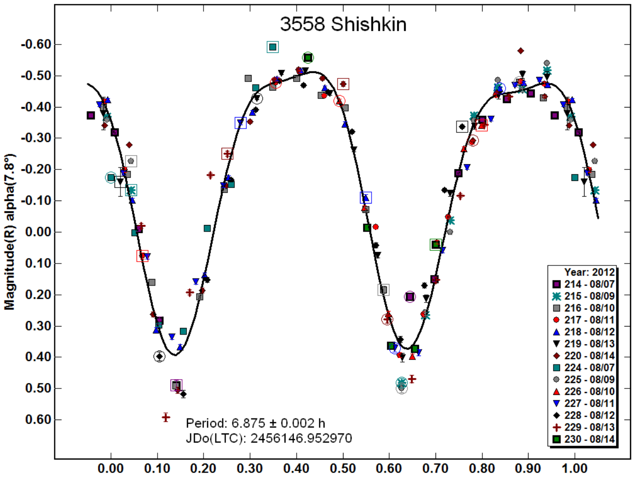

2730 Barks
Magnitude(V) alpha(5.9°)
Year: 2012
303 - 08/07
304 - 08/09
305 - 08/10
306 - 08/10
307 - 08/11
308 - 08/11
309 - 08/12
310 - 08/12
312 - 08/13
313 - 08/14
314 - 08/14
Period: 6.0836 ± 0.0013 h
JDo(LTC): 2456147.079785

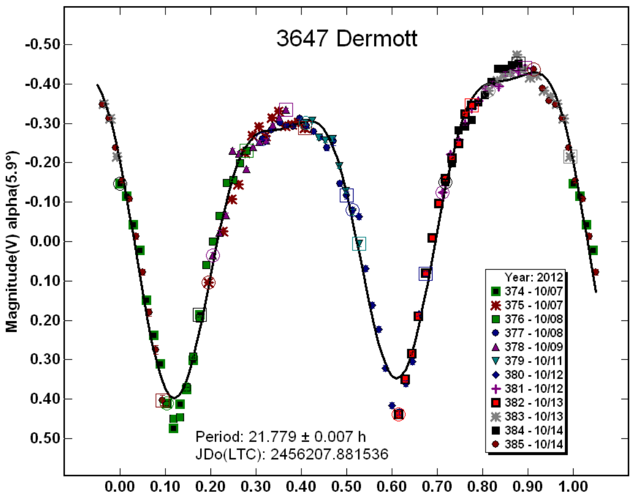

2308 Schilt
Magnitude(R) alpha(12.7°)
Year: 2012
374 - 08/07
375 - 08/07
376 - 08/09
377 - 08/10
378 - 08/10
379 - 08/11
380 - 08/11
381 - 08/12
382 - 08/12
383 - 08/13
384 - 08/13
385 - 08/14
386 - 08/14
Period: 9.759 ± 0.002 h
JDo(LTC): 2456146.951486


3024 Hainan
Magnitude(R) alpha(5.5°)
Year: 2012
327 - 09/11
328 - 09/11
329 - 09/12
330 - 09/12
333 - 09/14
336 - 09/15
337 - 09/15
338 - 09/18
339 - 09/20
340 - 09/21
342 - 09/21
343 - 09/22
344 - 09/22
345 - 09/23
346 - 09/23
Period: 11.746 ± 0.004 h
JDo(LTC): 2456181.861742


2512 Tavastia
Magnitude(V) alpha(5.1°)
Year: 2012
388 - 10/17
389 - 10/17
390 - 10/18
391 - 10/19
392 - 10/19
393 - 10/22
394 - 10/22
397 - 10/24
398 - 10/24
Period: 7.296 ± 0.003 h
JDo(LTC): 2456217.966022


3140 Stellafane
Magnitude(V) alpha(6.6°)
Year: 2012
315 - 09/03
316 - 09/03
318 - 09/04
319 - 09/06
320 - 09/06
322 - 09/07
324 - 09/08
325 - 09/09
327 - 09/10
328 - 09/10
329 - 09/02
Period: 19.232 ± 0.014 h
JDo(LTC): 2456173.130277


3558 Shishkin
Magnitude(R) alpha(7.8°)
Period: 6.875 ± 0.002 h
JDo(LTC): 2456146.952970
Year: 2012
214 - 08/07
215 - 08/09
216 - 08/10
217 - 08/11
218 - 08/12
219 - 08/13
220 - 08/14
224 - 08/07
225 - 08/09
226 - 08/10
227 - 08/11
228 - 08/12
229 - 08/13
230 - 08/14


3647 Dermott
Magnitude(V) alpha(5.9°)
Period: 21.779 ± 0.007 h
JDo(LTC): 2456207.881536
Year: 2012
374 - 10/07
375 - 10/07
376 - 10/08
377 - 10/08
378 - 10/09
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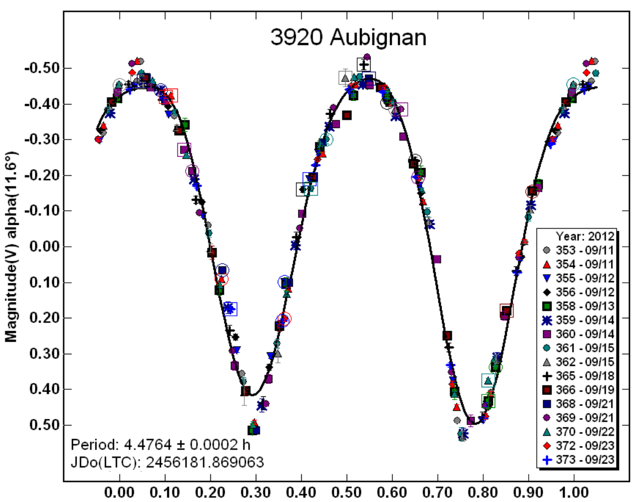
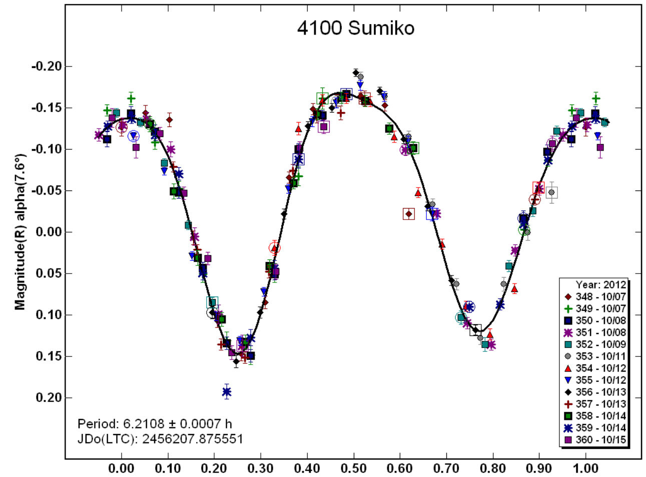
383 - 10/13
384 - 10/14
385 - 10/14


3920 Aubignan
Magnitude(V) alpha(11.6°)
Period: 4.4764 ± 0.0002 h
JDo(LTC): 2456181.869063
Year: 2012
353 - 09/11
354 - 09/11
355 - 09/12
356 - 09/12
358 - 09/13
359 - 09/14
360 - 09/14
361 - 09/15
362 - 09/15
365 - 09/18
366 - 09/19
368 - 09/21
369 - 09/21
370 - 09/22
372 - 09/23
373 - 09/23


4100 Sumiko
Magnitude(R) alpha(7.6°)
Period: 6.2108 ± 0.0007 h
JDo(LTC): 2456207.875551
Year: 2012
348 - 10/07
349 - 10/07
350 - 10/08
351 - 10/08
352 - 10/09
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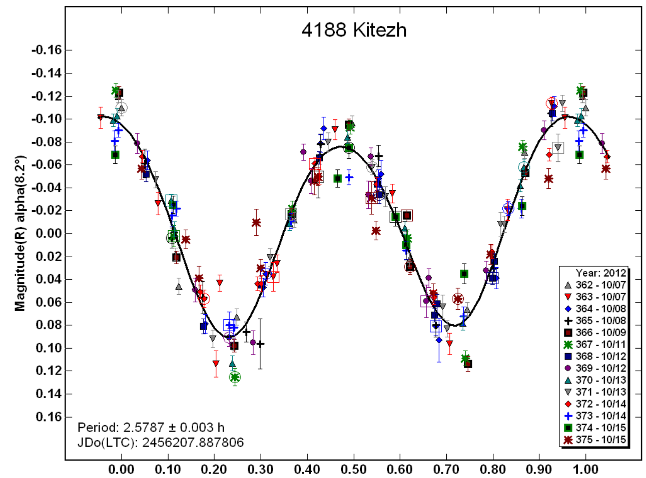
359 - 10/14
360 - 10/15


4188 Kitezh
Magnitude(R) alpha(8.2°)
Period: 2.5787 ± 0.003 h
JDo(LTC): 2456207.887806
Year: 2012
362 - 10/07
363 - 10/07
364 - 10/08
365 - 10/08
366 - 10/09
367 - 10/11
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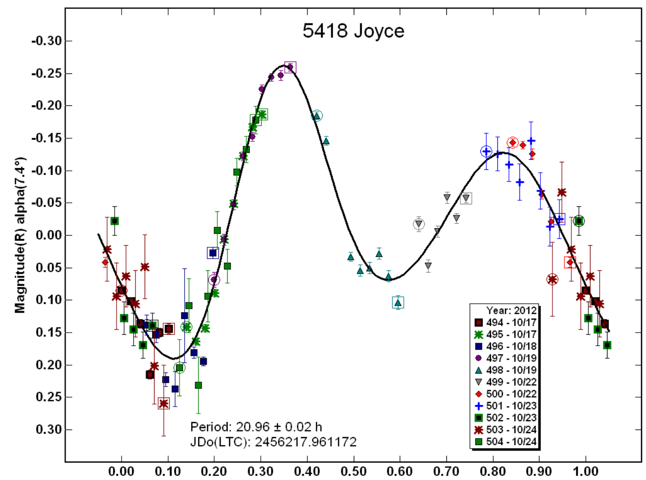
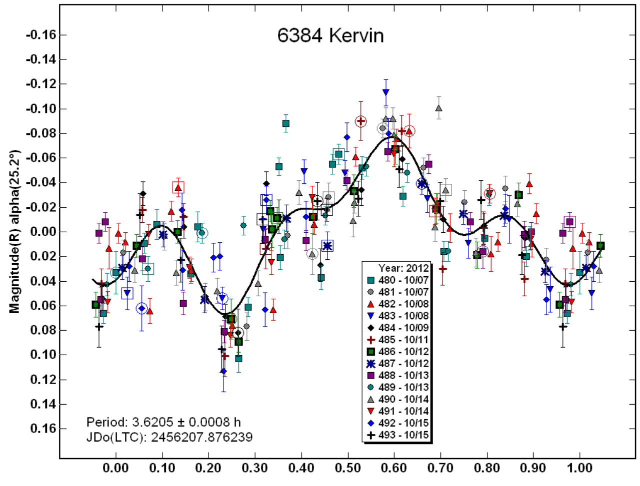
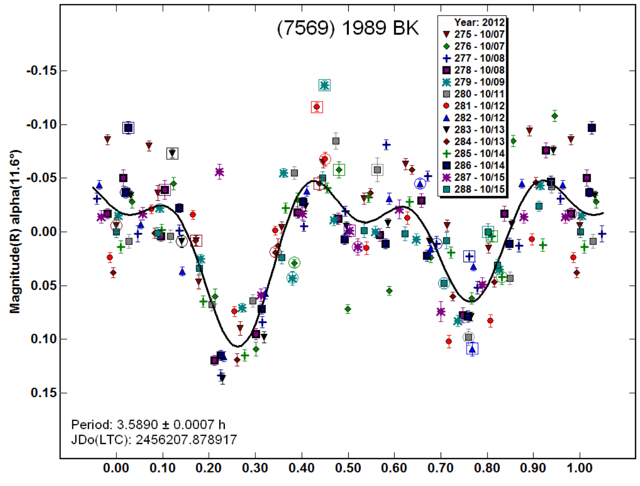
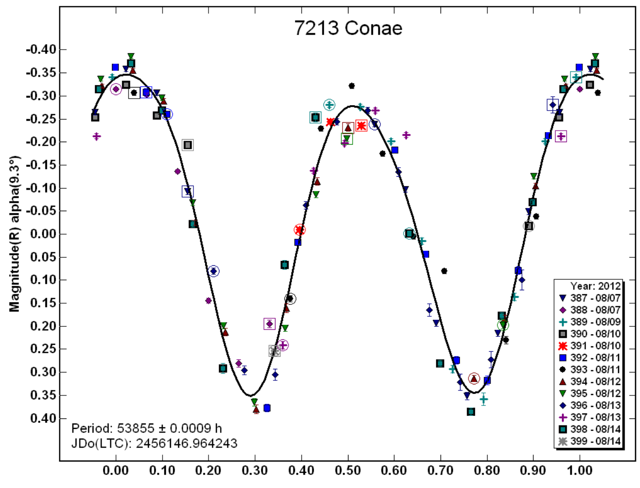
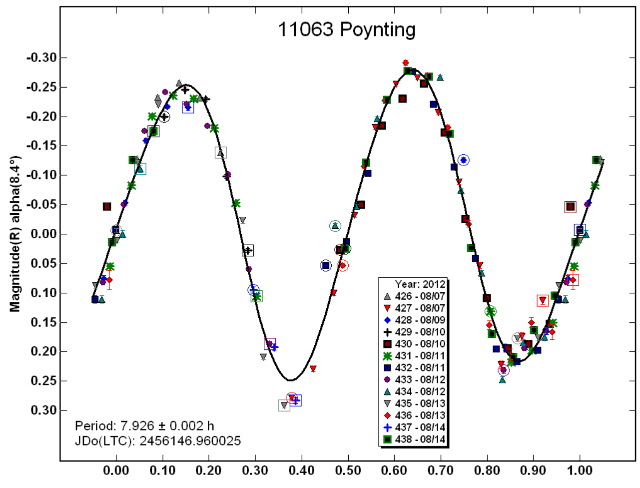
374 - 10/15
375 - 10/15

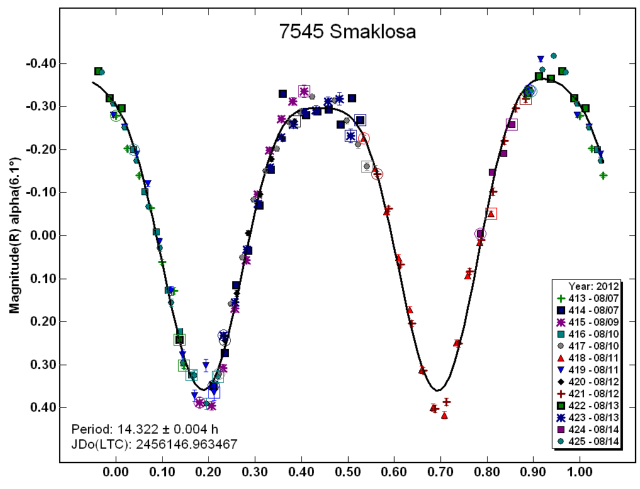

5418 Joyce
Magnitude(R) alpha(7.4°)
Period: 20.96 ± 0.02 h
JDo(LTC): 2456217.961172
Year: 2012
494 - 10/17
495 - 10/17
496 - 10/18
497 - 10/19
498 - 10/19
499 - 10/22
500 - 10/22
501 - 10/23
502 - 10/23
503 - 10/24
504 - 10/24

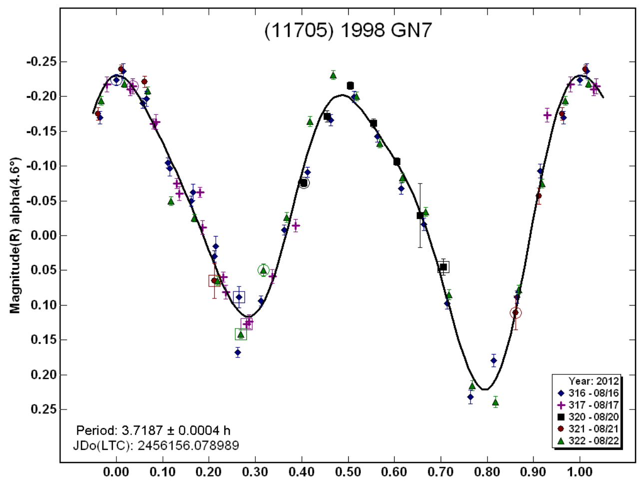

6384 Kervin
Magnitude(R) alpha(25.2°)
Year: 2012
480 - 10/07
481 - 10/07
482 - 10/08
483 - 10/08
484 - 10/09
485 - 10/11
486 - 10/12
487 - 10/12
488 - 10/13
489 - 10/13
490 - 10/14
491 - 10/14
492 - 10/15
493 - 10/15
Period: 3.6205 ± 0.0008 h
JDo(LTC): 2456207.876239

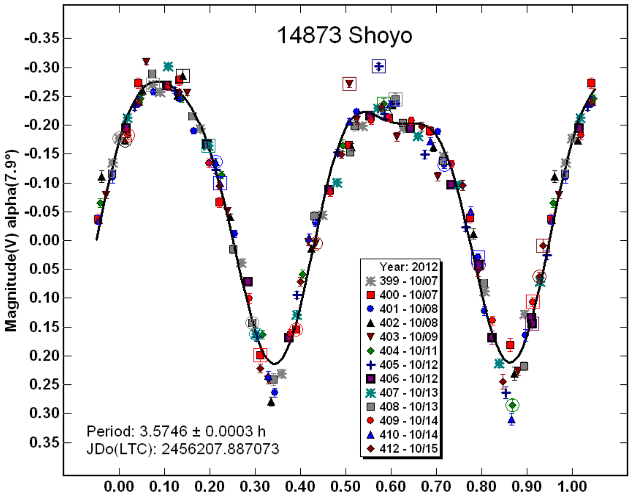

(7569) 1989 BK
Magnitude(R) alpha(11.6°)
Year: 2012
275 - 10/07
276 - 10/07
277 - 10/08
278 - 10/08
279 - 10/09
280 - 10/11
281 - 10/12
282 - 10/12
283 - 10/13
284 - 10/13
285 - 10/14
286 - 10/14
287 - 10/15
288 - 10/15
Period: 3.5890 ± 0.0007 h
JDo(LTC): 2456207.878917

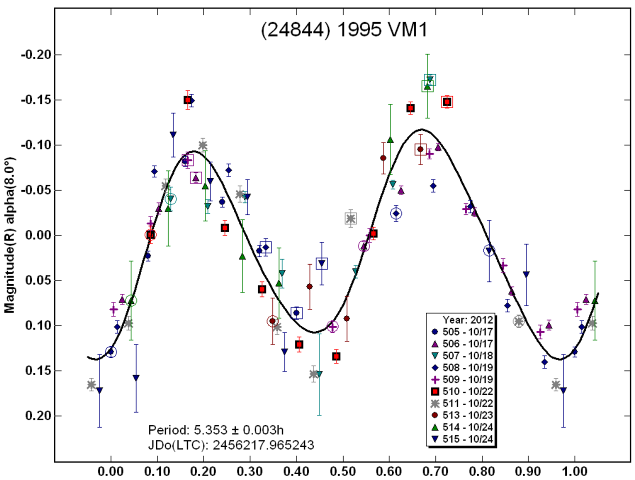

7213 Conae
Magnitude(R) alpha(9.3°)
Year: 2012
387 - 08/07
388 - 08/07
389 - 08/09
390 - 08/10
391 - 08/10
392 - 08/11
393 - 08/11
394 - 08/12
395 - 08/12
396 - 08/13
397 - 08/13
398 - 08/14
399 - 08/14
Period: 53855 ± 0.0009 h
JDo(LTC): 2456146.964243

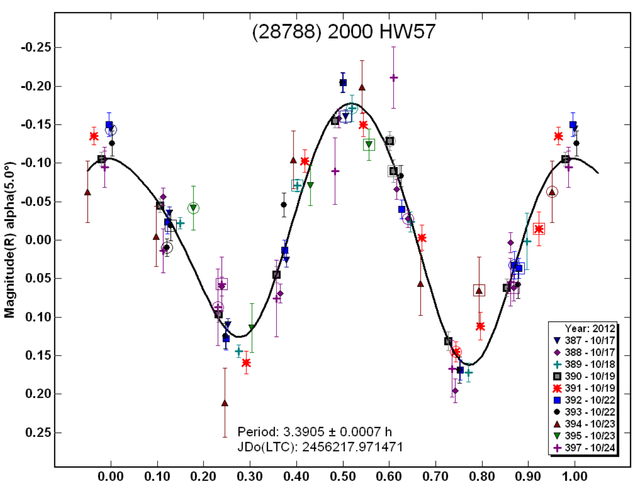

11063 Poynting
Magnitude(R) alpha(8.4°)
Year: 2012
426 - 08/07
427 - 08/07
428 - 08/09
429 - 08/10
430 - 08/10
431 - 08/11
432 - 08/11
433 - 08/12
434 - 08/12
435 - 08/13
436 - 08/13
437 - 08/14
438 - 08/14
Period: 7.926 ± 0.002 h
JDo(LTC): 2456146.960025


7545 Smaklosa
Magnitude(R) alpha(6.1°)
Year: 2012
413 - 08/07
414 - 08/07
415 - 08/09
416 - 08/10
417 - 08/10
418 - 08/11
419 - 08/11
420 - 08/12
421 - 08/12
422 - 08/13
423 - 08/13
424 - 08/14
425 - 08/14
Period: 14.322 ± 0.004 h
JDo(LTC): 2456146.963467


(11705) 1998 GN7
Magnitude(R) alpha(4.6°)
Year: 2012
316 - 08/16
317 - 08/17
320 - 08/20
321 - 08/21
322 - 08/22
Period: 3.7187 ± 0.0004 h
JDo(LTC): 2456156.078989







BINARY NATURE FOR THE ASTEROID 1052 BELGICA

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(Received: 20 March)

Photometric observations of main-belt asteroid 1052 Belgica show its binary nature with an orbital period P_{orb} = 47.26 ± 0.02 h. The rotational light curve of the primary has a period P_1 = 2.7097 ± 0.0001 h with an amplitude of 0.08 mag. The lower limit on the secondary-to-primary mean diameter ratio is 0.36 ± 0.02. The measured absolute visual magnitude is H = 12.17 ± 0.05 mag and the slope parameter G = 0.24 ± 0.03. The diameter is estimated to be D = 11 □ 2 km.

The main-belt asteroid 1052 Belgica was reported as a lightcurve photometry opportunity in the *Minor Planet Bulletin* (Warner et al., 2012). Lightcurve observations were carried out from several observers over the period spanning from 2012 November 17 to 2013 January 5 for a total of 49 days and seventeen observing sessions (Table I). The equipment used for observations is reported in Table II.

All images were calibrated with dark and flat-field frames. Differential photometry was done using *MPO Canopus* (Warner, 2012). The V and R magnitudes were calibrated using the method described by Dymock and Miles (2009) and CMC14 stars with near-solar color indexes selected by using Vizier (2012). The same method was also applied to the clear filter observations after conversion to R magnitudes using previously determined transformation coefficients.

Lightcurve Analysis

The lightcurves obtained by Franco and Ferrero from Italy showed attenuation events (Fig.3), these events were not present in the lightcurves of Martinez in the USA, acquired in the same time. This made us to suspect that the attenuations were due to eclipse/occultation events with a periodicity of 24 h or multiples. The data were sent then to Pravec who confirmed that it was a binary system. The authors have announced the discovery through the CBET 3372, published on Jan. 7, 2013.

The period analysis was done using *MPO Canopus*, which implements the FALC analysis algorithm developed by Harris et al. (1989) and the Dual Period Search feature, specific for binary asteroids.

Data analysis shows a synodic primary period $P_1 = 2.7097 \pm 0.0001$ h (Fig.1) with an amplitude of 0.08 ± 0.02 mag, that suggests a nearly spheroidal shape, and an orbital period $P_{orb} = 47.26 \pm 0.02$ h (Fig.2). The depth of the secondary event, observed on 2012 Dec. 11.9 (0.13 mag) gives a lower limit on the secondary-to-primary mean diameter ratio $D_2/D_1 = 0.36 \pm 0.02$.

The session of 2013 Jan 5 has registered an attenuation event that likely was due to the transit of the shadow of the secondary in front of the primary at high phase angle of 16.3° (Fig.4).

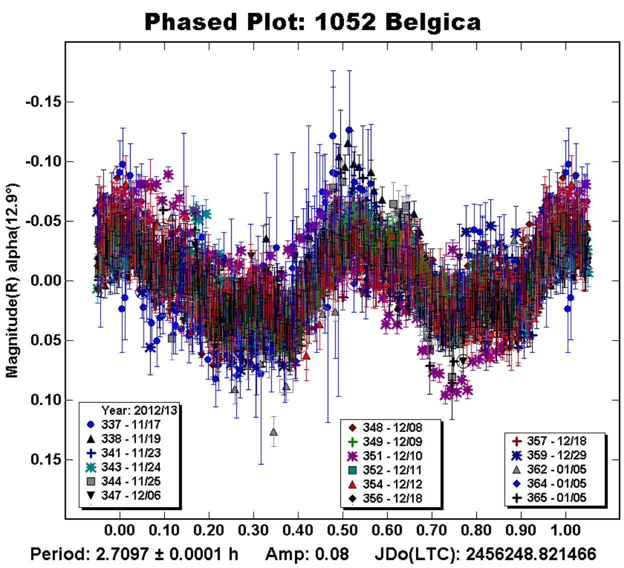

Figure 1: The rotational lightcurve of the primary with secondary removed has a period of 2.7097 ± 0.0001 h with an amplitude of 0.08 ± 0.02 mag.

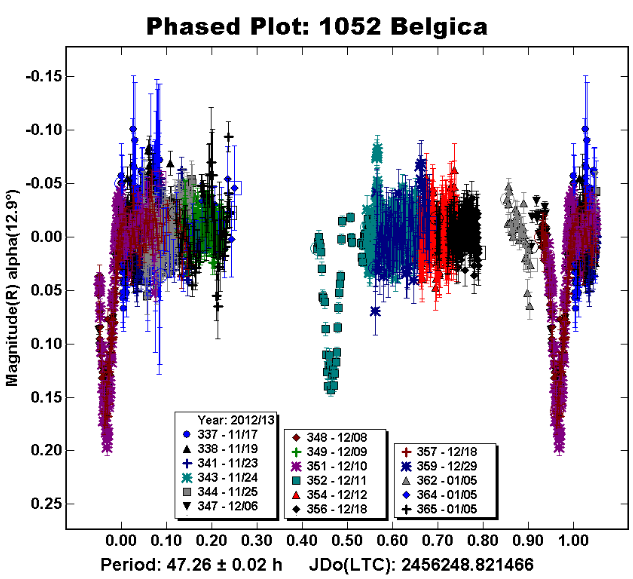

Figure 2: The orbital period of 47.26 ± 0.02 h with primary removed.

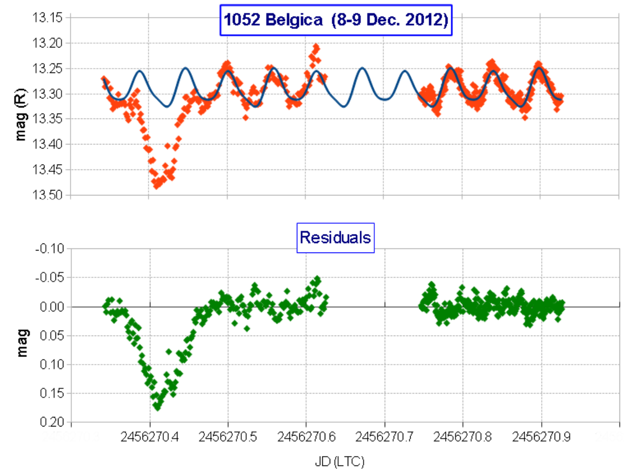

Figure 3: (Top) Two lightcurves acquired by Ferrero and Martinez on December 8-9, the first of which shows an attenuation event. The data points (red color) are superimposed to the rotational period (blue color). (Bottom) Residuals after the rotational period has been subtracted.

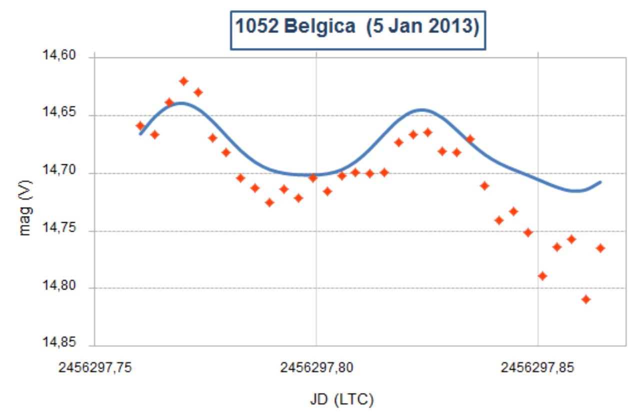

Figure 4: The attenuation event occurred on January 5, due likely to the transit of the shadow of the secondary in front of the primary at high phase angle (16.3°).

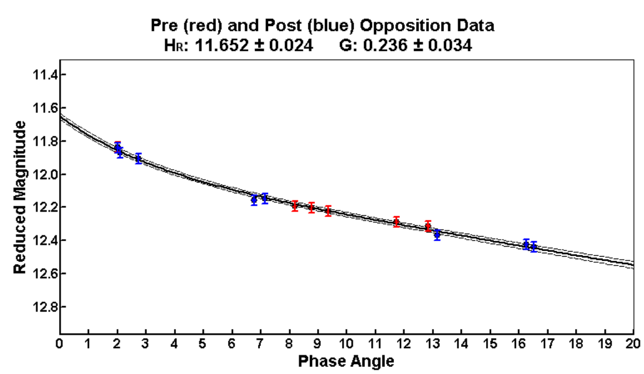

Figure 5: Reduced magnitude vs phase angle for estimate $H_R = 11.65 \pm 0.02$ mag and $G = 0.24 \pm 0.03$.

The Small Bodies Node (*http://pdssbn.astro.umd.edu/*) reports for this asteroid a S-type taxonomic class with a color index (B-V) = 0.90 ± 0.02. The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. For each lightcurve the R mag was measured as half peak-to-peak amplitude with *Peranso* (polynomial fit), excluding eclipse/occultation events. Table III shows the used data.

We have achieved $H_R = 11.65 \pm 0.02$ mag and $G = 0.24 \pm 0.03$ (Fig.5) that we convert to $H_V = 12.17 \pm 0.05$ with the R to V transformation formula:

$$V = R + 0.533 * (B - V) + 0.037 \quad (1)$$

obtained via linear regression from the Loneos star catalogue published as "UBVRI photometry of faint field stars" (Skiff, 2007) within the range: $0.4 < (B-V) < 1.0$.

For the S-type asteroid, the geometric albedo is $p_V = 0.197 \pm 0.051$ (Pravec et al. 2012). Using this result, we can estimate the diameter D with the formula by Pravec and Harris (2007):

$$D_{(km)} = \frac{1329}{\sqrt{p_v}} 10^{-0.2Hv} \quad (2)$$

This leads to an estimated diameter D = 11 ± 2 km, a value which agrees with the WISE mission value of 10.41 ± 0.08 km.

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1	Nov 17.33 – 17.50	H13	50	CR
2	Nov 19.32 – 19.53	H13	45	CR
3	Nov 23.30 – 23.53	H13	40	CR
4	Nov 24.30 – 24.53	H13	40	CR
5	Nov 25.30 – 25.52	H13	35	CR
6	Dec 06.83 – 07.07	A81	300	CR
7	Dec 08.85 – 09.13	B88	120	R
8	Dec 09.25 – 09.43	H13	35	CR
9	Dec 10.85 – 11.12	B88	120	R
10	Dec 11.81 – 12.14	A81	300	CR
11	Dec 12.25 – 12.42	H13	35	CR
12	Dec 18.24 – 18.42	H13	35	CR
13	Dec 18.76 – 19.13	A81	300	CR
14	Dec 29.79 – 30.02	B88	180	R
15	Jan 05.23 – 05.37	H06	240	V
16	Jan 05.73 – 06.05	A81	600	R
17	Jan 05.79 – 06.03	B88	240	R

Table I. Observations list.

Observer	Telescope	CCD	Filters
Martinez, Lenomiya Observatory, Casa Grande, Arizona, USA (MPC H13)	SCT 0.28-m	SBIG ST8-XME	Clear filter
Franco, Balzaretto Observatory, Rome, Italy (MPC A81)	SCT 0.20-m f/5.5	SBIG ST7-XME	Clear and Custom Scientific Cousins R
Ferrero, Bigmuskie Observatory, Monbercelli, Asti, Italy (MPC B88)	RC 0.30-m f/8	SBIG ST9	Astrodon Cousins R
Padovan, iTelescope network near Mayhill, NM, USA (MPC H06)	SCT 0.25-m f/3.4	SBIG ST10-XME	Astrodon Johnson V

Table II. Observers and equipment list.

Year/Month/Day	UT	R mag	α (°)
2012 11 17	10:14	12.31	-12.82
2012 11 19	08:57	12.29	-11.72
2012 11 23	10:03	12.22	-9.36
2012 11 24	09:54	12.20	-8.77
2012 11 25	09:33	12.19	-8.18
2012 12 06	21:00	11.84	-2.01
2012 12 09	01:02	11.84	+2.01
2012 12 09	07:57	11.87	+2.08
2012 12 11	01:34	11.91	+2.73
2012 12 18	07:57	12.16	+6.76
2012 12 18	23:12	12.15	+7.13
2012 12 29	21:27	12.37	+13.16
2013 01 05	06:45	12.42	+16.26
2013 01 05	21:09	12.44	+16.53

Table III. The R magnitude at half peak-to-peak amplitude, used for compute H_R and G.

PERIOD DETERMINATION FOR SLOW ROTATORS (9247) 1998 MO19 AND (66419) 1999 NR13

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Photometric measurements yielding period and amplitude results for asteroids (9247) 1998 MO19 and (66419) 1999 NR13 were performed during their 2013 favorable oppositions. Both asteroids were found to be slow rotators, with synodic rotation periods respectively equal to 11.479 ± 0.001 h and 56.709 ± 0.011 h.

Asteroids (9247) 1998 MO19 and (66419) 1999 NR13 appeared on the CALL web site as asteroid photometry opportunities due to reaching 2013 favorable apparitions and having no defined lightcurve parameters. Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) using a 0.3-m Meade LX-200R reduced to f/6.9. The CCD imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536 x 1024 array of 9-micron pixels and 23 x 16 arcminute field-of-view. 2x2 binning was used, yielding an image scale of 1.77 arcseconds per pixel. The camera was always worked at –10C and off-axis guided by means of a SX Lodestar camera and *PHD Guiding* (Stark Labs) software. Image acquisition was done with *MaxIm DL5* (Diffraction Limited). All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.0.20 with a differential photometry technique. The data were light-time corrected. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors according to recommendations by Warner (2007) and Stephens (2008). Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

(9247) 1998 MO19. A total of 10 nights were exclusively devoted to observe this main-belt asteroid from 2013 February 21 through March 17. Imaging exposure was 180 seconds. About 54 hours of effective observation and more than 1,000 data points were required in order to solve the lightcurve. Over the span of observations, the phase angle varied from 11.1º to 8.7º to 8.8º, the phase angle bisector ecliptic longitude from 170.9º to 170.6º, and the phase angle bisector ecliptic latitude from –24.0º to –22.5º. The rotational period was determined (for the first time) to be 11.479 ± 0.001 h along with a peak-to-peak amplitude of 0.35 ± 0.04 mag. Neither clear evidence of tumbling nor binary companion were seen in the lightcurve.

(66419) 1999 NR13. A total of 15 nights were exclusively devoted to observe this Mars-crossing asteroid from 2013 January 19 through February 10. Imaging exposure was 150 seconds. About 82 hours of effective observation and more than 2,100 data points were required in order to solve the lightcurve. Over the span of observations, the phase angle varied from 18.6º to 17.2º to 18.7º, the phase angle bisector ecliptic longitude from 136.5º to 140.4º, and the phase angle bisector ecliptic latitude from –15.6º to –22.2º. The rotational period was determined (for the first time) to be 56.709 ± 0.011 h along with a peak-to-peak amplitude of 0.80 ± 0.05 mag. Neither clear evidence of tumbling nor binary companion were seen in the lightcurve.

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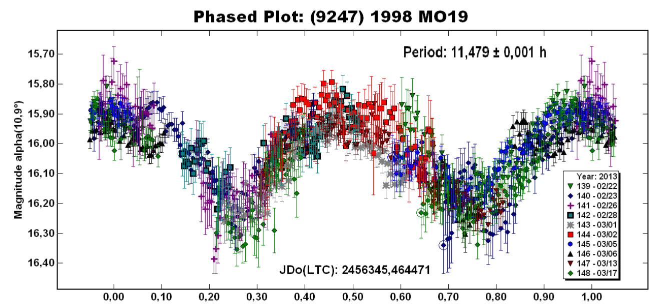

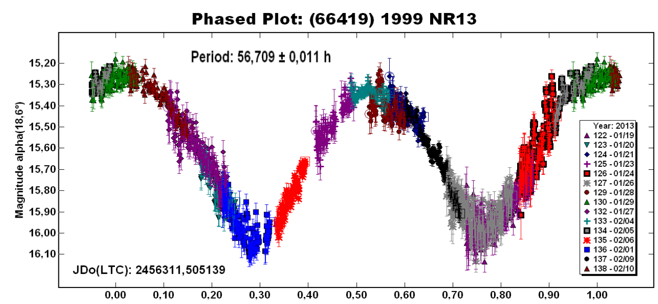

ETSCORN OBSERVED ASTEROIDS: RESULTS FOR SIX ASTEROIDS DECEMBER 2012 – MARCH 2013

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(Received: 9 April)

Lightcurves for 6 main-belt asteroids have been obtained: 852 Wladilena, 1822 Waterman, 1827 Atkinson, 2182 Semirot, 2334 Cuffey and 5317 Verolacqua between 2012 Dec 08 and 2013 Mar 16.

The Etscorn Campus Observatory ECO (2013) has three Celestron 0.35-m Schmidt Cassegrain telescopes used for asteroid lightcurve research. Two of the telescopes are equipped with SBIG STL-1001E CCD camera systems. The third uses an SBIG ST-10 with an Optec 0.5x focal reducer. The STL-1001E CCDs have unbinned

1024x1024, 24 micron pixels providing 1.25 arc seconds per pixel with a field of view of approximately 22 x 22 arc minutes. The ST-10 with the 0.5x focal reducer used 2x2 binned pixels. The image size was 1092x736 with 13.6 micron pixels. This provided a plate scale of 1.28 arc seconds per pixel and the field of view is approximately 20 x 16 arc minutes. Exposures for all objects were either 180 or 300 seconds depending on the asteroid's brightness. All asteroids were imaged through a clear filter. The CCDs were cooled to –20°C to –30°C depending on the ambient temperature.

The telescopes are controlled and the images are collected with Software Bisque's THEsky V6 and CCDsoft V5. On each night a set of 11 flat field images were median combined and used as a master flat for the flat field process which was done using the batch processing of *MPO Canopus* version 10.4.1.0, Warner (2012). Dark frames were automatically subtracted within CCDSoft while light curves were process with *MPO Canopus*. The synodic periods were obtained within *MPO Canopus* using the Fourier method developed by Harris *et. al* (1989)

Asteroid Summaries

Six asteroids were observed and summaries are presented below. The discovery information and multiple designations were obtained from the JPL Small Body Database Search Engine, (2013). The lightcurves for all of these asteroids can be found in the Asteroid Light Curve Database, ALCDEF, (2013).

852 Waladilena is a main-belt asteroid discovered on 1916 Apr 02 by S. Belyavskij at Simei. It is also known as 1916 S27, A913 SB and A9324 WJ. It was observed on 6 nights between 2013 Jan 18 and 2013 Feb 10. A synodic period of 4.613 ± 0.001 h and an amplitude of 0.29 ± 0.05 mag. was obtained. This asteroid was observed because it was listed as an Inversion Modeling Candidate by Warner et. al., (2013). This asteroid has now been observed at 3 different oppositions with the L_{PAB} and B_{PAB} shown in the table below.

UT date	L_{PAB}	B_{PAB}	Reference
1982 Oct 15	11.0	-8.3	Harris, (1999)
2010 Feb 27	164.7	20.6	Behrend, (2010)
2010 Mar 27	164.1	19.9	Polishook,(2012)
2013 Feb 01	115.0	28.0	this paper

1822 Waterman is a main-belt asteroid discovered at Goethe Link Observatory, Brooklyn, IN on 1950 Jul 25 as part of the Indiana Asteroid Program, IAP, (2013). It is also known as 1950 OO, 1943 EB, 1953 MA and 1963 TT. It was observed on 4 nights between 2013 Jan 19 and 2013 Jan 23. A synodic period of 7.581 ± 0.002 h and an amplitude of 0.51 ± 0.05 mag. was obtained. The light curve has a simple bimodal shape. However while the minima are equal the maxima differ by 0.05 mag.

1827 Atkinson is a main-belt asteroid discovered on 1962 Sep 07 as part of the Indiana Asteroid Program IAP, (2013). It is also known as 1962 RK, 1931 VC, 1955 Fl, 1967 TL and 1973 EQ. It was observed on 5 nights between 2013 Feb 16 and 2013 Mar 19. A synodic period of 3.757 ± 0.001 h and an amplitude of 0.24 ± 0.10 mag. was obtained. The night of 2013 Feb 23 has a short series of points with a deviation from the determined curve. These obscurities are believed to be caused by a reported short period of cloud coverage the night of imaging.

2182 Semirot is a main-belt asteroid discovered at Goethe Link Observatory, Brooklyn, IN on 1953 Mar 21 as part of the Indiana Asteroid Program IAP, (2013). It is also known as 1953 FH1, 1937 KF, 1942 FN, 1953 GY, 1955 UT, 1972 TM4, 1975 EU1, 1975 EU3 and 1978 VB8. It was observed on 5 nights between 2013 Jan 31 and 2013 Feb 10. A synodic period of 8.328 ± 0.002 h and an amplitude of 0.32 ± 0.05 mag. was obtained. The lightcurve has a simple bimodal shape.

2334 Cuffey is a main-belt asteroid discovered at Goethe Link Observatory, Brooklyn, IN on 1962 Apr 27 as part of the Indiana Asteroid Program IAP, (2013). It is also known as 1962 HD, 1949 QK, 1955 FK1, 1959 NM , 1962 JQ, 1966 PR and 1982 DK5. It was observed on 3 nights between 2013 Feb 11 and 2013 Feb 14. A synodic period of 5.858 ± 0.002 h and an amplitude of 0.37 ± 0.05 mag. was obtained.

5317 Verolacqua is a main-belt asteroid discovered by C. S. Shoemaker on 1983 Feb 11 at Mount Palomar (MPC 675). It is also known as 1983 CE, 1970 EH, 1983 CB1 and 1987 BF3. It was observed on 7 nights between 2012 Dec 08 and 2013 Feb 02. A synodic period of 3.022 ± 0.002 h and an amplitude of 0.65 ± 0.10 mag. was obtained.

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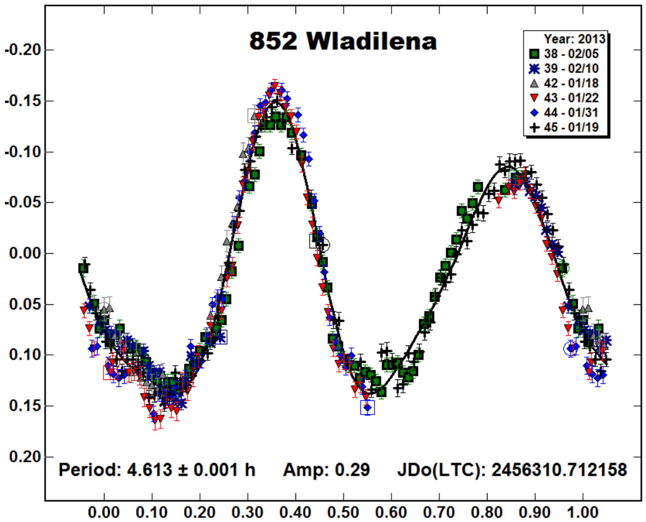
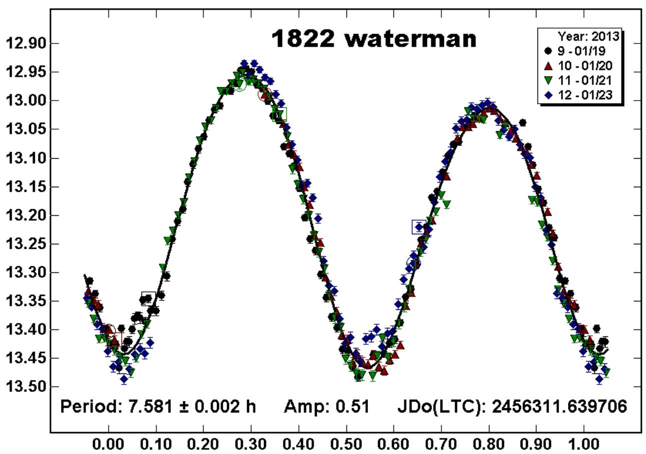

852 Wladilena
Year: 2013
38 - 02/05
39 - 02/10
42 - 01/18
43 - 01/22
44 - 01/31
45 - 01/19
Period: 4.613 ± 0.001 h
Amp: 0.29
JDo(LTC): 2456310.712158


1822 waterman
Year: 2013
9 - 01/19
10 - 01/20
11 - 01/21
12 - 01/23
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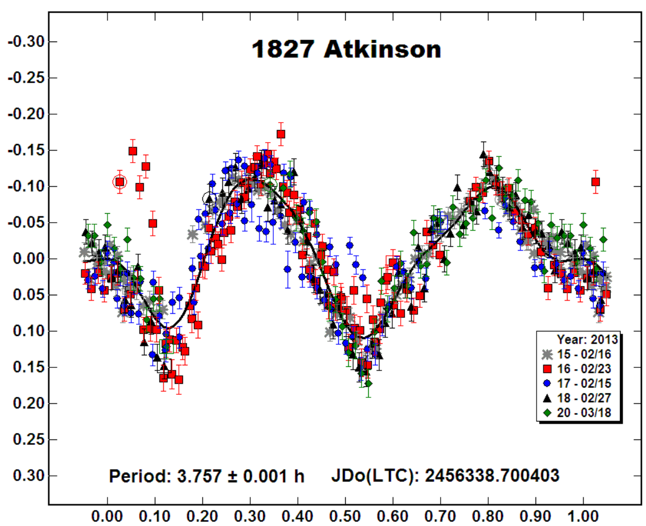
Amp: 0.51
JDo(LTC): 2456311.639706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15 - 02/16
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17 - 02/15
18 - 02/27
20 - 03/18
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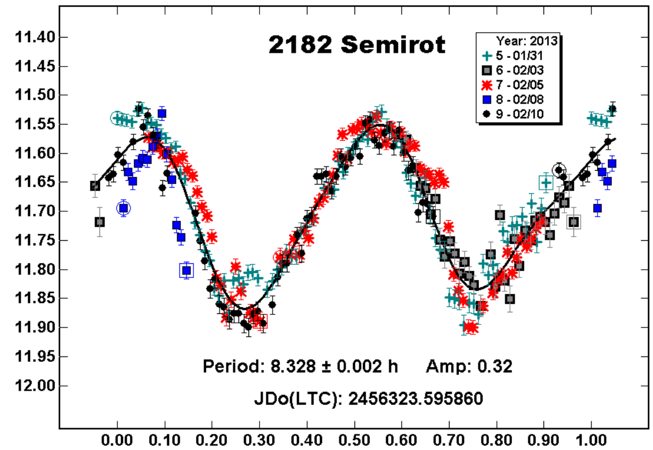
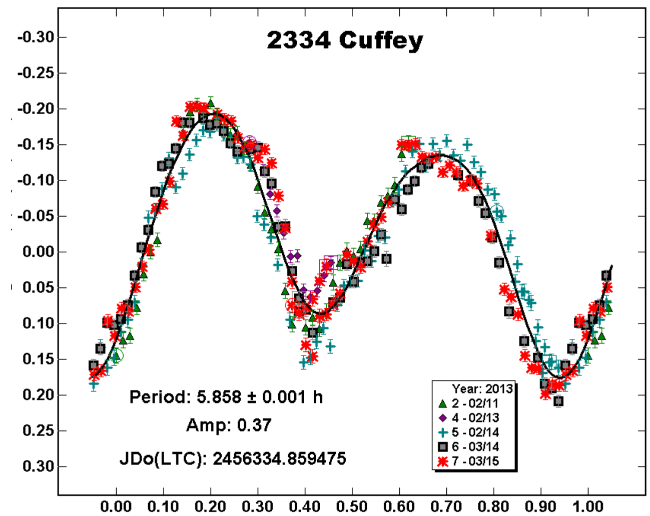
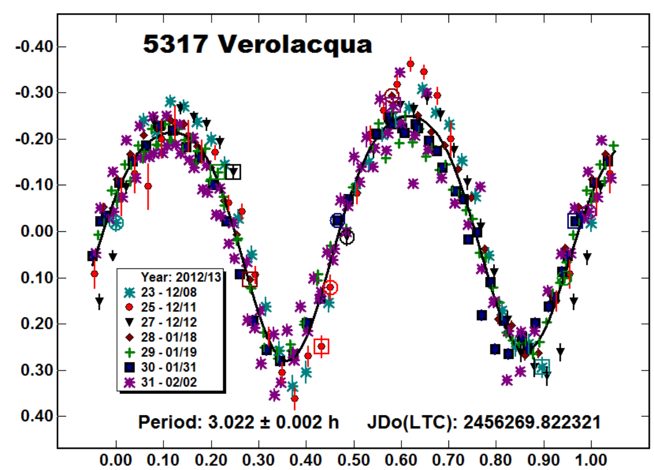
JDo(LTC): 2456338.700403


2182 Semirot
Year: 2013
5 - 01/31
6 - 02/03
7 - 02/05
8 - 02/08
9 - 02/10
Period: 8.328 ± 0.002 h
Amp: 0.32
JDo(LTC): 2456323.595860


2334 Cuffey
Year: 2013
2 - 02/11
4 - 02/13
5 - 02/14
6 - 03/14
7 - 03/15
Period: 5.858 ± 0.001 h
Amp: 0.37
JDo(LTC): 2456334.859475


5317 Verolacqua
Year: 2012/13
23 - 12/08
25 - 12/11
27 - 12/12
28 - 01/18
29 - 01/19
30 - 01/31
31 - 02/02
Period: 3.022 ± 0.002 h
JDo(LTC): 2456269.822321

PHOTOMETRIC ANALYSIS OF 4611 VULKANEIFEL

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CCD photometric observations of main-belt asteroid 4611 Vulkaneifel over 7 nights in late 2012 and early 2013 determined a synodic rotation period of 3.756 ± 0.001h with a lightcurve amplitude of 0.60 ± 0.1 mag.

Asteroid 4611 Vulkaneifel was discovered April 5, 1989 by Geffert, M., and is a main-belt asteroid with an orbital period of 4.23 years (JPL 2012). It has an absolute magnitude of 12.5 and a spectral type: B, (JPL/MPC 2012).

I report observations made from 2012 Dec 20 to 2013 Jan 12 at the Frank T. Etscorn Campus Observatory using a Celestron C-14, a 0.35m telescope with a 0.5 focal reducer. Images were obtained with a SBIG ST-10XME CCD camera set at -25°C, binned at 2x2 giving a pixel size of 13.6 microns. This configuration results in 1.28 arcsec/pixel resolution and a FOV of approximately 20'x16' arcmins. A clear filter was used in all images with exposure times of 3 minutes. Telescope control employed *TheSky 6* and camera control was achieved via *CCDSoft*. All images were dark subtracted and flat field corrected, and a light curve was obtained using the software package *MPO CANOPUS*. (Warner 2012). As shown in Fig. 1, our photometric measurements are well fit by a synodic period of 3.756 ± 0.001h with lightcurve amplitude of 0.60 ± 0.1 mag. Fig.2 shows the period spectrum fit.

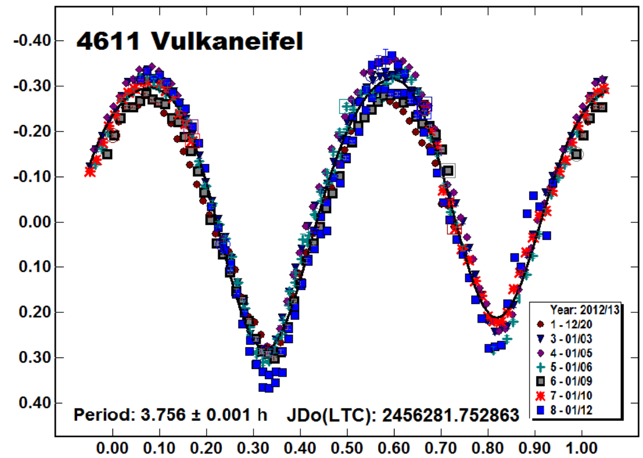

Fig. 1 Phased Plot Vulkaneifel

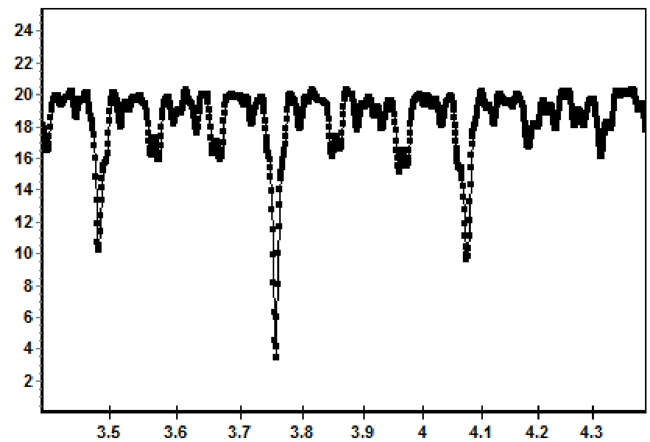

Fig. 2 Period Spectrum showing the best fit.

Acknowledgements

I would like to thank Frank T. Etscorn, Dr. Dan Klinglesmith, Jon Spargo, Judy Stanley, and all others involved in the founding and activities of the campus observatory. I would also like to thank my family. The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Technology (NMIMT). Student support at NMIMT is given by NASA EPScOR grant NNX11AQ35A.

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LIGHTCURVE ANALYSIS FOR 4611 VULKANEIFEL

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The lightcurve for main-belt asteroid 4611 Vulkaneifel was determined from data obtained between January 11 and February 1, 2013. The analysis of the data found a synodic period of P = 3.756 ± 0.001 h and amplitude A = 0.70 ± 0.05 mag.

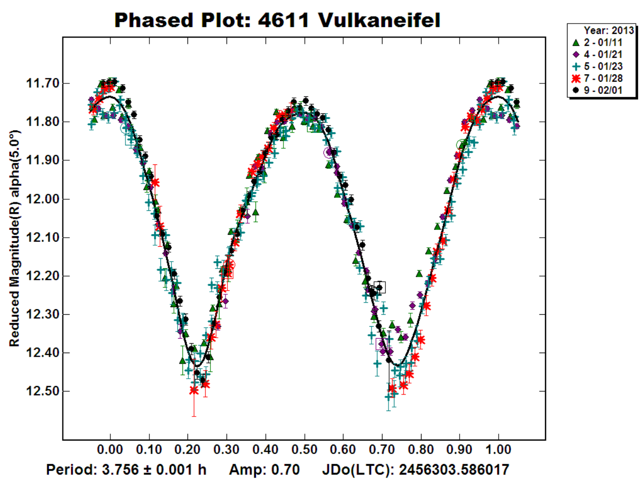
The main-belt asteroid, 4611 Vulkaneifel, was discovered by M. Geffert in 1989 and is named after the Bonn region of Germany, which contains many craters and volcanic remnants (Schmadel 2003). The authors are part of a course at Phillips Academy, taught by C. Odden. As a class, the authors observed and analyzed the data for 4611 Vulkaneifel, collaborating in early 2013 to determine

[1] The annotated authors contributed equally to the research

its rotation period and lightcurve amplitude.

Observations at the Phillips Academy Observatory were conducted with a 0.4-m f/8 DFM Engineering telescope using an SBIG 1301-E CCD camera with a 1280 x 1024 array of 16-micron pixels. The resulting image scale was 1.0 arcsecond per pixel. Exposures were 240 s working at –35° C. All images were dark and flat field corrected, guided, unfiltered, and unbinned. Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. Data merging and period analysis was done within *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris *et al*. (1989).

The data were analyzed by all listed authors, with E. Carrolo and G. Freund producing the lightcurve below. They determined a best fit of 3.756 ± 0.001 h with amplitude of 0.70 ± 0.05 mag. The final data set contained 334 points. This period agrees with the results of Hanus *et al* in their analysis of 4611 Vulkaneifel and other minor planets using Catalina Sky Survey data.



Acknowledgements

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Special thanks to Brian Warner for his advice regarding *Canopus* and for developing the CALL website. This site helped the authors choose 4611 Vulkaneifel.

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ROTATION PERIOD DETERMINATIONS FOR 102 MIRIAM, 108 HECUBA, 221 EOS, 255 OPPAVIA, AND 745 MAURITIA, AND A NOTE ON 871 AMNERIS

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Synodic rotation periods and amplitudes have been found for 102 Miriam 23.625 ± 0.001 hours, 0.08 ± 0.01 magnitudes; 108 Hecuba 14.256 ± 0.001 hours, 0.12 ± 0.02 magnitudes; 221 Eos 10.443 ± 0.001 hours, 0.08 ± 0.01 magnitudes; 255 Oppavia 19.499 ± 0.001 hours, 0.16 ± 0.02 magnitudes with 3 unequal maxima and minima per cycle; 745 Mauritia 9.945 ± 0.001 hours, 0.12 ± 0.02 magnitudes. For 871 Amneris observations on 2 consecutive nights suggest a rotation period of several days with amplitude > 0.35 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. In all cases the lightcurve of the double period has been examined and shows complete or nearly complete phase coverage with the two halves almost the same, and may be safely rejected.

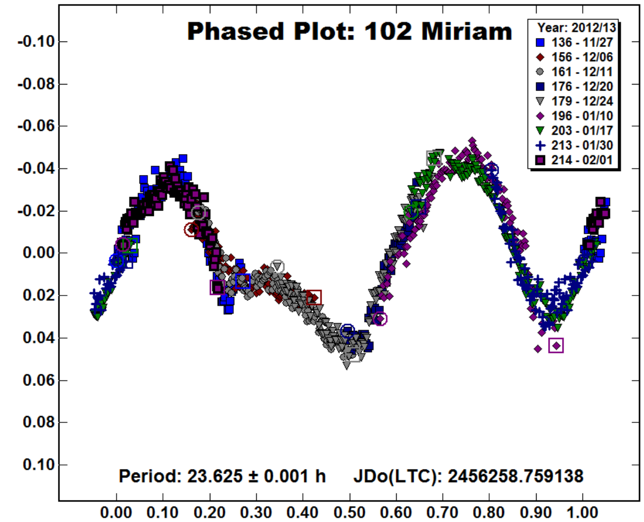
<u>102 Miriam.</u> Previous period determinations are by Shevchenko et al. (1997), 15.789 hours; Riccioli et al. (2001), 15.853 hours; Johnson et al. (2008) 15.789 hours; all providing lightcurves with the usual 2 maxima and minima per cycle; and this writer (Pilcher, 2008), 23.613 hours with 3 unequal maxima and minima per cycle and who also claimed a period near 15.8 hours was ruled out. All of these results were obtained near ecliptic longitude 25 degrees. New observations near ecliptic longitude 120 degrees were planned with the specific goal of unambiguously distinguishing between periods near 15.8 hours and 23.6 hours. All of these claimed periods are slightly less than Earth commensurate, and the segment of lightcurve observed from a single location circulates slowly to the right, with about 60 days required for a complete circulation. Therefore observations were continued from 2012 Nov. 27 to 2013 Feb. 1, and to investigate both sides of a lightcurve phased to a suggested period near 15.8 hours the interval between successive sessions was set to an odd number of days. The new observations on 9 nights are definitive. They

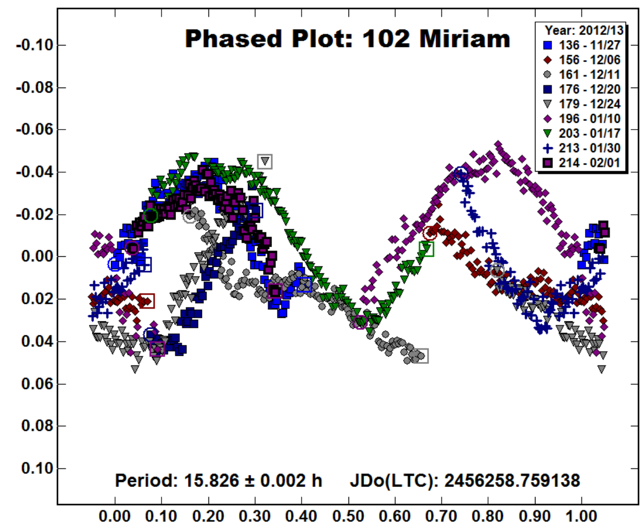
provide a good fit to a lightcurve phased to 23.625 ± 0.001 hours with amplitude 0.08 ± 0.01 magnitudes. This is compatible with the 23.613 hours obtained near ecliptic longitude 25 degrees and again absolutely rules out a period near 15.8 hours. It is noteworthy that while the lightcurve of 102 Miriam has 3 maxima and minima per cycle near ecliptic longitude 25 degrees, it has near ecliptic longitude 120 degrees the usual two maxima and minima per cycle.

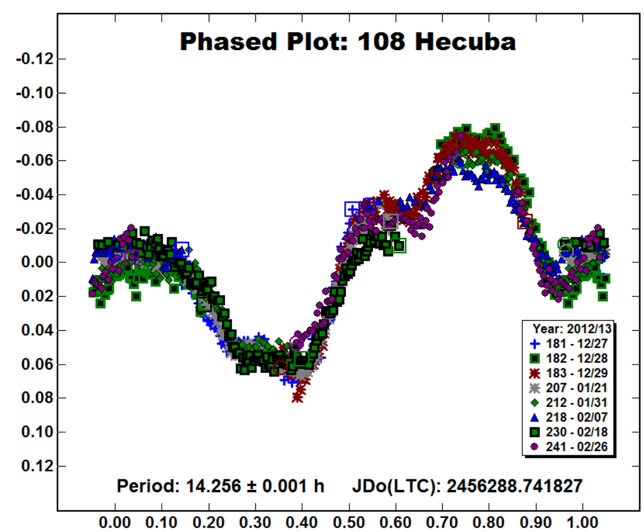
It is instructive to note that all preceding lightcurves are compatible with a period near 23.6 hours, and to explain how acceptance of the 15.8 hour period persisted for many years. As explained previously observations must be continued for at least 60 days to cover the entire lightcurve. Prior to the current investigation all observations had been made within 10 degrees of ecliptic longitude 25 degrees, where 102 Miriam is near perihelion and at its brightest. Hence corresponding sections of the lightcurve included in the data sets should look the same. Pilcher (2008), with 8 sessions 2007 Sept. 14 – Nov. 19, was the first to cover the complete circulation. This lightcurve shows three similar maxima, two similar minima, and one minimum much deeper than the others. While careful examination reveals small but distinct differences among these 3 maxima and the two similar minima, they could easily be overlooked by someone expecting a bimodal lightcurve. Shevchenko et al. (1997) obtained 11 sessions 1974 Sept. 20.2 to Oct. 30.0. In most cases this would be sufficient to cover the entire lightcurve. But in this case given the rate of circulation this observation set covered only about 2/3 of the total lightcurve.. It is suggested, but cannot be proved with data currently available, that the single deep minimum that would have revealed the 23.6 hour period was the segment that was not covered. Riccioli et al. (2001) present a highly symmetric bimodal lightcurve based on observations on 7 nights 1994 Oct. 26 – Nov. 3 which fit a period 15.853 ± 0.002 hours with amplitude 0.08 magnitudes. No one session exceeded 6 hours. Such a symmetric lightcurve could be interpreted in terms of a period near 7.9 hours or 23.6 hours. In both cases the same maximum would be observed on all nights, which explains the observed symmetry. Indeed it is rare that a true bimodal lightcurve exhibits this high degree of symmetry. There are now many published examples of reliable rotation periods based on lightcurves with fairly small amplitude and only one maximum and minimum per cycle. Anyone obtaining a symmetric bimodal lightcurve of small amplitude should immediately suspect the period is only half as great as the bimodal lightcurve suggests. In the case of 102 Miriam the period turned out to be 3/2 as great as suggested by a bimodal lightcurve. Johnson et al. (2008) obtained sessions on only 3 nights 2007 Oct. 18, 19, 20. These overlap in time, and from an observatory with terrestrial longitude not far removed, the more extensive data set by Pilcher (2008). The Johnson et al. (2008) lightcurve could be fit at least as well to a period of 3/2 of their 15.789 hours, and their included segment corresponds well with the segment of Pilcher's lightcurve obtained on Oct. 19.

A lightcurve of the new data phased to a period near 15.8 hours shows a complete misfit and again rules out the shorter period.

108 Hecuba. Previous period determinations are by Behrend (2005), 19.8 hours; Blanco et al. (1994), 14.46 hours; and Warner (2007), 17.859 hours. New observations on 8 nights 2012 Dec. 27 – 2013 Feb. 26 provide a good fit to a lightcurve with period 14.256 ± 0.001 hours and amplitude 0.12 ± 0.02 magnitudes. The period spectrum shows no significant minima between 12 and 22 hours except at 14.256 hours. Among the previous period determinations this is consistent only with the 14.46 hours by Blanco et al. (1994).

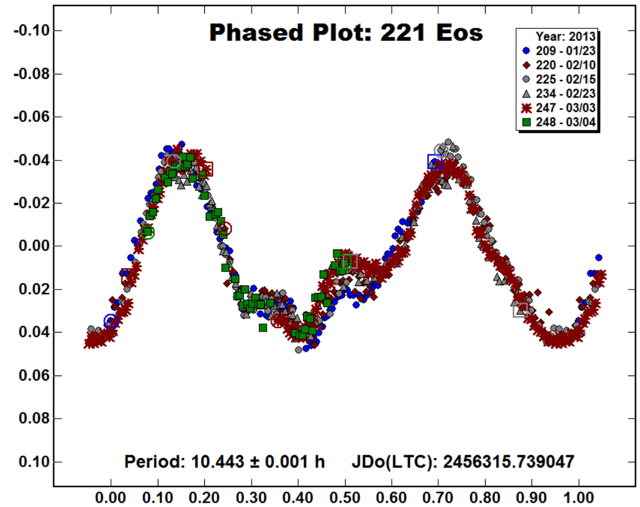




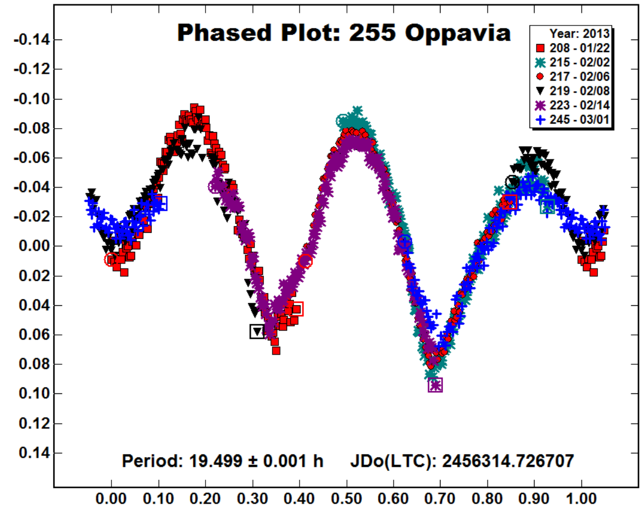


221 Eos. Previous period determinations are by Behrend (2007), 20.4 hours; Harris and Young (1980), 10.45 hours; and Harris and Young (1983), 10.436 hours. New observations on 6 nights 2013 Jan. 23 – Mar. 4 provide a good fit to a lightcurve with period 10.443 ± 0.001 hours and amplitude 0.08 ± 0.01 magnitudes. This period is consistent with Harris and Young (1980 and 1983), and

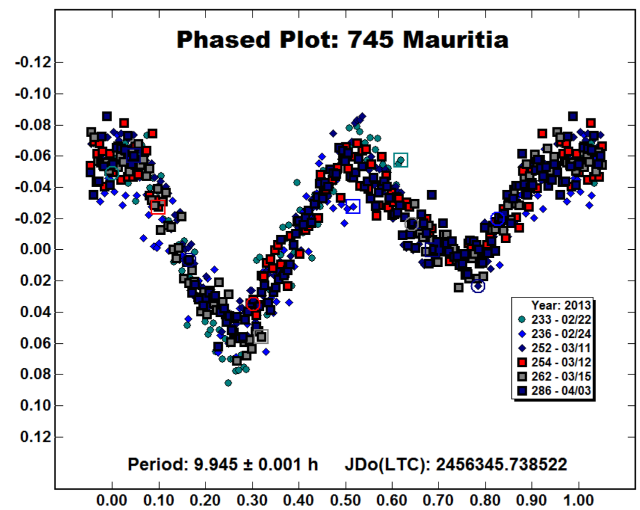
not with Behrend (2013). A bump in the rising part of the lightcurve near phase 0.50 became larger through the interval of observation from phase angle 13 degrees Jan. 23 to 2 degrees Mar. 4. Careful inspection of the lightcurve shows that this increase occurred steadily throughout the well-spaced set of observations. The two halves of a trial lightcurve phased to the double period of 20.866 hours displayed both the bump and its height increase over time in a highly symmetrical manner. It would require a very high degree of symmetry in the asteroid shape over a 180 degree rotation to produce such a feature which was not only an irregularity but one which changed uniformly with change in phase angle. The probability of such shape symmetry in a real asteroid is extremely small, and the double period may be confidently rejected.



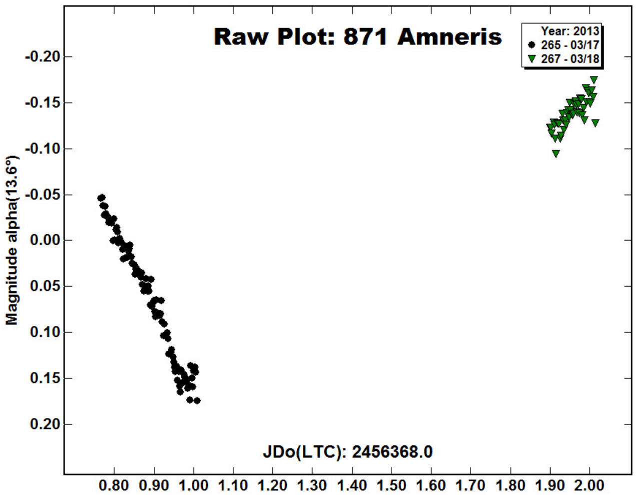
255 Oppavia. Previous period determinations are by Behrend (2008), 14.3 hours; and Ditteon et al. (2010), 19.57 hours. New observations on 6 nights 2013 Jan. 22 - Mar. 1 provide a good fit to a lightcurve phased to 19.499 ± 0.001 hours, amplitude 0.16 ± 0.02 magnitudes, and 3 unequal maxima and minima per cycle. An attempt to fit to a lightcurve with 2/3 of this period and the usual 2 maxima and minima per cycle provided a gross misfit, and the 2/3 period is definitively ruled out. Although this period disagrees with Behrend (2012), it is consistent with Ditteon et al. (2010). It is significant that the new data near ecliptic longitude 160 degrees produce a lightcurve with three maxima and minima per cycle while the much sparser set by Ditteon et al. (2010) near ecliptic longitude 220 degrees produce a lightcurve with two maxima and minima per cycle. This unusual behavior is also found for 102 Miriam as described previously



745 Mauritia. The Asteroid Lightcurve Data Base (Warner et al., 2012) shows no previous observations. New observations on 6 nights 2013 Feb. 22 - Apr. 3 provide a good fit to a lightcurve phased to 9.945 ± 0.001 hours and amplitude 0.12 ± 0.01 magnitudes.



871 Amneris. The Asteroid Lightcurve Data Base (Warner et al., 2012) shows no previous observations. New observations were made on consecutive nights of March 17 and 18. The 25 x 25 arcminute field of the SBIG STL-1001E CCD enabled the same two comparison stars to be used on both nights. Even if there are errors in their catalog magnitudes the calibrated asteroid magnitudes should be consistent. A raw lightcurve of the calibrated data suggests a rotation period of several days and an amplitude > 0.35 magnitudes. Such a target requires many sessions over a long time interval for its complete solution and it was decided to acquire no more data at the current apparition. The next favorable opposition occurs in early 2016 and a campaign involving an international collaboration of northern hemisphere observers is recommended at that time.



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THREE ASTEROIDS WITH CHANGING LIGHTCURVES: 12 VICTORIA, 177 IRMA, AND 215 OENONE

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During their early 2013 apparitions the lightcurve shape and inferred rotation period for 12 Victoria, 177 Irma, and 215 Oenone changed considerably. These changes are described and approximate synodic periods and amplitudes are derived: 12 Victoria 8.661 ± 0.001 hours, 0.05 ± 0.01 magnitudes; 177 Irma 13.858 ± 0.001 hours, 0.24 ± 0.02 magnitudes; 215 Oenone 27.93 ± 0.01 hours, 0.19 ± 0.02 magnitudes.

Asteroid lightcurves are not as highly repetitive as those of most variable stars. These changes are caused by changing phase angle and viewing aspect. Frequently these changes are not considered in producing composite lightcurves including all sessions on the observed object. Over intervals of 10 to 15 days they are usually sufficiently small to be scarcely detectable. Over intervals of 2 months or more they may considerable, and provide important information for spin/shape modeling. In this paper I consider three cases for which a single asteroid showed an unusually great change in form of lightcurve. I present three lightcurves of each object, two over short time intervals during which the change was fairly small, and one covering the entire interval of observation. In interpreting the two shorter interval lightcurves we must recognize that these changes are occurring slowly and steadily throughout the apparition, and not that the lightcurve somehow changed suddenly between the first and second selected intervals. Careful examination of the shorter interval lightcurves does show detectable transition from the early interval shape to the later interval shape.

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, R filter for the bright object 12 Victoria and clear filter for much fainter 177 Irma and 215 Oenone. 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.

12 Victoria. Warner et al. (2012) state a period of 8.6599 hours based on several independent and mutually compatible determinations. New lightcurves were obtained to contribute to improving a lightcurve inversion model. Four sessions 2013 Jan. 6 - Feb. 13 at phase angles 18 to 8 degrees provide a good fit to a lightcurve of period 8.6610 ± 0.0001 hours, amplitude 0.05 ± 0.01 magnitudes and shown in Figure 1. Three sessions 2013 Feb. 28 - Mar. 30 at phase angles 5 to 13 degrees provide a good fit to a lightcurve of period 8.6622 ± 0.0001 hours, amplitude 0.05 ± 0.01 magnitudes, shown in Figure 2. The changes in shape seem more closely related to before versus after opposition rather than to phase angle. A single lightcurve including all seven sessions (Figure 3) shows much greater variation among the sessions and a somewhat different derived period of 8.6607 hours. It is not clear which of these three periods should be accepted and somewhat conservatively I suggest a synodic period 8.661 ± 0.001 hours. This is fully compatible with previous determinations.

177 Irma. Previous period determinations are by Wetterer et al. (1999), 14.208 hours; and Pilcher (2012), 13.856 hours. Two sessions of new observations were obtained near 11 degrees phase angle 2013 Feb. 11 and 16. These provide only 85% phase coverage with a good fit to a lightcurve phased to period 13.855 hours, amplitude 0.26 ± 0.02 magnitudes, and shown in Fig. 4. Five additional sessions were obtained 2013 March 20 - April 8 at phase angles increasing from 0.2 degrees to 6 degrees. These are shown in Fig. 5 providing a good fit and complete multiple phase coverage to a period 13.858 ± 0.001 hours, amplitude 0.24 ± 0.02 magnitudes. Figure 6 is a plot of all seven sessions which is also a good fit to a period of 13.858 ± 0.001 hours. A plot of the five sessions March 20 - April 8 to the double period 27.716 hours provides about 96% phase coverage with the two halves nearly identical. Producing such a symmetric lightcurve requires that the target asteroid have a shape both irregular and highly symmetric over a 180 degree rotation. The probability that a real asteroid could have such a shape is extremely small and the double period may be safely rejected.

The year 2013 observations are consistent with the 13.856 hours found from a dense data set by Pilcher (2012) in late 2011. The 14.208 hour period by Wetterer et al. (1999) is based on observations 1998 Jan. 27, 28, and March 1. Their data are probably good, but a period based on observations on consecutive nights is not sufficiently accurate for the number of cycles between Jan. 28 and March 1 to be reliably counted. The discordance may be attributed to an incorrect cycle count.

215 Oenone. The Asteroid Lightcurve Data Files (Warner et al. 2012) state only an indeterminate period > 20 hours. Eight sessions 2013 Jan. 12 - 24 at a very small range of phase angles 17 to 15 degrees provide a good fit to a somewhat asymmetric bimodal lightcurve with period 27.937 ± 0.004 hours, amplitude 0.19 ± 0.02 magnitudes, shown in Figure 7. These data also provide nearly complete phase coverage to the double period of 55.866 hours which features a lightcurve the two halves of which are highly symmetric. As with 177 Irma as described above such a symmetric but somewhat irregular lightcurve requires that the target asteroid have a shape both irregular and highly symmetric over a 180 degree rotation. Again the double period may be safely rejected. Five additional sessions 2013 Feb. 5 - Mar. 7 at phase angles 11 to 1 degrees provide a good fit to a lightcurve of greatly different shape but the same period, 27.937 ± 0.001 hours, Figure 8. Over this interval the data provide considerably less than full phase coverage to the double period. When all 13 sessions are combined in a single lightcurve (Figure 9) the misfit between the earlier and later sessions is considerable, and a best fit period of 27.913 ± 0.001 hours with amplitude 0.18 ± 0.02 magnitudes is obtained. It is again not clear which of these two periods should be accepted and again somewhat conservatively a synodic period 27.93 ± 0.01 hours is suggested.

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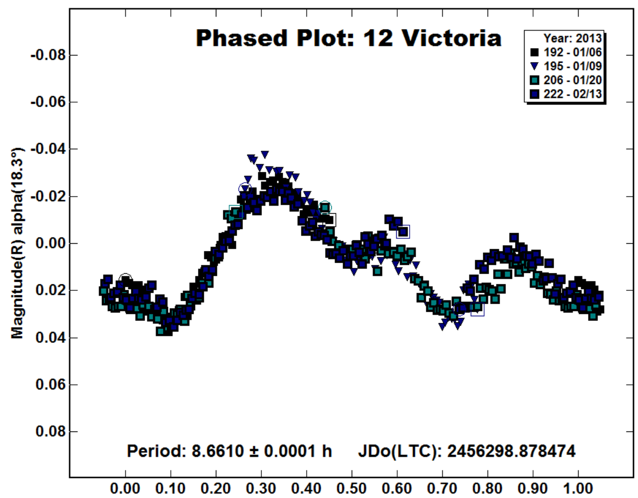

Figure 1. Lightcurve of 12 Victoria for the interval 2013 Jan. 6 - Feb. 13.

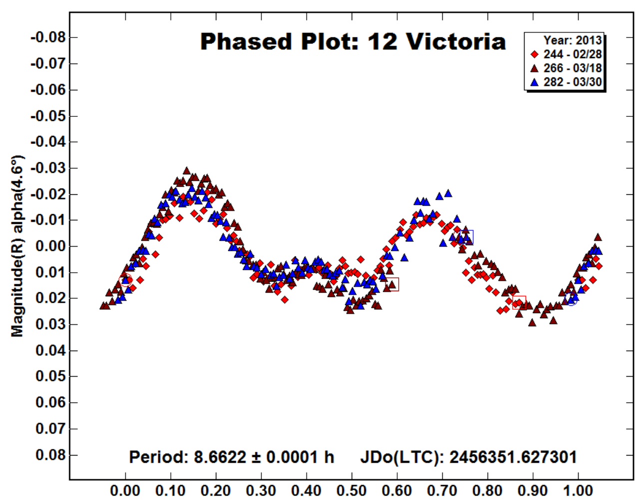

Figure 2. Lightcurve of 12 Victoria for the interval 2013 Feb. 28 - Mar. 30.

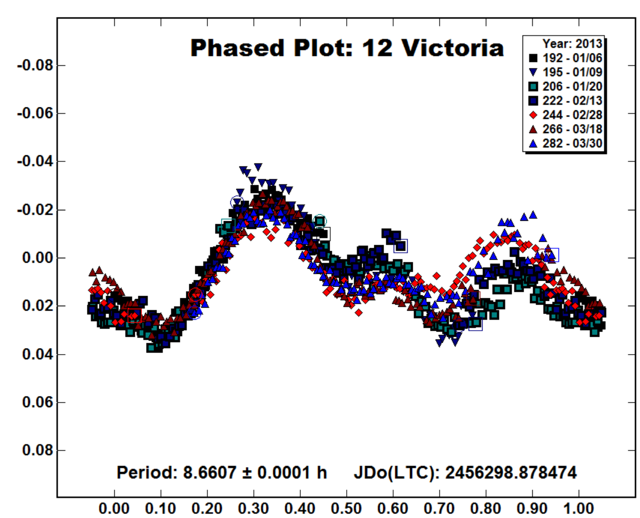

Figure 3. Lightcurve of 12 Victoria for the interval 2013 Jan. 6 - Mar. 30.

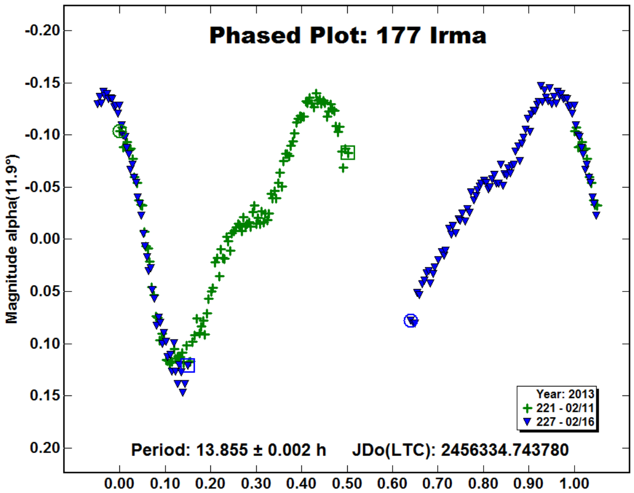

Figure 4. Lightcurve of 177 Irma for the interval 2013 Feb. 11 - 16.

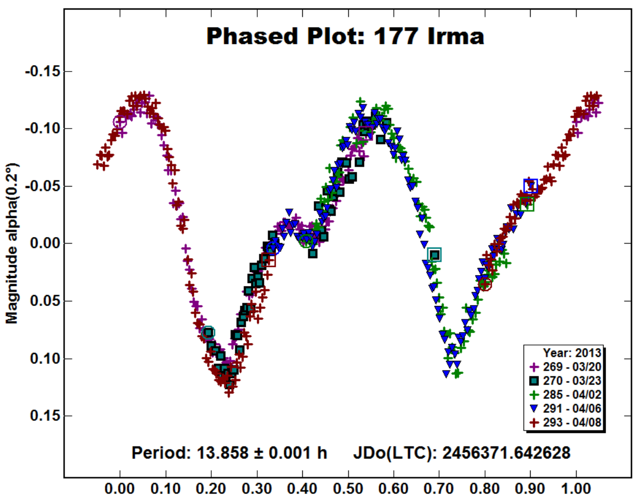

Figure 5. Lightcurve of 177 Irma for the interval 2013 Mar. 20 - Apr. 8.

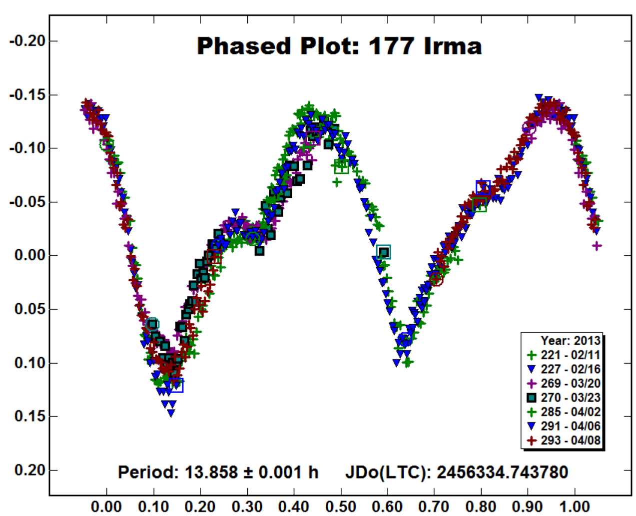

Figure 6. Lightcurve of 177 Irma for the interval 2013 Feb. 11 - Apr. 8.

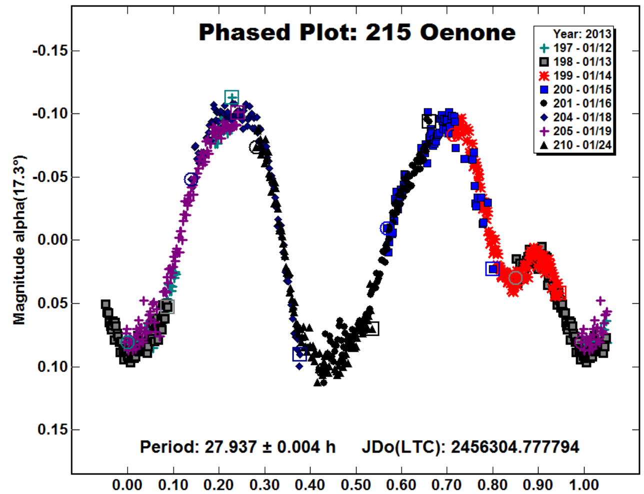

Figure 7. Lightcurve of 215 Oenone for the interval 2013 Jan. 12 - 24.

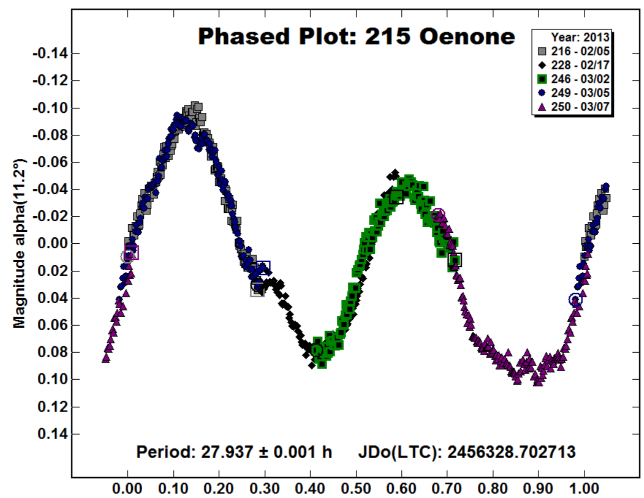

Figure 8. Lightcurve of 215 Oenone for the interval 2013 Feb. 5 - Mar. 7.

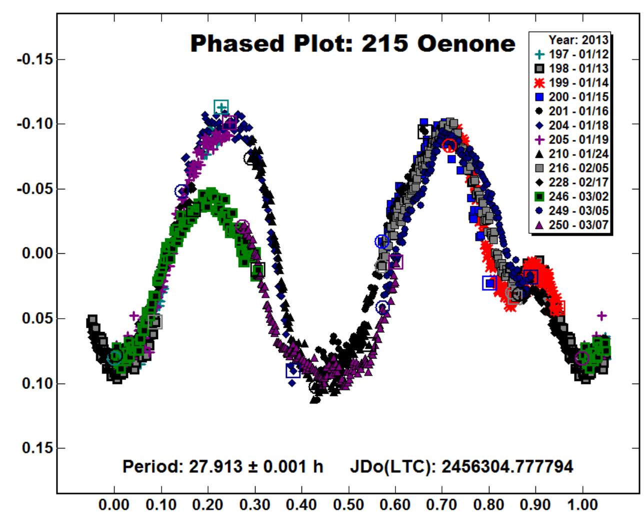

Figure 9. Lightcurve of 215 Oenone for the interval 2013 Jan. 12 - Mar. 7.

THE OSIRIS-REX TARGET ASTEROIDS! PROJECT: A SMALL TELESCOPE INITIATIVE TO CHARACTERIZE POTENTIAL SPACECRAFT MISSION TARGET ASTEROIDS

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The Target Asteroids! citizen science program will support the NASA OSIRIS-REx asteroid sample return mission by characterizing asteroids that may be targets of future sample return missions and by analyzing asteroids which are analogs of the OSIRIS-REx target (101955) Bennu. Obtaining numerous low-precision photometric observations over a range of solar phase angles will provide direct measurements of the phase function, absolute magnitude, color and rotation period, and indirect measurements of the taxonomy, albedo and size.

Target Asteroids! is a citizen science program conducted as part of the Education and Public Outreach of the NASA OSIRIS-REx asteroid sample return mission. We invite both novice and experienced observers to obtain and submit observations of a select group of asteroids that are viable spacecraft sample return candidates. The OSIRIS-REx mission will launch in 2016, rendezvous with the potentially hazardous near-Earth asteroid (NEA) (101955) Bennu (formerly 1999 RQ36) in 2018, and return samples to Earth in 2023. While the main focus is to obtain observations before OSIRIS-REx arrives at Bennu, the observing program may continue well beyond the lifetime of the OSIRIS-REx mission. Observers submit astrometric observations directly to the *Target Asteroids!* program and the IAU Minor Planet Center. Photometric observations and FITS format data are to be submitted directly to the program. We emphasize that, while observers provide the *Target Asteroids!* program with access to their observations, the observations belong to the observer and as such observers may continue to use them as they wish (i.e. publish them, submit them to other programs, etc.).

Program Goals

Target Asteroids! is driven by two goals. The first is to encourage astronomers, both amateur and professional, to make astrometric, photometric, and spectroscopic observations of possible spacecraft sample return near-Earth asteroid targets. Though most are too faint or poorly-placed for observation by even the largest telescopes, a good number of NEAs are bright enough to be within reach of modest-sized equipment. Small telescope photometry can provide direct measurements of the phase function, absolute magnitude, color, and rotation period as well as indirect determinations of the taxonomy, albedo, and size.

The second goal is to increase our knowledge of the near-Earth asteroid population and, in particular, the OSIRIS-REx target asteroid. Though Bennu is very well characterized, there are still gaps in our understanding. This is especially true for observations at very low (< 15°) and very high (> 100°) phase angles. These phase angle observations will allow the OSIRIS-REx team to better define the photometric properties of Bennu prior to encounter and assist in the design of science acquisition sequences when at the asteroid.

We also aim to better understand the characteristics of asteroids in orbits similar to Bennu's. Not only are these objects good candidates for sample return, but they also share a similar history with Bennu. Dynamical evolution studies have shown that asteroids on Bennu-like orbits originally came from the inner part of the Main Belt between ~2.0 and 2.5 AU (Bottke *et al.* 2002). It is very possible that carbonaceous objects on Bennu-like orbits are related to Bennu in that they may have come from the same collision-produced asteroid family in the inner Main Belt (Campins *et al.* 2010; Walsh *et al.* 2013).

Selection of the Targets

The *Target Asteroids!* observing campaign is primarily based on a list of NEAs optimal for spacecraft sample return compiled by the NASA OSIRIS-REx asteroid mission team. The list is constrained to objects with absolute magnitude $H < 21.5$, perihelion distance (q) > 0.8 AU, aphelion distance (Q) < 2.0 AU, and inclination (i) < 8°. The list currently consists of 80 NEAs though the list will grow as new discoveries are made. The most up-to-date list can be found at the *Target Asteroids!* website at

http://osiris-rex.lpl.arizona.edu/?q=target_asteroids

Constraints on absolute magnitude are based on the finding that a majority of objects with $H > 21.5$, corresponding to diameters greater than ~150 meters, are very rapid rotators with rotation periods on the order of minutes to tens of minutes (Pravec and Harris 2000; Hergenrother and Whiteley 2011). Such short rotation periods not only make near-asteroid spacecraft operations difficult but also raise questions as to whether regolith is even present on the surface for sampling. Constraints on perihelion, aphelion, and inclination are based on limiting the amount of energy required to rendezvous with the asteroid and return samples back to Earth. Difficult to reach asteroids require larger launch vehicles and mission lengths. Additionally, asteroids with perihelia smaller than 0.8 AU require major modifications to the spacecraft to handle the hotter thermal conditions while asteroids with aphelia beyond 2.0 AU require larger solar panels.

Since many of the sample return targets are faint, the program was expanded to include special cases, namely asteroids that will also shed light on the properties of Bennu and analogous asteroids. These asteroids include analog NEAs and large Main Belt asteroids. One of the benefits of this expansion is that many of these analogous asteroids will be bright enough to be observed with small telescope and DSLR-equipped observers.

What the Data Tell Us

A common question is what can small telescopes tell us about a NEA that we couldn't learn with large multi-meter class telescopes? Large telescopes can be used to determine rotation periods, colors, taxonomies, albedos, and such. However, these observations usually require many different large telescopes equipped with specialized instruments. Due to the intense competition for use of large telescopes, it is doubtful enough time would be awarded to study all of the asteroids on the target list.

While smaller telescopes cannot produce high S/N observations for many faint objects, they do have the advantage of making many observations. Even lower S/N observations are useful if made often over different observing geometries. This is why our main goal is to acquire photometry of asteroids over a large range of phase angles. The relationship between the brightness of an asteroid and its phase angle (the Sun-asteroid-observer angle) is called its phase function (see Fig. 1).

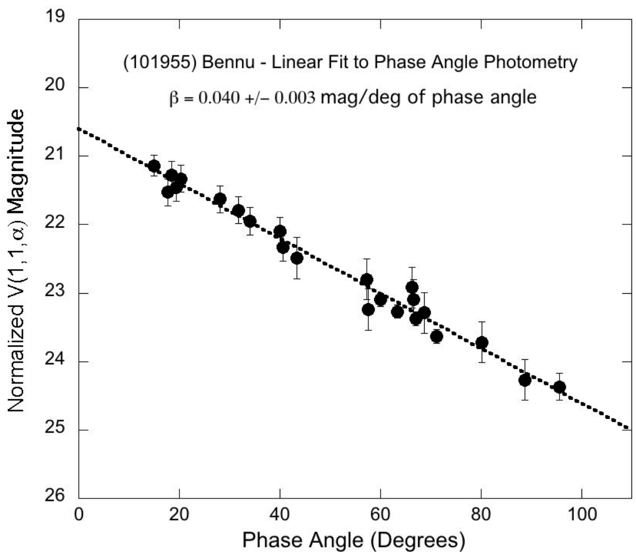

Figure 1. Linear phase function for the OSIRIS-REx target (101955) Bennu. Observations were made with a variety of telescopes over many nights during the 2005-2006 and 2011-2012 apparitions. The slope of the linear part of the phase function is 0.040 ± 0.003 magnitudes per degree of phase angle.

Determining how the light scattering properties of the surface of an asteroid change with phase angle provides us with many important parameters. Though phase functions are usually non-linear especially at very low and high phase angles, they are close to linear at phase angles between ~20° and 70°. The slope of the linear part of the phase function is directly correlated with albedo (Belskaya and Shevchenko 2000; Oszkiewicz *et al.* 2012; Hergenrother *et al*. 2013). Highly reflective asteroids with albedos of ~0.4 or greater have phase slopes of ~0.02 magnitudes per degree of phase angle while dark asteroids (like Bennu) with low albedos on the order of ~0.05 or less have phase slopes of ~0.04 magnitude per degree of phase angle (see Fig. 2).

Modeling the non-linear shape of the phase function and extrapolating it to a phase angle of 0° produces a value for the absolute magnitude (*H*). The combination of our knowledge of *H* and albedo gives an estimate for the size of the asteroid. If observations are acquired in different broadband filters (such as BVRI) at varying phase angles, changes in the color of the asteroid with phase angle can be derived. Broadband colors are used to determine the taxonomy and type.

Use of either a V or R filter when obtaining phase function photometry is desirable. We acknowledge that use of a filter can severely affect the amount of signal recorded especially for smaller aperture telescopes. As a result, we welcome unfiltered photometry. We will work with observers to determine the transformation coefficients for their cameras in order to transform their measurements to V or R.

Usually, when determining the brightness of an asteroid at a certain phase angle, care must be made to account for changes in the asteroid's brightness due to rotation. In short, a lightcurve is required. For most asteroids this requires many hours, and sometimes days, of observations. This is not only a burden on most observers but limits the number of objects we can study. Instead, by obtaining a large number of photometric measures, we can reduce the "noise" caused by rotation and produce an accurate phase function.

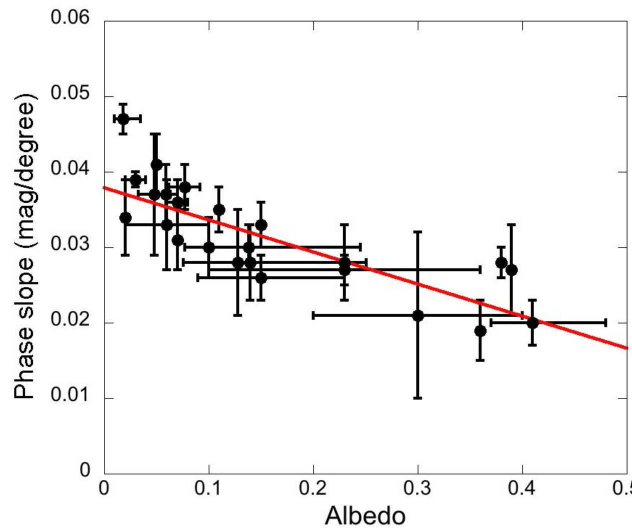

Figure 2. Correlation between the slope of the linear part of a phase function and albedo for near-Earth asteroids with known albedo measurements. The linear fit to the albedo/phase slope data points is y = 0.038 – 0.04x.

Even though we don't require a rotational lightcurve to directly derive a phase function and indirectly derive albedo and size, knowing the rotation period and lightcurve amplitude is important for selecting an asteroid for future sample return missions. We do ask that observers attempt to measure the lightcurve of our targets even if lightcurves are of a lower priority than phase angle photometry.

Every quarter a summary of *Target Asteroids!* list objects brighter than V = 20 will be published in the *Minor Planet Bulletin*. The summary for the 2013 July-September quarter is contained in this issue on pages 166-168.

Additional information on the OSIRIS-REx *Target Asteroids!* program, including how to register, instructions, FAQs, and an updated list of targets, can be found at the OSIRIS-REx website:

http://osiris-rex.lpl.arizona.edu/?q=target_asteroids

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TARGET ASTEROIDS! OBSERVING TARGETS FOR JULY THROUGH SEPTEMBER 2013

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Asteroids to be observed by the *Target Asteroids!* program during the period of July to September 2013 are presented. 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, hence, 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 (formerly 1999 RQ36), the target asteroid of the NASA OSIRIS-REx sample return mission.

Even though many of the observable objects for this program are faint, acquiring a large number of low S/N observations allows many important parameters of the asteroid to be determined. For example, an asteroid’s phase function can be constrained by obtaining photometry taken over a wide range of phase angles. There is a direct correlation between the phase function and albedo. 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 introduction to the program can be found in this issue of the Minor Planet Bulletin on pages 164-166.

July to September 2013 Targets

There are many list asteroids that are observable in very large telescopes. For this observing plan only objects that become brighter than V = 20.0 are listed. A short summary of our knowledge about 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).

The July to September 2013 targets are split up into four sections: 1) Carbonaceous *Target Asteroids!* List targets, 2) *Target Asteroids!* List targets of unknown type, 3) Non-carbonaceous *Target Asteroids!* List targets, and 4) Other asteroids analogous to the OSIRIS-REx target Bennu.

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 Sergio Foglia of the International Astronomical Search Collaboration (IASC) at

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

Carbonaceous Target Asteroids! List Objects

(7350) 1993 VA (a=1.36 AU, e=0.39, i=7.3°, H = 17.0)
Infrared observations from the WISE spacecraft found an albedo of 0.04-0.06 and diameter of ~2.4 km. Though no other information is known about 1993 VA, the low albedo suggests it is carbonaceous. As a possible carbonaceous asteroid, it is analogous to the OSIRIS-REx target Bennu.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	16 23.7	-09 50	0.84	1.77	18.8	19	145
07/11	16 16.0	-11 04	0.93	1.80	19.2	24	135
07/21	16 13.1	-12 23	1.04	1.82	19.6	27	125
07/31	16 14.6	-13 44	1.15	1.84	19.9	30	116
08/10	16 19.7	-15 04	1.27	1.86	20.2	31	108
08/20	16 27.8	-16 20	1.39	1.87	20.4	32	101
08/30	16 38.4	-17 32	1.52	1.88	20.6	33	94
09/09	16 51.1	-18 39	1.64	1.88	20.8	33	88
09/19	17 05.6	-19 38	1.76	1.89	21.0	32	81
09/29	17 21.6	-20 29	1.87	1.89	21.1	31	75

Target Asteroids! Objects of unknown type

(163249) 2002 GT (a=1.34 AU, e=0.33, i=7.0°, H = 18.5)
Unlike the other objects on the *Target Asteroids!* List which are potential spacecraft targets, 2002 GT is an actual spacecraft target. The Deep Impact/EPOXI spacecraft is scheduled to fly-by this asteroid in 2020. Currently little is known about this object (no rotation period, no taxonomy, no albedo, etc.). As a result, an international observing campaign has being organized. In June of 2013, the asteroid peaked in brightness at V = 16.3 which is the brightest it gets before the 2020 fly-by. *Target Asteroids!* members are especially encouraged to obtain astrometry and photometry for this important spacecraft target.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	19 38.8	+73 51	0.12	1.01	17.2	91	83
07/11	02 23.3	+78 28	0.14	0.97	18.1	107	65
07/21	04 28.0	+64 17	0.17	0.93	19.0	116	56
07/31	05 05.9	+52 31	0.20	0.91	19.4	116	54
08/10	05 32.0	+43 39	0.25	0.90	19.5	111	55
08/20	05 55.4	+36 51	0.30	0.90	19.5	105	59
08/30	06 18.3	+31 26	0.34	0.91	19.5	97	63
09/09	06 40.4	+26 55	0.39	0.93	19.5	90	67
09/19	07 01.2	+22 59	0.42	0.96	19.5	83	72
09/29	07 20.1	+19 25	0.45	1.00	19.5	77	77

(163364) 2002 OD20 (a=1.36 AU, e=0.37, i=4.2°, H = 18.8)
Little is known about this potential spacecraft target. It peaked at a relatively bright magnitude 13.9 in late May though it was located at a low declination of -34° at that time. The asteroid should have been observed over a wide range of phase angles during the previous quarter.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	16 30.4	-17 09	0.26	1.24	17.5	25	149
07/11	16 43.8	-16 45	0.34	1.30	18.3	28	143
07/21	16 56.8	-16 47	0.43	1.36	18.9	31	136
07/31	17 10.2	-17 02	0.52	1.41	19.5	34	130
08/10	17 24.6	-17 22	0.63	1.46	20.1	35	124
08/20	17 39.9	-17 41	0.74	1.51	20.5	36	118
08/30	17 56.1	-17 58	0.86	1.56	20.9	37	112
09/09	18 13.1	-18 10	0.98	1.60	21.3	37	107
09/19	18 30.8	-18 13	1.11	1.64	21.6	37	101
09/29	18 49.1	-18 08	1.24	1.67	21.9	37	96

2002 NV16 (a=1.24 AU, e=0.22, i=3.5°, H = 21.3)
2002 NV16 is another potential target with little known about it. Unfortunately it only gets as bright as 19th magnitude.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	16 55.3	+01 13	0.18	1.17	19.2	30	145
07/11	16 34.3	+03 10	0.16	1.13	19.2	42	132
07/21	16 16.8	+04 12	0.15	1.10	19.3	54	120
07/31	16 03.8	+04 27	0.14	1.07	19.4	65	108
08/10	15 54.5	+04 06	0.12	1.04	19.5	76	97
08/20	15 46.6	+03 22	0.11	1.01	19.6	87	87
08/30	15 35.2	+02 20	0.09	0.99	19.6	100	75
09/09	15 12.0	+00 49	0.07	0.98	19.9	116	61
09/19	14 16.9	-01 42	0.05	0.97	21.5	140	38

2007 CN26 (a=1.29 AU, e=0.27, i=7.6°, H = 20.8)
2007 CN26 is yet another potential spacecraft target with little known about it. It peaks at V=16.5 in early September. The close approach presents a good opportunity to observe it over a wide range of phase angles from 26° to ~130°. In addition to phase photometry, color and lightcurve photometry are also high priorities.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	12 09.0	+33 38	0.23	0.97	21.0	96	71
07/11	12 20.4	+34 25	0.20	0.95	21.0	104	66
07/21	12 27.9	+35 52	0.16	0.95	21.0	112	60
07/31	12 26.3	+38 30	0.12	0.95	21.0	122	53
08/10	12 02.9	+43 10	0.08	0.96	21.2	132	44
08/20	10 15.9	+50 36	0.05	0.98	20.9	140	38
08/30	05 16.3	+27 30	0.03	1.00	17.0	102	76
09/09	03 16.6	-06 46	0.06	1.04	16.7	59	119
09/19	02 34.2	-17 37	0.09	1.07	17.3	41	136
09/29	02 09.0	-21 29	0.13	1.11	17.9	32	145

2010 AF30 (a=1.32 AU, e=0.37, i=3.1°, H = 21.5)
Nothing is known about the physical characteristics of 2010 AF30. It peaks at V=17.7 in late July. When the asteroid is brighter than V=20 it is located in the far southern sky. It is possible that this object is a rapid rotator with a rotation period of less than an hour based on its faint absolute magnitude of 21.5.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/11	06 35.3	-22 32	0.05	0.98	21.1	132	46
07/21	01 35.2	-57 29	0.05	1.04	17.7	67	111
07/31	22 25.4	-46 30	0.10	1.10	18.1	33	145
08/10	21 39.2	-38 29	0.15	1.16	18.8	20	157
08/20	21 21.5	-33 39	0.22	1.21	19.7	19	157
08/30	21 14.8	-30 13	0.29	1.27	20.5	22	152
09/09	21 14.5	-27 28	0.37	1.33	21.3	26	145
09/19	21 18.6	-25 07	0.46	1.38	21.9	29	138
09/29	21 26.0	-22 58	0.57	1.43	22.5	32	130

Non-carbonaceous Target Asteroids! List objects

(3361) Orpheus (a=1.21 AU, e=0.32, i=2.7°, H = 19.0)
Orpheus is a V-type asteroid with a rotation period of 3.6 h and lightcurve amplitude of ~0.3 magnitudes. Orpheus should have a relatively high albedo similar to other V-type asteroids. Phase function photometry over a range of phase angles will allow us to confirm whether its albedo is high.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	00 24.8	+05 18	1.17	1.57	21.9	40	91
07/11	00 41.1	+07 02	1.07	1.55	21.7	41	97
07/21	00 56.7	+08 38	0.96	1.53	21.5	40	102
07/31	01 11.3	+10 04	0.85	1.51	21.2	40	108
08/10	01 24.8	+11 18	0.75	1.48	20.8	39	114
08/20	01 36.7	+12 15	0.65	1.45	20.4	37	120
08/30	01 46.4	+12 52	0.55	1.42	19.9	35	127
09/09	01 53.1	+13 01	0.46	1.38	19.4	31	135
09/19	01 55.7	+12 32	0.38	1.34	18.7	26	145
09/29	01 52.8	+11 10	0.31	1.29	18.0	19	156

2001 QC34 (a=1.13 AU, e=0.19, i=6.2°, H = 20.0)
All that is known about 2001 QC34's physical characteristics is that it is a Q- or O-type asteroid. Phase function and lightcurve photometry will shed more light on this viable spacecraft target.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	23 26.3	+04 27	0.65	1.34	21.5	47	105
07/11	23 37.5	+07 47	0.58	1.34	21.2	45	110
07/21	23 45.7	+11 08	0.52	1.33	20.9	43	116
07/31	23 49.9	+14 29	0.46	1.33	20.5	40	123
08/10	23 49.0	+17 45	0.41	1.32	20.1	36	130
08/20	23 41.5	+20 43	0.36	1.30	19.7	31	138
08/30	23 26.5	+23 04	0.32	1.29	19.3	27	145
09/09	23 04.3	+24 18	0.29	1.27	18.9	23	150
09/19	22 38.0	+23 58	0.27	1.24	18.7	24	150
09/29	22 13.2	+22 04	0.26	1.22	18.8	30	143

Other Asteroids Analogous to the OSIRIS-REx Target Bennu

(268) Adorea (a=3.09AU, e=0.14, i=2.4°, H = 8.3)
Adorea is a Themis family member. Spectrally it has been classified as a C-, F- and X-type asteroid. All of these taxonomic types are suggestive of a carbonaceous nature. Albedo measurements from the IRAS spacercraft in the early 1980s found it to be a dark object with an albedo of 0.04. It has a ~8.35 to 8.61 h rotation period with an amplitude of ~0.25 magnitudes. On July 31 it will be at opposition at a phase angle of 0.1° and V magnitude of 12.6.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	21 05.9	-16 47	2.32	3.21	13.3	10	145
07/11	21 00.3	-17 18	2.26	3.22	13.1	7	156
07/21	20 53.3	-17 53	2.23	3.23	12.9	4	168
07/31	20 45.5	-18 31	2.23	3.24	12.7	0	179
08/10	20 37.6	-19 06	2.25	3.26	12.9	3	170
08/20	20 30.5	-19 37	2.31	3.27	13.2	7	158
08/30	20 24.7	-20 02	2.39	3.28	13.4	10	147
09/09	20 20.8	-20 19	2.49	3.29	13.6	12	136
09/19	20 19.0	-20 28	2.61	3.30	13.8	14	126
09/29	20 19.3	-20 29	2.74	3.31	13.9	16	117

(1241) Dysona (a=3.19AU, e=0.10, i=23.5°, H = 9.5)
Dysona has been spectrally classified as a P, D or C-type carbonaceous asteroid. IRAS measured its albedo at 0.04. It has a 7.8 h rotation period with an amplitude of ~0.2 magnitudes. On August 16 it will be at opposition at a phase angle of 0.2° and V magnitude of 13.2.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	22 16.1	-15 45	2.15	2.89	14.3	16	129
07/11	22 11.9	-15 07	2.05	2.90	14.1	13	139
07/21	22 05.5	-14 33	1.98	2.90	13.9	10	150
07/31	21 57.0	-14 04	1.93	2.91	13.7	6	161
08/10	21 47.1	-13 36	1.91	2.92	13.4	2	173
08/20	21 36.8	-13 09	1.91	2.92	13.4	2	175
08/30	21 27.1	-12 40	1.95	2.93	13.7	6	163
09/09	21 18.8	-12 09	2.01	2.94	13.9	9	152
09/19	21 12.5	-11 35	2.10	2.94	14.1	13	141
09/29	21 08.6	-10 58	2.20	2.95	14.3	15	130

(1439) Vogtia (a=4.00AU, e=0.12, i=4.2°, H = 10.5)
ECAS filter photometry of Vogtia suggests that it has a spectrum very similar to Bennu. Albedo measurements from the IRAS spacecraft in the early 1980s also suggest that it is a dark object. It has a 12.95 h rotation period with an amplitude of 0.33 magnitudes. On May 13 it was at opposition at a phase angle of 0.4° and magnitude of 15.9.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	14 56.0	-18 50	3.34	4.04	16.8	11	128
07/11	14 55.5	-18 49	3.47	4.05	16.9	13	118
07/21	14 56.5	-18 54	3.62	4.06	17.1	14	109
07/31	14 59.2	-19 06	3.77	4.07	17.2	14	100
08/10	15 03.3	-19 23	3.93	4.08	17.3	14	92

(7753) 1988 XB (a=1.47AU, e=0..48, i=3.1°, H = 18.6)
1988 XB is a dark carbonaceous B-type asteroid. This makes 1988 XB the same taxonomic type as the OSIRIS-REx target asteroid Bennu. In July, the asteroid is brighter than 18th magnitude and observable at large phase angles. After being too close to the Sun for observation, 1988 XB will become observable again in September though it will be a more difficult object to observe than it was in July.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	13 03.3	-15 38	0.13	1.05	16.8	72	101
07/11	11 17.4	-09 08	0.12	0.97	17.9	108	66
07/21	09 33.5	-00 15	0.13	0.90	21.6	145	31
08/20	07 30.6	+14 29	0.33	0.77	21.3	130	36
08/30	07 35.5	+16 10	0.43	0.76	20.5	113	44
09/09	07 50.6	+17 01	0.52	0.78	20.2	99	50
09/19	08 11.1	+17 14	0.61	0.82	20.2	88	55
09/29	08 33.4	+16 58	0.68	0.88	20.2	79	59

(137126) 1999 CF9 (a=1.77 AU, e=0.60, i=5.5°, H = 17.9)
1999 CF9 is a 0.9-km Q-type NEA. It has a medium to high albedo and no information is known of its rotation state. During the current quarter it will pass within 0.06 AU of Earth. The close approach presents a good opportunity to observe a Q-type asteroid over a wide range of phase angles from 26° to ~130°. It reaches maximum brightness in late August at V=14.4. In addition to phase photometry, color and lightcurve photometry are also high priorities.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	09 49.0	+19 30	0.66	0.71	19.7	96	44
07/11	10 17.7	+18 33	0.52	0.72	19.9	110	41
07/21	10 44.6	+17 46	0.39	0.75	20.3	123	39
07/31	11 13.7	+16 56	0.27	0.82	20.5	132	36
08/10	12 01.5	+15 03	0.16	0.90	19.8	135	39
08/20	14 36.0	+04 27	0.07	0.99	16.1	107	69
08/30	19 40.5	-17 04	0.10	1.09	14.6	39	137
09/09	21 11.2	-18 42	0.20	1.18	16.0	27	148
09/19	21 43.6	-18 13	0.32	1.28	17.1	26	146
09/29	22 02.2	-17 24	0.44	1.37	18.0	28	140

(277475) 2005 WK4 (a=1.01 AU, e=0.24, i=9.8°, H = 20.1)
No physical characteristics of 2005 WK4 are known. Its upcoming flyby of Earth at a distance of 0.02 AU allows for a large range of phase angles to be observed (30° to 130°). It reaches maximum brightness on August 12 at V=13.9. In addition to phase photometry, color and lightcurve photometry are also high priorities.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	08 45.7	+48 53	0.21	0.86	22.7	136	36
07/11	08 43.0	+52 01	0.15	0.90	22.7	141	34
07/21	08 18.0	+55 09	0.10	0.94	22.0	142	35
07/31	06 44.8	+56 51	0.05	0.98	19.6	134	44
08/10	01 39.8	+07 53	0.02	1.02	14.1	68	111
08/20	23 11.1	-38 53	0.06	1.06	15.3	30	149
08/30	22 29.1	-44 32	0.11	1.10	16.8	32	145
09/09	22 12.9	-44 57	0.16	1.13	17.8	36	139
09/19	22 08.2	-43 43	0.21	1.16	18.6	40	133
09/29	22 10.4	-41 41	0.27	1.19	19.3	43	127

(285263) 1998 QE2 (a=2.42 AU, e=0.57, i=12.9°, H = 16.5)
Spitzer IR observations of 1998 QE2 suggest it is a dark object with an albedo of 0.06. Such a dark albedo means it is likely carbonaceous. 1998 QE2 reached V = 10.6 on June 2/3. In the current quarter it is still relatively bright though the change in phase angle is minimal.

DATE	RA	DEC	Δ	r	V	PH	Elong
07/01	19 00.0	+20 45	0.19	1.16	14.8	38	136
07/11	19 08.2	+19 45	0.26	1.22	15.4	34	138
07/21	19 13.5	+17 46	0.33	1.29	16.0	31	140
07/31	19 18.4	+15 15	0.41	1.36	16.5	28	141
08/10	19 24.3	+12 33	0.50	1.43	17.0	27	140
08/20	19 31.6	+09 53	0.60	1.51	17.5	27	138
08/30	19 40.4	+07 26	0.71	1.58	18.0	27	134
09/09	19 50.8	+05 17	0.83	1.66	18.4	28	129
09/19	20 02.4	+03 29	0.96	1.74	18.9	29	124
09/29	20 15.2	+02 03	1.11	1.81	19.3	29	119

LIGHTCURVE ANALYSIS IN SEARCH OF BINARY ASTEROIDS

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Observations of the following asteroids were done in collaboration with observatories and observers around the world. The results were high precision rotational periods that when further investigated could reveal the presence of a satellite in the system. The following periods were obtained. 1979 Sakharov, P = 7.5202 ± 0.0003 h; 2709 Sagan, P = 5.254 ± 0.001 h; 3034 Climenhaga, $P1$ = 2.737485 ± 0.000008 h, $P2$ = 18.954 ± 0.001 h; 3076 Garber, P = 2.7595 ± 0.0002 h; 3704 Gaoshiqi, P = 9.7727 ± 0.0005 h; (15430) 1998 UR31, P = 2.5273 ± 0.0002 h; (29729) 1999 BY1, P = 4.52779 ± 0.00006 h.

Observations of seven asteroids were performed as part of the effort of the Photometric Survey of Asynchronous Binary Asteroids work group Pravec (2009). The asteroids were selected using strict parameters based on the work of Pravec (2006). All observatories and their respective instruments used are tabulated in Table. Tables 3–8 list the observatories and their observing sessions.

Oey, Higgins and Warner used *MPO Canopus* photometric reduction software to further process and export their data. These data were later compiled and easily merged for use with other Canopus users. Pollock used *Mira* for data reduction. At Abastumani and Kharkiv, ASTPHOT software (Mottola et al. 1995) was used for the aperture photometry. The details of their observational method and data reduction were given in Krugly et al. (2002). The other observers used their own proprietary software for photometric reduction. The exported data usually consisted of Julian Date and the relative magnitude. These data when imported into Canopus provide the light curve that can be merged with the existing data pool. *MPO Canopus* period analysis software incorporates the Fourier algorithm (FALC) developed by Harris (1989).

Data for all targets in this paper were gathered over several nights. In general these asteroids were selected based on an H value greater than 12. Typically the data were first analyzed to determine the primary rotational period. When there was sufficient data gathered to determine the primary rotation period, the search for the presence of a satellite or satellites was carried out. The asteroid would be considered a confirmed binary if its light curve showed both a secondary period and mutual (eclipses) events. When the orbital geometry of the asteroid satellite system does not coincide with that of earth and the sun, the mutual events are not detectable. In such cases if the light curve had two periodic components then these asteroids were labeled as probable binaries. Both 3034 Climenhaga and (15430) 1998 UR31 belong to this group.

For 2709 Sagan and (29729) 1999 BY1 there were no detectable secondary period signatures at all so these objects were classified as single asteroids. For the asteroids 1979 Sakarov, 3076 Garber and 3704 Gaoshiqi there were detections of attenuations in their light curves that indicated mutual events. However these events were not adequately captured on multiple nights needed to confirm the actual event occurrence. Furthermore there were no detectable secondary period components that allow the verification of a probable binary.

1979 Sakharov has attracted a considerable amount of attention from the author and co-authors. This asteroid pair showed limited deviations from observations by Oey and Warner however no indications of any deviations were present in the data from Ondrejov or Modra even with low (0.01m) calibrated error. 1979 Sakharov is still a strong candidate for binary detection during a favorable future apparition.

3034 Climenhaga was shown to be a probable binary with a primary rotational period of 2.737485 ± 0.000008 h and a secondary rotational period of 18.954 ± 0.001 h. However due to an unfavorable viewing angle, no eclipse events were visible in the light curves to confirm the presence of this satellite. The light curve was the result of an observing campaign that spanned over a period of 5 months between observers in Australia and South America. Since the range of observations covers a Phase Angle of more than 60 degrees, future apparitions will need to cover a different geometry of viewing angle to show the eclipses.

All binary asteroid candidates' observations should be started when they are approaching opposition and at adequate brightness

Name	Date Range (mm/dd/yyyy)	H	Period (h)	Amp (m)	PA	LPAB	BPAB
1979 Sakharov	08/03/2011 – 09/30/2011	13.6	7.5202 ± 0.0003	0.12 ± 0.02	14,3,14	338	6
2709 Sagan	01/30/2011 – 02/06/2011	13.0	5.254 ± 0.001	0.10 ± 0.01	3	133	-4
3034 Climenhaga (P1)	05/01/2009 – 10/19/2009	12.5	2.737485 ± 0.000008	0.10 ± 0.03	31,4,28	294,337	-6,-2
3034 Climenhaga (P2)	05/01/2009 – 10/19/2009	12.5	18.954 ± 0.001	0.05 ± 0.05	31,4,28	293,337	-6,-2
3076 Garber	11/18/2009 – 11/29/2009	13.7	2.7595 ± 0.0002	0.15 ± 0.05	5,10	54	-7
3704 Gaoshiqi	07/15/2010 – 09/01/2010	12.5	9.7725 ± 0.0005	0.20 ± 0.05	10,4,15	309	8
(15430) 1998 UR31	04/22/2010 – 06/13/2010	14.0	2.5273 ± 0.0002	0.10 ± 0.04	7,4,24	219,226	6,1
(29729) 1999 BY1	10/01/2009 – 10/03/2009	13.4	4.5279 ± 0.0001	0.70 ± 0.05	6,28	110,117	-8,0,6

Table 1. H is taken from the MPCORB file. PA is the solar phase angle. If three values are given, the phase angle reached a minimum during the range of observations. LPAB and BPAB are, respectively, the phase angle bisector longitude and latitude.

to allow sufficient time to do follow-up observations in case a satellite is discovered. Unfortunately, the observations of 3076 Garber were started past opposition causing limited observation time and resulting in a lightcurve of lesser quality. There were two possible attenuations but these were unconfirmed. Further follow up observations in a future apparition will be needed.

(15430) 1998 UR31 has not been worked on previously. There were two clear attenuations seen on the May 6 and 7 sessions. However since no further attenuations were detected, this asteroid's binary status could not be confirmed. On the other hand, when Warner worked on the data, a second period of 23.96h was found suggesting that it is a probable binary.

Acknowledgements

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Mottola S., De Angelis, G., Di Martino, M., Erikson, A., Hahn, G., Neukum, G. (1995) "The Near-Earth objects follow-up program: first results." *Icarus* **117**, 62-70.

Obs	MPC code	Telescope	Camera	Filter
Abastumani	119	0.70-m Maksutov	IMG6303E (FLI)	clear
Kharkiv	121	0.70-m Cassegrain -Newtonian	ML47-10 (FLI)	R and V
Modra	118	0.60-m	Apogee AP-8	Clear
Ondrejov	557	0.65-m	Apogee AP-7P	R
Palmer Divide	716	0.35-m SCT	STL-1001E (SBIG)	Clear
Leura	E17	0.35-m SCT	ST8XME (SBIG)	Clear
Kingsgrove	E19	0.25-m SCT	ST9XE (SBIG)	Clear
Hunters Hill	E14	0.35 m SCT	ST 1001 XE	Clear
PROMPT	-	0.45 m	Apogee Alta	Clear

Table 2. Observatories and instrumentation details

Observatory	Sessions
Abastumani	33, 37
Kharkiv	29, 36, 35, 38
Modra	1, 2, 3, 10,18,21, 26, 30
Ondrejov	5, 6, 9, 15, 20, 31,
Palmer Divide	11, 14
Leura	7, 8, 12, 13, 16, 17, 19, 23, 24, 25, 28, 32

Table 3. The session numbers in phased plot of 1979 Sakharov.

Observatory	Sessions
Modra	5
Leura	1, 2, 3, 4

Table 4. Session numbers in phased plot of 2709 Sagan.

Observatory	Sessions
Prompt	12, 13, 14, 15, 16, 17, 18, 19
Leura	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Hunters Hill	11

Table 5. Session numbers in phased plots of 3034 Climenhaga.

Observatory	Sessions
Prompt	1,2
Leura	5, 6, 9
Hunters Hill	3, 4, 7, 8

Table 6. Session numbers in phased plot of 3076 Garber.

Observatory	Sessions
Prompt	12, 13
Leura	1, 2, 3, 4, 5, 6, 7, 8, 9,10, 11

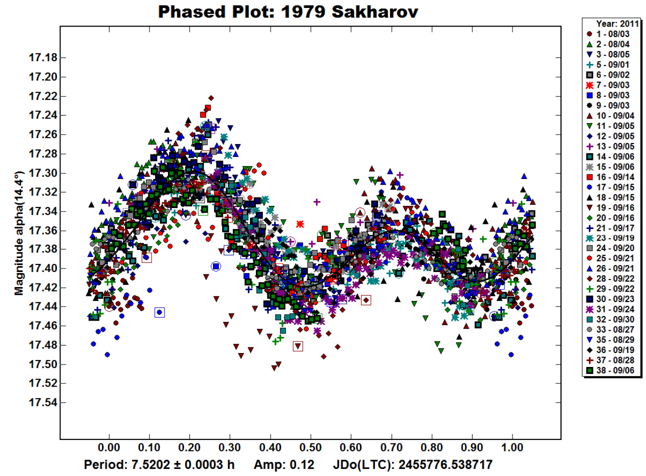
Table 7. Session numbers in phased plot of 3704 Gaoshiqi

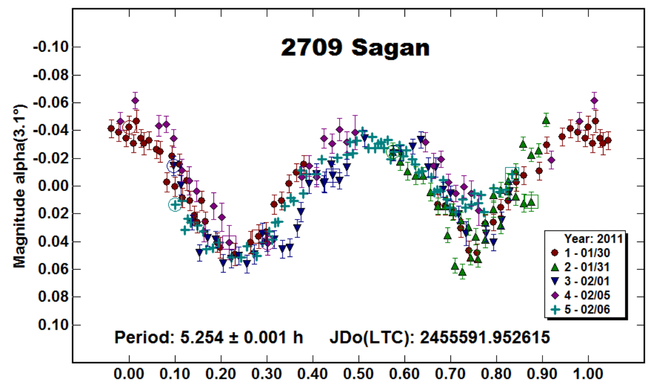
Observatory	Sessions
Hunters Hill	2
Leura	1, 3, 4, 5, 6

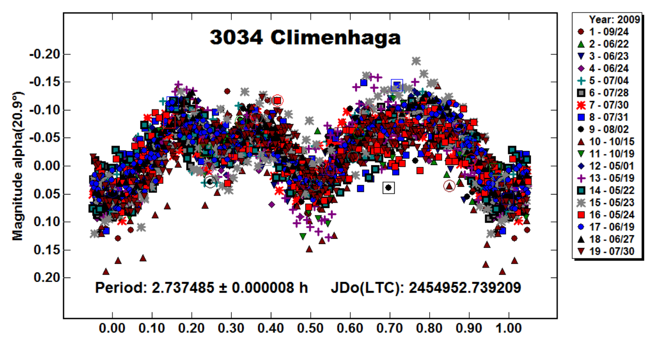
Table 8. Session numbers in phased plot of 29729 1999 BY1

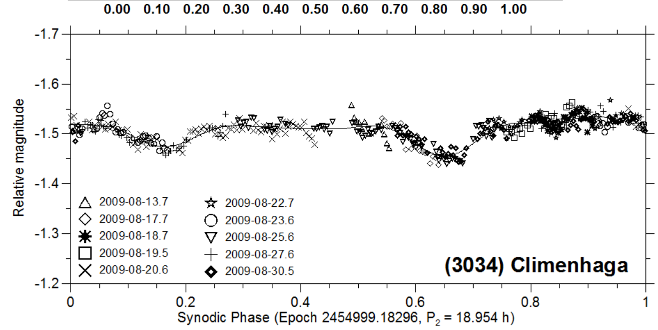
Observatory	Sessions
Abastumani	17
Leura	1 ,2 , 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16
Kingsgrove	3
Kharkiv	7, 9

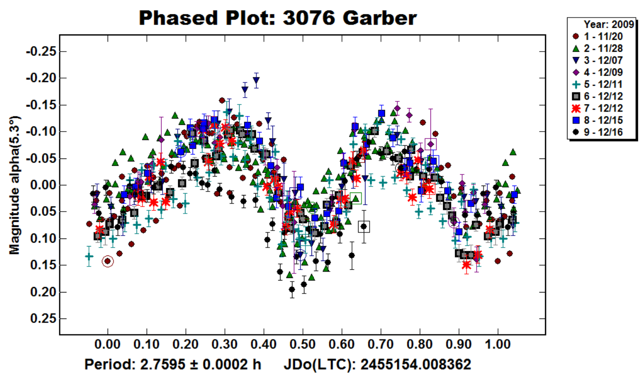
Table 9. Session numbers in phased plot of 15430 1998 UR31

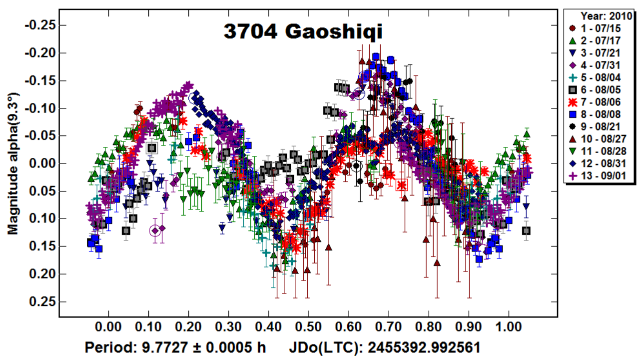


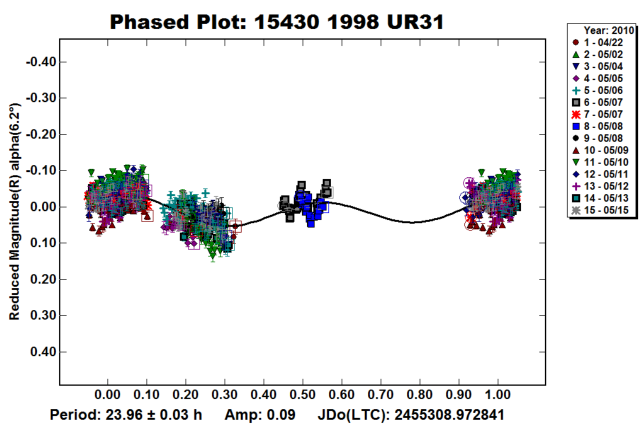


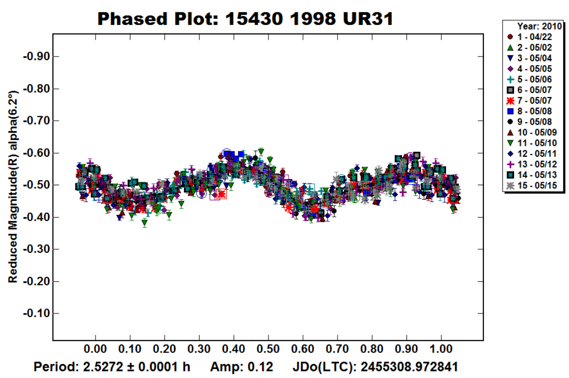


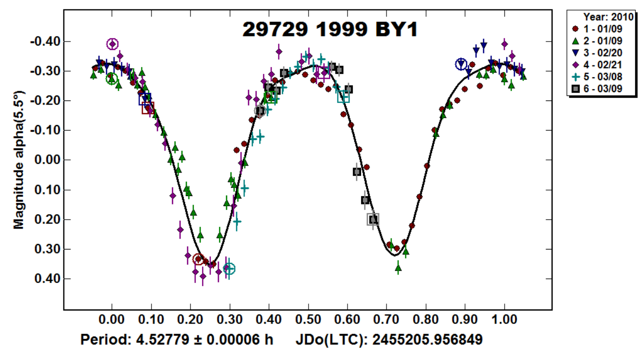












GENERAL REPORT OF POSITION OBSERVATIONS BY THE ALPO MINOR PLANETS SECTION FOR THE YEAR 2012

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Observations of positions of minor planets by members of the Minor Planets Section in calendar year 2012 are summarized.

During the year 2012 a total of 630 positions of 165 different minor planets were reported by members of the Minor Planets Section. Of these 37 are CCD images (denoted C), and all the rest are approximate visual positions.

The summary lists minor planets in numerical order, the observer and telescope aperture (in cm), UT dates of the observations, and the total number of observations in that period. The year is 2012 in each case.

Positional observations were contributed by the following observers:

Observer, Instrument	Location	Planets	Positions
Bookamer, Richard E. 41 cm f/4.5 Newtonian	Sebastian, Florida USA	5	18
Faure, Gerard (7C) 40 cm Meade LX200 SBIG ST237 CCD	Col de l'Arzelier, France	4	16
Harvey, G. Roger 74 cm Newtonian 30 cm S-C at Portal, Arizona, USA	Concord, North Carolina, USA	124	432
Hubbell, Jerry 20 cm RC+CCD	Locust Grove, Virginia, USA	7	30C
Hudgens, Ben 30 cm f/4.9 Dobsonian 41 cm f/4.5 Dobsonian	Stephenville, TX USA	27	62
Pryal, Jim 20 cm f/10 Schmidt-Cassegrain 12 cm f/8.22 refractor	Federal Way, WA USA and environs	17	38
Watson, William W. 20 cm Celestron	Tonawanda, NY USA and vicinity.	9	34

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2012)	NO. OBS.
1 Ceres	Harvey, 30	Dec 13	3
2 Pallas	Pryal, 20	Oct 7	2
5 Astraea	Watson, 20	Apr 14-19	2
6 Hebe	Watson, 20	Mar 14-27	4
8 Flora	Watson, 20	Mar 15-27	7
11 Parthenope	Pryal, 20	Sep 12	2
13 Egeria	Hubbell, 20	Dec 28	4C
32 Pomona	Pryal, 20	Oct 12	2
56 Melete	Pryal, 20	Oct 6-7	2
59 Elpis	Pryal, 20	Sep 19	2
60 Echo	Pryal, 20	Oct 10	2
72 Feronia	Pryal, 20	Sep 15	2
79 Eurynome	Pryal, 20	Oct 6-7	2
85 Io	Pryal, 20	Oct 6-7	2
116 Sirona	Watson, 20	Apr 14-19	2
187 Lamberta	Hubbell, 20	Dec 28	4C
193 Ambrosia	Hubbell, 20	Dec 28	4C
234 Barbara	Watson, 20	Aug 19-21	4
236 Honoria	Pryal, 20	Sep 15	2
241 Germania	Pryal, 20	Oct 7	2
359 Georgia	Pryal, 20	Sep 17-19	4
433 Eros	Pryal, 12	Jan 11-Feb 3	4
	Watson, 20	Jan 28	2
532 Herculina	Pryal, 20	Oct 10	2
602 Marianna	Watson, 20	Aug 19-Sep 15	7
612 Veronika	Hubbell, 20	Jul 3-7	6C
779 Nina	Pryal, 20	Sep 19	2
787 Moskva	Pryal, 20	Sep 13	2
827 Wolfiana	Faure, 40	Sep 14	2
	Hudgens, 30	Sep 6-7	4
867 Kovacia	Hudgens, 30	Dec 11	2
980 Anacostia	Pryal, 20	Oct 10	2
1007 Pawlowia	Faure, 40	Sep 14	2
1049 Gotho	Hudgens, 30	Sep 7	2
1198 Atlantis	Hudgens, 30	Sep 7	2
1207 Ostenia	Hudgens, 41	Mar 26	2
1301 Yvonne	Bookamer, 41	Feb 12	3
1394 Algoa	Hudgens, 41	May 17-18	2
1395 Aribeda	Harvey, 74	Nov 17	3
1437 Diomedes	Hudgens, 41	Feb 14	2
1465 Autonoma	Hudgens, 41	Mar 26	2
1528 Conrada	Hudgens, 41	Jun 21-24	2
1575 Winifred	Hudgens, 41	Mar 12	2
1660 Wood	Bookamer, 41	Feb 12	3
1694 Kaiser	Bookamer, 41	Oct 21	3
1714 Sy	Hudgens, 41	Mar 26	2
1760 Sandra	Hudgens, 41	May 17-18	2
1774 Kulikov	Harvey, 74	Nov 14	3
1834 Palach	Harvey, 74	Nov 9	3
1841 Masaryk	Hudgens, 41	Mar 26	2
1924 Horus	Hudgens, 41	Feb 14	2
1945 Wesselink	Harvey, 74	Sep 24	3
1957 Angara	Hudgens, 41	May 17-18	2
1960 Guisan	Hudgens, 41	May 17-18	2
2177 Oliver	Harvey, 74	Nov 11	3
2227 Otto Struve	Harvey, 74	Nov 11	3
2374 Vladvysotskij	Hudgens, 30	Sep 7	2
2427 Kobzar	Harvey, 74	Nov 11	3
2498 Tsesevich	Harvey, 74	Sep 24	3
2527 Gregory	Harvey, 74	Sep 22	3
2635 Huggins	Hudgens, 41	Mar 26-Apr 23	3
2718 Handley	Harvey, 74	Oct 13	3
2890 Vilyujsk	Harvey, 74	Oct 20	3
3174 Alcock	Harvey, 74	Nov 17	3
3178 Yoshitsune	Bookamer, 41	Feb 19	3
	Hudgens, 41	Feb 14	2
3341 Hartmann	Harvey, 74	Nov 10	3
3351 Smith	Harvey, 74	Sep 22	3
3373 Kottebelia	Harvey, 74	Nov 17	3
3382 Cassidy	Harvey, 74	Oct 12	3
3442 Yashin	Harvey, 74	Nov 17	3
3483 Svetlov	Harvey, 74	Jan 1	3
3494 Purple Mountain	Harvey, 74	Sep 15	3
3518 Florena	Harvey, 74	Jul 27	3
3664 Anneres	Harvey, 74	Dec 23	3
3708 1974 FV1	Harvey, 74	Sep 24	3
3713 Pieters	Harvey, 74	May 27	3
3764 Holmesacourt	Harvey, 74	Feb 13	3
3784 Chopin	Harvey, 74	May 20	3
3795 Nigel	Harvey, 74	May 13	3
3813 Fortov	Hudgens, 30	Sep 7	2
3920 Aubignan	Hudgens, 30	Sep 7	2
4179 Toutatis	Harvey, 30	Dec 8-13	18
	Watson, 20	Dec 13	4
4192 Breysacher	Harvey, 74	Aug 26	3
4300 Marg Edmondson	Harvey, 74	Oct 12	3
4373 Crespo	Harvey, 74	Nov 10-11	3
4694 Festou	Harvey, 74	Sep 8	3
4712 Iwaizumi	Harvey, 74	Nov 11	3
4724 Brocken	Hudgens, 41	Jun 21-24	2
4875 Ingalls	Harvey, 74	Aug 25	3
4949 Akasofu	Harvey, 74	Nov 10-11	3
4975 Dohmoto	Harvey, 74	Nov 11	3
5097 Axford	Harvey, 74	Aug 26	3
5139 Rumoi	Harvey, 74	Apr 15	3
5140 Kida	Harvey, 74	Sep 10	3
5162 Piemonte	Harvey, 74	Nov 17	3
5229 1987 DE6	Harvey, 74	Sep 10	3

PLANET	OBSERVER & APERTURE (cm)	OBSERVING PERIOD (2012)	NO. OBS.
5323 Fogh	Harvey, 74	Oct 20	3
5366 Rhianjones	Harvey, 74	Jul 27	3
5369 Virgiugum	Harvey, 74	Aug 13	3
5380 Sprigg	Harvey, 74	May 27	3
5463 Danwelcher	Harvey, 74	Oct 21	3
5512 1998 VD7	Harvey, 74	Nov 11	3
5537 1964 TA2	Harvey, 74	Sep 10	3
5580 Sharidake	Harvey, 74	Nov 17	3
5619 Shair	Harvey, 74	Aug 25	3
	Hudgens, 30	Sep 7	2
5757 Tichá	Harvey, 74	Apr 16	3
5826 1990 DB	Harvey, 74	Apr 15	3
6092 Johnmason	Harvey, 74	Aug 13	3
6223 Dahl	Harvey, 74	Oct 20	3
6314 1990 SO16	Harvey, 74	Jan 2	3
6376 Schamp	Harvey, 74	Aug 13	3
6421 1993 XS1	Harvey, 74	Oct 21	3
6447 Terrycole	Harvey, 74	Nov 11	6
6449 Dukara	Harvey, 74	Jan 1	3
6507 1982 QD	Harvey, 74	Nov 17	3
6599 Tsuko	Harvey, 74	Sep 10	3
6600 Qwerty	Harvey, 74	Nov 10	3
6742 Biandepei	Harvey, 74	May 26	6
6992 Minano-Machi	Harvey, 74	May 20	3
7160 Tokunaga	Harvey, 74	Oct 20	3
7187 Isobe	Harvey, 74	Aug 17	3
7189 Kuniko	Harvey, 74	Sep 24	3
7254 Kuratani	Harvey, 74	Oct 21	3
7282 1989 BC	Harvey, 74	Feb 12	3
7449 Dollen	Harvey, 74	Sep 10	3
7530 Mizusawa	Harvey, 74	Aug 25	3
7676 1995 WN8	Harvey, 74	May 13	3
8297 Gérardfaure	Faure, 40	Mar 25	7C
8930 Kubota	Harvey, 74	Nov 11	3
9069 Hovland	Harvey, 74	Nov 10	3
9564 Jeffwinn	Harvey, 74	Aug 17	3
10155 Numaguti	Harvey, 74	Oct 20	3
10811 Lau	Harvey, 74	Jan 1	3
11003 Andronov	Harvey, 74	Oct 20	3
11006 Gilson	Harvey, 74	Sep 8	3
11171 1998 FB42	Harvey, 74	Sep 8	3
11363 Vives	Harvey, 74	Oct 12	3
11438 Zeldovich	Harvey, 74	Sep 15	3
12304 1991 SR1	Harvey, 74	Sep 24	3
12999 Torún	Harvey, 74	Oct 21	3
13904 Univinnitsa	Harvey, 74	Sep 10	3
14000 1993 FZ55	Harvey, 74	Sep 15	3
14385 Holdridge	Hubbell, 20	Jul 7	3C
14625 1998 UH31	Harvey, 74	Jan 1	3
14870 1990 SM14	Harvey, 74	Aug 25	3
16058 1999 JP75	Harvey, 74	Jan 1	3
19311 1996 VF3	Harvey, 74	Jan 2	3
19336 1997 AF	Harvey, 74	Nov 10	3
19469 1998 HV45	Harvey, 74	Nov 11	3
19926 1979 YQ	Harvey, 74	Oct 22	3
20899 2000 XB3	Harvey, 74	Jul 27	3
22141 2000 VH36	Harvey, 74	Nov 11	3
22331 1992 AC1	Harvey, 74	Dec 23	3
23468 Kannabe	Harvey, 74	Oct 12	3
26895 1995 MC	Harvey, 74	Aug 13	3
27260 1999 XF164	Harvey, 74	Jul 27	3
28913 2000 OT	Hudgens, 41	Feb 14	2
37655 Illapa	Harvey, 74	Aug 9	6
42776 Casablanca	Faure, 40	Mar 14	5
43232 2000 AH178	Harvey, 74	Oct 12	3
46436 2002 LH5	Harvey, 74	Aug 13	3
47035 1998 WS	Hudgens, 41	Feb 14	2
49483 1999 BP13	Harvey, 74	Jan 30	3
58143 1983 VD7	Harvey, 74	Nov 10	3
72036 2000 XM44	Harvey, 74	Apr 16	3
136993 1998 ST49	Harvey, 74	Oct 12	6
141018 2001 WC47	Harvey, 74	Apr 12	6
153958 2002 AM31	Harvey, 74	Jun 28	6
162004 1991 VE	Harvey, 74	Nov 4	6
162421 2000 ET70	Bookamer, 41	Feb 19	6
	Harvey, 74	Feb 4	6
192642 1999 RD32	Harvey, 74	Feb 12	6
203471 2002 AU4	Harvey, 74	Dec 23	6
214869 2007 PA8	Harvey, 74	Sep 22-24	6
	Watson, 20	Nov 7	2
329338 2001 JW2	Harvey, 74	Nov 4	6
345705 2006 VB14	Harvey, 74	Dec 3	6
1927 LA	Hudgens, 41	Feb 14	2
2005 WD	Harvey, 74	Nov 9	6
2007 LE	Harvey, 74	May 31	6
2011 WY134	Harvey, 74	May 10	6
2012 KP24	Harvey, 74	May 28	6
2012 LZ1	Harvey, 74	Jun 16	6
	Hudgens, 41	Jun 16	7
2012 NJ	Harvey, 74	Jul 15	6
2012 OQ	Harvey, 74	Jul 23	6
2012 QG42	Harvey, 74	Sep 8	6
	Hubbell, 20	Sep 12	9C
2012 QF49	Harvey, 74	Oct 20	6

(27568) 2000 PT6: A NEW HUNGARIA BINARY

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Analysis of CCD photometric observations of the Hungaria asteroid (27568) 2000 PT6 shows that the asteroid is a binary system. The primary has period of 3.4885 ± 0.0002 h. No mutual events were observed, i.e., occultations or eclipses. However, there is a strong secondary period with a bimodal lightcurve of 16.356 ± 0.003 h. This secondary lightcurve indicates a slightly elongated satellite of somewhat irregular shape that may be tidally-locked to its orbital period. The discovery of the satellite led to a revision of previous results from 2011.

The Hungaria asteroid (27568) 2000 PT6 was observed by Warner (2012) and a period of 3.624 h reported. This was based on three sessions over eight days spaced four days apart. As part of the program at the Palmer Divide Observatory (PDO) to obtain spin axis models for Hungaria asteroids, the asteroid was observed again in 2013 March and April. The results were considerably different from those in 2011.

The observations at PDO were started on 2013 March 11 using a 0.35-m Schmidt-Cassegrain and SBIG STL-1001E CCD camera. Exposures were 240 seconds and unfiltered. The last PDO observations were on March 19, at which time the observatory was closed in preparation for moving it to the Center for Solar System Studies (CS3) site in Landers, CA. Since the PDO observations indicated something unusual and the analysis results were ambiguous, Stephens started a run of six consecutive nights from April 2-7. The CS3 observations were made with a 0.35-m Schmidt-Cassegrain and SBIG STL-1001E. Exposures were 300 seconds and unfiltered. These additional data would prove to be critical to finding a solution.

All images were measured in *MPO Canopus*. The dual-period feature in that program, based on the FALC algorithm developed by Harris (Harris *et al.*, 1989) was used to subtract one of the periods from the data set in an iterative process until both periods remained stable. Night-to-night calibration of the data was done using the Comp Star Selector feature in *MPO Canopus*. Catalog magnitudes for the comparison stars were derived from J-K to BVRI formulae developed by Warner (2007) using stars from the 2MASS catalog (Skrutskie *et al.*, 2006). A description of this method was described by Stephens (2008).

The analysis using only the PDO data found two possible periods for the primary of the suspected binary system, one of about 3.49 h and one near 3.62 h, the same as found in 2011. The secondary period was about 16.3 h. The 3.62 h period is almost exactly 2/9 of 16.3 h. Such "coincidences", i.e., periods that are integral fractions of one another, are often the result of the Fourier analysis finding a harmonic of the shorter period. The PDO data set alone could not eliminate the possibility. However, when the CS3 data were incorporated, providing a total span of 27 days, an unambiguous solution of P_1 = 3.4885 ± 0.0002 h was found. The full data set phased to this period is shown in Figure 1.

The secondary lightcurve has a period of 16.353 ± 0.003 h (Figure 2). There are no obvious signs of mutual events, i.e., occultations or eclipses. Instead, there is a bimodal lightcurve with somewhat flat maximums and an unusual number of three minimums. This lightcurve is believed to represent a slightly elongated satellite, possibly with a significant concavity (crater), that may be tidally-locked to the orbital period. The latter could be established by observations at a future apparition where mutual events are observed, if the satellite's orientation allows.

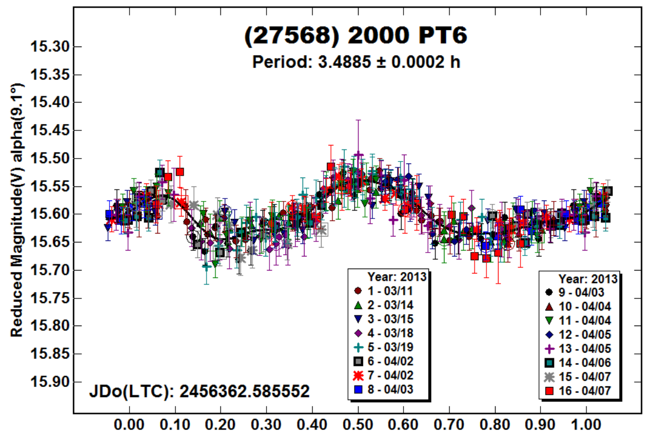

Figure 1. The primary lightcurve for 2000 PT6 from 2013.

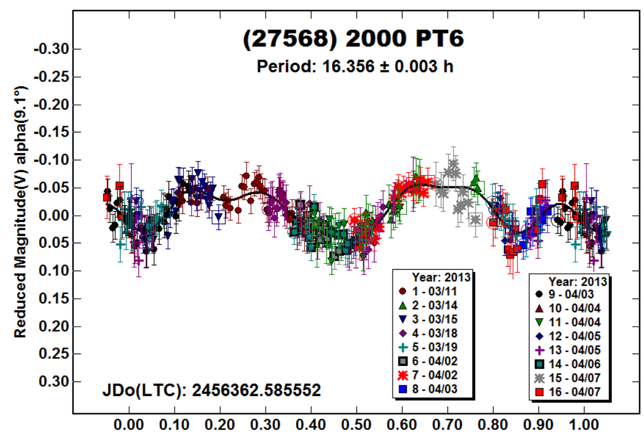

Figure 2. The secondary lightcurve for 2000 PT6 from 2013.

Revising the 2011 Results

Given the results from the 2013 data, the data from 2011 were revisited to see if their analysis showed any signs of a satellite and/or if they could be fit to a period near 3.49 h. When doing a period scan between 3.3 and 3.8 h, the one of 3.624 h was favored. There was a secondary minimum in the period spectrum near 3.49 h (see Figure 3). It should be noted that the three sessions from 2011 were spaced four days apart and that the difference in the periods is almost exactly two rotations over that period. As was seen from the 2013 observations, a more protracted data set was required to find a definitive solution.

The 2011 data were forced to a period near 3.49 h. The result is shown in Figure 4. The lightcurves at this period and the original 3.624 h are indistinguishable on first glance. Under most circumstances, it would be reasonable to believe that the 2011 data set was sufficient to find the correct solution. This serves as a cautionary tale, specifically one of trying to obtain data sets that are not so widely-spaced in order to remove rotational aliases.

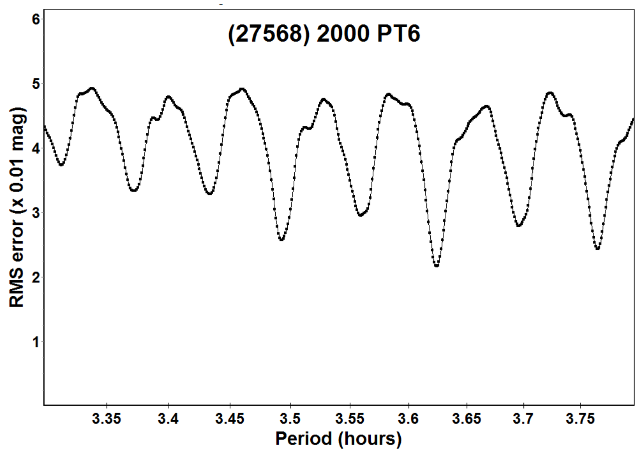

Figure 3.The period spectrum for 2000 PT6 from the 2011 data.

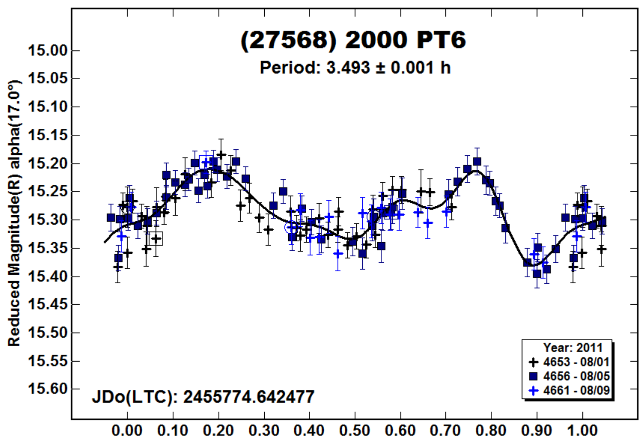

Figure 4. The lightcurve of 2000 PT6 forced to 3.493 h.

Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G and by National Science Foundation grant AST-1032896.

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LIGHTCURVE ANALYSIS FOR NEAR-EARTH ASTEROID 2012 TC4

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A lightcurve for asteroid 2012 TC4 was obtained using images from HUT Observatory. Observations were made on UT October 10, 2012.

On Friday, October 12, 2012, asteroid 2012 TC4, estimated to be 17 meters in diameter, passed within 59,000 miles of Earth, roughly 25 percent of the distance to our Moon. Images of this NEO were captured on October 10, 2012, from the HUT Observatory in Eagle, Colorado. The newly discovered object had an obviously fast rotation period given how it appeared to flicker as raw images appeared during the observing session. There was considerable correspondence in real-time on the MPML discussion list regarding the nature of the object and optimal observing strategies.

The images were made available to students at Phillips Academy, who generated a lightcurve for the asteroid and determined the period. The HUT telescope is a .40-m f/8 Ritchey-Chrétien reflector by DFM Engineering. Observations were made with an Apogee Alta model U47 CCD camera. Exposures were 30 seconds working at -40° C. All images were dark and flat-field corrected, unfiltered, and binned 2x2 for an effective image scale of 1.65 arcsec/pixel. Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. All comparison stars were selected to have approximately solar color by using the "comp star selector" tool of *MPO Canopus*. Data merging and period analysis were also done with *MPO Canopus*, the latter using an implementation of the Fourier analysis algorithm of Harris (FALC; Harris *et al.*, 1989).

The resulting lightcurve consists of 730 data points. The data were taken in six series because of the object's fast motion. The short period necessitated unusually short exposures, which in turn increased the signal-to-noise ratio. Although there is some scatter in the data, the period spectrum strongly favors the adopted period P = .2036 ± 0.0001 h (12.22 ± .006 minutes). 1/2P, 3/2P and 2P also yielded low rms values, but we reject these in favor of the bimodal solution. The resulting lightcurve has amplitude 0.86 mag. The period is in excellent agreement with that reported by Polishook and Warner.

Acknowledgments

Work at the Phillips Academy Observatory is supported by the Israel Family Foundation. Work at the HUT Observatory is supported by the Mittelman Family Foundation.

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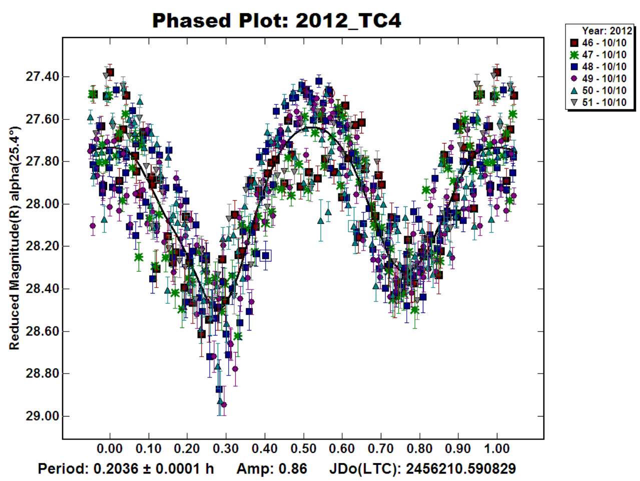

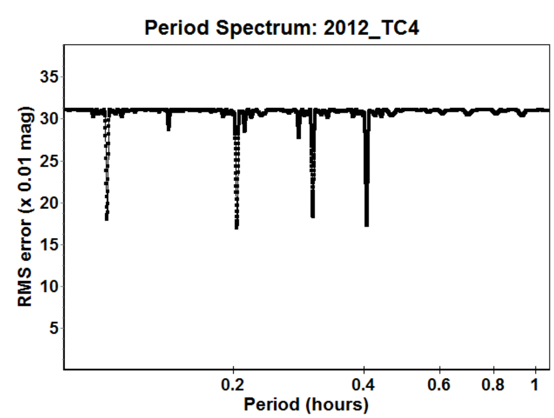

LIGHTCURVE AND H-G PARAMETERS FOR ASTEROID 2007 MCCUSKEY

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An international collaboration resulted in the determination of the synodic period and the H and G parameters for the asteroid 2007 McCuskey. The synodic period is 8.603 ± 0.001 h with an amplitude of 0.18 ± 0.03 mag. The absolute magnitude, H, was determined to be 12.06 ± 0.05 mag. The opposition parameter, G, was determined to be 0.06 ± 0.04. We were also able to determine a V-R color index of 0.34 ± 0.04. Both the color index and the G value are compatible with a C-Type Asteroid. The diameter is estimated to be D = 21 ± 4 km.

The asteroid 2007 McCuskey (1963 SQ) was discovered on 1963 Sep 22 by the Indiana Asteroid Program, IAP (2013) at the Goethe Link Observatory, Brooklyn, IN. Observations during the current opposition were obtained at the Etscorn Campus Observatory ECO, (2013) and the Balzaretto Observatory BO, (2013). At the Etscorn Campus Observatory a Celestron C-14 telescope equipped with an Optec 0.5x focal reducer and a SBIG ST10CME CCD was used to acquire the asteroid images. The combination gives approximately 20 x 16 arc minute FOV with an image size 1092 x 736, 13.6-micron pixels. The plate scale is 1.28 arc seconds per pixel. The exposures were 180 seconds through clear and Red filters. The CCD was cooled to between -15°C and -25°C depending on the night time temperature.

At the Balzaretto Observatory a Meade LX200 8-inch telescope equipped with a SBIG ST7XME CCD was used to acquire the asteroid images. The FOV is 21 x 14 arc minutes with 765 x 510 9-micron pixels giving a plate scale of 1.65 arc seconds per pixel. Images were obtained through a clear filter with 300 second exposures and in V, and R bands with 600 second exposures. The CCD was cooled to -25°C.

At both observatories the images were processed with *MPO Canopus*, Warner (2012). The synodic period was obtained within *MPO Canopus* using the Fourier method developed by Harris *et. al* (1989).

<u>Lightcurve and Synodic Period.</u> Figure 1 shows the composite lightcurve for 2007 McCuskey. The asteroid was observed on 10 nights from 2013 Mar 01 through 2013 Apr 03. 1220 data points are used for the composite lightcurve. The synodic period was determined to be 8.603 ± 0.001 h. The amplitude is estimated to be 0.18 ± 0.03 mag. On all nights except 2013 Mar 13 (session 7, red asterisks) four or more comparison stars with solar colors, from the CMC14 star catalogue, using the method described by Dymock and Miles (2009), were used to determine the asteroid magnitudes.

The asteroid was observed in V and R band at Balzaretto Observatory on April 3 in an alternating sequence (VRVR...). This allowed us to find the color index of V-R = 0.34 ± 0.04 (mean of 19 values). This value is consistent with a low albedo C-type asteroid (Shevchenko and Lupishko, 1998).

H and G Parameters. The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. For each lightcurve the R mag was measured as half peak-to-peak amplitude with Peranso (Vanmunster, 2010) via polynomial fit. We have achieved H_R = 11.72 ± 0.03 mag and G = 0.06 ± 0.04 (Figure 2) that we convert to H_V = 12.06 ± 0.05 mag, adding the V-R color index value. The G value is also consistent with a C-type asteroid (Shevchenko and Lupishko, 1998).

For a C-type asteroid, the geometric albedo is pV = 0.06 □ 0.02 (Shevchenko and Lupishko, 1998). Using this result, we can estimate the diameter D with the formula by Pravec and Harris (2007):

$$D_{(km)} = \frac{1329}{\sqrt{p_v}} 10^{-0.2Hv} \qquad (1)$$

This leads to an estimated diameter D = 21 □ 4 km, a value that is close to the WISE mission value of 25.73 ± 0.09 km.

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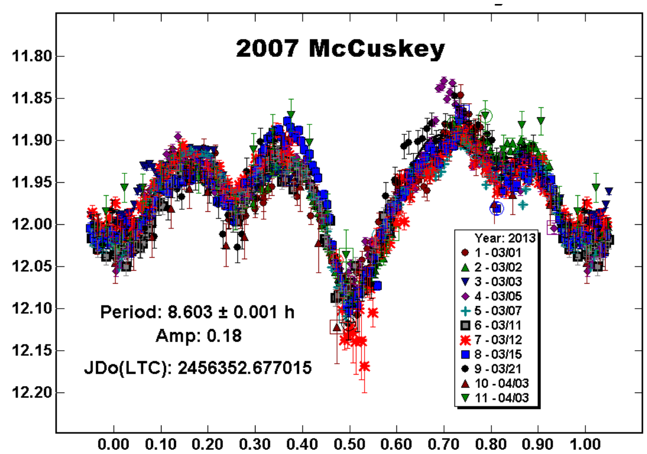

Figure 1: The composite lightcurve of 2007 McCuskey shows a period of 8.603 ± 0.001 h with an amplitude of 0.18 ± 0.03 mag.

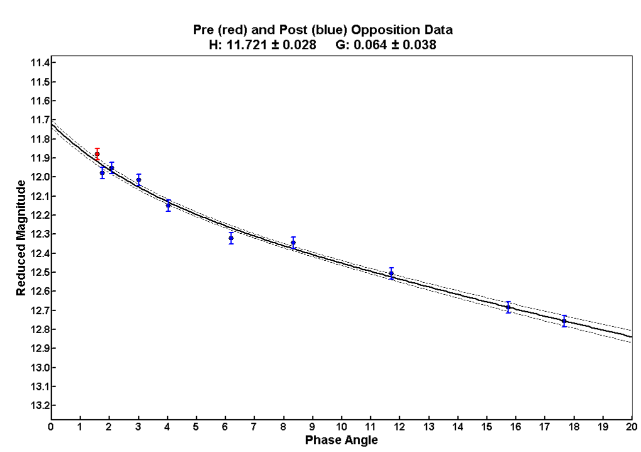

Figure 2: Reduced magnitude vs phase angle for estimate H_R = 11.72 ± 0.03 mag and G = 0.06 ± 0.04.

LIGHTCURVE OF 729 WATSONIA

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CCD photometric observations of the main-belt asteroid 729 Watsonia were obtained from Santana Observatory (MPC 646) in 2013 January - February. The period of 25.230 ± 0.003 h with an amplitude of 0.17 mag. updates a previously reported result.

The main-belt asteroid 729 Watsonia was previously observed on seven nights in 2000 June by Malcolm (2000) with contributed observations by the author at Santana Observatory. A period of 16.71 h with an amplitude of 0.22 mag. was reported.

The 2012 data from the observations at Santana could not be phased to the 16.71 h period. The period spectrum from the 2012 data shows a strong preference for a 25.230 h period, which is a 3:2 aliases of 16.7 h period. An Excel spreadsheet containing the original magnitudes measurements with a phased plot was located.

Changing the period of that 2000 plot resulted a lightcurve covering 40 percent of the period (Figure 2) and shows that each of the sessions never exceeded an observing run of 5 hours. All seven sessions covered the same portion of the rephrased lightcurve. Given the good fit of the 2012 data to the 25.230 h period, and the 2:3 aliases of the 2000 data, this period is preferred.

The 2012 data was obtained between phase angle 15 and 7.6 with a phase angle bisector longitude (PABL) of 157 and a phase angle bisector latitude (PABB) of 10. 1,471 data points over eight nights were obtained.

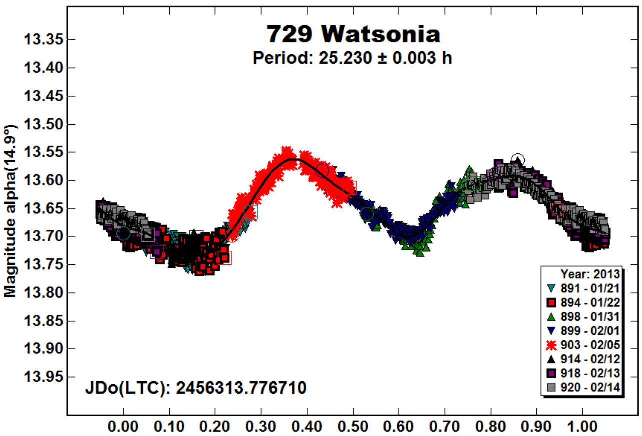

Figure 1: Lightcurve of 729 Watsonia using 2012 data from Santana Observatory.

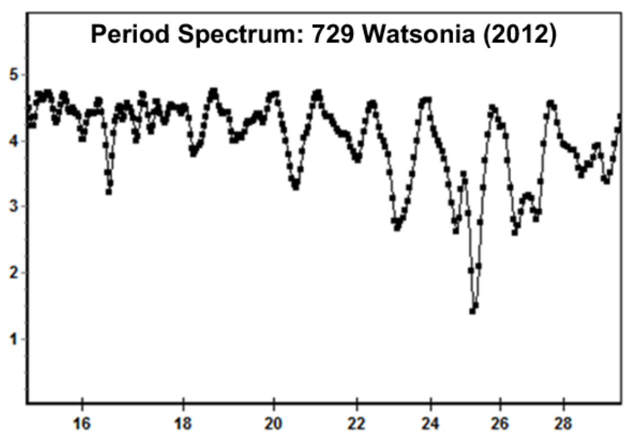

Figure 2: Period spectrum using 2012 data from Santana.

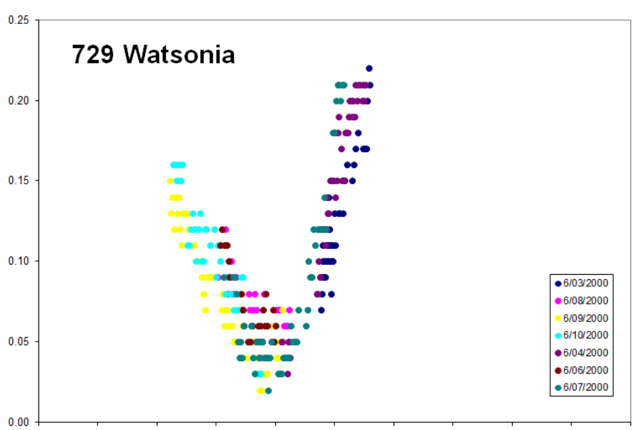

Figure 3: Rephased lightcurve of 729 Watsonia using 2000 data.

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2013 JULY-SEPTEMBER

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

We present lists of "targets of opportunity" for the period 2013 July-September. For background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188. 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) documentation for an explanation of the U code:

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

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.

The first list is an *abbreviated list* of those asteroids reaching V < 15.0 at brightest during the period and have either no or poorly-constrained lightcurve parameters. An asterisk (*) follows the name if the asteroid is reaching a particularly favorable apparition.

The goal for these asteroids is to find a well-determined rotation rate. The target list 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

In a general note, small objects with periods up to 4 hours or even longer are possible binaries. For longer periods (4-6 hours or so), the odds of a binary may be less, but the bonus is that the size of the secondary, if it exists, is likely larger (see Pravec *et al.* (2010), *Nature* **466**, 1085-1088), thus eclipses, if they occur, will be deeper and easier to detect.

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, e.g., a maximum, 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. Without knowing the period and/or the amplitude at the time, that reduction becomes highly uncertain. 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 using average light, which is the method used for values listed by the Minor Planet Center.

The third list is of those asteroids needing only a small number of lightcurves to allow spin axis and/or shape modeling. Those doing work for modeling should contact Josef Ďurech at the email address above and/or visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site for existing data and models:

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

The fourth list gives a brief ephemeris for planned radar targets. Supporting optical observations to determine the lightcurve period, amplitude, and shape are needed to supplement the radar data. *High-precision work, 0.01-0.02 mag, is preferred, especially if the object is a known or potential binary*. Those obtaining lightcurves in support of radar observations should contact Dr. Benner directly at the email given above.

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

As always, we encourage observations of asteroids even if they have well-established lightcurve parameters and especially if they are lacking good spin axis and/or shape model solutions. Every lightcurve of sufficient quality supports efforts to resolve a number of questions about the evolution of individual asteroids and the general population. For example, pole directions are known for only about 30 NEAs out of a population of 8000. This is hardly sufficient to make even the most general of statements about NEA pole alignments, including whether or not the thermal YORP effect is forcing pole orientations into a limited number of preferred directions (see La Spina *et al.*, 2004, *Nature* **428**, 400-401). Data from many apparitions can help determine if an asteroid's rotation rate is being affected by YORP, which can also cause the rotation rate of a smaller, irregularly-shaped asteroid to increase or decrease. See Lowry *et al.* (2007) *Science* **316**, 272-274 and Kaasalainen *et al.* (2007) *Nature* **446**, 420-422.

The ephemeris listings for the optical-radar listings include lunar elongation and phase. Phase values range from 0.0 (new) to 1.0 (full). If the value is positive, the moon is waxing – between new and full. If the value is negative, the moon is waning – between full and new. The listing also includes the galactic latitude. When this value is near 0°, the asteroid is likely in rich star fields and so may be difficult to work. It is important to emphasize that the ephemerides that we provide are only guides for when you might observe a given asteroid. Obviously, you should use your discretion and experience to make your observing program as effective as possible.

Once you've 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.

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Lightcurve Opportunities

#	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
458	Hercynia	07 01.3	14.4	-12	22.3	0.33-0.35	2
618	Elfriede*	07 02.2	12.3	-18	14.801	0.12-0.20	2
1228	Scabiosa	07 02.3	15.0	-25			
6271	Farmer*	07 03.2	14.7	-28	250.	0.13-0.22	2
29742	1999 BQ12*	07 08.8	14.9	-26	4.3	0.7	1+
10731	1988 BL3	07 09.3	15.0	-18	28.02	0.23-0.41	2
1409	Isko	07 11.7	14.7	-12	11.6426	0.20	2
961	Gunnie	07 11.9	14.7	-40			
3977	Maxine*	07 11.9	14.6	+0			
1159	Granada	07 12.1	14.4	-42	31.	0.28	2
1886	Lowell*	07 12.2	14.7	-35			
6307	Maiztegui	07 12.6	14.9	-20	4.68	0.15	2
1686	De Sitter*	07 12.7	14.2	-23			
576	Emanuela*	07 12.8	12.2	-25	8.192	0.05-0.06	2-
2543	Machado*	07 13.1	14.1	-47	31.72	0.15	2
589	Croatia	07 13.6	13.5	-7	11.7	0.16	2
4226	Damiaan	07 13.6	14.2	-13	24.	0.05	1
2104	Toronto	07 14.3	14.5	-4	8.9669	0.32	2+
6032	Nobel	07 14.7	14.9	-6			
455	Bruchsalia	07 14.9	11.1	-35	11.838	0.10-0.35	2+
1753	Mieke	07 15.2	14.8	-36	8.8	0.2	2
916	America	07 15.6	13.8	-35	38.	0.28	1
741	Botolphia	07 16.5	13.6	-24	23.93	0.12- 0.4	2-
1043	Beate	07 16.7	13.7	-12	44.3	0.47	2+
866	Fatme*	07 18.8	13.6	-26	20.03	0.06-0.21	2
1629	Pecker*	07 19.1	14.2	-15	8.2166	0.08	2
6914	Becquerel	07 19.4	14.8	-24			
859	Bouzareah	07 19.6	14.6	-40	23.2	0.13	2-
421	Zahringia	07 19.7	15.0	-9	6.42	0.07-0.12	2
722	Frieda*	07 20.1	13.7	-32		0.04	
1145	Robelmonte	07 20.3	13.7	-29	9.01	0.05-0.18	2
1646	Rosseland	07 20.6	14.4	-20	69.2	0.13	2
582	Olympia	07 20.7	14.0	+8	36.	0.05- 0.6	2
9938	Kretlow*	07 20.8	15.0	-25			
6386	Keithnoll	07 22.2	14.1	-20	3.1381	0.08	2+
874	Rotraut	07 22.9	14.7	-5	14.586	0.24	2
862	Franzia	07 24.1	13.5	-20	7.52	0.07-0.22	2
481	Emita	07 24.6	12.7	-32	14.35	0.09-0.30	2
1186	Turnera	07 25.2	13.1	-36	12.066	0.25-0.34	2+
1351	Uzbekistania	07 26.7	14.6	-32	73.9	0.20-0.34	2
2829	Bobhope*	07 27.0	13.8	-28	6.0888	0.50-0.55	2
7536	Fahrenheit*	07 27.0	14.6	-19			

Lightcurve Opportunities (cont'd)

#	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
305	Gordonia	07 28.7	13.9	-13	16.2	0.16-0.17	2
931	Whittemora	07 30.5	13.9	-23	19.2	0.2	2
1952	Hesburgh	08 01.4	14.9	-34	47.7	0.18	2
1799	Koussevitzky	08 02.5	14.8	-10	6.325	0.25	2
3002	Delasalle	08 02.5	14.4	-21			
2437	Amnestia	08 02.8	14.6	-12	85.	0.45	2
1042	Amazone	08 02.9	14.4	-46	540.	0.10-0.25	2
569	Misa	08 03.9	13.9	-17	13.52	0.25	2
1073	Gellivara*	08 04.0	14.8	-20	11.32	0.35	2
4333	Sinton*	08 04.3	14.7	-15			
2138	Swissair	08 05.9	14.5	-21			
17939	1999 HH8*	08 06.5	14.9	-19	5.1	0.18-0.26	2
6495	1992 UB1	08 10.1	14.9	-3	5.697	0.29-0.45	2
52760	1998 ML14*	08 12.4	15.0	-31	14.98	0.12	2
503	Evelyn	08 13.5	13.5	-21	38.7	0.30- 0.5	2
1337	Gerarda	08 13.7	14.8	-5	12.52	0.23	2
1315	Bronislawa	08 14.1	14.3	-4	9.565	0.16-0.24	2
3581	Alvarez*	08 14.1	14.3	+38	33.42	0.06	2
823	Sisigambis	08 16.4	13.9	-8	146.	0.05- 0.7	2
2873	Binzel	08 16.6	14.8	-21			
570	Kythera	08 20.2	13.0	-10	8.12	0.15-0.18	2
1358	Gaika*	08 20.2	14.2	-16			
1372	Haremari*	08 20.3	14.3	-12	15.25	0.12	2
581	Tauntonia	08 20.6	14.6	-33	16.54	0.07-0.20	2
1683	Castafiore*	08 21.6	13.9	-11	13.931	0.66	2+
1048	Feodosia	08 22.4	13.6	-33	10.46	0.14	2
19082	Vikchernov*	08 22.4	14.9	-12			
1290	Albertine	08 22.7	14.9	-8			
5847	Wakiya*	08 25.3	14.5	-1	23.95	0.10	1
11574	d'Alviella*	08 25.5	14.7	-17	12.549	0.15	2
3768	Monroe*	08 25.7	14.4	-12			
2089	Cetacea	08 26.5	13.9	-30	39.12	0.25-0.40	2
774	Armor	08 29.7	12.3	-1	25.107	0.11-0.34	2
8992	Magnanimity*	08 29.7	14.7	-1			
1714	Sy	08 29.8	14.8	-1		0.95	
702	Alauda	08 30.0	11.9	+13	8.348	0.07-0.10	2
1486	Marilyn*	08 30.2	14.0	-9	2.2837	0.40	1+
2430	Bruce Helin	08 30.2	14.2	-53	128.	0.6	2
3300	McGlasson	08 30.2	14.1	-30	22.91	0.16	2
1149	Volga	08 31.4	14.3	+8	27.5	0.26	2
4729	Mikhailmil'	09 01.4	14.0	-4	17.74	0.36	2-
7234	1986 QV3*	09 01.5	14.4	-15			
527	Euryanthe*	09 03.6	13.1	-17	26.06	0.11	2-
5913	1990 BU*	09 04.2	14.2	+0	52.	0.10	1
6434	Jewitt*	09 04.2	14.7	-19			
1184	Gaea*	09 04.6	14.2	-11	2.94	0.09-0.25	2
2865	Laurel	09 04.7	14.4	+1	21.5	0.15	2
3346	Gerla	09 04.7	15.0	-19			
3257	Hanzlik	09 04.8	14.6	-15			
346	Hermentaria	09 05.1	10.6	-19	28.43	0.07-0.20	2
357	Ninina*	09 05.7	12.9	-16	35.98	0.12	2
1385	Gelria*	09 05.8	13.8	-15		0.36	
2244	Tesla	09 05.8	14.9	-17			
1728	Goethe Link	09 08.9	14.3	+6	81.	0.39	2
3770	Nizami*	09 09.2	15.0	-5			
1347	Patria	09 13.2	14.6	+11	29.5	0.12	2
768	Struveana	09 15.2	14.2	-22	8.76	0.26-0.54	2+
2107	Ilmari	09 15.2	14.7	+7		0.06	
5001	EMP*	09 15.2	14.3	-4			
1005	Arago*	09 15.5	13.7	-1	8.7819	0.22	2
1124	Stroobantia	09 18.0	14.5	-7	16.39	0.15	1
1118	Hanskya	09 19.1	14.2	+11	15.61	0.18-0.38	2
676	Melitta	09 19.7	13.0	-10	7.87	0.04-0.20	2
1010	Marlene*	09 20.6	14.0	-7	31.06	0.17-0.32	2+
449	Hamburga	09 20.7	13.2	-5	18.263	0.08-0.17	2+
892	Seeligeria	09 21.0	14.0	-2	41.4	0.15	2
596	Scheila	09 23.8	13.4	-17	15.851	0.06-0.09	2+
1622	Chacornac	09 24.0	14.3	+0	12.206	0.24-0.25	2
1461	Jean-Jacques	09 24.7	14.6	-19	16.56	0.09	2
541	Deborah	09 25.0	13.8	+9	13.91	0.04-0.07	2+
8265	1986 RB5	09 25.3	14.9	-8			
384	Burdigala	09 26.3	12.8	-5	21.1	0.03	2-
10262	Samoilov*	09 26.5	14.6	-11			
1468	Zomba*	09 27.4	13.7	+23	2.77	0.3	2
3255	Tholen*	09 30.4	14.3	+28	3.	0.08	1
994	Otthild*	09 30.5	12.7	+5	5.95	0.09-0.15	2+
1839	Ragazza	09 30.5	15.0	-9			
3171	Wangshouguan	09 30.7	14.9	-4			

Low Phase Angle Opportunities

#	Name	Date	α	V	Dec	Period	Amp	U
389	Industria	07 02.8	0.17	11.0	-23	8.53	0.18-0.34	3
1496	Turku	07 09.2	0.41	13.4	-23	6.47	-0.51	3-
559	Nanon	07 11.7	0.32	12.5	-21	10.059	0.09-0.26	3
8	Flora	07 20.0	0.56	8.7	-22	12.865	0.03-0.11	3
862	Franzia	07 24.1	0.14	13.5	-20	7.52	-0.13	2
2213	Meeus	07 30.0	0.05	13.9	-19			
268	Adorea	07 31.9	0.15	12.6	-19	7.80	0.15-0.20	3
202	Chryseis	08 03.1	0.41	12.0	-16	23.670	0.04-0.23	3
569	Misa	08 03.9	0.13	13.9	-17	13.52	-0.25	2
28	Bellona	08 07.4	0.73	11.4	-14	15.706	0.03-0.31	3
1148	Rarahu	08 12.5	0.69	13.5	-13	6.5447	-0.94	3-
1241	Dysona	08 15.9	0.18	13.2	-13	8.6080	-0.25	3-
52	Europa	08 19.0	0.97	10.9	-16	5.6304	0.08-0.20	3
570	Kythera	08 20.1	0.83	13.1	-10	8.120	0.15-0.18	2
1683	Castafiore	08 21.7	0.36	13.9	-11	13.931	-0.66	2+
1638	Ruanda	08 23.1	0.19	14.0	-11	4.2397	0.06-0.10	3
1874	Kacivelia	08 24.7	0.55	13.6	-10			
1486	Marilyn	08 30.3	0.19	14.0	-09	2.2837	-0.40	1+
263	Dresda	08 31.9	0.66	13.6	-07	16.809	0.32-0.55	3
171	Ophelia	09 01.3	0.86	13.2	-11	6.66535	0.14-0.46	3
839	Valborg	09 01.3	0.21	12.9	-08	10.366	-0.19	3
1062	Ljuba	09 02.3	0.14	13.9	-08	33.8	-0.17	3
955	Alstede	09 13.4	0.24	12.9	-04	5.19	-0.27	3
435	Ella	09 13.5	0.93	12.1	-05	4.623	0.30-0.45	3
1005	Arago	09 15.4	0.61	13.8	-01	8.7819	-0.22	2
892	Seeligeria	09 20.9	0.35	14.0	-02	41.40	-0.15	2
124	Alkeste	09 24.2	0.24	11.5	+01	9.921	0.08-0.15	3
139	Juewa	09 24.2	0.11	12.1	+00	20.991	-0.20	3
1035	Amata	09 24.8	0.14	13.4	+00	9.081	-0.44	3
69	Hesperia	09 28.3	0.12	11.1	+02	5.655	0.09-0.24	3
94	Aurora	09 29.5	0.29	11.5	+03	7.22	0.03-0.18	3
1610	Mirnaya	09 29.9	0.35	14.0	+03			

Shape/Spin Modeling Opportunities

There are two lists here. The first is for objects for which good occultation profiles are available. These are used to constrain the models obtained from lightcurve inversion, eliminating ambiguous solutions and fixing the size of asteroid. Lightcurves are needed for modeling and/or to establish the rotation phase angle at the time the profile was obtained. The second list is of those objects for which another set of lightcurves from one more apparitions will allow either an initial or a refined solution.

Occultation Profiles Available

		Brightest			LCDB DATA		
#	Name	Date	Mag	Dec	Period	Amp	U
580	Selene	07 05.7	14.7	-23	9.47	0.27	3-
559	Nanon	07 11.7	12.5	-21	10.059	0.09-0.26	3
47	Aglaja	07 27.0	11.0	-26	13.178	0.02-0.17	3
81	Terpsichore	08 01.8	12.4	-27	10.943	0.06-0.10	3
93	Minerva	08 07.2	10.8	-27	5.982	0.04-0.20	3
78	Diana	08 07.6	12.4	-20	7.2991	0.02-0.30	3
476	Hedwig	08 12.8	11.7	-05	27.33	0.13	3
238	Hypatia	09 12.3	11.7	+00	8.8745	0.07-0.17	3
324	Bamberga	09 13.3	8.1	+05	29.43	0.07-0.12	3
139	Juewa	09 24.2	12.1	+00	20.991	0.20	3
124	Alkeste	09 24.2	11.4	+01	9.921	0.08-0.15	3
205	Martha	09 29.5	12.8	+09	14.912	0.10-0.50	3-
94	Aurora	09 29.6	11.5	+03	7.22	0.03-0.18	3
3171	Wangshouguan	09 30.7	14.9	-04			

Inversion Modeling Candidates

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
686	Gersuind	07 03.9	11.9	-04	6.3127	0.30-0.37	3
252	Clementina	07 07.4	14.1	-08	10.864	0.32-0.44	3
851	Zeissia	07 07.9	14.2	-20	9.34	0.38-0.53	3
1496	Turku	07 09.2	13.4	-23	6.47	0.51	3-
1379	Lomonosowa	07 10.4	14.2	+01	24.488	0.63	3
6307	Maiztegui	07 12.6	14.9	-20	4.68	0.15	2
333	Badenia	07 14.8	13.5	-27	8.192	0.20-0.33	3-
762	Pulcova	07 16.2	13.0	-25	5.839	0.18-0.30	3
2036	Sheragul	07 18.3	13.9	-28	5.41	0.60-1.50	3
4713	Steel	07 19.5	14.5	-35	5.199	0.28-0.44	3
186	Celuta	07 21.9	11.3	-45	19.842	0.4 -0.55	3
1446	Sillanpaa	07 24.6	15.0	-29	9.6602	0.55	3
1503	Kuopio	07 28.4	14.2	-23	9.957	0.77	3
540	Rosamunde	07 29.2	13.5	-09	9.336	0.40-0.66	3-
1388	Aphrodite	08 07.0	14.7	-33	11.9432	0.35-0.65	3
6495	1992 UB1	08 10.1	14.9	-03	5.697	0.29-0.45	2
1900	Katyusha	08 10.2	14.7	-09	9.4999	0.56-0.74	3
503	Evelyn	08 13.5	13.5	-21	38.7	0.30-0.5	2
1835	Gajdariya	08 14.2	15.0	-14	6.3276	0.50	3
1423	Jose	08 16.1	14.3	-18	12.307	0.68-0.85	3
756	Lilliana	08 18.0	14.8	+12	7.834	0.18-0.99	3
1547	Nele	08 18.9	14.6	-04	7.100	0.30-0.45	3-
104	Klymene	08 21.7	12.6	-16	8.984	0.3	3
943	Begonia	08 23.5	14.9	-21	15.66	0.34	3
3300	McGlasson	08 30.2	14.1	-30	22.91	0.16	2
2430	Bruce Helin	08 30.2	14.2	-53	128.	0.6	2
3657	Ermolova	09 01.9	14.5	+02	2.6064	0.18-0.25	3
6406	1992 MJ	09 06.1	14.6	-11	6.819	1.18	3
1467	Mashona	09 07.7	12.7	+05	9.76	0.24	3
1728	Goethe Link	09 08.9	14.3	+06	81.	0.39	2
394	Arduina	09 09.3	12.0	-16	16.5	0.29-0.54	3
565	Marbachia	09 19.5	14.7	+11	4.587	0.20-0.65	3
1314	Paula	09 20.9	14.6	+08	5.9498	0.83	3
408	Fama	09 27.0	13.1	+13	202.10	0.05-0.58	3
994	Otthild	09 30.5	12.7	+05	5.95	0.09-0.14	2+

Radar-Optical Opportunities

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. Some of the targets may be too faint to do accurate photometry with backyard telescopes. However, accurate astrometry using techniques such as “stack and track” is still possible and can be helpful for those asteroids where the position uncertainties are significant. Note that the intervals in the ephemerides are not always the same and that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

MPC: *http://www.minorplanetcenter.org/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.

(52760) 1998 ML14 (Jun-Aug, H = 17.6, PHA)
Hicks *et al.* (1998) determined a rotation period of 14.98 h for this 1 km NEA. Follow-up observations would be a great help. The object is visible for a number of weeks. The phase angle increase dramatically over the span of the ephemeris. In such cases, it is better not to create a single composite lightcurve over that full period but multiple lightcurves based on subsets of data obtained about 1-2 weeks apart. This allows following the evolution of the lightcurve's amplitude and shape and provides even better modeling information.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/25	18 25.4	-31 10	0.40	1.41	16.7	5.8	172	23	-0.96	-9
07/02	18 15.4	-31 53	0.34	1.35	16.4	8.2	169	118	-0.32	-7
07/09	18 02.0	-32 34	0.28	1.29	16.1	14.6	161	152	+0.01	-5
07/16	17 44.9	-33 08	0.24	1.23	15.9	23.0	152	65	+0.49	-2
07/23	17 23.8	-33 30	0.20	1.17	15.7	33.0	141	44	-1.00	+1
07/30	16 56.9	-33 31	0.16	1.12	15.4	44.8	129	142	-0.47	+6
08/06	16 19.7	-32 50	0.12	1.07	15.2	59.4	115	123	-0.01	+12
08/13	15 21.0	-30 13	0.09	1.03	15.1	79.7	95	26	+0.34	+22

(153349) 2001 PJ19 (Jul-Aug, H = 18.0)
There is no previously determined period in the lightcurve database (LCDB; Warner *et al.*, 2009) for this 600-meter NEA. While the asteroid doesn't reach very low phase angles, the range is still substantial and so it may be worth obtaining blocks of data at several times and generating multiple lightcurves.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/20	00 23.1	+51 11	0.08	1.02	16.0	87.9	88	117	+0.89	-11
07/25	22 07.5	+35 58	0.10	1.07	15.7	56.6	119	42	-0.93	-16
07/30	21 18.6	+24 49	0.14	1.12	16.0	39.4	135	73	-0.47	-17
08/04	20 55.7	+18 03	0.19	1.18	16.5	30.0	145	130	-0.08	-17
08/09	20 42.9	+13 35	0.24	1.23	16.9	24.8	149	146	+0.04	-17
08/14	20 35.3	+10 23	0.30	1.28	17.4	22.4	151	89	+0.45	-18
08/19	20 30.8	+07 56	0.35	1.33	17.8	21.7	151	25	+0.94	-18
08/24	20 28.3	+05 59	0.41	1.38	18.2	22.1	149	60	-0.89	-18

2010 AF30 (Jul, H = 21.6)
The estimated size of this NEA (assuming taxonomic type S) is only 150 meters. In which case, there is a chance that it may have a rotation period of less than 2 hours and might even be tumbling. There are no entries in the LCDB.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/15	05 19.0	-41 38	0.05	1.00	18.9	106.7	71	98	+0.38	-34
07/16	04 49.9	-46 16	0.05	1.01	18.5	99.4	78	106	+0.49	-40
07/17	04 16.0	-50 21	0.05	1.01	18.2	92.2	85	110	+0.60	-45
07/18	03 37.7	-53 36	0.05	1.02	18.0	85.2	92	109	+0.70	-50
07/19	02 56.6	-55 52	0.05	1.02	17.8	78.5	99	103	+0.80	-54
07/20	02 15.1	-57 08	0.05	1.03	17.7	72.3	105	95	+0.89	-57
07/21	01 35.6	-57 29	0.05	1.04	17.7	66.6	111	84	+0.95	-59
07/22	01 00.1	-57 09	0.06	1.04	17.7	61.4	116	73	+0.99	-60

1627 Ivar (Jul-Nov, H = 13.2)
This may be one of the easier NEAs that you'll ever observe. It is bright (be careful about overexposing) and well-placed for more than 3 months. Here's a great opportunity to get multiple lightcurves over a range of phase angles. The period is well-known: 4.798 h. The amplitude has ranged from 0.25 to 1.4 mag.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	23 37.2	+07 29	0.32	1.13	12.5	62.4	101	22	-0.42	-51
07/21	00 58.9	+05 30	0.33	1.13	12.5	61.1	103	102	+0.95	-57
08/10	01 55.0	+01 09	0.34	1.18	12.5	54.2	110	143	+0.10	-58
08/30	02 21.6	-04 33	0.36	1.25	12.5	42.6	123	54	-0.35	-59
09/19	02 19.1	-10 17	0.40	1.34	12.5	28.3	141	46	+1.00	-63
10/09	01 56.6	-13 43	0.47	1.44	12.8	16.8	155	132	+0.19	-70
10/29	01 34.0	-13 23	0.60	1.55	13.5	17.8	152	126	-0.31	-73
11/18	01 25.0	-10 19	0.79	1.66	14.4	24.1	137	46	-1.00	-71

(7753) 1988 XB (Jul, H = 18.6)
There are no entries for this NEA in the LCDB. The estimated size ranges from 0.5 to 1.1 km, depending on the assumed albedo. The SMASS II survey found a taxonomic type of B, making it dark (low albedo) object, which leads to the larger size.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	13 03.3	-15 38	0.13	1.05	16.8	71.7	101	174	-0.42	+47
07/02	12 53.5	-15 10	0.13	1.04	16.8	75.0	98	165	-0.32	+48
07/03	12 43.5	-14 39	0.13	1.03	16.9	78.4	95	151	-0.23	+48
07/04	12 33.2	-14 06	0.12	1.03	17.0	81.9	91	137	-0.16	+49
07/05	12 22.7	-13 30	0.12	1.02	17.1	85.4	88	122	-0.09	+49
07/06	12 12.1	-12 52	0.12	1.01	17.2	89.0	84	108	-0.05	+49
07/07	12 01.3	-12 12	0.12	1.00	17.3	92.7	81	94	-0.02	+49
07/08	11 50.4	-11 29	0.12	1.00	17.4	96.4	77	79	+0.00	+49

(232691) 2004 AR1 (Jul-Aug, H = 19.8)
This NEA has an estimated size of about 300 meters. As such, its rotation period is probably 2 hours or more. This one is definitely for Southern Hemisphere observers.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/20	20 23.2	-51 15	0.24	1.23	18.3	25.1	149	49	+0.89	-35
07/25	20 10.7	-53 20	0.21	1.19	18.0	28.1	146	54	-0.93	-33
07/30	19 51.7	-55 35	0.18	1.16	17.7	32.6	142	108	-0.47	-30
08/04	19 21.8	-57 55	0.14	1.12	17.4	39.1	136	140	-0.08	-27
08/09	18 33.0	-60 02	0.12	1.09	17.1	48.1	127	107	+0.04	-21
08/14	17 11.0	-60 30	0.09	1.05	16.8	61.2	114	51	+0.45	-12
08/19	15 10.3	-54 32	0.07	1.02	16.8	81.8	94	66	+0.94	+3
08/24	13 14.2	-34 37	0.05	0.99	17.9	114.1	63	150	-0.89	+28

89 Julia (Jul-Nov, H = 6.6)
The rotation period for this inner main-belt asteroid is 11.38 hours. This makes it difficult for a single station to get complete coverage of the lightcurve without an prolonged campaign. A collaboration involving observers well-separated in longitude would be ideal. The estimated diameter is 151 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	23 50.5	+06 44	1.71	2.11	10.6	28.4	99	19	-0.42	-53
07/21	00 03.2	+11 56	1.49	2.10	10.3	26.6	112	91	+0.95	-49
08/10	00 05.3	+16 45	1.31	2.09	9.9	22.5	128	162	+0.10	-45
08/30	23 54.7	+20 31	1.18	2.09	9.4	16.4	144	79	-0.35	-40
09/19	23 34.4	+22 22	1.13	2.09	9.2	11.3	156	23	+1.00	-37
10/09	23 14.5	+22 01	1.16	2.09	9.3	13.6	150	109	+0.19	-36
10/29	23 06.0	+20 32	1.28	2.10	9.7	19.6	135	147	-0.31	-36
11/18	23 11.8	+19 15	1.46	2.12	10.2	24.2	119	66	-1.00	-38

324 Bamberga (Jul-Nov, H = 6.82)
This middle main-belt asteroid has an estimated diameter of 230 km. It's a type CP (Tholen, 1989), meaning is has a lower albedo on the order of 0.06. The rotation period of 29.4 h makes this another object where a collaboration among observers will have the best chance of securing a complete lightcurve.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
07/01	23 19.9	-06 57	1.37	1.98	10.3	28.7	111	31	-0.42	-60
07/21	23 33.7	-03 05	1.14	1.92	9.8	25.5	125	79	+0.95	-60
08/10	23 36.1	+00 34	0.96	1.87	9.2	19.2	143	178	+0.10	-57
08/30	23 25.2	+03 42	0.85	1.83	8.5	9.9	162	91	-0.35	-53
09/19	23 06.1	+05 55	0.81	1.80	8.2	6.8	168	7	+1.00	-48
10/09	22 51.5	+07 15	0.86	1.79	8.7	16.9	149	99	+0.19	-45
10/29	22 51.4	+08 22	0.97	1.78	9.3	25.2	130	159	-0.31	-44
11/18	23 06.4	+09 53	1.13	1.79	9.7	30.0	115	69	-1.00	-45

(277475) 2005 WK4 (Aug-Sep, H = 20.2, PHA)

2005 WK4 is an NEA with an estimated size of 280 meters. There are no entries in the LCDB for it. While brightest around mid-August, rapid sky motion at that time may make good photometry a bit difficult. If you have the resources and are in the Southern Hemisphere, observations soon after closest approach might be more productive.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
08/05	04 33.7	+49 22	0.03	1.00	17.0	116.5	62	48	-0.04	+1
08/10	01 40.2	+07 53	0.02	1.02	14.1	67.5	111	146	+0.10	-53
08/15	23 59.3	-27 53	0.03	1.04	14.3	34.4	144	107	+0.56	-78
08/20	23 11.2	-38 54	0.06	1.06	15.3	29.5	149	40	+0.98	-66
08/25	22 45.0	-42 55	0.08	1.08	16.1	30.4	147	64	-0.81	-60
08/30	22 29.2	-44 33	0.11	1.10	16.8	32.3	145	115	-0.35	-57
09/04	22 19.1	-45 04	0.13	1.11	17.3	34.2	142	143	-0.02	-55
09/09	22 12.8	-44 58	0.16	1.13	17.8	36.1	139	105	+0.13	-54

(137126) 1999 CF9 (Aug-Sep, H = 17.9, PHA)

The estimated diameter for this NEA is 800 meters. The rotation period is not known, or at least is not included in the LCDB. The end of August and early September may offer the best compromise between brightness, sky motion, and changing phase angle.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
08/20	14 35.9	+04 27	0.07	0.99	16.1	106.8	69	95	+0.98	+56
08/25	17 32.8	-10 08	0.07	1.04	14.4	65.7	111	118	-0.81	+12
08/30	19 40.4	-17 04	0.10	1.08	14.6	39.2	137	150	-0.35	-18
09/04	20 40.1	-18 31	0.15	1.13	15.3	29.7	146	162	-0.02	-32
09/09	21 11.2	-18 42	0.20	1.18	16.0	26.7	148	106	+0.13	-39
09/14	21 30.3	-18 32	0.26	1.23	16.6	26.0	148	41	+0.65	-43
09/19	21 43.6	-18 13	0.32	1.28	17.1	26.2	146	29	+1.00	-46
09/24	21 53.8	-17 50	0.38	1.33	17.6	26.9	143	91	-0.79	-48

2007 CN26 (Aug-Oct, H = 21.0, PHA)

As with many other asteroids presented this quarter, there is no reported rotation period in the LCDB. 2007 CN26 is an NEA with an estimated diameter of 200 meters. This puts it on the edge of being a candidate for having a rotation rate of less than 2 hours. Until you know one way or the other, keep exposures to a minimum but long enough so that scintillation noise doesn't dominate (~10 sec for backyard telescopes).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
08/30	05 16.7	+27 29	0.03	1.00	17.0	101.9	76	9	-0.35	-6
09/04	03 57.5	+05 45	0.04	1.02	16.5	75.2	103	85	-0.02	-34
09/09	03 16.8	-06 46	0.05	1.03	16.7	58.7	119	151	+0.13	-50
09/14	02 51.9	-13 37	0.07	1.05	17.0	48.3	129	116	+0.65	-59
09/19	02 34.3	-17 37	0.09	1.07	17.3	41.1	136	51	+1.00	-64
09/24	02 20.6	-20 03	0.11	1.09	17.6	35.6	141	42	-0.79	-68
09/29	02 09.1	-21 30	0.13	1.11	17.9	31.6	145	91	-0.33	-71
10/04	01 59.2	-22 14	0.15	1.13	18.2	28.7	147	140	-0.01	-74

(329437) 2002 OA22 (Aug-Oct, H = 19.3, PHA)

Behrend *et al.* (2012) report a period of 10.5 h for 2002 OA22, a 400 meter NEA. The period is based mostly on a single night of observations that appeared to include a maximum and minimum (0.41 mag amplitude). However, a second night showed a nearly flat lightcurve. For a period of 10.5 h, the tumbling damping time is about 1.4 Gyr, so it's not entirely out of the question that the asteroid is tumbling. Make no assumptions and go where the data lead.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
08/20	01 06.9	+20 43	0.20	1.14	18.0	48.6	123	71	+0.98	-42
08/27	01 17.7	+20 03	0.17	1.12	17.5	45.7	127	25	-0.63	-42
09/03	01 28.8	+18 21	0.14	1.11	17.0	42.2	133	105	-0.06	-44
09/10	01 41.2	+14 52	0.11	1.09	16.2	38.0	138	166	+0.22	-46
09/17	01 57.2	+07 53	0.08	1.07	15.4	33.7	144	69	+0.92	-52
09/24	02 23.6	-07 11	0.05	1.05	14.5	34.1	144	31	-0.79	-60
10/01	03 27.8	-39 41	0.04	1.02	14.3	57.5	121	96	-0.16	-55
10/08	07 33.0	-68 56	0.04	0.99	16.0	96.4	81	83	+0.11	-22

(152664) 1998 FW4 (Sep, H = 19.5, PHA)

Here's another NEA with no reported rotation period. The estimated diameter is 340 meters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
09/01	00 22.2	-01 31	0.29	1.28	18.6	20.4	154	103	-0.18	-63
09/05	00 29.6	-00 28	0.24	1.23	18.0	19.8	156	149	+0.00	-63
09/09	00 39.8	+01 04	0.19	1.19	17.5	19.8	157	160	+0.13	-62
09/13	00 55.6	+03 31	0.14	1.14	16.8	21.1	156	110	+0.54	-59
09/17	01 24.6	+08 02	0.10	1.09	16.1	26.0	152	61	+0.92	-54
09/21	02 34.2	+17 51	0.06	1.05	15.4	41.5	136	24	-0.97	-39
09/25	05 56.7	+32 26	0.05	1.01	16.0	84.8	93	24	-0.70	+4
09/29	09 18.1	+25 56	0.07	0.96	18.9	124.3	53	23	-0.33	+43

IN THIS ISSUE

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

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The deadline for the next issue (40-4) is July 15, 2013. The deadline for issue 41-1 is October 15, 2013.