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## 8077 HOYLE: A SHORT PERIOD ASTEROID

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The main-belt asteroid 8077 Hoyle was observed on 13 nights over a span of 47 days in 2012 April-May. A bimodal synodic period of 2.7454 ± 0.0002 h and an amplitude of 0.20 ± 0.02 mag. were obtained.

Observations of 8077 Hoyle were made at two observatories: Etscorn Campus Observatory (ECO, 2012) at New Mexico Institute of Mining and Technology in Socorro, NM, and the Southeastern Association for Research in Astronomy observatory, SARA (2012) at Kitt Peak National Observatory. The Etscorn observations were made with Celestron C-14 telescopes with SBIG STL-1001E CCDs, unbinned, 1024x1024 24-micron pixels. All exposures were 300 seconds through a clear filter. Image scale was 1.25 arcsec/pixel. The images were dark-subtracted and flat-field corrected using *MPO Canopus* (Warner, 2011). The reduced images were also processed with *MPO Canopus*. The images obtained at SARA were made with a 0.92-meter telescope and Apogee U42 CCD binned 2x2, which resulted in 27-micron pixels and a scale of 0.770 arcsec/pixel. The exposures were 120 seconds through a clear but IR-blocked filter. The telescope was remotely-controlled from Butler University. The images were bias and dark-subtracted and flat-field corrected using and then measured using *MPO Canopus* (Warner, 2011).

Images were obtained from 2012 April 5 through May 21. The asteroid was observed on 13 nights during that period. Most nights contained at least one complete cycle of the 2.7454 hour period. All except two nights had sufficient MPOSC3 stars that we were able to use the *MPO Canopus* Comp Star Selector system. We obtained more than 1000 measurements in the 13 nights of observation. Analysis of the combined data set found a period of 2.7454 ± 0.0002 h with an amplitude of 0.20 ± 0.02 mag. While there is a fair amount of scatter in the individual data points, when combined they produce a well-determined period, which was found by using an 8th order fit in the FALC analysis algorithm (Harris *et al.*, 1989).

Acknowledgements

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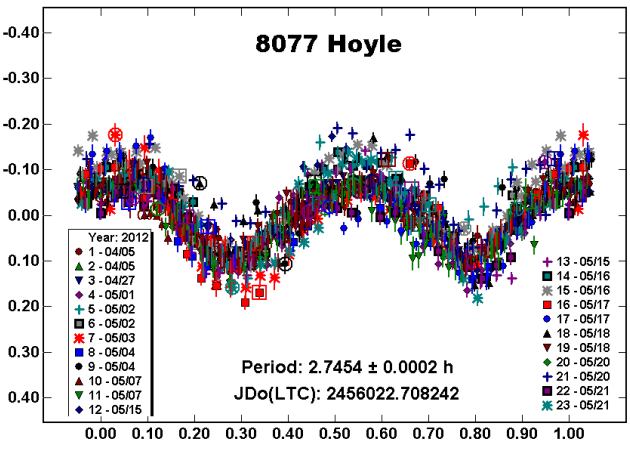

## ROTATION PERIOD DETERMINATION FOR 247 EUKRATE

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Analysis of observations from North America and Australia of the nearly Earth-commensurate asteroid 247 Eukrate obtained over an interval of more than three months resulted in finding a unique rotation period of 12.093 ± 0.001h, amplitude 0.14 ± 0.02 mag.

Observations made by FP at the Organ Mesa Observatory were made using a Meade 35-cm LX-200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD with an R filter. Exposures were 60 seconds, unguided. Analysis used differential photometry only. Observations by SD, GA, and TB, made remotely at Grove Creek Observatory, used a 25-cm SCT, SBIG STL-1001E CCD, and clear filter. Exposures were 30 seconds. Image measurement, lightcurve analysis, and data sharing were done with *MPO Canopus*. Because of the large number of data points, the data for the lightcurves presented here have been binned in sets of three points with a maximum time interval between points no greater than 5 minutes.

Previous period determinations for 247 Eukrate include 12 hours (Schober and Surdej, 1979) and 12.10 hours (Harris and Young, 1980), who based their results a on a more extensive data set. For an object with a period believed to be very close to Earth-commensurate, a series of lightcurves over a long time interval is required for full phase coverage. Observations at Organ Mesa Observatory began 2012 Jan 30, more than a month before opposition, and were obtained on 9 nights at intervals of 5 to 20 days through April 25 to cover the full cycle twice. These have been supplemented by additional observations on 2012 March 23 and May 17 from Grove Creek Observatory, New South Wales, Australia, to sample phases of the lightcurve on dates greatly differing from those on which it could be observed from Organ Mesa. Full phase coverage was also achieved for the double period, for which the two halves look almost identical to each other, and for which the double period can be safely rejected. We find an unambiguous period of 12.093 ± 0.001 h, amplitude 0.14 ± 0.02 magnitudes, in excellent agreement with Harris and Young (1980).

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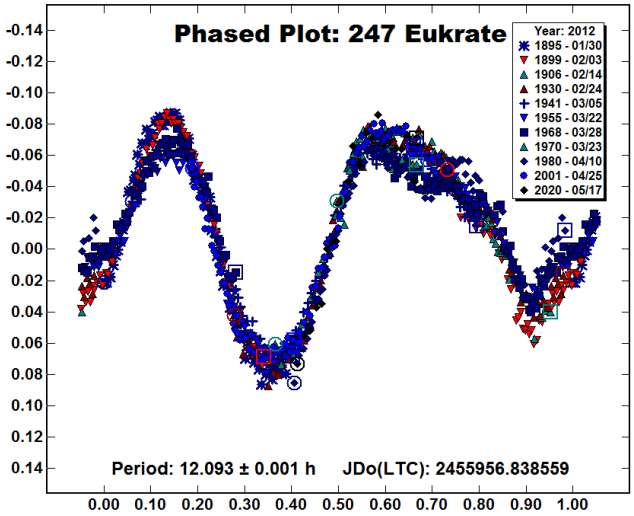


## EPOCH DATA IN SIDEREAL PERIOD DETERMINATION. I. INITIAL CONSTRAINT FROM CLOSEST EPOCHS

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Spin vector determination methods that use epoch information require establishing correct rotation counts over long time spans, which can involve ambiguities that are not necessarily correctly handled by purely statistical methods. I present an approach that can be used prior to spin vector analysis, to begin to check how well a given set of lightcurve epoch data can constrain the sidereal period. I also present two precepts to maximize the impact of observing efforts in cases where more epoch data are needed.

### Introduction

To determine a rotation period from lightcurves, the time interval $\Delta t$ elapsed between observations of some "epoch," such as a repeating feature, is divided by the number of rotations $n_{rot}$ that occurred during the time interval:

$$P = \Delta t / n_{rot} \qquad \text{(Eq. 1)}$$

If the lightcurve is not also observed sufficiently between the epochs, then establishing the number of rotations that occurred can be subject to ambiguity. Determining the correct number of elapsed rotations therefore is essential to determining the correct period. Incorrect periods calculated using incorrect numbers of elapsed rotations are known as alias periods.

Spin vector analyses can make use of epoch information in rotation lightcurves to determine an object's pole orientation and direction of spin. Doing so necessarily involves determining the sidereal rotation period, thus a prerequisite for spin vector analysis using epoch information is determining the correct numbers of rotations

that elapsed between every pair of observed epochs. Establishing the rotation count across the entire span of an epoch data set to determine the sidereal period is considerably more difficult than determining a synodic period from observations made within a single apparition, because epochs from different apparitions are separated by significant spans of time within which no observations are available, and the numbers of rotations involved are much larger than in the synodic case. Typically several thousand rotations elapse between the earliest and latest epochs, providing plenty of opportunity for a miscount. Some hints about determining sidereal periods are available in the literature; e.g., Taylor and Tedesco (1983), Magnusson (1986), Kaasalainen et al. (2001), but comprehensive "how-to" information is generally lacking.

When faced with the problem of identifying a correct solution from among aliases, it is important to understand that calculating a period based on an incorrect number of rotations is a systematic error rather than a statistical error. This distinction matters because least-squares methods can yield spurious results when errors other than independent and normally-distributed measurement errors are present. Statistical methods must therefore be used with caution in this context, especially when the epoch data are not plentiful. Instead, a more robust approach is to first rule out alias periods by considering the sampling issues directly.

This first of two papers concerns only the initial constraint on the sidereal period, to describe an approach to check how well a given set of lightcurve epoch data begins to constrain the period. The test can be used before proceeding with spin vector analysis to check whether more epoch data are needed to identify the correct period solution, and to help plan observing programs. A second paper will describe a method for calculating the sidereal period constraints themselves given a set of epoch data.

## Method

The best single-apparition constraint on the synodic period is used to check how precisely the rotations between epochs observed during the closest available pair of apparitions can be counted. Estimating an appropriate uncertainty for the synodic period is important because it will be used to establish the initial constraints on the sidereal period. An approach that seems well-suited for this purpose is to inspect trial folded composite lightcurves, adjusting the folding period upward and downward to check self-consistency of the resulting composite within the brightness uncertainties of the individual observations. Judging the composite's consistency accurately at the 68% formal one-sigma confidence level is difficult, and also would yield a smaller range of possible sidereal periods than we will wish to test; instead, it is easier and more appropriate for the present purpose to adjust the trial periods farther until the composite is just barely consistent, estimating a more inclusive confidence interval of something like 99%. To emphasize that this estimate isn't a conventional one-sigma error, I subscript it as $\sigma_{99}$ in this paper.

Given the best single-apparition synodic period $P_{syn}$ and uncertainty $\sigma_{99}(P_{syn})$, the number of rotations elapsed during a time interval $\Delta t$ is given by rearrangement of Eq. 1:

$$n_{rot} = \Delta t / P \qquad \text{(Eq. 2)}$$

Every rotation contributes $\sigma_{99}(P_{syn})$ of uncertainty in time, so the accumulated uncertainty over the entire interval, in units of rotations, is

$$\sigma_{99}(n_{rot}) = \sigma_{99}(P_{syn})\ \Delta t / P_{syn}^2 \qquad \text{(Eq. 3)}$$

For purposes of counting alias periods the uncertainty is rounded to the nearest half rotation, because the lightcurves are doubly periodic and at this point one cannot assume that half-rotations can be distinguished:

$$\sigma_{99}(N_{rot}) = 0.5\ \mathrm{INT}(0.5 + 2\ \sigma_{99}(n_{rot})) \qquad \text{(Eq. 4)}$$

The true rotation count could be either smaller or larger than the nominal estimate, and every 0.5 increment in rotation count yields another alias period, so the total number of possible periods from among which the correct period needs to be identified is

$$N_{per} = 4\ \sigma_{99}(N_{rot}) + 1 \qquad \text{(Eq. 5)}$$

Fewer alias periods is better because it reduces the need to decide among possible rotation counts; thus the best possible outcome at this stage is $N_{per} = 1$ in which case rotations are counted over the interval without ambiguity, and the lone period result obtained must be the correct one.

On the other hand, if more than one rotation count is possible at this stage then additional work will be needed to eliminate the spurious alias results and identify the correct count. Eqs. 3–5 suggest a way to test whether obtaining additional epoch data can reduce the number of solutions that need to be checked, in that minimizing both $\sigma_{99}(P_{syn})$ and $\Delta t$ will yield the best constraint on the rotation count. This observation leads to the following two precepts for designing a lightcurve epoch observing program for sidereal period determination:

Precept 1: Determine the synodic rotation period as precisely as possible. Along with the standard observing procedures to achieve high quality photometry and dense coverage in rotational phase, include epoch data from at least one apparition during which lightcurves were observed throughout the apparition's entire time span. A winter apparition is favored because it maximizes the number of usable lunations. A longer time span of observations during an apparition reduces the uncertainty in the derived synodic period $\sigma(P)$ because the uncertainty in the interval between epochs $\sigma(\Delta t)$ will then be divided by a larger number of rotations:

$$\sigma(P) = \sigma(\Delta t) / n_{rot} \qquad \text{(Eq. 6)}$$

Precept 2: Include epochs observed during two consecutive apparitions, because epochs closest in time but not during the same apparition necessarily must be in consecutive apparitions. Note that the intervals between consecutive apparitions can vary significantly depending on the object's orbital eccentricity, in which case it is preferable to observe a pair of apparitions from among those that occur closest in time.

## Discussion

Epoch data which satisfies both precepts yields the smallest $N_{per}$ and thus the best initial constraint on the sidereal period; in most cases I would expect such a data set to yield an unambiguous rotation count, or perhaps a very small number of aliases. If the constraint allows more than one possible period then every solution should be individually checked, and retained until and unless it can be convincingly ruled out.

An epoch data set that doesn't satisfy the precepts will allow more alias periods. Having many possible solutions is a strong indication that there are not enough data to confidently determine the sidereal period.

To illustrate the improvement with attention to epoch sampling I present as an example the data set of asteroid (347) Pariana, which was observed during its 2009 apparition by Caspari (2010). The author combined the new data with lightcurves from two earlier apparitions to report a sidereal period result which seems to have been selected based on a statistical approach. I will use Eqs. 3–5 to test what degree of ambiguity is present within the initial constraint on the sidereal period, based on $\Delta t$, $P_{syn}$, and $\sigma_{99}(P_{syn})$.

In the Pariana data set the interval $\Delta t$ is about 93 months between the closest epochs not in the same apparition, which are six apparitions apart in 1991 and 1999. The synodic rotation period $P_{syn}$ is 4.052 h, with reported errors (assumed 1-sigma) estimated separately from pre- and post-opposition lightcurve subsets. The period uncertainty for use in Eq. 3 should properly be estimated directly from a combined analysis of the original data over the entire 52-day interval observed, but for illustration purposes only I'll use the available information to approximate the uncertainty of a period derived from the combined data. The precision of the combined time interval will be limited by the greater noise in the 16-day span of post-opposition data, so I scale their reported period error $\sigma(P_{syn})$ = 0.004 h by the ratio 16/52, which simply divides the same interval error by the larger number of rotations that occur over the longer 52-day span. Then I adopt $\sigma_{99} \approx 2.5\sigma$ yielding a final estimate of 0.003 h for $\sigma_{99}(P_{syn})$.

The result is that the Pariana epochs allow about 50 alias periods within the initial constraint on the sidereal period, a significant ambiguity which suggests that the reported sidereal period solution is spurious. Caspari (2010) also reported a corresponding spin vector solution based on a nonlinear iterative inversion algorithm (Kaasalainen et al., 2001) which requires the sidereal period as an initial input value, so if the sidereal period is spurious then so is the pole solution.

The Pariana data set can be made markedly more suitable for constraining the sidereal period with additional lightcurve observations that satisfy the two precepts described earlier:

1. Observe a future apparition for a span longer than was observed in 2009. For example, if the observations during the 2009 apparition had begun at the start of the preceding lunation then the total span of available epochs would be 60% longer, and data of comparable quality recorded then would have reduced the number of alias periods by that same amount.

2. Observe lightcurves during a consecutive pair of future apparitions as close as possible in time. Pariana's orbit eccentricity 0.16 is large enough that the time intervals between consecutive apparitions vary in length by nearly a factor of two; the shortest intervals occur when one of the opposition dates is in July or August. For example, if Pariana were observed in 2012 February and 2013 July then $\Delta t$ would be about 17 months, reducing by more than 80% the number of alias periods.

Making both of the above improvements to the Pariana data set reduces the expected number of alias periods for the initial sidereal period constraint to about 3, few enough to convincingly check individually.

## Conclusion

Authors determining sidereal rotation periods from lightcurves need to be aware of the issue of alias periods, and use analysis methods that explicitly address identifying and resolving ambiguous solutions for rotation counts. Attention to epoch sampling in the observing program can reduce the number of alias periods. Robust strategies are needed to reliably identify the correct period from among aliases, or to establish the degree to which the best result is ambiguous; in particular, if a statistical approach ultimately is involved then one must be mindful of its limitations in this context.

Finally, note that while significant ambiguity in the rotation count for the initial sidereal constraint considered here would suggest that the epoch data are insufficient to determine the sidereal period, an unambiguous rotation count at this initial stage does not by itself guarantee that the full data set is sufficient to unambiguously count rotations over the longer intervals of the entire data set, or that the sidereal period thus obtained is accurate enough. In the second paper I will describe a method to estimate bounds on the range(s) of sidereal periods that are consistent with an entire data set of epochs.

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## A DETERMINATION OF THE ROTATIONAL PERIOD OF 8882 SAKAETAMURA

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CCD Observations of 8882 Sakaetamura were taken on nine nights between 2012 Jan 7 and 29. Analysis of the data found a synodic period of 4.874 ± 0.002 h with a lightcurve amplitude of 0.60 ± 0.1.

8882 Sakaetamura is a main-belt asteroid that was discovered on 1994 Jan 10 by K. Endante and K. Watanabae at Kitami. Alternate designations for this asteroid are 1994 AP2 and 1987 GX (JPL, 2012). Observations were made at the Frank T. Etscorn Observatory located on the campus of the New Mexico Institute of Mining and Technology. The equipment used for observations included a 0.35-m *f*/11 Cassegrain mounted on a Paramount ME and SBIG STL-1001E CCD camera. All images were taken through a clear filter and the exposure times were 180 seconds. The images were flat-corrected and dark-subtracted and then aligned using *CCDSoft 5* (Software Bisque). The period analysis and lightcurve generation were done using *MPO Canopus* (MPO Software).

The period analysis found a synodic period for 8882 Sakaetamura of 4.874 ± 0.002 h. This is different from the period reported by Hamanowa and Hamanowa (2005), who found 2.838 h with an amplitude of 0.66 mag. Their solution was a monomodal lightcurve which, given the amplitude, is not likely and so a period approximately double what they found would be more probable. On the other hand, the solution is almost identical to the one of 4.8742 ± 0.002 h found by Hills (2012).

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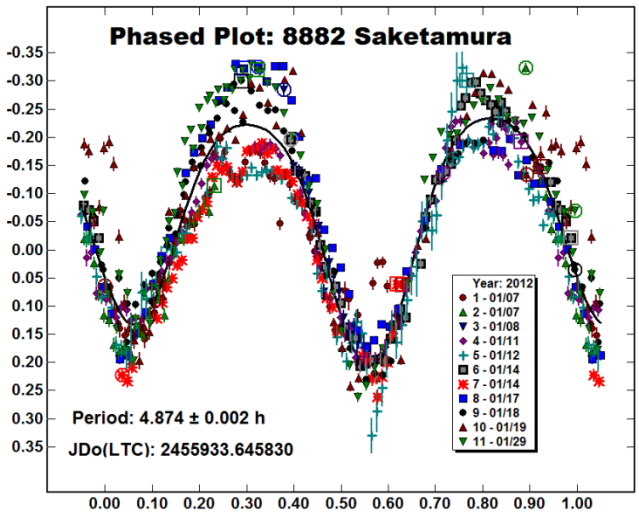


## LIGHT CURVE FOR 8345 ULMERSPATZ

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The main-belt asteroid 8345 Ulmerspatz was observed by a collaboration of four observatories on 24 nights between 2011 Nov 24 and 2012 Jan 12, covering solar phase angles between –22.58° and +10.48°. The average synodic period for the entire observing period is estimated to be 17.1192 ± 0.0008 h with an amplitude of 0.70 ± 0.10 mag.

The main-belt asteroid 8345 Ulmerspatz was discovered on 1987 January 22 by E. W. Elst at the European Southern Observatory. The orbital period is 3.575 years and inclination 23.4º. Over the years, it has carried designations 1987 BO1, 1968 YB, and 1994 AU2 (JPL, 2012). It is named for the Ulmerspatz (sparrow) copper statuette originally on top of the roof of the cathedral of Ulm. The legend goes that a sparrow, building its nest, showed the builders of Ulm how to move a large beam through a small entrance door.

CCD observations of 8435 Ulmerspatz were obtained by a collaboration of four observatories from late 2011 to early 2012. The Etscorn Campus Observatory used a 35.6-cm *f*/11 Schmidt-Cassegrain telescope and SBIG STL-1001E CCD with 1024x1024 24-micron pixels, which gave a plate scale of 1.25 arcseconds/pixel. The exposure time for all images was 180 seconds through a clear filter. The CCD was cooled to –30ºC or –35ºC, depending on the night-time temperature. The images processed with dark frames and flat fields and then aligned using IDL routines developed by Klinglesmith (Visual Information Solutions, 2012). The processed images were measured with *MPO Canopus* (Warner, 2011). The Bigmuskie Observatory used a 30-cm *f*/8 Ritchey-Chretien and SBIG ST-9 with 512x512 20-micron pixels resulting in a plate scale of 1.72 arcseconds/pixel. The exposure time for all images was 240 seconds through an R

| Start | Stop | Phase | Period (h) | Perr | Amp | Aerr |
|---|---|---|---|---|---|---|
| 2011-11-24 | 2011-12-02 | -22.6 | 17.1128 | 0.0150 | 0.60 | 0.05 |
| 2011-12-03 | 2011-12-08 | -17.9 | 17.1724 | 0.0072 | 0.60 | 0.05 |
| 2011-12-16 | 2011-12-24 | -9.4 | 17.0840 | 0.0060 | 0.65 | 0.05 |
| 2011-12-26 | 2011-12-29 | -2.4 | 17.1508 | 0.0060 | 0.67 | 0.10 |
| 2011-12-31 | 2012-01-03 | 1.6 | 17.0316 | 0.0132 | 0.57 | 0.05 |
| 2012-01-05 | 2012-01-12 | 5.2 | 17.1300 | 0.0060 | 0.80 | 0.10 |

Table I. Observing circumstances and lightcurve analysis results for specific date ranges. The columns are: starting date and ending date (yyyy-mm-dd) of the subset of data, solar phase angle, period and period error in hours, amplitude and amplitude error in magnitude.

Astrodon filter. The CCD was cooled to –30ºC. Images were corrected with dark frames and flat fields with the routines found in *MPO Canopus* (Warner, 2011) and then, with the same software, measured to produce the lightcurve data.

Phillips Academy Observatory used a 0.4-m *f*/8 DFM classsical Cassegrain and SBIG 1301E CCD with 1280x1024 20-micron pixels resulting in a plate scale of 1.00 arcseconds/pixel. The exposure time for the unguided images was 180 seconds through a clear filter. The CCD was cooled to –30ºC. All images were dark-subtracted and flat-field corrected. The processed images were measured with *MPO Canopus* (Warner, 2011). The Bassano Bresciano Observatory used a 0.32-m *f*/3.1Schmidt telescope and HX-516 CCD. Exposure times were 120 seconds through a clear filter. 2x2 binning was used for all images, resulting in a plate scale of 3 arcseconds/pixel. All images were flat-field and dark-frame corrected. The images were measured using *MPO Canopus* (Warner, 2011).

The combined lightcurve is shown in Figure 1. It consists of 48 sessions of *MPO Canopus* processed data. The individual lightcurves were adjusted so that, when available, the maximum portion of the lightcurves were lined up. Since we observed the asteroid from a solar phase angle of –22.48° (pre-opposition) through +10.48° (post-opposition), we have divided the data into six separate time intervals as shown in Figures 2-7. There is some variation in period and amplitude as a function of solar phase angle (Table I).

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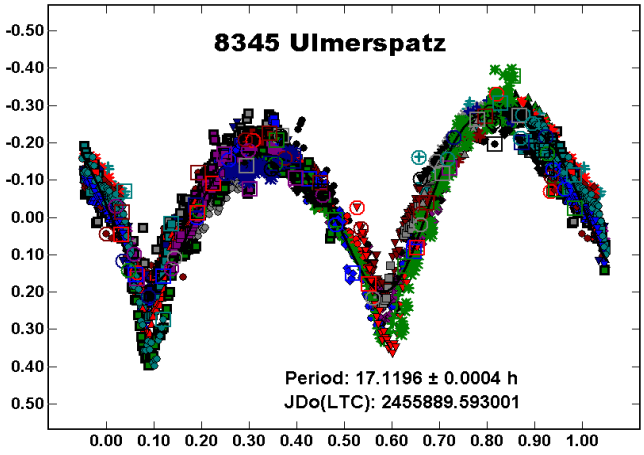


Figure 1. Lightcurve for 8345 Ulmerspatz using all data.

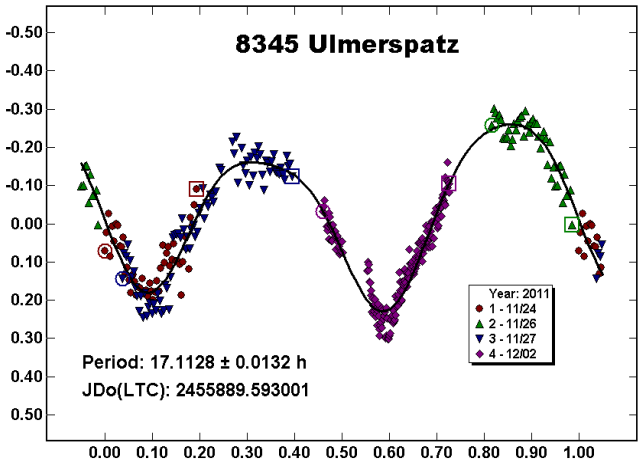


Figure 2. Lightcurve for 8345 Ulmerspatz, 2011 Nov 24 – Dec 2.

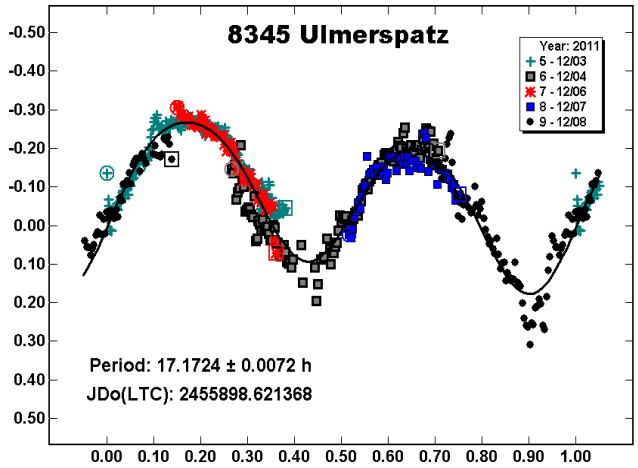


Figure 3. Lightcurve for 8345 Ulmerspatz, 2011 Dec 2 - 8.

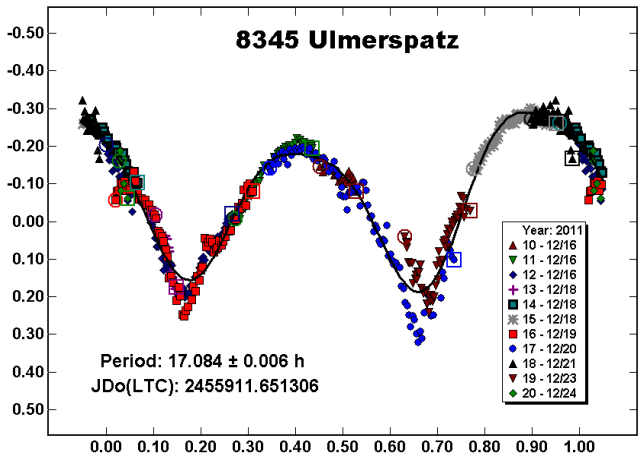


Figure 4. Lightcurve for 8345 Ulmerspatz, 2011 Dec 16 – 24.

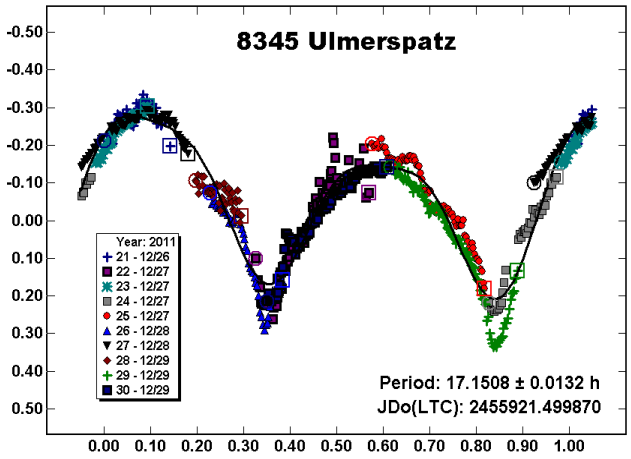


Figure 5. Lightcurve for 8345 Ulmerspatz, 2011 Dec 26 – 29.

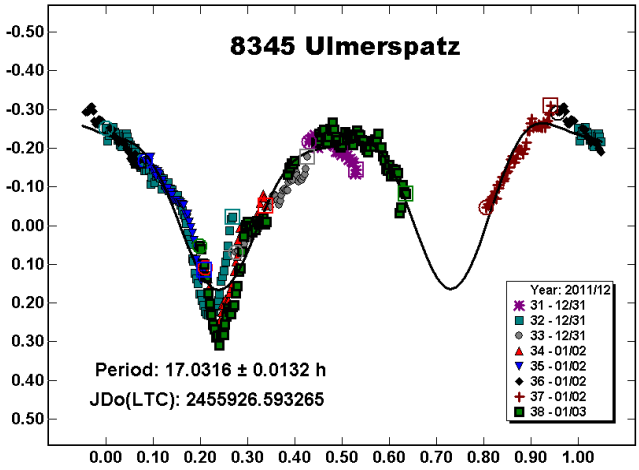


Figure 6. Lightcurve for 8345 Ulmerspatz, 2011/12 Dec 31 – Jan 3.

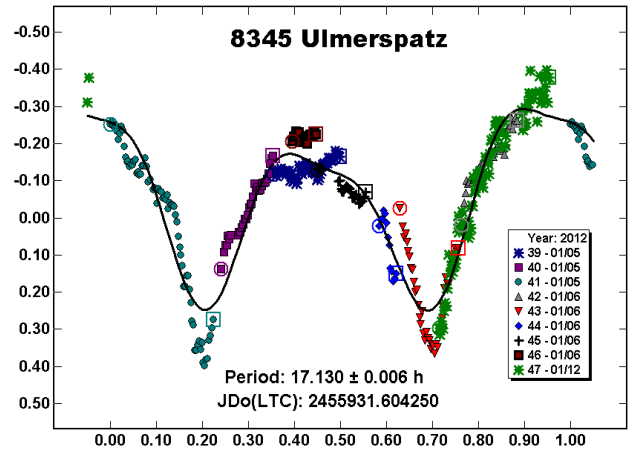


Figure 7. Lightcurve for 8345 Ulmerspatz, 2012 Jan 5 – 12.

## LIGHTCURVES OF 2423 IBARRURI AND 8345 ULMERSPATZ

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The synodic lightcurve period of 2423 Ibarruri is found to be 139.89 ± 0.03 h. The synodic lightcurve period of 8345 Ulmerspatz is found to be 17.14 ± 0.02 h. For 8345 Ulmerspatz, phase curve parameters are also determined: H = 13.75 ± 0.03, G = –0.14 ± 0.02.

The synodic rotation rates for 2434 Ibarruri and 8345 Ulmerspatz were determined from the analysis of CCD photometric observations at the Altimira Observatory. In addition a comparison of results was made when using the MPOSC3 (Bdw Publishing) or the APASS (Henden *et al*., 2012) catalogs.

2423 Ibarruri. This asteroid was studied with differential photometry at Altimira Observatory (G76), using a 0.28-m Schmidt-Cassegrain (SCT) and SBIG ST8-XE CCD imager with photometric B, V, and R-band filters. The general observing cadence was R-R-V-V-B-B-... throughout each night in order to provide nearly simultaneous multi-color photometry. Images were reduced in the standard way with dark, flat, and bias frames. Comparison stars were chosen for near-solar color index with the "comp star selector" of *MPO Canopus;* all photometric reductions were also done with *MPO Canopus*. Because of the low signal-to-noise ratio, B-band images are not used for this report.

A total of 15 nights (separated by intervals of bad weather) from 2011-10-09 to 2011-11-17 UT were devoted to this asteroid, encompassing solar phase angles from α ~ –9.1° to α ~ +18.4°. There were no indications of changes in the lightcurve shape over this range of solar phase angles but the gaps in the phased lightcurve may be hiding some "shadowing" effects. The resulting lightcurve, phased to the best-fit period *P* = 139.89 h is shown in Figure 1. This is based on V-band data only, but there is no evidence of changing color index with rotational phase when the R-band data are included. The color index was determined to be V-R = 0.43 ± 0.03. This result confirms the period found by Ferrero (2012). My data do not display a plausible lightcurve when phased to the alternate period (*P* ~ 73 h) suggested by Vander Haagen (2012).

8345 Ulmerspatz

This project had two objectives: to take advantage of the favorable apparition of 8345 Ulmerspatz to determine its lightcurve and phase curve; and to use the recently-released APASS photometric catalog to determine comp star magnitudes.

Images were made at Altimira Observatory, predominantly unfiltered ("C-band"). A few R- ,V- and B-band images were taken on most nights but they are not shown in this report because of their low signal-to-noise ratio. Images were gathered on 14 nights spanning the interval 2011-12-26 through 2012-02-24 UT. This interval covered solar phase angles from α ~ –2.3°, to a minimum of α ~ 0.2°, and then continued to α ~ +27.6°.

APASS Catalog. The southern California weather during this project did not provide any clear/steady/stable nights suitable for calibration of comp star magnitudes. Data Release 6 of the AAVSO's APASS photometric catalog (Henden, *et al*., 2012) contains accurate V-band photometry for all of the comp stars used on all nights of this project. The APASS V-band magnitudes were inserted into the comp-star data blocks of *MPO Canopus* to put the differential photometry onto a standard baseline. There is, of course, a danger in using V-band magnitudes with C-band images. However, since the asteroid color and the comp-star colors are all nearly the same, the risk of differential-color effects is low. In addition, previous experiments with the Altimira Observatory equipment to measure the "C to V" transform (using Landolt standard stars) have shown that the C-to-V conversion is surprisingly good over a fairly wide range of (B-V) color.

Examination of the APASS photometry for the comp stars showed that the *MPO* "comp star selector" does a fine job of selecting stars with near-solar color. The APASS-reported B-V colors of the 70 comp stars used for this project averaged $B\text{-}V_{avg} = 0.67 \pm 0.10$ (std dev). The correlation between APASS V and MPOSC V magnitudes is also very good: the standard deviation of $[V_{APASS} - V_{MPOSC}]$ was about $\sigma \sim 0.11$, which is comparable to the original design specifications for the MPOSC. So, the MPOSC V-magnitudes are generally reliable. The key features of using the APASS photometry (rather than the MPOSC magnitudes) are (a) APASS magnitudes are actually measured in V, instead of being based on a correlation between IR magnitudes and B-, V-, R-magnitudes; (b) the accuracy of APASS magnitudes can be assessed for each individual star – generally ±0.05 mag or better for the stars used here – whereas the MPOSC accuracy can only be assessed statistically across the entire catalog; and (c) the use of APASS magnitudes corrects the few stars for which MPOSC V-magnitudes seem discordant.

The downside of using APASS is that each query of the catalog will only search a small field (less than a few degrees diameter). This means that each night's set of comp stars requires a separate query of the APASS database. Each query returns the data on all of the stars in the requested field; then the output table must be searched to find the comp stars that were used. It's a bit cumbersome, but the confidence in comp star magnitudes makes it worth the effort for determining the phase curve of an asteroid.

Lightcurve. There are two reports of lightcurves and periods for this asteroid 8345: Klinglesmith (2012) reported $P = 17.12$ h and Strabla *et al*. (2012) reported $P = 17.416$ h. Both of these are based on data taken at the same apparition as the present study. If only the nights with low solar phase angle ($-3° < \alpha < +4°$) are considered, a nice double-peaked lightcurve is found, as shown in Figure 2, with a best-fit synodic period $P = 17.13 \pm 0.02$ h. The shape of this lightcurve is essentially identical to that seen by Klinglesmith (2012).

At large solar phase angle ($\alpha > 18°$) after opposition, the shape of the lightcurve changed dramatically, having much deeper primary and secondary minima, as shown in Figure 3. This is presumably a shadowing effect, which suggests a complex shape for this object.

Phase curve. The phase curve was determined based on the APASS V-magnitudes of the comp stars, using the method developed by Harris *et al*. (1989). The resulting phase curve, describing the peak brightness of the rotational lightcurve as a function of solar phase angle, is shown in Figure 4. The best-fit parameters are: $H = 13.75 \pm 0.03$; $G = -0.14 \pm 0.02$.

These parameters, and the curve shown, exclude the data from 2012-02-24 (phase angle $\alpha = 27.6°$) because the short interval of observations that night and the changing shape of the lightcurve at large solar phase angle made it unreliable to extrapolate the peak brightness of the lightcurve. The negative slope parameter is somewhat unusual, but similar results have been reported before, e.g. Lagerkvist and Williams (1987), Harris (1989), and Warner (2007).

The data gathered by Strabla et al (2012) and posted on ALCDEF also captured the night of minimum solar phase angle, and so offered a valuable check on the phase curve. Their comp star magnitudes were taken at face value, except for the night of UT 2012-01-12, on which their comp star magnitudes were noticeably different from the APASS V-magnitudes for the indicated star. Applying the APASS magnitudes for the comp stars on that night (but making no change to Strabla's other nights), and combining their data with mine, yielded the phase curve shown in Figure 5, which is characterized by $H = 13.76 \pm 0.02$ and $G = -0.13 \pm 0.02$, within the stated errors of the values reported here.

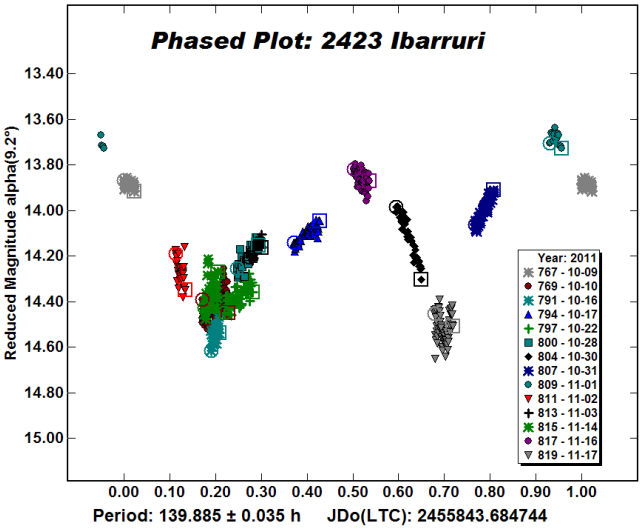


Figure 1: Lightcurve of 2423 Ibarruri in V-band, phased to 139.89 h.

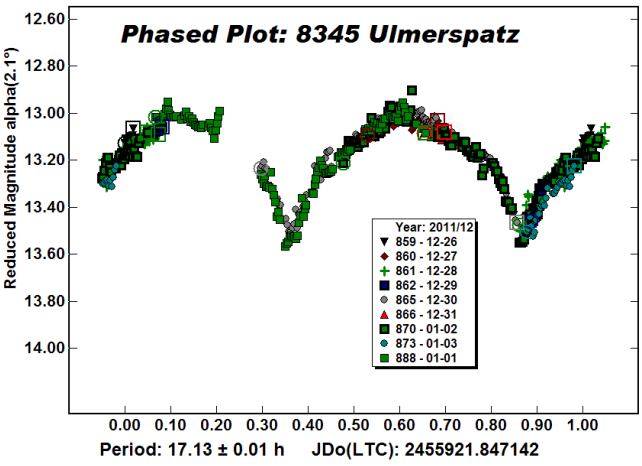


Figure 2: Lightcurve of 8345 Ulmerspatz at low solar phase angle, phased to P = 17.13 h.

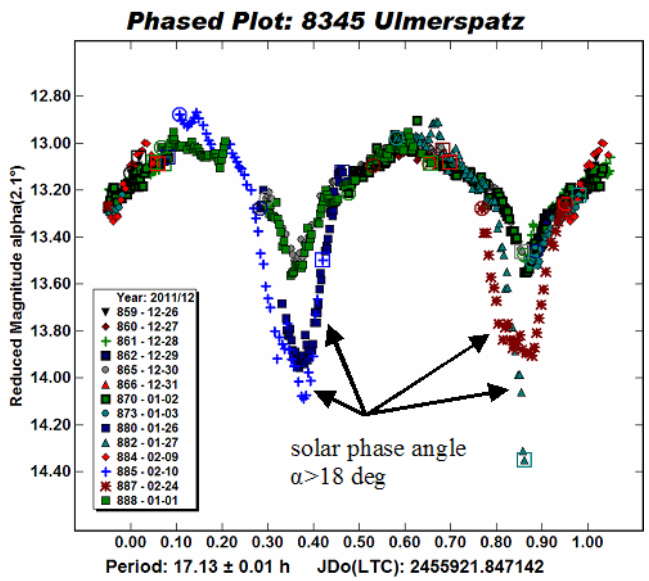


Figure 3: Lightcurve of 8345 Ulmerspatz, phased to $P$ = 17.13 h, showing the dramatic increase in amplitude at large solar phase angles (α > 18°), presumably caused by shadowing of a complex surface.

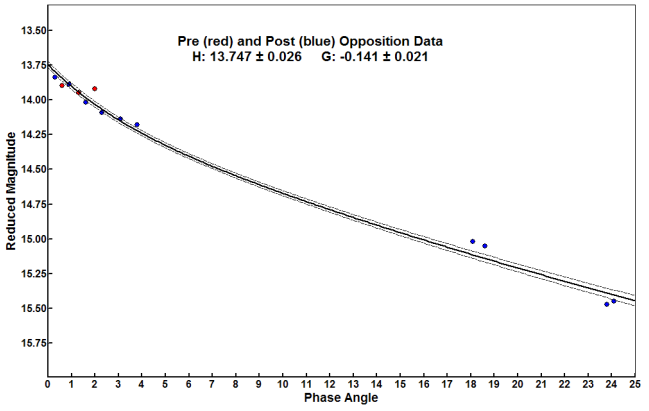


Figure 4: Phase curve of 8345 Ulmerspatz, based on data from Altimira Observatory (this study), with best-fit slope parameter $G$ = –0.14.

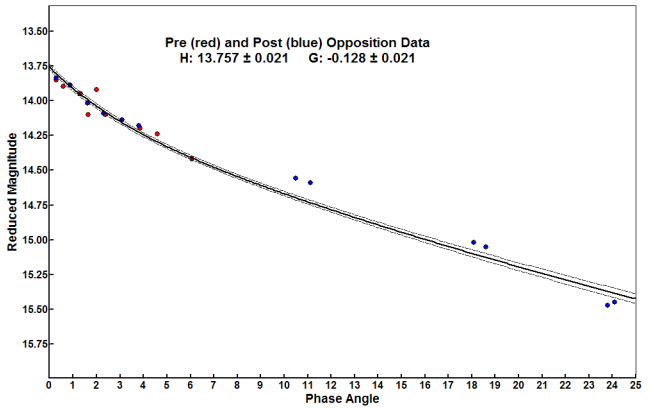


Figure 5: Phase curve of 8345 Ulmerspatz, combining data from this study with Strabla's data (from the same apparition) as posted on ALCDEF, giving consistent H and G parameters.

Acknowledgements

This research made use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. This research made use of the ALCDEF database maintained by the Minor Planet Center. I thank Mr. Luca Strabla and the Bassano Bresciano Astronomical Observatory for making their lightcurve data publically available on the ALCDEF database.

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## LIGHTCURVE AND ROTATION PERIOD DETERMINATION FOR MINOR PLANET 3397 LEYLA

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(Received: 19 May)

Photometric observations of Mars-crossing minor planet 3397 Leyla (1964 XA) was undertaken in March 2012. The resulting synodic rotation period of 3.098 ± 0.002 h and amplitude, A = 0.29 ± 0.05 mag was measured and determined from five nights of observations.

Cherryvalley Observatory (MPC Code I83) is a small observatory operated by the author and located in rural County Meath, Ireland. Observations from Cherryvalley Observatory were conducted with a 0.2-m *f*/10 Schmidt-Cassegrain Telescope (SCT) on a GEM mount using an SBIG STL-1301E CCD camera with a 1280x1024 array of 16-micron pixels fitted with an R-band photometric filter. The resulting image scale was 1.50 arcsecond per pixel. Exposures were 120 seconds each. The CCD camera working temperature was –30˚ C on average. All light images were dark and flat-field corrected, guided, and unbinned. For analysis, the light-time corrected mid-exposure times were used in *MPO Canopus v10.4.0.20* (Bdw Publishing). 365 useful data points were used in calculations from a total data set of 643, which were obtained over five nights of observations spanning 23 days.

Imaging, focus, and plate solving were done with *CCDSoft v5* and *TheSky6 Professional*. Data were reduced in *MPO Canopus* (Bdw Publishing) using differential photometry to facilitate easy exportation. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colours, chosen by using the *MPO Canopus* Comp Star Selector feature. The Cousins R Magnitudes for the comparisons were derived using the 2MASS to BVRI formulae developed by Warner (2007). Period analysis was completed using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 1989).

3397 Leyla. This asteroid was discovered by R. Burnham and N. G. Thomas in 1964 from Flagstaff. It is a Mars-crosser, defined approximately by an orbit of 1.3 AU < $q$ < 1.666 AU and $a$ < 3.2 AU. Its diameter is estimated to be 5.3 ± 0.5 km. The absolute magnitude is $H$ = 13.60 and phase slope parameter is $G$ = 0.226 ± 0.047. The asteroid was reported as a lightcurve opportunity in the *Minor Planet Bulletin* (Warner *et al.*, 2012).

Observations of 3397 Leyla were made 2012 March 4-27 resulting in a data span of 552 hours (approximately 178 rotational cycles).

Table I gives the observation circumstances. PAB is the phase angle bisector (see Harris *et al.*, 1984, for the derivation of the PAB).

The lightcurve (Figure 1) demonstrates a classical bimodal shape of two distinct minimums and maximums. The period solution of 3.098 ± 0.002 h is in agreement with earlier work by Klinglesmith (2012) from 154 data points with a rating of U = 1+ (Warner *et al.*, 2009). Based upon additional observations by Cherryvalley Observatory, the Klinglesmith period appears correct and the lightcurve presented here rates U = 2+ and possibly U = 3-. Leyla was well-placed for observation from Cherryvalley Observatory and, with a reported synodic period of approximately 3 hours, it is usually easy to get good coverage in a single night and so have a relatively dense data sets for analysis.

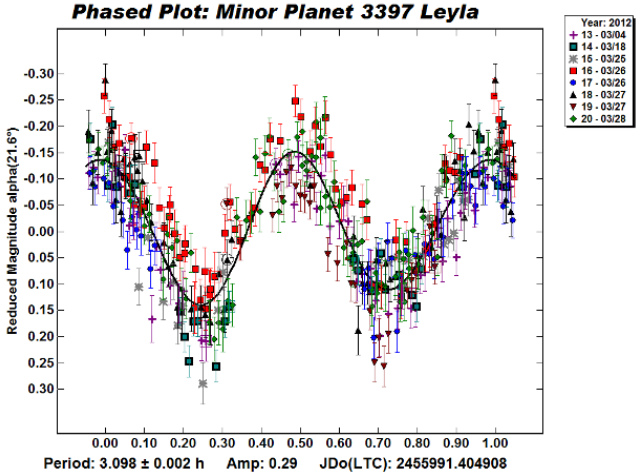


Figure 1. The lightcurve of 3397 Leyla shows a period of 3.098 ± 0.002 h with an amplitude of 0.29 ± 0.05 mag.

Acknowledgements

The author wishes to express gratitude to Brian Warner for his helpful insights and the *MPO Canopus* software which really makes asteroid lightcurve work much easier, enjoyable, and faster. The author also wishes to express gratitude to David McDonald of Celbridge Observatory (J65) Co. Kildare Ireland for his guidance.

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| Date 2012 | Time (UT) | Ph (deg) | Earth Dist (AU) | V-mag Predicted | Sun Dist (AU) | CCD Exposure (s) Each | LPAB (deg) | BPAB (deg) | CCD Total Frames | CCD Frames | Filter Band |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mar-04 | 00:00:00 | 21.7 | 0.834 | 15.1 | 1.718 | 120 | 153 | +27 | 74 | 57 | R |
| Mar-18 | 00:00:00 | 23.0 | 0.885 | 15.3 | 1.747 | 120 | 155 | +23 | 64 | 29 | R |
| Mar-25 | 00:00:00 | 24.3 | 0.923 | 15.5 | 1.764 | 120 | 157 | +21 | 137 | 93 | R |
| Mar-26 | 00:00:00 | 24.5 | 0.929 | 15.5 | 1.766 | 120 | 157 | +21 | 201 | 90 | R |
| Mar-27 | 00:00:00 | 24.7 | 0.936 | 15.5 | 1.769 | 120 | 157 | +21 | 167 | 96 | R |
| | | | | Ā = 15.4 | | | | | T = 643 | T = 365 | |

Table I. Observing Circumstances of 3397 Leyla between 2012 March 04th to March 27th

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Warner, B.D., Harris, A.W., Pravec, P., Durech, J., and Benner, L.A.M. (2012). "Lightcurve Photometry Opportunities: 2012 January – March." *Minor Planet Bul.* **39**, 31-34.

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

Warner, B.D. (2012). MPO Software, Canopus version 10.4.0.20 Bdw Publishing *http://www.minorplanetobserver.com*

## A REQUEST TO POST YOUR LIGHTCURVE INVERSION MODELS

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We request that all authors of published lightcurve inversion papers, past and current, submit their results to the DAMIT lightcurve inversion website for permanent retention and ready availability to interested people.

An increasing number of people are using the lightcurve inversion software to produce good quality lightcurve inversion models and publishing them in the *Minor Planet Bulletin.* We are requesting that after publication, you submit your data to second author Durech at *durech@sirrah.troja.mff.cuni.cz*. Please use the format of shape and data files as they are produced by *LCInvert*, as published by Brian Warner. We wish to post these on the DAMIT website for asteroid lightcurve inversion models, *http://astro.troja.mff.cuni.cz/projects/asteroids3D*. This database archive is described by Durech et al. (2010). Here they are available to all interested people, and full reference to the authors of the model is also provided. This is analogous to the ALCDEF site for lightcurves. Submission to ALCDEF has become a standard procedure which is being followed nowadays by most of the authors who publish lightcurves in the *Minor Planet Bulletin.* We hope that submission of published lightcurve inversion models to DAMIT will also become a standard procedure. And we encourage the authors of all past as well as current published lightcurve inversion models to make them available to DAMIT.

Reference

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

## ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2012 JANUARY-APRIL

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Photometric data for 29 asteroids were collected over 35 nights of observing during 2012 January-April at the Oakley Southern Sky Observatory. The asteroids were: 225 Henrietta, 648 Pippa, 862 Franzia, 1311 Knopfia, 1714 Sy, 1985 Hopmann, 2145 Blaauw, 2234 Schmadel, 2464 Nordenskiold, 2550 Houssay, 2698 Azerbajdzhan, 2903 Zhuhai, 3810 Aoraki, 3968 Koptelov, 4790 Petrpravec, 4892 Chrispollas, 4950 House, 5374 Hokutosei, 6321 Namuratakao, 6574 Gvishiani, 6972 Helvetius, (7036) 1995 BH3, (15269) 1990 XF, (19774) 2000 OS51, (21976) 1999 XV2, (30185) 2000 GT95, (30432) 2000 LM20, (44443) 1998 UY19, and (90076) 2002 VS95.

Twenty-nine asteroids were observed from the Oakley Southern Sky Observatory in New South Wales, Australia, on the nights of 2012 January 16-19, 21-23, February 11, 13-14, 16-17, 21-23, March 23-26, 29-31, April 2, 10-13, 16, 19-21, 24-26, 29. Through analyzing the data, we were able to find light curves for 12 asteroids. During this period, New South Wales experienced much rain and cloud coverage. Of the 12 lightcurves found, seven were for asteroids that had no previously published period. Out of the remaining five asteroids with lightcurves, only two agreed with previously published results.

The asteroids were selected based upon their position in the sky an hour after sunset. Then, asteroids with no previously published period were given higher priority than those asteroids that already have a published period. Finally, asteroids with uncertain periods were given priority in hopes that their previously published period could be improved. The telescope used was an *f*/8.1 0.5-meter Ritchey-Chretien optical tube assembly mounted on a Paramount ME mount. The camera was a Santa Barbara Instrument Group STL-1001E CCD camera with a clear filter. The image scale was 1.2 arcseconds per pixel with varied exposure times between 20 and 210 seconds. Calibration of the images was done using master twilight flats, darks, and bias frames. All calibration frames were created using *CCDSoft*. *CCDSoft* was also used to process the images and *MPO Canopus* was used to measure the images.

We have the first reported observations of the period of the following asteroids: 2145 Blaauw, 2234 Schmadel, 2464 Nordenskiold, 2698 Azerbajdzhan, 5374 Hokutosei, 6972 Helvetius, (15269) 1990 XF.

225 Henrietta. Our result is close to the period of 7.360 ± 0.001 h found by Chiorny (2007) but not within experimental uncertainty. Our result is closer to the period of 7.356 ± 0.001 h found by Michalowski *et al.* (2000). However, since these are all synodic periods, which can change from one apparition to the next depending on the behavior of the phase angle bisector (i.e., the sidereal-synodic period difference), and the periods are within 2-sigmas, all the results can be considered mutually consistent.

| Number | Name | Dates mm/dd 2012 | Data Points | Period (h) | PE (h) | Amp (mag) | Amp Err |
|---|---|---|---|---|---|---|---|
| 225 | Henrietta | 03/23 24 26 29, 04/02 | 61 | 7.352 | 0.003 | 0.18 | 0.02 |
| 648 | Pippa | 03/23 24 26, 29,04/02 | 67 | 9.263 | 0.001 | 0.31 | 0.03 |
| 862 | Franzia | 04/19-21 24 26 29 | 153 | | | 0.22 | 0.04 |
| 1311 | Knopfia | 01/16-19 21 22 | 78 | | | 0.25 | 0.05 |
| 1714 | Sy | 03/23-26 29-31, 04/02 | 86 | | | 0.95 | 0.03 |
| 1985 | Hopmann | 02/11 13 14 16 21-23 | 127 | 17.478 | 0.004 | 0.34 | 0.04 |
| 2145 | Blaauw | 02/11 13 14 16 17 21-23 | 193 | 12.141 | 0.003 | 0.18 | 0.03 |
| 2234 | Schmadel | 04/1013 16 | 84 | 15.63 | 0.02 | 0.25 | 0.02 |
| 2464 | Nordenskiold | 02/11 13 14 16 17 22 23 | 44 | 5.2089 | 0.0008 | 0.51 | 0.03 |
| 2550 | Houssay | 01/1619 21 22 | 126 | | | 0.50 | 0.05 |
| 2698 | Azerbajdzhan | 01/16-19 21 | 78 | 27.20 | 0.05 | 0.70 | 0.05 |
| 2903 | Zhuhai | 04/10-13 | 76 | 5.263 | 0.002 | 0.34 | 0.02 |
| 3810 | Aoraki | 02/11 13 14 16 17 21 23 | 267 | | | 0.06 | 0.01 |
| 3968 | Koptelov | 03/23-26 29-31, 04/02 | 100 | | | 0.11 | 0.04 |
| 4790 | Petrpravec | 02/11 13 14 16 17 22 23 | 45 | | | 0.02 | 0.005 |
| 4892 | Chrispollas | 03/23 24 26 29-31, 04/02 | 102 | | | 0.10 | 0.01 |
| 4950 | House | 01/16-18 21-23 | 92 | | | 0.18 | 0.02 |
| 5374 | Hokutosei | 02/11 13 14, 2/16-2/17, 2/21-2/23 | 139 | 6.8 | 0.1 | 0.50 | 0.04 |
| 6321 | Namuratakao | 1/17-1/19, 1/21-1/23 | 113 | | | 0.06 | 0.01 |
| 6574 | Gvishiani | 4/19-4/21, 4/24-4/26, 4/29 | 122 | | | 0.20 | 0.04 |
| 6972 | Helvetius | 1/16-1/19, 1/21-1/23 | 96 | 16.35 | 0.03 | 0.46 | 0.03 |
| 7036 | 1995 BH3 | 3/23-3/26, 3/29-3/31, 4/2 | 112 | 11.283 | 0.003 | 0.58 | 0.04 |
| 15269 | 1990 XF | 4/19-4/21, 4/24-4/26, 4/29 | 154 | 26.80 | 0.02 | 0.55 | 0.06 |
| 19774 | 2000 OS51 | 4/19-4/21, 4/24-4/26, 4/29 | 102 | | | 0.12 | 0.03 |
| 21976 | 1999 XV2 | 3/23-3/26, 3/29-3/31, 4/02 | 110 | | | 0.17 | 0.02 |
| 30185 | 2000 GT95 | 3/23-3/26, 3/29-3/31, 4/02 | 115 | | | 0.18 | 0.04 |
| 30432 | 2000 LM20 | 4/10-4/13, 4/19-4/21, 4/24, 4/26 | 180 | | | 0.70 | 0.1 |
| 44443 | 1998 UY19 | 4/10-4/13, 4/19-4/21, 4/24, 4/26 | 187 | | | 0.05 | 0.02 |
| 90076 | 2002 VS95 | 4/10-4/13 | 42 | | | 0.08 | 0.03 |

Table I. Observing dates and results.

648 Pippa. Our data are inconsistent with a period of 5.2 ± 0.3 h found by Behrend (2004), which was rated as U = 1+ (a little better than "likely wrong") in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009).

1985 Hopmann. Our results agree within experimental uncertainty with 17.480 ± 0.002 h found by Stephens (2012).

2903 Zhuhai. Our results are inconsistent with a period of 6.152 ± 0.001 h found by Alvarez *et al*. (2004).

(7036) 1995 BH3. Our result is close to a period of 11.245 ± 0.002 h found by Galad *et al*. (2010), but not within experimental uncertainty. The differences here are more than might be explained by variations in the synodic period at different apparitions. Follow-up observations are encouraged to refine the solution.

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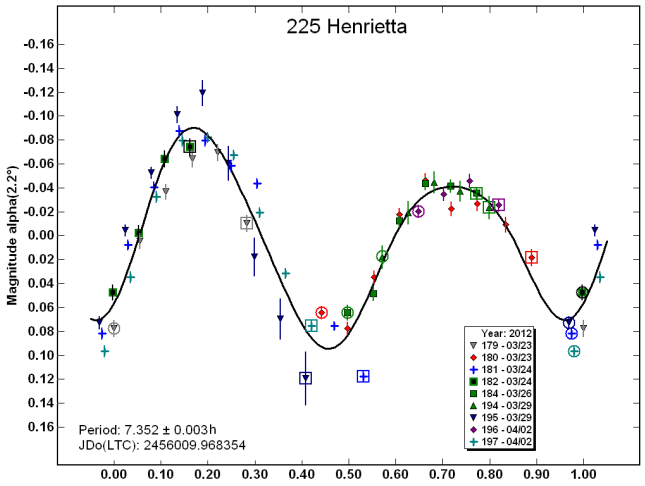
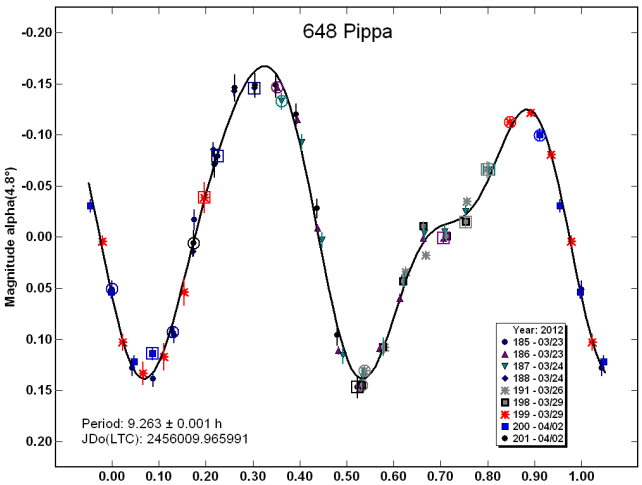
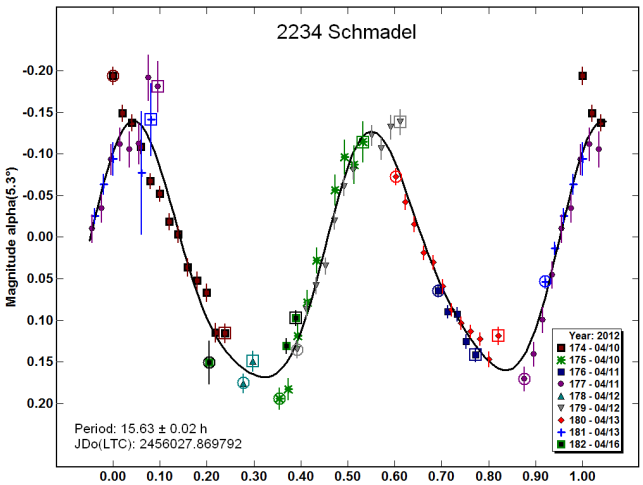
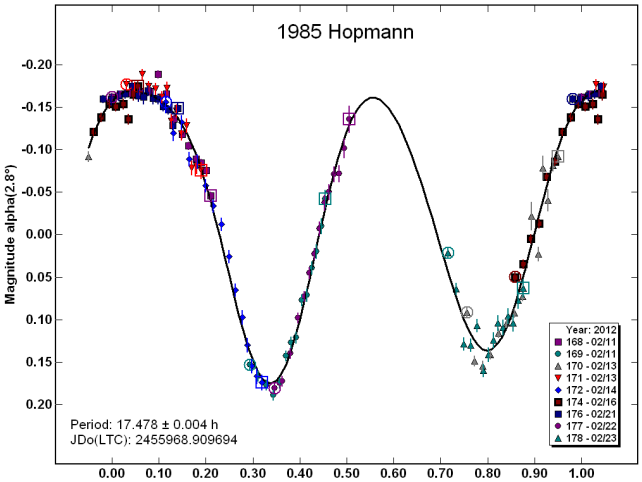
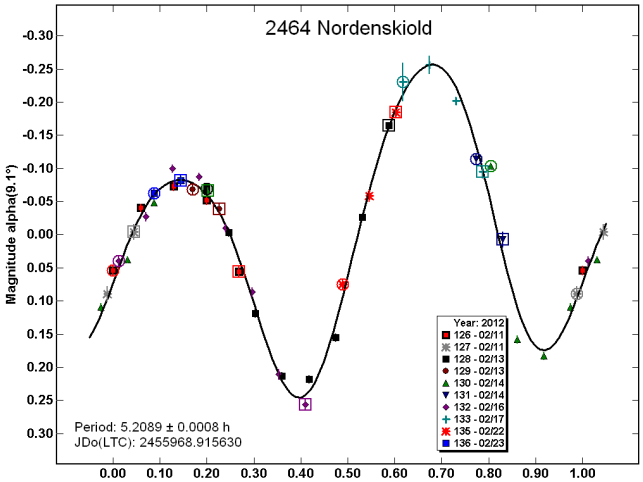
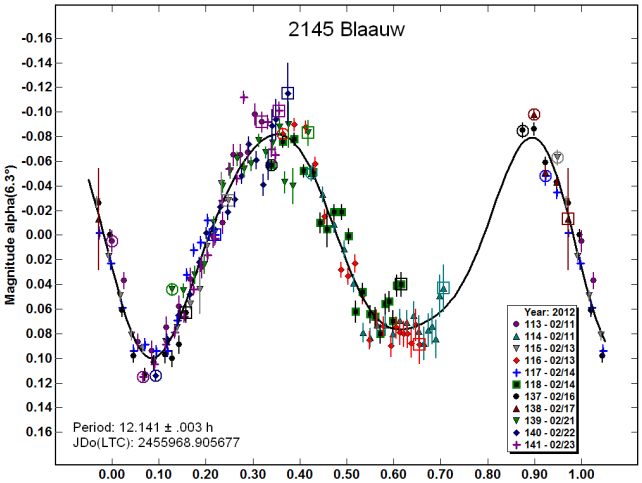



648 Pippa
Magnitude alpha(4.8°)
Period: 9.263 ± 0.001 h
JDo(LTC): 2456009.965991
Year: 2012
185 - 03/23
186 - 03/23
187 - 03/24
188 - 03/24
191 - 03/26
198 - 03/29
199 - 03/29
200 - 04/02
201 - 04/02


2234 Schmadel
Magnitude alpha(5.3°)
Period: 15.63 ± 0.02 h
JDo(LTC): 2456027.869792
Year: 2012
174 - 04/10
175 - 04/10
176 - 04/11
177 - 04/11
178 - 04/12
179 - 04/12
180 - 04/13
181 - 04/13
182 - 04/16


1985 Hopmann
Magnitude alpha(2.8°)
Period: 17.478 ± 0.004 h
JDo(LTC): 2455968.909694
Year: 2012
168 - 02/11
169 - 02/11
170 - 02/13
171 - 02/13
172 - 02/14
174 - 02/16
176 - 02/21
177 - 02/22
178 - 02/23


2464 Nordenskiold
Magnitude alpha(9.1°)
Period: 5.2089 ± 0.0008 h
JDo(LTC): 2455968.915630
Year: 2012
126 - 02/11
127 - 02/11
128 - 02/13
129 - 02/13
130 - 02/14
131 - 02/14
132 - 02/16
133 - 02/17
135 - 02/22
136 - 02/23


2145 Blaauw
Magnitude alpha(6.3°)
Period: 12.141 ± .003 h
JDo(LTC): 2455968.905677
Year: 2012
113 - 02/11
114 - 02/11
115 - 02/13
116 - 02/13
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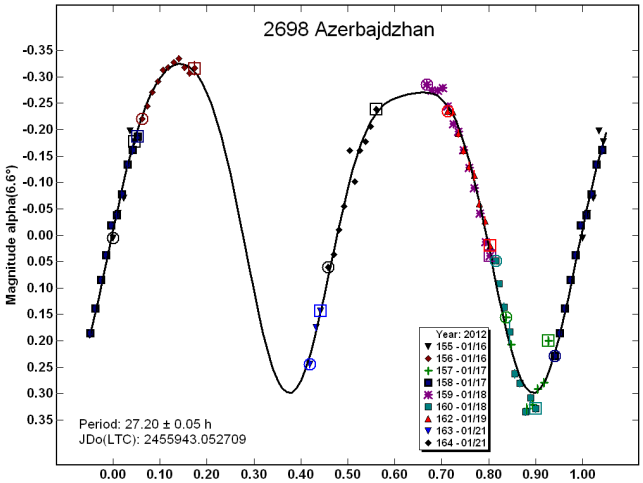
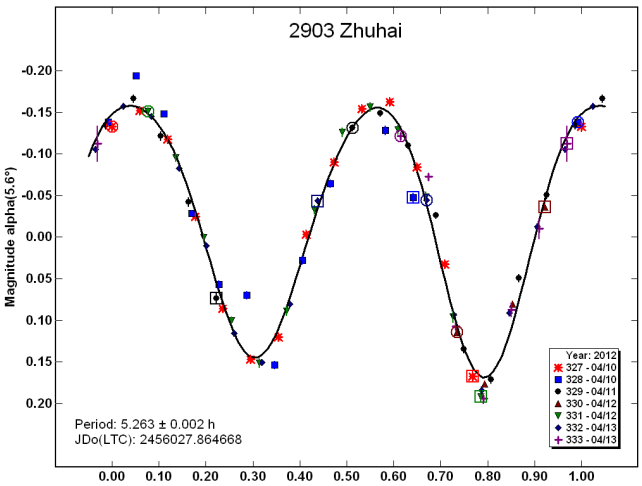
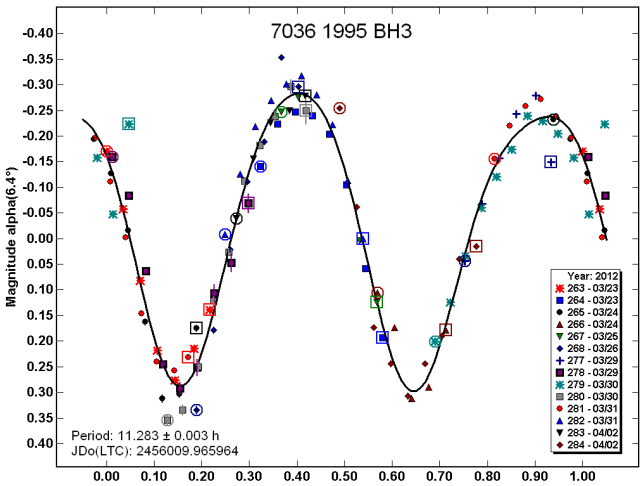
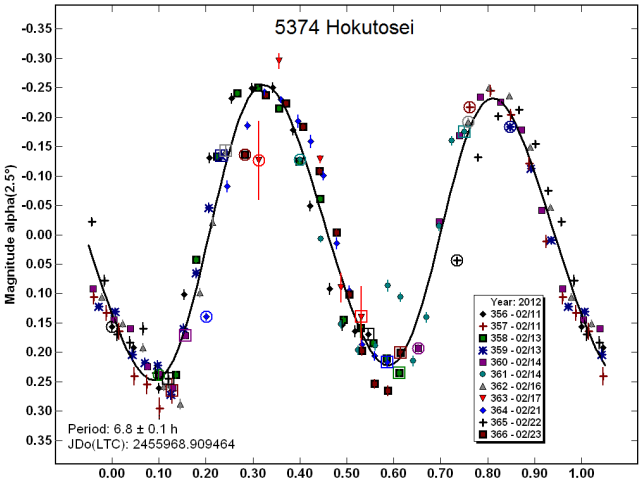
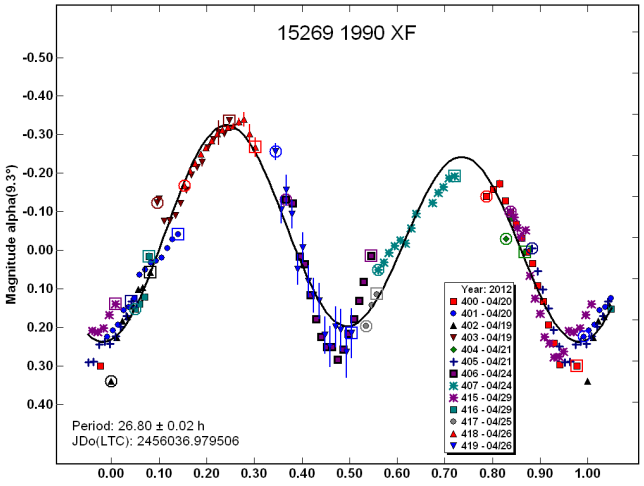
138 - 02/17
139 - 02/21
140 - 02/22
141 - 02/23

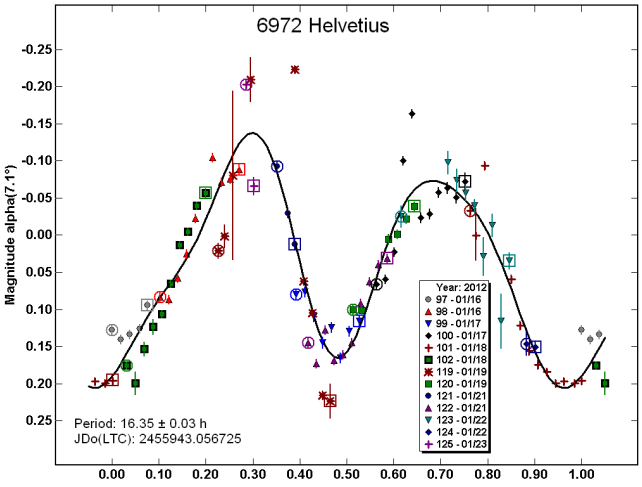

2698 Azerbajdzhan
Magnitude alpha(6.6°)
Period: 27.20 ± 0.05 h
JDo(LTC): 2455943.052709
Year: 2012
155 - 01/16
156 - 01/16
157 - 01/17
158 - 01/17
159 - 01/18
160 - 01/18
162 - 01/19
163 - 01/21
164 - 01/21




## LIGHTCURVE INVERSION FOR 47035 (1998 WS)

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Observations of (47035) 1998 WS between 2012 January and April showed a large change in lightcurve shape. By combining sparse data from the Catalina Asteroid Survey with our dense data set, we have been able to determine a preliminary spin axis and shape model. The synodic period is on the order of 3.995 h. The amplitude ranged from 0.10 to 0.20 mag.

The Mars-crossing asteroid 47035 (1998 WS) has also been designated 1976 UA21 and 1982 GD. It has an orbital period of 4.33 years. Astrometric observations have been made during 11

oppositions (JPL Small-Body Database Browser, 2012). During the 2012 apparition, Klinglesmith and Skiff observed the asteroid between January and April. Observations in January were made at Etscorn Campus Observatory by Klinglesmith. Observations in March were made at Lowell Observatory by Skiff. Observations were made at both locations in April.

The Etscorn observations were made with a Celestron 0.35-m Schmidt-Cassigrain telescope with an SBIG STL-1001E CCD, unbinned, 1024x1024 24-micron pixels. All exposures were 180 seconds through a clear filter. The images were dark-subtracted, flat-field corrected, and aligned using *IDL* procedures (Visual Information Solutions, 2012). The reduced images were then processed by *MPO Canopus* (Warner, 2012). The Lowell Observations were all taken with the Lowell 0.78-m *f*/8 reflector with a e2v chip 2x2k in size binned 2x2. Exposures were 90 s with an Rc filter. Image scale was 0.9 arcsec/pixel. Measurements were made using *MPO Canopus* using a 13-pixel diameter aperture for differential photometry. The photometric zero-points were set using SDSS r' magnitudes incorporated in the MPOSC3 catalog in *MPO Canopus*.

## The Lightcurve and Synodic Period

The solar phase angle did not change by a large amount during the apparition, being 31° on January 10, reaching a minimum of 27.5° on February 22, and increasing to 30.6° on April 6. However, the lightcurve shape changed significantly (Figures 1-5) due to changes in the viewing aspect as defined by the phase angle bisector (PAB) This is the vector connecting the center of the asteroid and the midpoint of the great circle arc between the sub-Earth and sub-solar points (see Magnusson *et al.*, 1989). The caption for Figures 1-5 gives the PAB (longitude, latitude) either as a single value or, as in Figure 1, the values for the end points of the date range.

Initial analysis lead to the conclusion that the period was $P \sim 7.995$ h, which was used to generate a spin axis and shape model. However, the period required a quadaramodal lightcurve, four minima and maxima per cycle, for the data in 2012 April and the resulting shape model, viewed from the poles, was almost a square. This prompted a second look at the solution where it was determined that the half-period, $P \sim 3.995$ h, was more likely correct since it would mean that the lightcurve evolved from a monomodal curve (probably a near pole-on viewing aspect) to a more typical bimodal lightcurve later in the apparition (a more equatorial viewing aspect). Analysis of asteroid lightcurve amplitudes (Harris, 2012) favors the shorter solution with less complex curve.

Figure 1 shows the lightcurve from 2012 January 10-20 when the lightcurve has a monomodal shape and amplitude $A \sim 0.12$ mag. By late January (Figure 2), the lightcurve started to show indications of having two maxima with the maximum range still $A \sim 0.12$ mag. In Figure 3, in late February, the shape was similar to the one in Figure 2 but with some subtle changes. By early- to mid-March (Figure 4), the lightcurve took on a significantly different shape, showing even stronger signs of a second maximum while the amplitude was $A \sim 0.13$ mag. The final data set from April 6 (Figure 5) showed a distinctly bimodal lightcurve with an amplitude $A \sim 0.20$ mag.

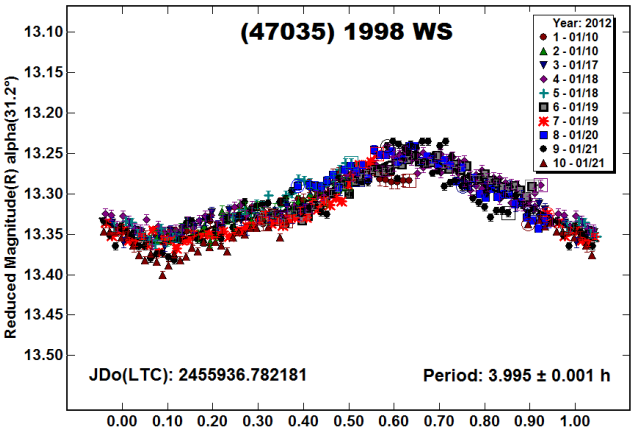


Figure 1. Lightcurve for 2012 Jan 10-21. PAB (120.1, +41.6) – (123.5, +40.5).

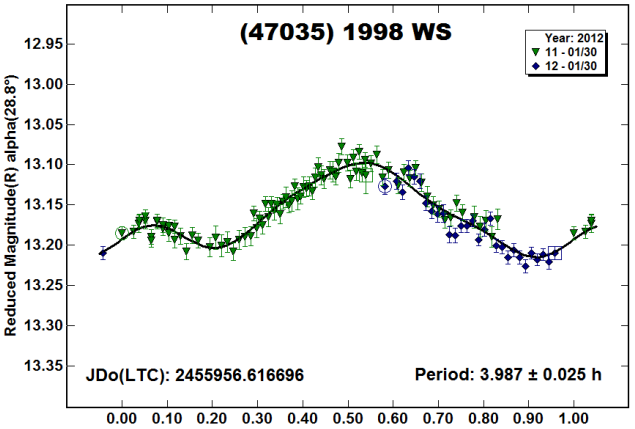


Figure 2. Lightcurve for 2012 Jan 30. PAB (125.9, +38.9).

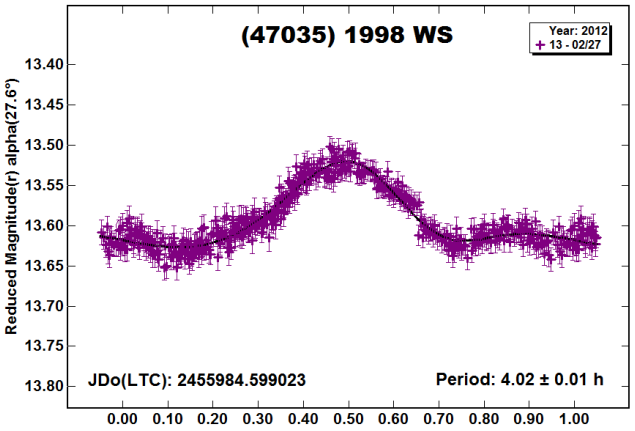


Figure 3. Lightcurve for 2012 Feb 27. PAB (133.3, +31.3).

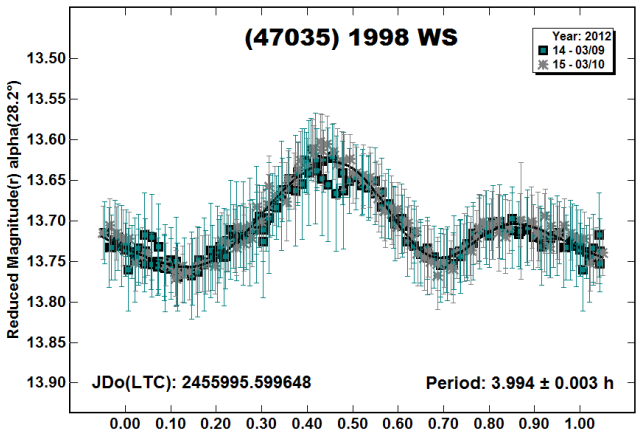


Figure 4. Lightcurve for 2012 March 9-10. PAB (136.5, +27.4).

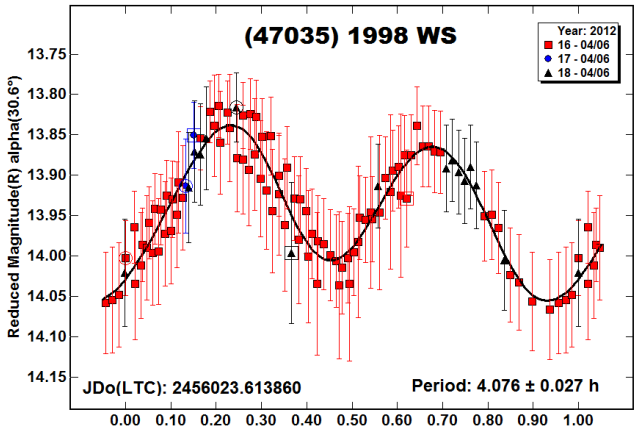


Figure 5. Lightcurve for 2012 Apr 6. PAB (145.8, +18.0).

## Finding a Spin Axis and Shape Model

Usually, even when sparse data are used (see, e.g., Hanus *et al.*, 2011), having dense data from a single apparition is not enough to find a reliable spin axis and/or shape model. This is because the PAB values change very little over the apparition or, even if they do, the data set doesn't cover a sufficiently large range of PAB values. That was not the case here and so it was felt that it might be possible to derive a spin axis and shape model even though the dense data set was from a single apparition.

This approach has been tried successfully in the past. Kaasalainen *et al.* (2003) derived what is considered to be a good model of (5587) 1990 SB under similar circumstances, mostly because the dense data covered a large range of phase angles and the asteroid lightcurve showed significant changes in period and amplitude over the apparition, which, again, is what happened here. The data set reported in the paper by Koff *et al.* (2002) was the foundation for the model by Kaasalainen *et al.* That paper shows the significant changes that occurred over the apparition and gave hope for finding a model. As a test, using only the data from the Koff paper and no sparse data, Warner was able to recreate the Kaasalainen *et al.* model with the spin axis was within 10° of their solution and the shapes were very comparable.

In asteroid spin axis and shape modeling, it is critical that an unambiguous period first be established. Kaasalainen (2004) showed that the use of sparse data (a small handful of data points per night over a large time span) allows establishing a unique period, especially when combined with dense data (the typical lightcurves presented in the *MPB*). However, this is true only if the sparse data are of sufficient photometric quality and cover a large range of PAB longitudes. We were lucky in this case in that a good set of sparse data from the Catalina Sky Survey was available via the AstDys web site (*http://hamilton.dm.unipi.it/astdys2/*). The set included data not only from longitudes well-removed from the dense data (Figure 6) but with a latitude range of +40° to –10°. The quality of the CSS data is not always the best – it is usually too noisy – but in this case it supplemented the available dense data to the point where we could find a reliably unique sidereal period.

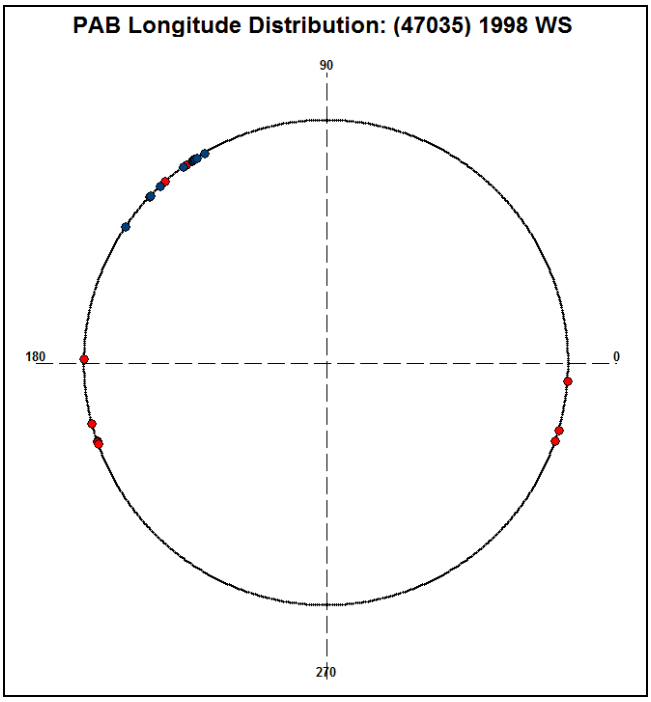


Figure 6. PAB longitude distribution for dense (blue) and sparse (red) data.

Using *MPO LCInvert* (Warner, 2012), which implements lightcurve inversion code developed by Kaasalainen and Durech (see Durech *et al.*, 2009, and references therein), we first did a period search that looked for the sidereal period with the minimum ChiSq value. This search can find many local minimums and so it's necessary to cover a sufficient range of values centered on the suspected period to assure that the correct period is found. This is a very CPU-intensive process. In this case, looking for a period in the range of 3.95 – 4.05 h took almost 18 hours of CPU time on a 1.8 GHz PC. Figure 7 is a plot of the period search spectrum, which shows a decided minimum. While we chose the discrete period at the bottom of the "dip", it would have been better to use an algorithm that found a more accurate minimum, one that most likely was between the discrete data points. However, it should be noted that the period search algorithm steps sizes are managed in such a way to help avoid "stepping over" the best solution

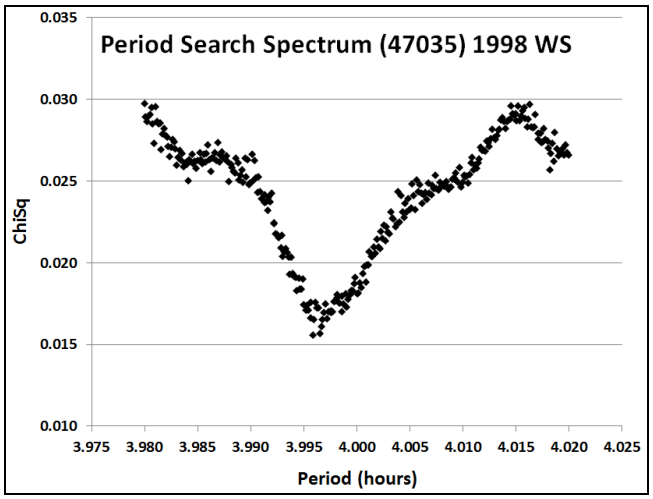


Figure 7. The period search spectrum from MPO LCInvert for (47035) 1998 WS. In this case, there is a decided minimum in the spectrum, which gave confidence in proceeding with a model search.

Once a period search has been done and a reliable period found, that result is used to examine the fit to each of more than 300 models with discrete longitude/latitude poles. In this search, the longitude and latitude are fixed but the period is allowed to "float." This search results in a plot like the one show in Figure 8. Low ChiSq values are represented by blue regions, the lowest ChiSq value indicated by a dark blue region. As the ChiSq value increases, the color evolves from blue to aqua to green, to yellow, to orange, and then to red. The highest ChiSq value is represented by a dark red (maroon) region.

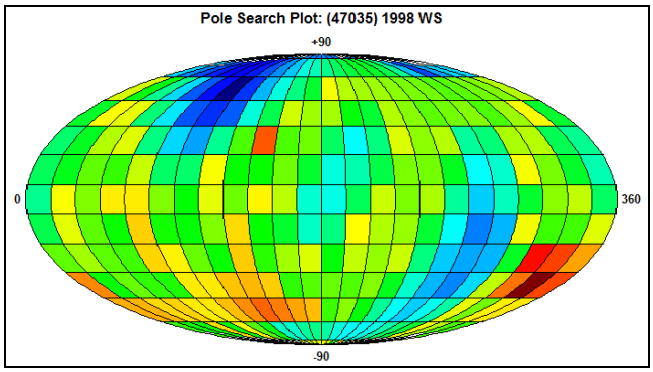


Figure 8. Pole search plot. ChiSq values increase from lowest (blue) to highest (red).

Ideally, one hopes for a plot with a single small area of dark blue and mostly greens to red for the rest. In some cases, there will be a second region of bluer colors. This is a result of the inversion process that often generates two pole solutions, usually differing by 180° in longitude but sometimes being "mirrored", i.e., 180° off in longitude and a latitude about equally above (or below) the ecliptic plane. A positive latitude indicates prograde rotation while a negative latitude indicates retrograde rotation. In our solution, Figure 8 shows a very strong preference for a pole at about (90°, +70°).

The pole search was refined using this initial solution as the starting point, this time allowing the longitude and latitude to float as well as the period. The final result was ($\lambda$ = 72.5, $\beta$ = +70.9, $P$ = 3.99590 ± 0.00001 h). The pole uncertainty is about ± 10° (a circle of that radius about the given position). The period uncertainty is determined by the period and total time span of the data set and is equal to the time for a 10° rotation error over the total span of the data set.

Figure 9 shows the shape model for the asteroid, giving views from the north and south poles as well as in the asteroid's equatorial plane with a Z-axis rotation of 0° and 90°. Besides putting trust in a "reasonable shape" and the pole search results, the results can be checked by plotting the model's lightcurve against the actual data. Figures 10 (early January) and 11 (early April) show two such comparisons. These give the relative intensity (not magnitude) of the lightcurve, normalized to 1.0, with the model curve in black and the actual data in red. The fits are very good and so add confidence in the final solution.

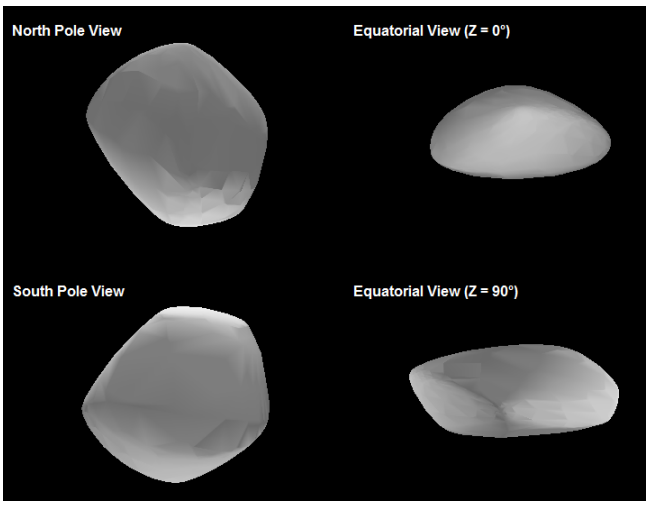


Figure 9. Shape model for (47035) 1998 WS. Clockwise from upper left: North Pole view; equatorial view, Z rotation = 0°, equatorial view, Z rotation = 90°; and South Pole view.

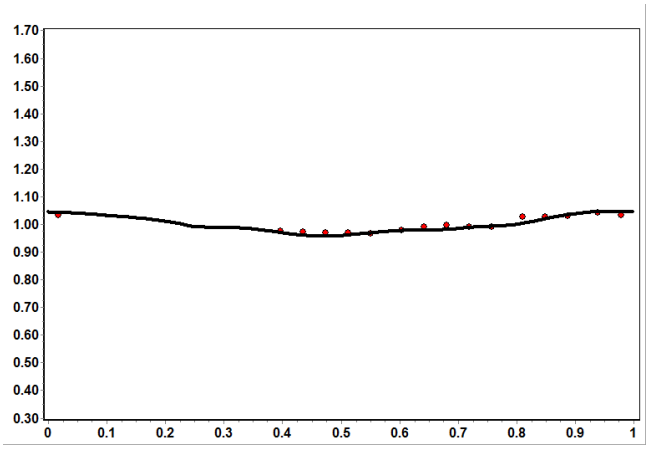


Figure 10. Comparison of model (black) and data (red) curves for 2012 Jan 10.

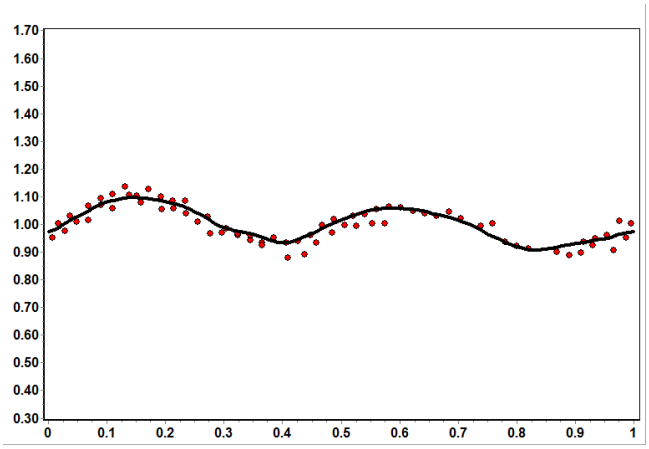


Figure 11. Comparison of model (black) and data (red) curves for 2012 Apr 6.

As mentioned earlier, we did two models, one based on periods of about 4 and 8 hours. While the fit of the model to the data for the 8-hour period was also good, the shape was less reasonable ("too square") and the pole search results were less definitive. More to the point, however, is that the ChiSq values for both the period search and pole search were significantly lower, almost half, for the shorter period. This gives further reason to believe that the shorter period of about 4 hours is the correct one. It's very likely that additional dense data, especially at an apparition with the PAB longitude about 90° from the one in 2012, will refine both the period and the pole.

We *strongly* caution that this was a rare set of fortunate circumstances that allowed finding what appears to be a good spin axis solution based on dense data from only one apparition. In the *large* majority of cases, even with good sparse data, obtaining a solution of reasonable and sufficient confidence requires having a much larger set of good-quality sparse data and, more important, dense lightcurve data sets from at least three apparitions.

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## ROTATION PERIOD DETERMINATIONS FOR 47 AGLAJA, 252 CLEMENTINA, 611 VALERIA, 627 CHARIS, AND 756 LILLIANA

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Synodic rotation periods and lightcurve amplitudes have been found for 47 Aglaja: 13.175 ± 0.002 h, 0.09 ± 0.01 mag; 252 Clementina: 10.864 ± 0.001 h, 0.37 ± 0.02 mag; 611 Valeria: 6.977 ± 0.001 h, 0.08 ± 0.01 mag; 627 Charis: 27.888 ± 0.002 h, 0.35 ± 0.02 mag; and 756 Lilliana: 7.834 ± 0.001 h, 0.17 ± 0.01 mag.

All observations reported here were made at the Organ Mesa Observatory using a Meade 35-cm LX-200 GPS Schmidt-Cassegrain (SCT), SBIG STL-1001E CCD, and clear filter. Exposures were unguided. Analysis used differential photometry only. Image measurement and lightcurve analysis were done by *MPO Canopus*. Because of the large number of data points, the data for the lightcurves presented here have been binned in sets of three points with a maximum time interval between points no greater than 5 minutes. In all cases, full or at least nearly-full phase coverage was obtained for the double period. When phased to the double period the two halves of the lightcurve looked the same within variations to be expected from observational error or changing phase angle. The probability of the double period being the correct one is extremely small and I reject all double-period solutions.

47 Aglaja. Several independent investigations listed in the Asteroid Lightcurve Data Base (Warner *et al.*, 2012) are all consistent in showing a period near 13.178 hours. New observations were obtained on 6 nights from 2012 Apr 2 - May 7 to contribute to a

lightcurve inversion model. From these observations analysis found a period 13.175 ± 0.002 h, amplitude 0.09 ± 0.01 magnitudes, in complete agreement with previous studies.

252 Clementina. Previous period determinations for this asteroid are by Warner (2008, 10.862 h), Behrend (2012, 10.862 h), and Saylor and Leake (2012, 10.9 h). From new observations on 5 nights form 2012 Mar 23 - Apr 13, a period of 10.864 ± 0.001 h and amplitude 0.37 ± 0.02 mag were determined. This result is consistent with earlier studies.

611 Valeria. Previous period determinations for 611 Valeria are by Koff (2001, 10.80 h) and Behrend (2012, 6.98 h). Analysis of data obtained on 5 nights from 2012 Apr 15 - May 12 found a period of 6.977 ± 0.001 h, amplitude 0.08 ± 0.01 mag. This result is consistent with the period reported by Behrend (2012) and rules out the 10.8 hour period reported by Koff (2001).

627 Charis. The only previous published attempt to find a period is by Behrend (2012), who states a provisional period of 48 h. The period given in the LCDB (Warner *et al.*, 2012) based on the Behrend lightcurve, is >24 h, meaning that the period was longer than this but no reasonable period could be assigned. Analysis of the data obtained on 14 nights from 2012 Apr 25 - June 21 finds a period of 27.888 ± 0.002 h, amplitude 0.35 ± 0.02 mag.

756 Lilliana. Previous period determinations for Lilliana are by Szekely *et al.* (2005, 9.361 h), Warner (2008, 9.262 h), Warner (2010, 9.37 h), and Behrend (2012, 6.15 h). Amplitudes reported ranged from 0.07 to 0.99 magnitudes, but should be viewed with caution since they are inferred from discordant periods. New observations were obtained on 10 nights from 2012 Apr 5 - June 11. Analysis of the data found a period of 7.834 ± 0.001 h, amplitude 0.17 ± 0.02 magnitudes. The period spectrum of the new data is presented to show that these are inconsistent with any of the previously published periods. Brian Warner (personal communication) reports that a 7.834 hour period is a plausible solution within both the year 2007 measurements reported in Warner (2008) and the year 2001 measurements reported in Warner (2010). The large range of amplitudes at different orientations in the sky appears to be qualitatively real, but will require re-analysis of the respective data sets using the correct period to make quantitative assessments of amplitude at different aspects. 756 Lilliana could be a very interesting object for spin/shape modeling.

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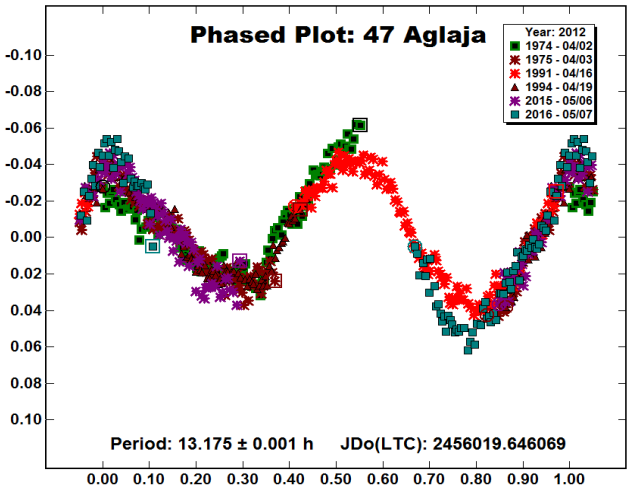


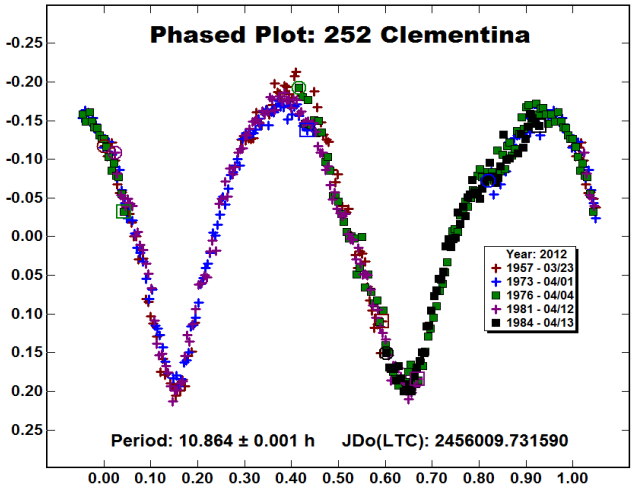


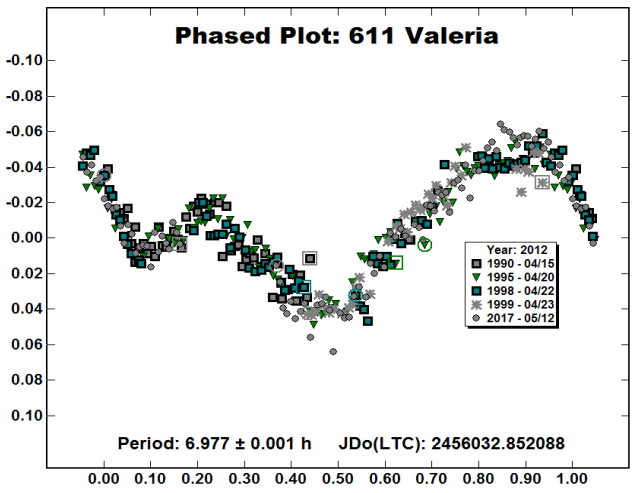

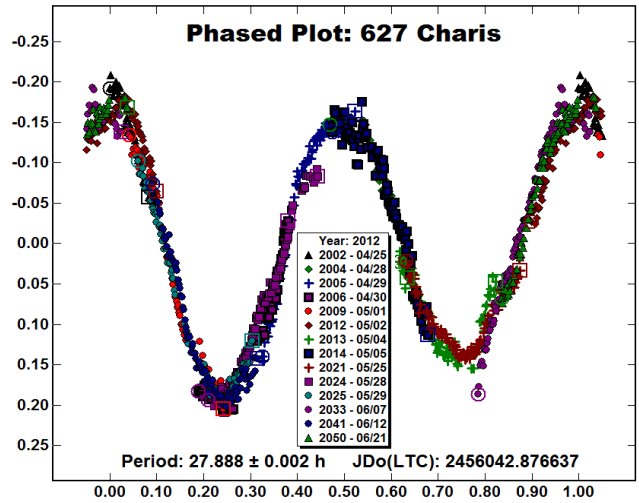


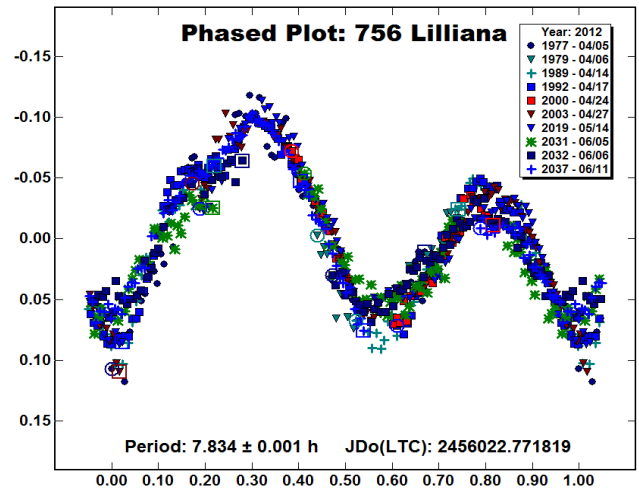


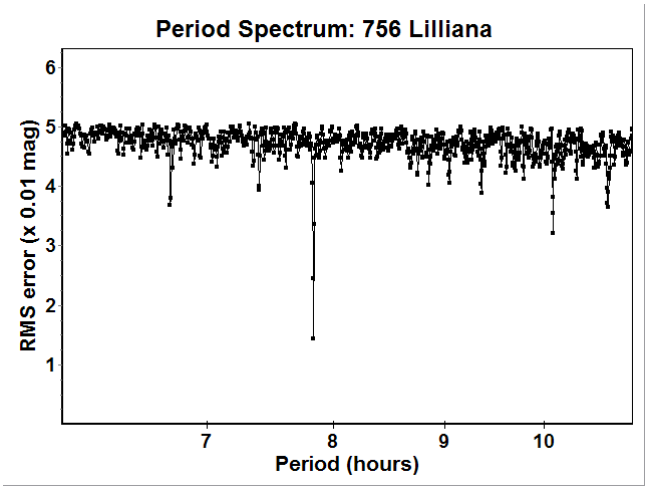


## ROTATION PERIOD DETERMINATION FOR 801 HELWERTHIA

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A consortium of observers from Australia, Europe, and North America have obtained lightcurves of the previously unobserved asteroid 801 Helwerthia. The period spectrum between 10 and 50 hours is presented, all minima on which have been carefully investigated. We strongly prefer a rotation period 23.93 ± 0.01 hours, amplitude 0.15 ± 0.03 magnitudes, with almost complete phase coverage, and consider all other alias periods to be highly unlikely.

First author Pilcher chose to observe 801 Helwerthia because the Asteroid Lightcurve Data Base (Warner et al. 2012) showed no previous observations. Observations on the first four nights 2012 March 24 - 31 suggested a period very close to that of the Earth. Full phase coverage would require observations from longitudes widely distributed around the Earth. Andrea Ferrero; the team of Luca Pietro Strabla, Ulisse Quadri, and Roberto Girelli; both from Italy; the team of Rasuli Inasaridze, Yurij Krugly, and Igor Molotov, observing from Kharkiv, Ukraine, and from Abastumani, Georgia Republic; and Julian Oey from Australia; all kindly contributed additional observations. We present the period spectrum between 10 and 50 hours, and explain our observational basis for considering 23.93 ± 0.01 hours, hereafter called the preferred period, to be much more likely than the other alias periods. By examining the period spectrum we immediately rule out all periods except 1/2P (half period), P, 3/2P, 2P (double period), where P is considered 23.93 hours. We present lightcurves based on all observations 2012 Mar. 24 - Apr. 27

phased to all of these trial periods. The rising sections in the 23.93 hour lightcurve between phases 0.3 - 0.5, (Sessions 1985, 1986, 1987, 1988, Apr. 5, 9, 10, and 12, respectively) and 0.7 - 0.85 (Sessions 1982, 1997, 2007, 2008, Apr. 11, 20, 21, 27, respectively) have considerably different slopes. These superimpose between phases 0.5 and 0.8 in the half period representation with sufficient misfit to rule out the half period. In the 3/2 P representation, the small slope session 1987, Apr. 10; and large slope sessions 1982, Apr. 11; and 1997, Apr. 20, respectively, again superimpose with considerable misfit. Still further evidence against the 3/2 period is found from segments separated by 1/3 cycle, 1958, 1969, 1971, 1972, Mar. 24, 29, 30, 31, respectively, appearing nearly identical. This would require a shape model those parts of which produce the identical segments being irregular yet symmetric over a 120 degree rotation, an unlikely occurrence. Consider segments 1958, Mar. 24 and 1971, Mar 30 at phase 0.0 – 0.2; 1969, Mar. 29 at phase 0.3 – 0.5; and 1972, Mar. 31 near phase 0.65 – 0.85. All were obtained over a small time interval and range of phase angles 11.4 - 8.6 degrees, and all look the same. Furthermore segments 1982, Apr. 11; and 1997, Apr. 20; near phase 0.50 – 0.65; look the same as segments 2007, Apr. 21; and 2008, Apr. 27; near phase 0.15 – 0.30. These are again over a small range of phase angles 4.1 - 6.6 degrees.

To consider the likelihood of the double period being the correct one, we consider the following. If a lightcurve is phased to twice the real period, it shows left and right halves which are identical. Conversely if a lightcurve phased to a trial period shows nearly identical left and right halves, this probably indicates the trial period is twice the real period. An alternative interpretation is that the shape of the asteroid is symmetric over a 180 degree rotation. The probability of such symmetry for a real asteroid is extremely small, and smaller still for an irregular lightcurve. In most cases this interpretation may be safely rejected. This argument is most effective when both halves of the lightcurve are from observations closely spaced in time. Otherwise changes in shape of the lightcurve resulting from changes in phase angle and aspect angle between line of sight and polar axis may cause the right and left halves to look different even when the single period is the correct one.

For an object with period very close to that of Earth, as in our preferred period, each participating observatory samples the same segment of the lightcurve on all nights. In this investigation the segment in the 23.93 hour lightcurve between phases 0.0 and 0.3 was sampled at the Organ Mesa Observatory. With an assumed period near one day, sessions 1958, March 24; 1969, March 29; 1971, March 30; and 1972, March 31; within a range of phase angles 11.4 - 8.6 degrees; all superpose on the preferred period lightcurve at phases 0.0 – 0.30. Sessions 1958, March 24; and 1971, March 30, correspond on the double period representation to phases 0.0 – 0.15. Sessions 1969, March 29; and 1972, March 31, between phases 0.5 and 0.65, lie on the alternate half of the double period representation. Segments between phases 0.0 – 0.15 and 0.5 – 0.65, respectively, look the same, and by the criterion of the previous paragraph constitute evidence against the double period. These segments were sampled again on sessions 1993, April 18; and 1996, April 21, respectively, at which time the minimum had become deeper with phase angle decreasing to 3.6, 4.3 degrees, respectively. These two sessions again occupy alternate halves at phases 0.0 – 0.15 and 0.5 – 0.65, respectively, of the double period. Not only do they look identical, the changes from the March data were also the same. This is further evidence against the double period. Observations of sessions 1982, April 11, and 1997, April 20, respectively, from Bigmuskie Observatory; and sessions 2007, April 21, and 2008, April 27, from Bassano Bresciano Observatory are of the lightcurve segment between phases 0.70 and 1.00 on the preferred period representation. On the double period representation sessions 1982, April 11; 2007, April 21; and 2008, April 27; respectively, occupy phases 0.35 – 0.5, and session 1997, April 20 occupies phase 0.85 – 1.0, alternate halves of the double period. Again they look the same. The segment between phases 0.25 and 0.5 on the preferred period representation was sampled from Kingsgrove Observatory as sessions 1985, Apr 5; 1986, April 9; 1987, April 10; and 1988, April 12; respectively. On the double period sessions 1985, Apr. 5; and 1986, Apr. 9 lie between phases 0.15 – 0.20. Somewhat longer sessions 1987, Apr. 10; and 1988, Apr. 12; respectively, lie between phases 0.6 – 0.75 and include a larger part of the lightcurve. Although the data are somewhat sparser, those between phases 0.15 – 0.20 and 0.65 – 0.70, respectively, have no significant differences which could constitute evidence in favor of the double period.

In summary, we show that the double period model has nearly identical left and right halves over about 50% of the whole cycle, and a distinct change in the appearance of 30% of it is the same for both right and left halves. The probability of the double period being the correct one seems almost as small as if the whole double period cycle were sampled and showed nearly identical right and left halves. We have confidence that the 23.93 hour period is the correct one even although phase coverage is slightly incomplete.

We note that a preferred period of 23.939 ± 0.004 hours is obtained from all observations 2012 Mar. 24 - Apr. 27. A single session at phases 0.05 - 0.30 was obtained 2012 May 13 at a much larger phase angle 12.6 degrees. The depth of the minimum sampled in this session was much greater than when sampled earlier, a consequence of the change of phase angle. When combined with all earlier observations the preferred period decreases to 23.920 ± 0.002 hours, which we illustrate with a lightcurve phased to the preferred period which adds the May 13 observations. This is a reminder that the real error in a period determination by the Harris FALC algorithm (Harris et al., 1989) is several times as large as the formal error. We therefore more conservatively present our preferred period as 23.93 ± 0.01 hours, amplitude 0.15 ± 0.03 magnitudes.

The observing cadance by FP at Organ Mesa Observatory is such that a much larger number of data points were acquired there than by AF at Bigmuskie, LS and colleagues at Bassano Bresciano, RI at Abastumani, YK at Kharkiv University, and JO at Kingsgrove Observatories. To make more legible the large number of data points in the segments of the lightcurve included by Organ Mesa observations, they have been binned in sets of three points with a maximum of five minutes between points.

The following table provides details of the individual sessions. Column headings refer to: Obs: Observer code: AF, Andrea Fererro, 0.3m f/8 RC SBIG ST9 CCD; RI, Raguli Inasaridze and colleagues, 0.7m Maksutov, IMG6063E (FLI) CCD in primary focus; YK, Yurij Krugly and colleagues, 0.7m Cassegrain-Newtonian, ML47-10 (FLI) CCD at Newtonian focus; JO, Julian Oey, 0.25 m f/11 S-C, SBIG ST-9XE CCD; FP, Frederick Pilcher, 0.35m f/10 S-C, SBIG STL-1001E CCD; LS, Luca Pietro Strabla, Ulisse Quadri, Roberto Girelli, 0.32 m f/3.1 S-C, Starlight HX-516 CCD; Sess, session number; Date in calendar year 2012; UT of first and last observations of the session; Data Pts, number of data points in session; PA, phase angle.

| Obs | Sess | Date | UT | Data Pts | PA |
|---|---|---|---|---|---|
| FP | 1958 | Mar 24 | 5:17 - 12:20 | 240 | 11.4 |
| FP | 1969 | Mar 29 | 4:56 - 12:11 | 307 | 9.4 |
| FP | 1971 | Mar 30 | 4:51 - 12:09 | 332 | 9.0 |
| FP | 1972 | Mar 31 | 4:52 - 12:07 | 326 | 8.6 |
| AF | 1982 | Apr 11-12 | 21:15 - 3:35 | 92 | 4.1 |
| JO | 1985 | Apr 5 | 13:19 - 14:52 | 22 | 6.4 |
| JO | 1986 | Apr 9 | 11:24 - 13:04 | 19 | 4.9 |
| JO | 1987 | Apr 10 | 11:00 - 16:32 | 22 | 4.5 |
| JO | 1988 | Apr 12 | 10:21 - 16:18 | 25 | 4.0 |
| FP | 1993 | Apr 18 | 3:13 - 11:06 | 349 | 3.6 |
| FP | 1996 | Apr 21 | 2:54 - 10:52 | 374 | 4.3 |
| AF | 1997 | Apr 20-21 | 20:40 - 3:25 | 92 | 4.2 |
| LS | 2007 | Apr 21-22 | 22:39 - 1:04 | 51 | 4.5 |
| LS | 2008 | Apr 27-28 | 19:40 - 1:51 | 136 | 6.6 |
| YK | 2010,1 | Apr 16-17 | 18:00 - 0:33 | 126 | 3.5 |
| RI | 2015,6 | Apr 17-18 | 21:41 - 0:49 | 36 | 3.5 |
| RI | 2017 | Apr 18 | 17:00 - 18:42 | 28 | 3.6 |
| FP | 2018 | May 13 | 2:46 - 9:20 | 300 | 12.7 |

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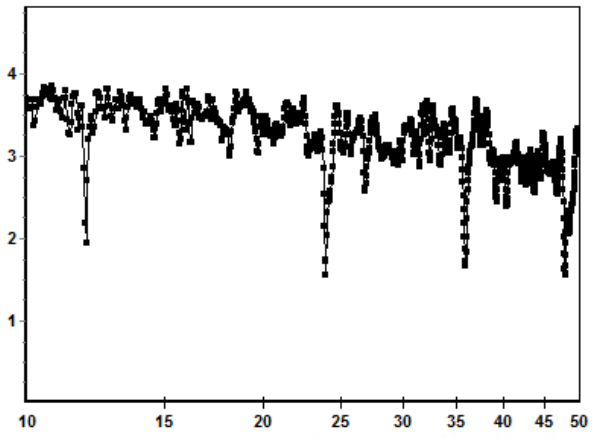

Figure 1. Period spectrum of 801 Helwerthia, hours.

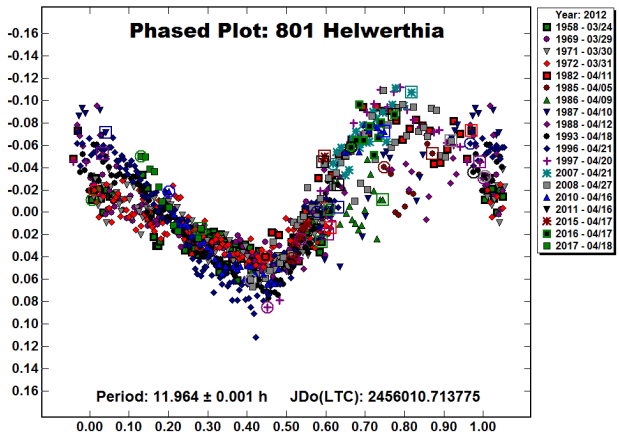


Figure 2. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to 1/2 the preferred period, 11.964 hours.

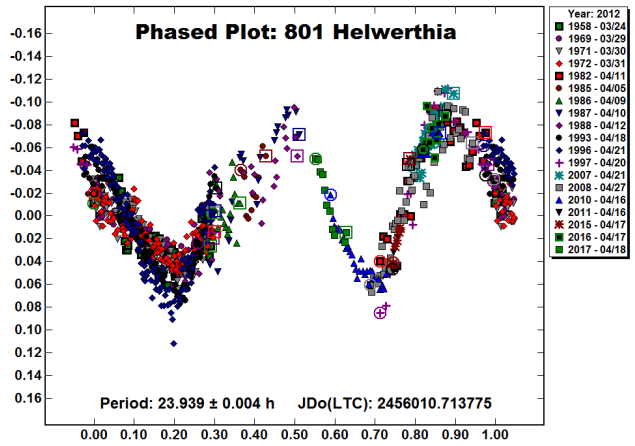


Figure 3. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to the preferred period of 23.939 hours.

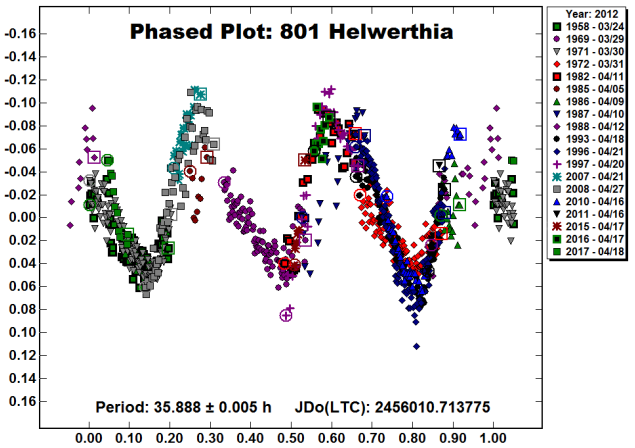


Figure 4. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to 3/2 the preferred period, 35.888 hours.

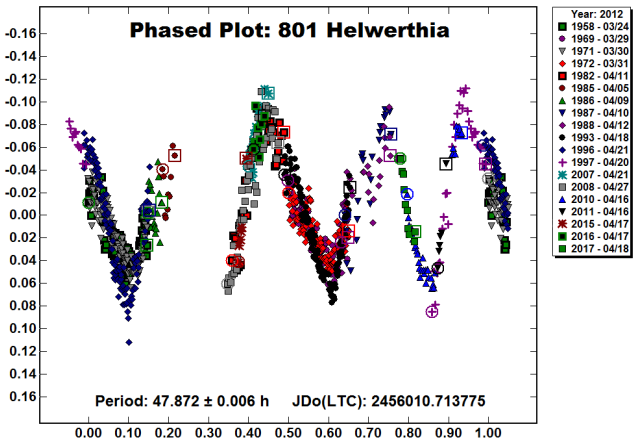


Figure 5. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - Apr. 27 phased to the "double period," 47.872 hours, twice the preferred period.

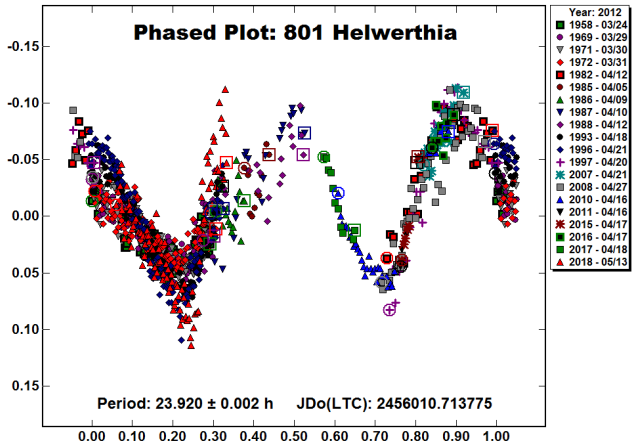


Figure 6. Lightcurve of 801 Helwerthia based on observations 2012 Mar. 24 - May 13 phased to the preferred period of 23.920 hours.

## LIGHTCURVE FOR 2074 SHOEMAKER

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Analysis of CCD photometric observations of the Hungaria asteroid 2074 Shoemaker in 2012 showed a low amplitude lightcurve of 0.08 mag. No definitive period could be found, with those of 2.8, 2.5, and 2.4 hours having nearly equal probability. No evidence was found of a satellite, which was suspected based on data from a previous apparition.

The Hungaria asteroid 2074 Shoemaker was observed by Stephens (2004) in late 2003. At the time, a period of 57.02 h and amplitude of 0.45 mag was reported. The images were remeasured and the new data analyzed a few years later (Warner *et al.*, 2009). That analysis indicated a period of 2.5328 h with the possibility of a satellite with a period of, not so coincidentally, of 55.5 h. However, the evidence was far from conclusive. The asteroid was observed again in 2010 (Warner, 2011), where a period of 2.5338 h, amplitude 0.12 mag was found but no indications of tell-tale "mutual events" that could be attributed to a satellite.

In 2012, the authors again observed the asteroid with the hopes of confirming the 2.5 h period and to look for signs of a satellite. The observations at PDO were made using a 0.35-m Schmidt-Cassegrain (SCT) using an SBIG STL-1001E CCD camera. The observations at CS3 used a 0.35-m SCT and STL-1001E as well. All images were unfiltered. The data were put onto an internal standard system using R magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008). Circumstances allowed only short runs for each observing session, about 4 hours or less.

Analysis of the relatively sparse data set, less than 100 observations, found a low amplitude lightcurve, $A \sim 0.08$ mag. It was not possible to find a definitive period. The data best fit a period of 2.820 h. However, almost equally good fits could be found at 2.449 h and 2.523 h, the latter not far removed from the previous results. The phase angle bisector longitudes for the 2005 and 2012 apparitions differed by about 200 degrees, and so not much difference in the lightcurves would be expected. The 2010 apparition, $L_{PAB} = 312°$, was sufficiently different and, as expected if the asteroid was sufficiently elongated, the amplitude was larger. This indicates that the pole longitude might be around 20° (or 200°).

No indications were seen of mutual events from a satellite. Observations at the next apparition (2013 January, V ~ 16.3, Dec – 38°, $L_{PAB} \sim 132°$) are encouraged.

### Acknowledgements

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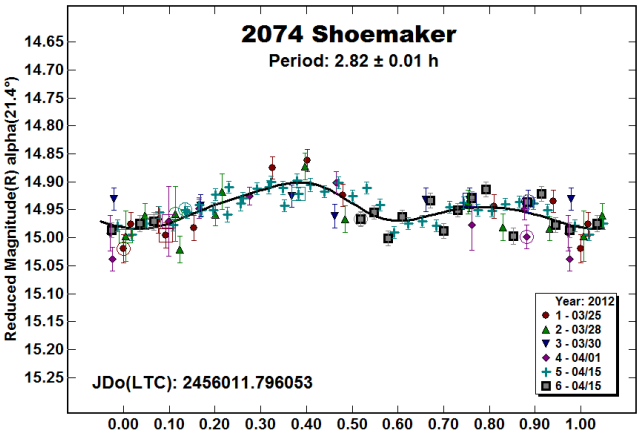

## ASTEROIDS OBSERVED FROM SANTANA, CS3 AND GMARS OBSERVATORIES: 2012 APRIL - JUNE

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(Received: 8 July)

Lightcurves of seven asteroids were obtained from Santana Observatory, Goat Mountain Astronomical Research Station (GMARS), and the Center for Solar System Studies (CS3): 412 Elisabetha, 1055 Tynka, 1424, Sundmania, 3493 Stepanov, (6254) 1993 UM3, and (33736) 1999 NY36.

Observations were made at Santana Observatory (MPC Code 646) using a 0.30-m Schmidt-Cassegrain (SCT) with a SBIG STL-1001E CCD camera, GMARS (MPC Code G79) or CS3 using a 0.40-m or 0.35-m SCT with a SBIG STL-1001E CCD camera. All images were unguided and unbinned with no filter. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). Except for (1055) Tynka, the asteroids were selected from the list of asteroid photometry opportunities published on the Collaborative Asteroid Lightcurve Link (CALL) website (Warner et al., 2012).

The results are summarized in the table below, as are individual plots. Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins V magnitudes based on 2MASS J-K colors (Warner 2007 and Stephens 2008).

412 Elisabetha. All images were acquired at Santana Observatory. Lagerkvist (1992) observed 412 Elisabetha on ten nights in August 1990 but did not report a period. Cooney (Cooney 2002) obtained data over five nights in January and February of 2002 reporting a period of 19.67 h; in good agreement with this result. Bernasconi (Behrend 2012) obtained data on two nights in June 2003 reporting a period of 13.99 h.

1055 Tynka. Tynka was in the field of view of the primary target, 412 Elisabetha and could only be followed for two nights. A third night was obtained over a month later to refine the period. Higgins and Pilcher (2009) obtained data over six nights from April to June 2009 reporting a period of 11.893 h which this result is in good agreement with. Roy (Behrend 2012) obtained data over two nights in April 2012 and reported a period of 5.98 h which appears to be the half period.

1424 Sundmania. Images on April 20 were acquired at GMARS. All others were acquired at Santana. Roy (Behrend 2012) obtained data over two nights in March 2012 and reported a period of 47 h which appears to be the half period.

1428 Mombasa. Observations on June 29 and 30 were obtained at CS3. All other observations were obtained from Santana. Roy (Behrend 2012) obtained data over two nights in February 2006 and reported a period of 17.57 h which is in fair agreement with this result. Hawkins (Hawkins 2007) obtained observations on four nights in May 2007 and reported a period of 17.12 h which is in good agreement with this result.

Although the observations refined previously published results, the period spectrum revealed a strong alias to either 25.3 h or 25.6 h. Using a 6th order fit, the 16.67 h solution is dominated by even-order harmonics while the 25 h solutions has odd and even harmonics of significant strength; unlikely at this amplitude and phase angle. Given the previously published results and a half-period of 8.33 h being found; the 16.67 h period is preferred. The plot is binned with the average of five data points presented as one for clarity in subtle features in the lightcurve.

3493 Stepanov. This asteroid does not have a previously reported period in the LCDB (Warner et al., 2012). All images were acquired at GMARS using the 0.35-m telescope.

(6254) 1993 UM3. All images were acquired at GMARS using the 0.35-m telescope. This asteroid does not have a previously reported period in the LCDB (Warner et al., 2012).

(33736) 1999 NY36. All images were acquired at GMARS using either the 0.4-m or 0.35-m telescopes. This asteroid does not have a previously reported period in the LCDB (Warner et al., 2012). Observations from April 20 to May 28, 2012 showed a typical bimodal lightcurve with an amplitude of about 0.5 magnitudes. However, observations obtained on June 9 and 10 showed a dramatic drop in magnitude suggesting that 33736 has non-principal axis of rotation.

The data for each of these asteroids was uploaded to the ALCDEF database (see Warner et al., 2011) on the Minor Planet Center's web site (MPC 2012).

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| # | Name | mm/dd/12 | Data Pts | α | $L_{PAB}$ | $B_{PAB}$ | Per (h) | PE | Amp (mag) | AE |
|---|---|---|---|---|---|---|---|---|---|---|
| 412 | Elisabetha | 05/10 – 05/17 | 1,145 | 6.9, 6.8 | 232 | 15 | 19.635 | 0.005 | 0.10 | 0.02 |
| 1055 | Tynka | 03/27 – 05/09 | 266 | 4.8, 2.8, 16.9 | 194 | 5 | 11.75 | 0.01 | 0.34 | 0.05 |
| 1424 | Sundmania | 03/22 – 04/30 | 1,207 | 5.0, 1.8, 8.0 | 195 | 5 | 93.73 | 0.03 | 0.42 | 0.03 |
| 1428 | Mombasa | 06/18 – 07/04 | 1,330 | 6.0, 10.2 | 260 | 12 | 16.67 | 0.01 | 0.16 | 0.02 |
| 3493 | Stepanov | 4/20 – 4/21 | 315 | 9.2, 8.8 | 221 | 9 | 6.112 | 0.002 | 0.82 | 0.02 |
| 6254 | 1993 UM3 | 4/22 – 4/29 | 395 | 4.3, 2.1 | 221 | 4 | 7.040 | 0.001 | 0.31 | 0.03 |
| 33736 | 1999 NY36 | 04/20 – 06-10 | 1,071 | 8.2, 4.3, 17.5 | 222 | 7 | 211 | 5 | | |

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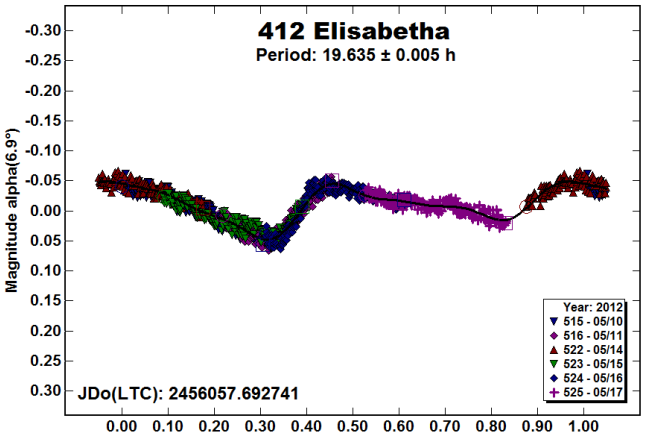


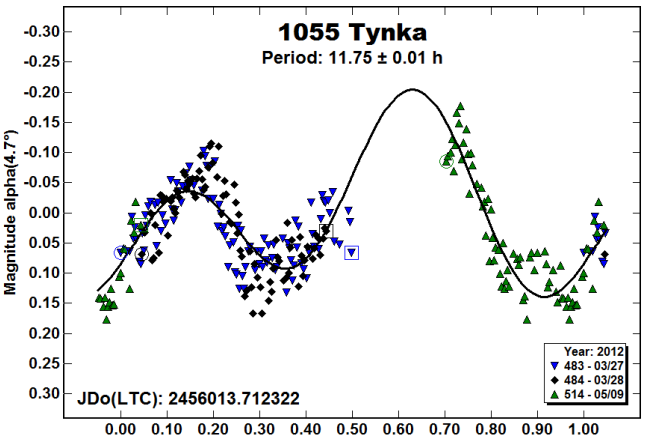


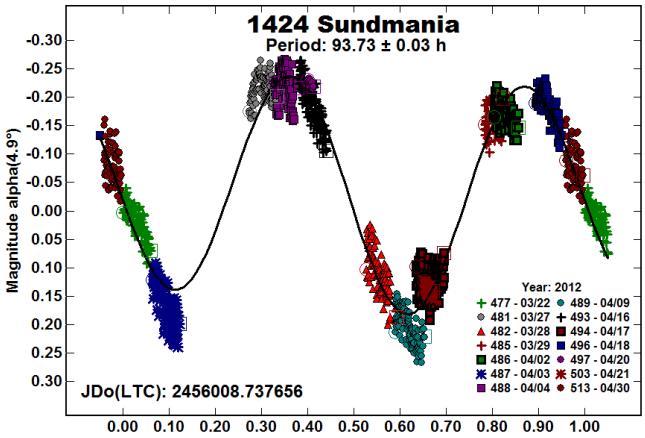


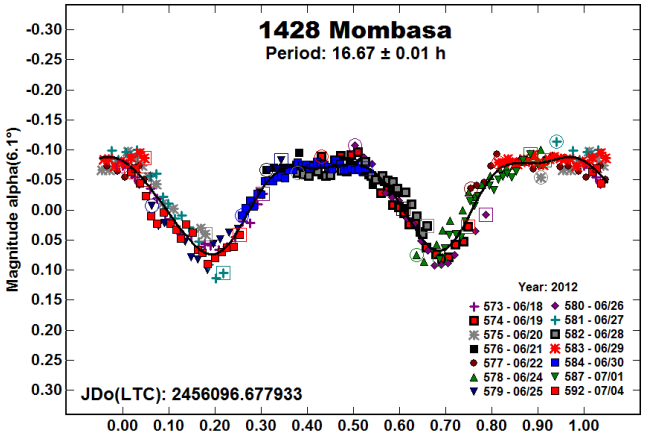


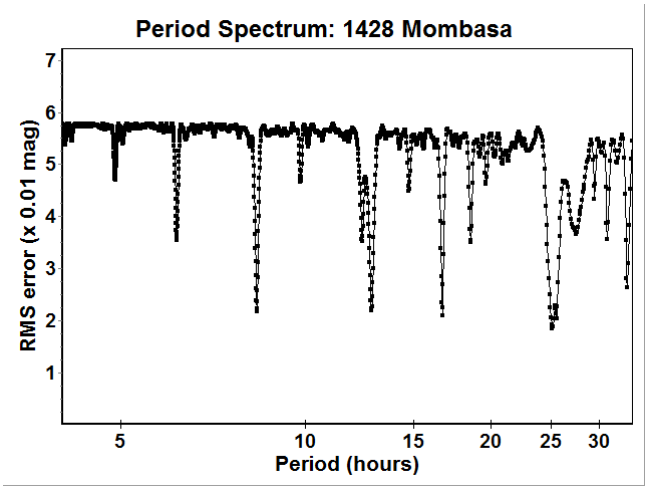

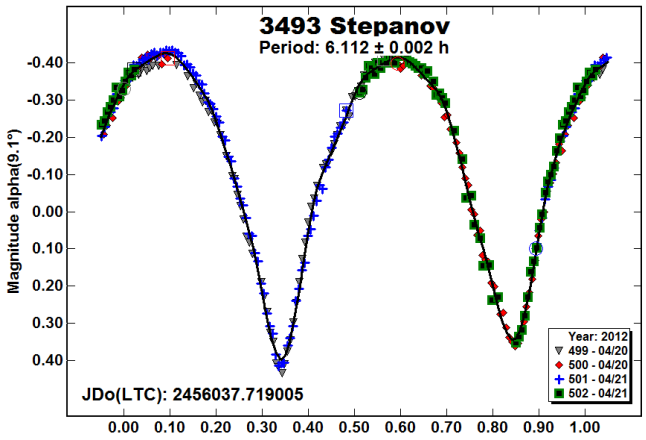


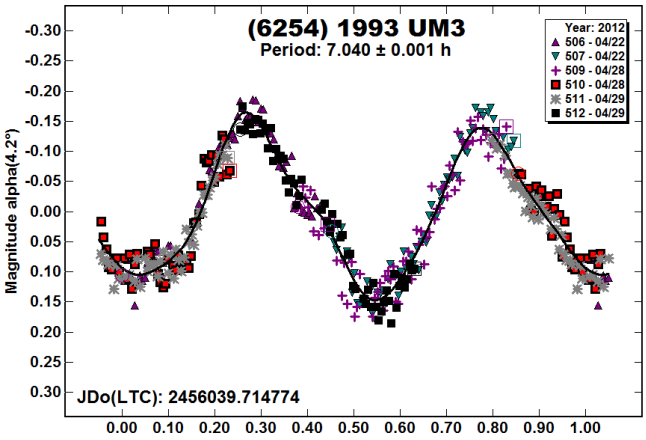


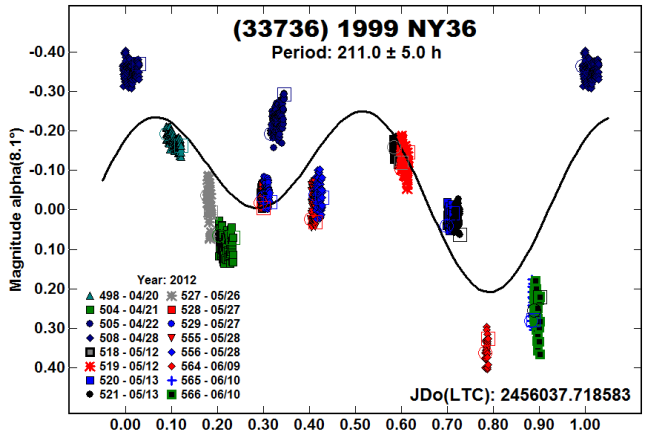


## ROTATION PERIOD DETERMINATION FOR 482 PETRINA

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A consortium of observers from Australia, Europe, and North America have obtained full phase coverage of 482 Petrina, and from these observations find a rotation period of 11.794 ± 0.001 hours, amplitude 0.10 ± 0.02 mag, with a highly unsymmetrical but bimodal lightcurve.

Previous rotation period and amplitude determinations for 482 Petrina all obtained different results: Behrend (2002), 18 hours and a single four hour lightcurve showing a minimum followed by a steep rise; Buchheim (2007), 15.73 hours, 0.48 magnitude, based on 2 nights 2006 March 22, 24 and showing two maxima and the intervening minimum but only half of the lightcurve; and Stephens (2009), 9.434 hours, 0.06 magnitude, with a nearly symmetric lightcurve based on 10 nights 2007 July 23 - Aug. 3.

One should note that the suggested 15.73 hour period is slightly less than 2/3, and 9.434 hours is slightly less than 2/5, respectively, that of Earth. In both cases the phase observable on alternate nights from a single location circulates slowly to the right. It could be interpreted as alternate sides of a symmetric lightcurve seen on successive nights. Observations by first author Pilcher on the first six nights 2012 May 26 - June 3 covered only the phases 0.00 to 0.65 in the lightcurve. These include only the maxima and the wide minimum. They appeared to be consistent with a 15.73 hour period. Starting June 8 the shallow and narrow minimum was observed. This observation ruled out the 15.73 hour period and suggested a period near 11.79 hours. Andrea Ferrero from Italy and Julian Oey from Australia were invited and kindly contributed additional observations which completed phase coverage within a short time frame.

A total of 19 sessions were obtained by the three observers 2012 May 26 - June 26. When phased to a period of 11.794 hours, they show a good fit except for several dips of 0.03 - 0.04 magnitudes, typical duration less than one hour. These might suggest satellite events. However no periodicity could be found among them. Several occur near the start or end of a long session at lower altitude where photometric accuracy is reduced. Hence we consider them very likely to be spurious.

Combining these new results with those of Buchheim (2007) and Stephens (2009) provides much information about the rotational properties of 482 Petrina. It can be shown that the data presented in the 15.73 hour period lightcurve by Buchheim (2007) and in the 9.434 hour period lightcurve by Stephens (2009) are both consistent with a period of 11.794 hours. Buchheim's

interpretation was of three rotational cycles between alternate nights; four rotational cycles actually fit Buchheim's data better. His observed amplitude of 0.48 magnitudes can only be achieved with a bimodal lightcurve. On his lightcurve with assumed 15.73 hour period the two maxima were separated by 0.4 rotational cycles or 6.3 hours. This is much closer to the 5.90 hours expected for an 11.794 hour period than the 7.86 hours expected for a 15.73 hour period. Stephens' observations, although they span an interval of 11 days, still cover only part of an 11.794 hour cycle due to the very slow circulation of the observable part of the lightcurve. It seems that he observed the region of the narrow minimum and more closely spaced maxima. His 9.434 hour period follows from a reasonable assumption of equally spaced maxima. He assumed that he was observing alternate minima on successive nights whereas he was actually observing the same minimum. A symmetric lightcurve necessarily results from such an assumed alias period. And his published lightcurve is indeed nearly symmetric.

Buchheim (2007) found 0.48 magnitude amplitude at longitude 184 degrees. In this study near longitude 268 degrees, latitude +23 degrees, an amplitude near 0.10 magnitudes is found. This shows that the latter is at near polar aspect while the former is at near equatorial aspect. The lightcurve by Stephens near longitude 295 degrees, latitude +22 degrees, is almost identical to the segment from phase 0.50 through 1.00 and continuing to 0.10 of the lightcurve in this study, amplitude of this one segment being 0.06 magnitudes. This suggests that the two studies are at nearly identical aspect angles between the line of sight and polar axis with the rotational pole half way between them near longitude 280 degrees, latitude +23 degrees, or conversely near 100 degrees, -23 degrees, respectively.

An amplitude as large as 0.48 magnitudes is obtained only for a bimodal lightcurve. Combined with the results of this study we can state that the synodic rotation period is 11.794 ± 0.001 hours, with no possibility of an alias. The ratio $a/b \geq 10^{0.4\mathrm{DeltaM}}$. For DeltaM = 0.48 in 2006 in near equatorial aspect, a/b for 482 Petrina is approximately 1.56. The ratio of minimum equatorial to polar radii b/c cannot be found from data obtained to date.

Caution should be given to all observers who obtain periods nearly commensurate, 1/3, 2/5, 1/2, 3/5, 2/3, 1/1, 4/3, 3/2, 5/3, 2, respectively, times the Earth's period. They are especially likely to infer an alias period in this circumstance. Either observations should be continued over a sufficiently long time interval, or collaboration should be obtained from observers at widely different longitudes, to obtain full phase coverage for all of these trial periods. If this is not feasible then the observer should acknowledge that the suggested period is not secure.

For 482 Petrina, when in this study the first observer encountered a nearly commensurate period he sought collaborators from widely spaced longitudes. This enabled the acquisition of a secure period. Indeed the authors of this paper have had several previous, and successful, collaborations for asteroids with periods nearly commensurate with Earth's. We strongly encourage other readers of this paper to follow our example.

The observing cadence by FP at Organ Mesa Observatory is such that a much larger number of data points were acquired there than at any of the other observatories. To make more legible the large number of data points in the segments of the lightcurve included by Organ Mesa observations, they have been binned in sets of three points with a maximum of five minutes between points.

The following table provides details of the individual sessions. Column headings refer to: Obs: Observer code: FP, Frederick Pilcher, 0.35 m f/10 S-C, SBIG STL-1001E CCD; AF, Andrea Fererro, 0.3m f/8 RC, SBIG ST9 CCD; JO, Julian Oey, 0.25 m f/11 S-C, SBIG ST-9XE CCD; Sess, session number; Date in calendar year 2012; UT of first and last data points of the session; Data Pts, number of data points in session.

| Obs | Sess | Date | UT | Data Pts |
|---|---|---|---|---|
| FP | 2022 | May 26 | 4:54 - 11:05 | 309 |
| FP | 2023 | May 27 | 4:47 - 11:03 | 261 |
| FP | 2026 | May 30 | 4:38 - 11:03 | 215 |
| FP | 2027 | Jun 1 | 4:48 - 8:45 | 143 |
| FP | 2028 | Jun 2 | 5:38 - 10:56 | 243 |
| FP | 2029 | Jun 3 | 4:39 - 11:00 | 165 |
| FP | 2034 | Jun 8 | 4:01 - 11:07 | 257 |
| FP | 2035 | Jun 9 | 3:54 - 11:11 | 311 |
| FP | 2036 | Jun 10 | 3:48 - 11:05 | 365 |
| FP | 2043 | Jun 14 | 4:41 - 11:02 | 208 |
| AF | 2044 | Jun 4-5 | 21:36 - 2:41 | 146 |
| FP | 2047 | Jun 19 | 3:12 - 11:05 | 240 |
| FP | 2048 | Jun 20 | 3:06 - 6:08 | 144 |
| JO | 2051 | Jun 15 | 10:36 - 15:45 | 54 |
| JO | 2052 | Jun 17 | 11:40 - 13:24 | 18 |
| JO | 2053 | Jun 18 | 10:07 - 13:55 | 41 |
| JO | 2054 | Jun 20 | 11:30 - 15:56 | 38 |
| AF | 2055 | Jun 20-21 | 21:38 - 2:27 | 125 |
| FP | 2057 | Jun 26 | 3:11 - 10:50 | 298 |

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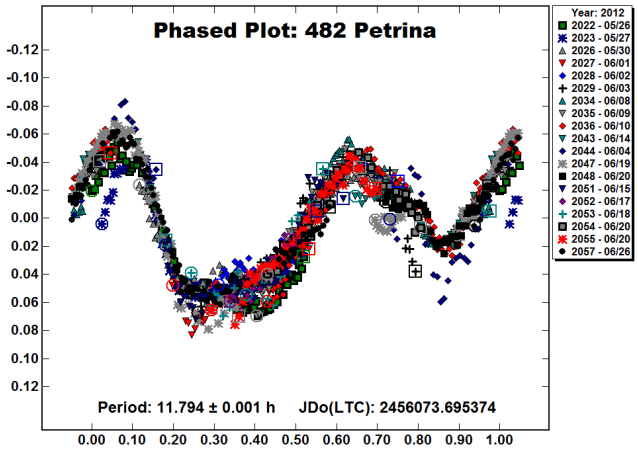

# LIGHTCURVE FOR THE HUNGARIA BINARY 5477 HOLMES

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CCD photometric observations of the known Hungaria binary 5477 Holmes were made in 2012. Analysis of the data confirmed the previously-determined rotation and orbital periods and size ratio of the secondary to primary. The data will useful for further modeling of the system.

The Hungaria asteroid 5477 Holmes was discovered to be binary in 2005 (Warner *et al.,* 2005; Warner *et al.*, 2011). At that time, a primary period of 2.9943 h and orbital period of 24.42 h were reported. The estimated size ratio, Ds/Dp, was 0.37 ± 0.02. Additional observations were made in 2007 (Pravec *et al.*, 2012). The combined data set was then used to refine the system parameters, increasing the size of the satellite slightly to Ds/Dp = 0.39 ± 0.02 and finding the pole of the satellite orbit (Pravec *et al.*, 2012).

The asteroid was observed again in 2012 by the authors to add to the data set for modeling. The observations at PDO were made using either a 0.5-m Ritchey-Chretien and FLI-1001E CCD camera or a 0.35-m Schmidt-Cassegrain (SCT) with an SBIG STL-1001E CCD camera. The observations at CS3 used a 0.35-m SCT and SBIG ST-10 CCD or a 0.4-m SCT with STL-1001E CCD. All images were unfiltered. The data were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008). The observations were made over the period of 2012 March 6 to April 18. Almost 700 data points were used in the analysis.

Warner used the dual period search feature in *MPO Canopus* to find the period of the primary ($P_1$ = 2.9932 ± 0.0002 h, amplitude 0.10 ± 0.01 mag) and the orbital period (24.37 ± 0.01 h). Both of these are in good agreement with the model from Pravec *et al.* (2012). The amplitude of the mutual events varied from about 0.17 to 0.20 mag, with a total eclipse being observed. This gives Ds/Dp = 0.38 ± 0.02, in excellent agreement with the model by Pravec *et al.* (2012).

Acknowledgements

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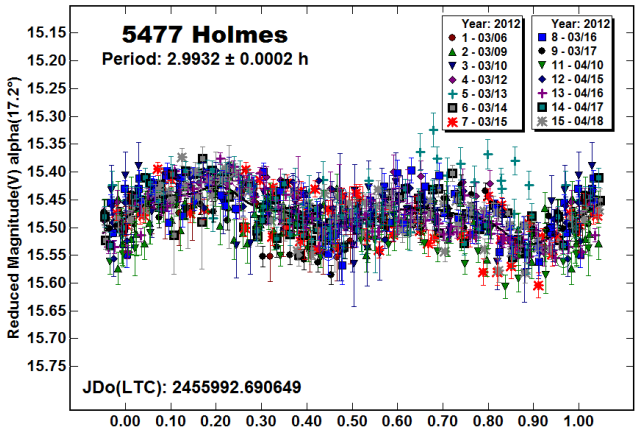


Figure 1. Lightcurve due only to the rotation of the primary in the binary system of 5477 Holmes.

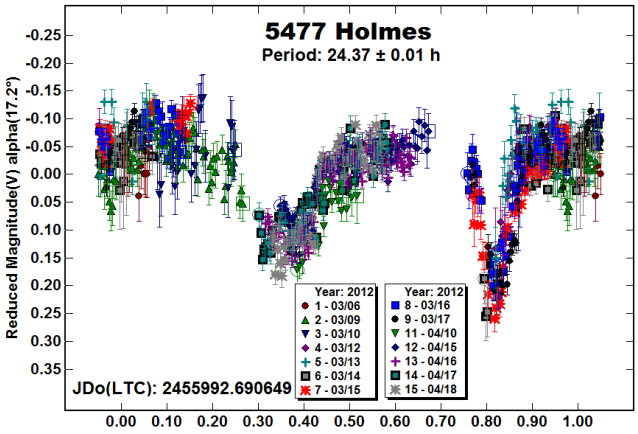


Figure 2. Lightcurve of 5477 Holmes after subtracting the rotation of the primary. The two "dips" at rotation phases ~0.3 and 0.8 are due to occultations/eclipses involving the satellite. The flat portion of the event at 0.3 phase indicates that the event was total. The magnitude drop of this event is used to calculate the size ratio of the two bodies, giving Ds/Dp = 0.38 ± 0.02.

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## LIGHTCURVE FOR 1090 SUMIDA

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(Received: 7 July)

Analysis of CCD photometric observations of the Phocaea asteroid 1090 Sumida in 2012 showed a low amplitude lightcurve of 0.11 mag. A period of 2.7181 h was determined by Fourier analysis. There were indications of a secondary period with several possible solutions. However, none of them were sufficiently convincing.

The Phocaea asteroid 1090 Sumida was observed by Wisniewski (1991), who reported a period of 2.750 h ($A$ = 0.22 mag) and by Behrend *et al.* (2004), who reported a period of 2.7194 h and $A$ = 0.28 mag. The period and the estimated size of the object, about 8 km, made it a good candidate for being binary even though neither of two previous observers reported any signs of a satellite.

Observations of the asteroid were started at PDO on 2012 June 9 as a "full moon project", i.e., it was bright enough to be worked despite the moon's phase and because there were no program targets among the Hungaria asteroids available at the time. A 0.30-m Schmidt-Cassegrain (SCT) and SBIG ST-9XE were used to obtain the unfiltered images. Analysis of the first night's data was able to find a period around 2.7 h but there were indications of unusual behavior in the curve, either due to systematic problems or a secondary period. Help was requested from Megna at CS3 to observe the asteroid almost simultaneously, which would help eliminate systematic issues. He used a 0.35-m SCT and SBIG ST-9 CCD camera, also unfiltered.

The data from both locations were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008). Night-to-night calibrations for each observer and between observers were generally within 0.05 mag or less of one another. On at least two nights both observers recorded what appeared to be "unusual behavior", i.e., significant deviations from the smoothed curve that appear in the plot. However, an additive dual period search by Warner, one best suited to lightcurve changes due to a satellite, could not find a stable secondary solution, even as more data were added to the analysis. Subtraction of some of the secondary periods does reduce the scatter in the plot, but not to the point of statistical significance.

High-precision observations at future apparitions are strongly encouraged.

### Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G, by National Science Foundation grant AST-1032896. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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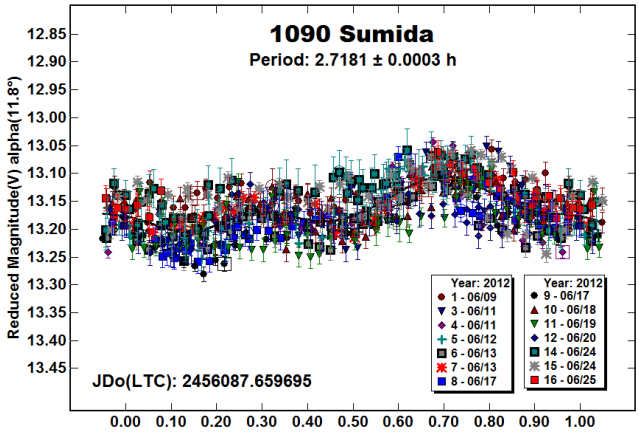

## LIGHTCURVE FOR 7758: A POSSIBLE BINARY?

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Analysis of CCD photometric observations of the Phocaea asteroid 7758 Poulanderson in 2012 found a period of 2.64753 ± 0.00007 h with A = 0.14 mag. Data from two nights showed a possible event due to a satellite. If true, the orbital period would appear to be long, with one solution falling between 59-60 hours and others ranging up to approximately 100 hours.

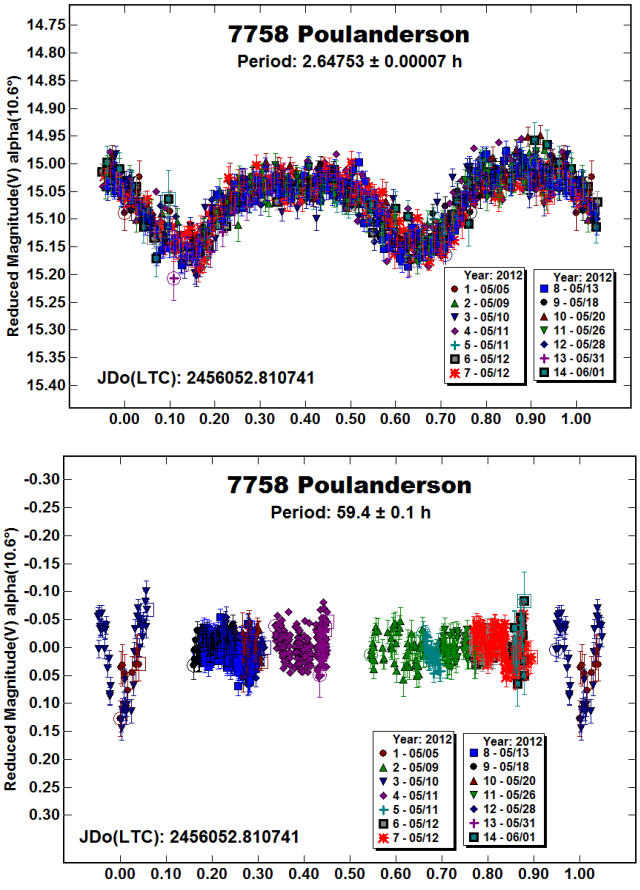
CCD photometric observations of the Phocaea asteroid 7758 Poulanderson were started at the Palmer Divide Observatory on 2012 May 5. That initial data set showed what might have been the end of a mutual event (occultation/eclipse) due to a satellite. Five nights later, a second event appeared to be captured, this time covering the entire duration and with an amplitude of $A_1$ ~ 0.12 mag. A preliminary solution for an orbital period indicated that $P_{orb}$ > 24 h. If so, a single station could not hope to obtain sufficient data over a reasonable time. A call for assistance was put out to a group of observers in Petr Pravec's binary asteroids program (Pravec et al., 2006), allowing data to be obtained from other parts of the U.S. as well as Europe and Chile. Table I shows the list of observers and equipment used.

The data from PDO, CS3, and SLMO were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008). The data from the other observers were merged to provide the best RMS fit. Warner used the dual-period search feature of *MPO Canopus* to analyze the data set, which included more than 900 observations obtained from 2012 May 5 through June 1, and found a primary period of 2.64752 ± 0.00007 h. Several possible periods could be fit to the two supposed events, one being 59.4 hours, which is shown in the plot below. The several orbital solutions, ranging up to ~100 h, are limited to those that produce the gap at about 0.5 rotational phase. This helps constrain the number of solutions but does not allow finding a unique one. Attempts to observe the opposing event (at 0.5 phase) based on the potential orbital periods failed.

High-precision observations, especially from multiple stations, are encouraged for future apparitions.

| Observer | ID | Equipment |
|---|---|---|
| Warner | PDO | 0.35-m SCT, STL-1001E |
| Stephens | CS3 | 0.35-m SCT, STL-1001E |
| Pray | SLMO | 0.50-m Newtonian, ST-10XME |
| Husárik | SPO | 0.61-m Newtonian, ST-10XME |
| Pollock | PROMPT | 0.46-m SCT, Alta U47 |
| Kušnirák<br>Horonoch | Ond | 0.60-m Newtonian, MI G2-3200 |

Table I. List of observers and equipment.




Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G, by National Science Foundation grant AST-1032896. The work at Skalnate Pleso has been supported by the Slovak Grant Agency for Sciences VEGA (Grant No. 2/0022/10). Research at Sugarloaf Mountain is supported by a Gene Shoemaker NEO Grant from the Planetary

Society. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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## LIGHTCURVE FOR 205 MARTHA

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CCD photometric observations of the main-belt asteroid 205 Martha were obtained from Santana Observatory (MPC 646) in 2012 May - June. The period of 14.912 ± 0.001 h updates several previously reported results.

The main-belt asteroid 205 Martha was previously observed on two nights in 1995 October by Chiorny (2007), who reported a period of 9.78 h. Those two nights resulted in no overlap of the lightcurve and appears to be an alias of this result. Saylor (2012) observed Martha for two nights in 2010 January, reporting a period of 11.8 h when assuming a monomodal lightcurve with no overlap of data from the two nights. Fome (Behrend, 2012) observed Martha over four nights in 2010 July with scatter in the observations greater than the amplitude of the lightcurve and reported a period of 11.92 h. Warner (2010) observed the asteroid over seven nights and could not match either of the two previous periods, reporting a period of 39.8 h.

The data from the observations at Santana could not be phased to any of the previously reported periods. Aliases of 11.4, 17.1, and 22.4 h were present in the period spectrum. To resolve the conflicts, the lightcurve was binned so that five data points were plotted as one average data point in order to reveal subtle changes in the lightcurve. Also, Warner's 2010 data were replotted at 14.91 h after adjusting the zero points for two sessions to see if they would provide a reasonable fit. The resulting lightcurve does miss a critical maximum at 0.55 rotation phase, but it is a plausible result. The period spectrum from the 2010 data shows a strong preference for the 14.9 h period and rejects the one near 9.8 hours as well as the additional aliases found with the 2012 data.

Given the good fit of the 2012 data to the 14.912 h period, and the 2010 data not excluding it, we prefer this period to all alternatives.

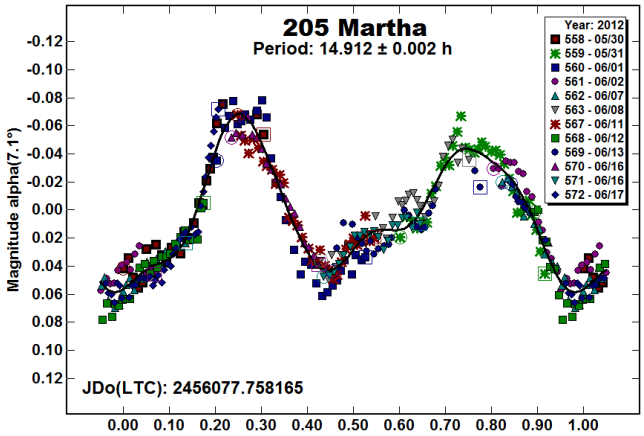


Figure 1: Lightcurve of 205 Martha using 2012 data from Santana.

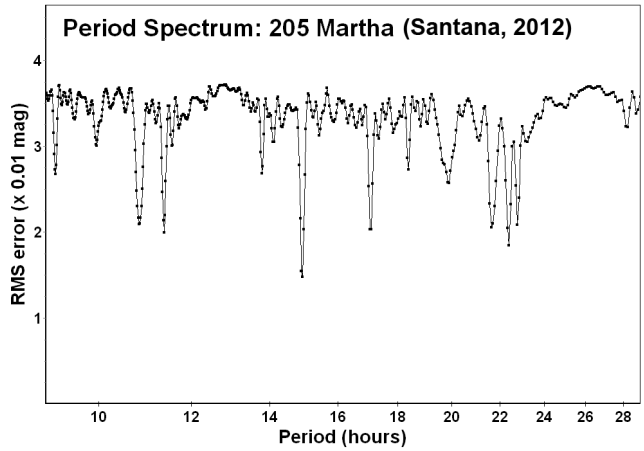


Figure 2: Period spectrum using 2012 data from Santana.

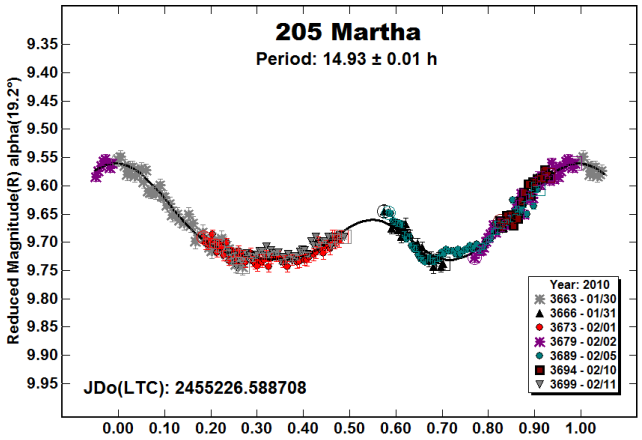


Figure 3: Warner's 2010 data forced to 14.91 h.

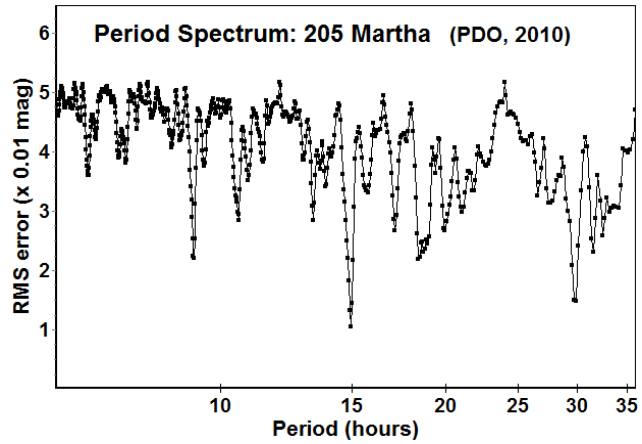


Figure 4: Period spectrum from Warner's 2010 data.

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## SHAPE AND SPIN AXIS MODEL FOR 161 ATHOR

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We present shape and spin axis model for main-belt asteroid 161 Athor. The model was obtained with lightcurve inversion process, using combined dense photometric data from apparition in 1979, 1980, 1982, 2008, 2009, 2010-11 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 7.280087 ± 0.000005 h and two mirrored pole solution at (λ = 350°, β = -6°) and (λ = 170°, β = 4°), with an error of ± 10 degrees.

The main-belt asteroid 161 Athor has been observed in recent years by Pilcher and Higgins in three consecutive apparitions, with wide phase angles and phase angle bisectors, optimal conditions for starting with a lightcurve inversion project. To improve the coverage at various aspect angles, we found in the literature further observations, whose lightcurves were downloaded from the Asteroid Photometric Catalogue (APC) by Lagerkvist et al. (2001) at: *http://asteroid.astro.helsinki.fi/apc*. The observational circumstances for the six apparitions are reported in Table I.

To obtain a more robust solution we have also used sparse data from USNO Flagstaff Station, as has been shown by Kaasalainen (2004), Ďurech et al. (2009). Sparse data were taken from the AstDys website (*http://hamilton.dm.unipi.it/astdys/index.php/*) for a total of 171 data points. Figures 1, 2 and 3 show respectively the PAB Longitude/Latitude distribution for the dense/sparse data and the phase curve for the sparse data. The lightcurve inversion process was performed using MPO LCInvert v.2.4. Software (Bdw Publishing), which implements algorithms and code provided by Mikko Kaasalainen and Josef Ďurech. For guidelines and a description of the modeling process see the LCInvert Operating Instructions manual and Warner et al. (2008).

Data Analysis

All data from thirty dense lightcurves and one sparse dataset were imported in *LCInvert* for analysis, assigning them a different weighting factor, respectively 1.0 and to 0.3. The first critical step is to find an accurate sidereal rotational period. For this, we started the period search centered on the average of the synodic periods found in the previously published work. The second crucial step is

to find the pole spin axis. The pole search was done using the "Fine" search option (612 fixed pole position with 10° longitude-latitude steps) and the previously found sidereal period set to "float". The "dark facet" weighting factor was increased from 0.1 (default) to 0.5 to keep the dark facet area below 1% of total area.

Data analysis shows a result clustered around two lower chi-square mirrored solution, centered at ($\lambda = 350°$, $\beta = 0°$) and ($\lambda = 170°$, $\beta = 10°$), see Figure 4 for log(chi-square) values distribution. These values were then refined by running again the pole search with the previous period/longitude/latitude set to "float". The two best solutions are reported in Table II with an averaged sidereal period. Typical errors in the pole solution are ± 10 degrees and the uncertainty in period has been evaluated as a rotational error of 10° over the total time-span of the observations.

We prefer the first solution as it has a stronger convergence, small chi-square and RMS values. Figure 5 shows the shape model with first solution and Figure 6 shows the good agreement between the model (black line) and observed lightcurves (red points). This pole solution agrees also with those reported by Pilcher and Higgins (2008) and independently by Ďurech (private communication) using more or less the same observational dataset.

Finally, the model and the data will be stored in Database of Asteroid Models from Inversion Techniques (DAMIT, Ďurech 2012).

| Year | #LCs | Data Points | PA° | PABL° | PABB° | Ref. |
|---|---|---|---|---|---|---|
| 1979 | 4 | 148 | 11/9 | 238 | -7 | (1) |
| 1980 | 3 | 16 | 7/13 | 57 | 7/8 | (2) |
| 1982 | 1 | 120 | 9/11 | 159 | 7 | (3) |
| 2008 | 12 | 1457 | 11/10 | 191 | 3/1 | (4) |
| 2009 | 3 | 714 | 20/10 | 359/2 | -6/-5 | (5) |
| 2010-11 | 7 | 1691 | 21/6 | 121/124 | 10/11 | (6) |

Table I. Observational circumstances for 161 Athor over six apparitions, a total of 30 lightcurves were used for lightcurve inversion analysis. References: (1) Debehogne and Zappala (1980), (2) Harris and Young (1989), (3) Carlsson and Lagerkvist (1983), (4) Pilcher and Higgins (2008), (5) Higgins/Pilcher on MPC Lightcurve Database and website: http://aslc-nm.org/161Athor2009.jpg, (6) Pilcher (2011).

| λ° | β° | Sidereal Period(h) | ChiSq | RMS |
|---|---|---|---|---|
| 350 | -6 | 7.280087 ±0.000005 | 1.2226 | 0.0163 |
| 170 | 4 | | 1.2632 | 0.0165 |

Table II. The two best spin axis solutions for 161 Athor.

Acknowledgement

The work of J. Ďurech was supported by grant P209/10/0537 of the Czech Science Foundation.

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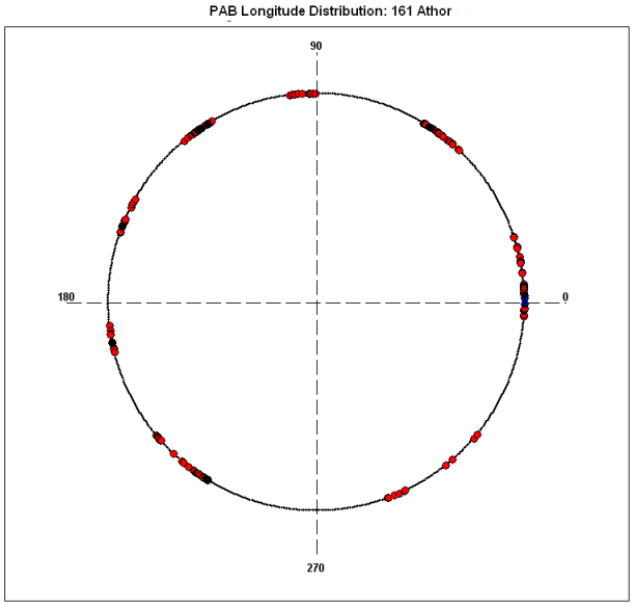


Figure 1. PAB Longitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

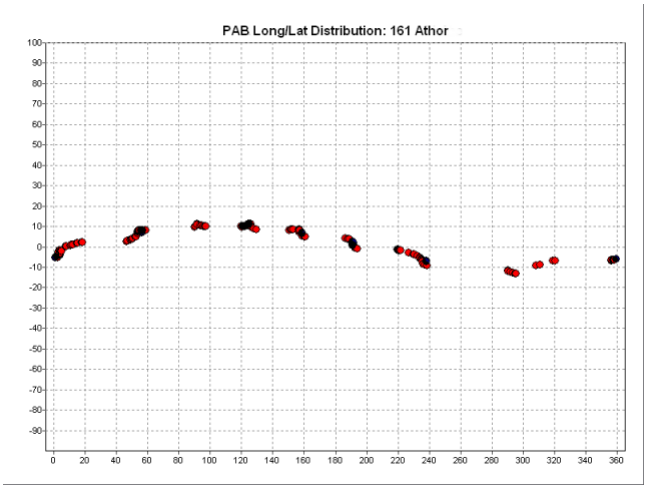


Figure 2. PAB Latitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

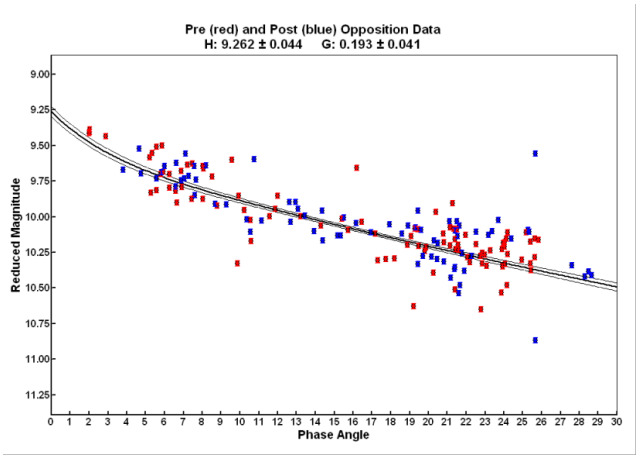


Figure 3. Visual reduced magnitude vs phase angle for sparse data from USNO Flagstaff Station.

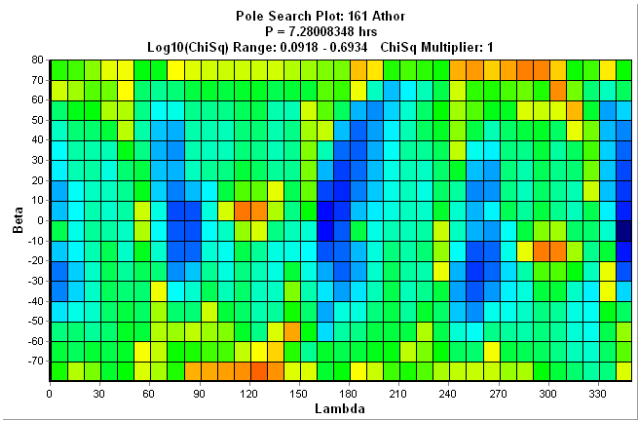


Figure 4. Pole Search Plot of log(ChiSq) values, where dark blue identify lower ChiSq values and Dark red underlying the worst solutions.

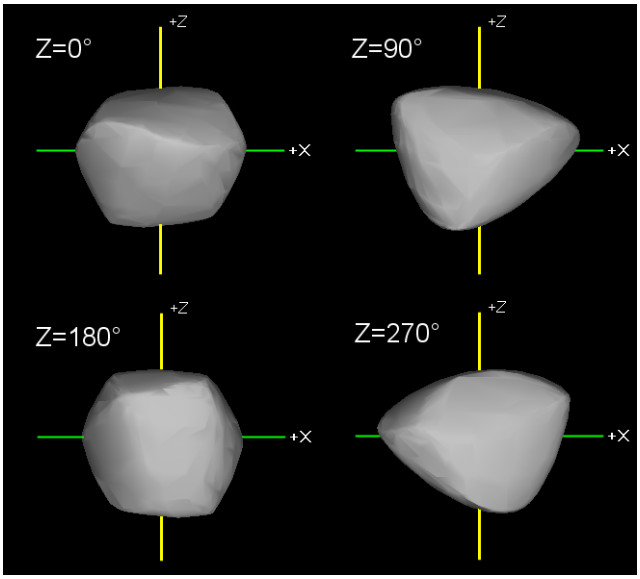


Figure 5. The shape model for 161 Athor (λ = 350°, β = - 6°).

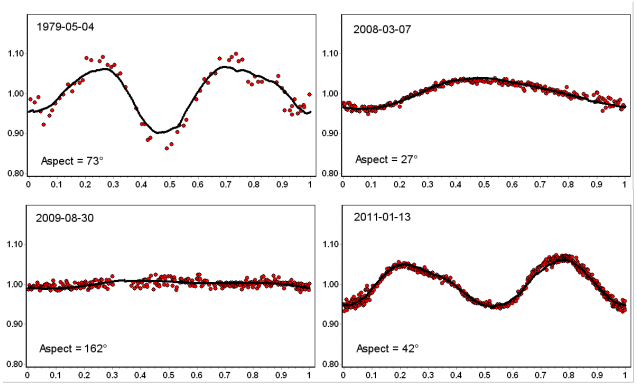


Figure 6. Comparison of model lightcurve (black line) versus a sample of four observed lightcurves (red points).

## LIGHTCURVE ANALYSIS FOR FOUR ASTEROIDS

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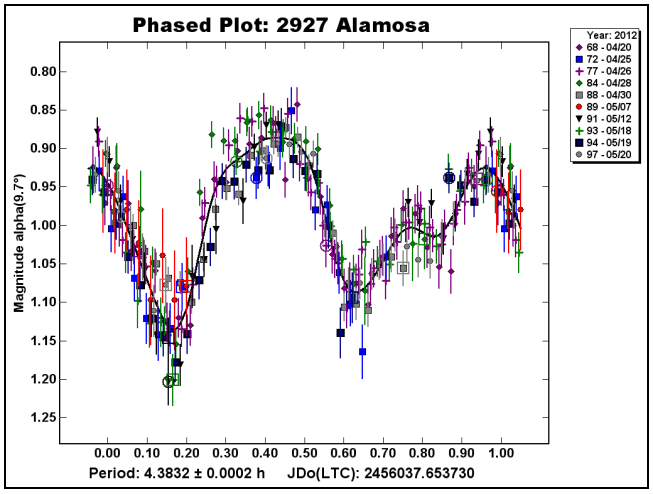
Lightcurves for four asteroids were obtained at Phillips Academy Observatory (PAO) and HUT observatory from 2012 March to May: 2927 Alamosa, 4419 Allancook, 5374 Hokutosei, and (28704) 2000 GU91.

Lightcurves for four asteroids were obtained at Phillips Academy Observatory and HUT Observatory between 2012 March and May. HUT and Phillips Academy Observatory have twin telescopes: a

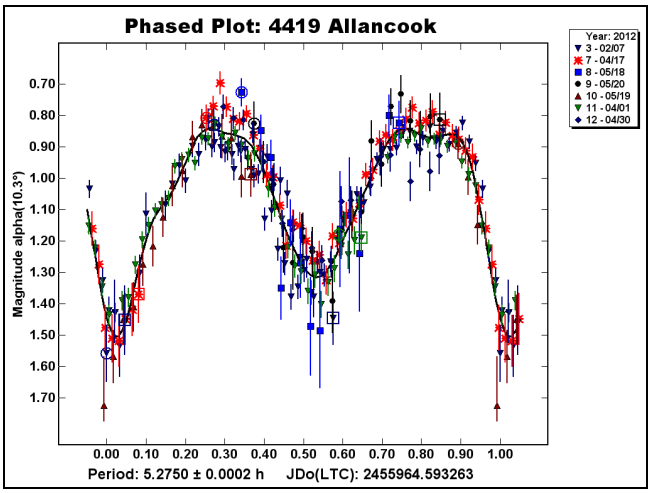
0.40-m *f*/8 Ritchey-Chretien reflector by DFM Engineering. Phillips Academy Observatory used an SBIG 1301-E CCD camera with a 1280x1024 array of 16-micron pixels. The resulting image scale was 1.0 arcseconds/pixel. Exposures were usually 450 seconds working at –25°C through a clear filter. All images were dark and flat-field corrected, guided, and unbinned. HUT observations were made with an Apogee Alta model U47 CCD. Exposures were 180 seconds working at –40°C through a Bessell R filter. Exposures were 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 was also done with *MPO Canopus,* the latter using an implementation of the Fourier analysis algorithm of Harris (FALC; Harris *et al.*, 1989). The combined data sets from both observatories were analyzed by Odden and French. A search of the Asteroid Lightcurve Database (LCDB; Warner *et al*., 2009) and other sources did not find previously reported lightcurve results for any of these asteroids.

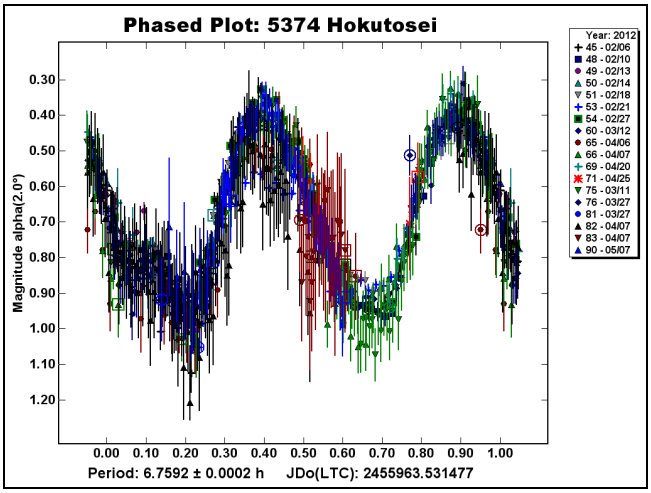
2927 Alamosa. Observations were conducted between 2012 April 20 and May 20 at Phillips Academy Observatory. The resulting lightcurve consists of 262 data points. An examination of the period spectrum between 3 and 12 hours indicates a period of 4.3832 ± 0.0002 h and amplitude 0.26 ± 0.03 mag. For trial periods in this range, the adopted period and its double gave the lowest RMS values. Other possibilities show at least one or two nights out of phase with the others and may be rejected. The resulting lightcurve is bimodal with a "wiggle" at 0.80 rotation phase angle. When the data are phased to the double period (8.766 hours), the two halves of the curve look the same within reasonable error.



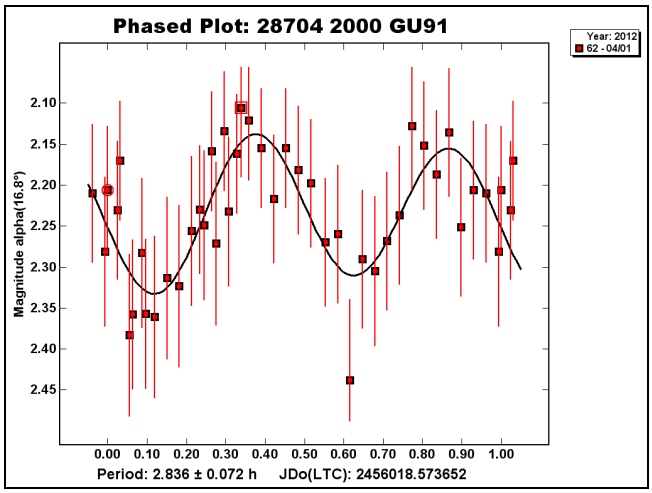

4419 Allancook. Observations of 4419 Allancook were conducted from 2012 February 7 to May 20 from Phillips Academy Observatory. Based on the amplitude of the lightcurve, 0.66 ± 0.02 mag, the bimodal solution is expected. An examination of the period spectrum between 3 and 12 hours indicates a period of 5.2750 ± 0.0002 h. Aliases of 4.752 hours and 5.928 also exhibit low RMS values, but visual inspection of lightcurves phased to those periods show at least two nights out of phase with the others and may be rejected.

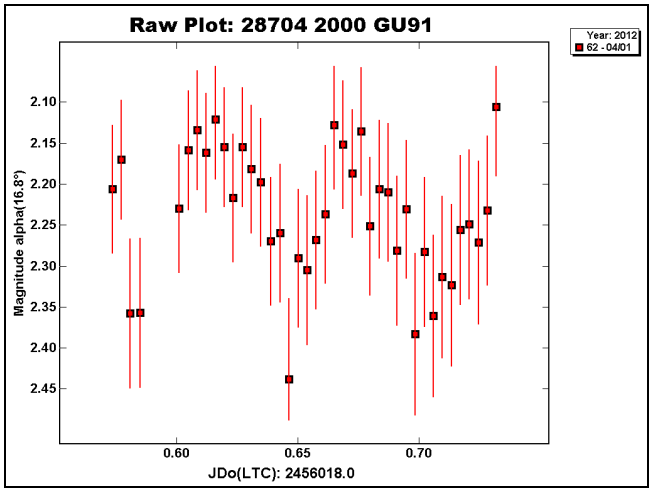



5374 Hokutosei. Observations of 5374 Hokutosei were conducted from 2012 February 2 until May 7 from the Phillips Academy and HUT Observatory. The resulting lightcurve consists of 797 data points. An examination of the period spectrum between 3 and 12 hours indicates a period of 6.7592 ± 0.0002 h and amplitude of 0.60 ± 0.05 mag. For trial periods in this range, the half period, true period and double period yield the lowest RMS values. When the data are phased to the double period (13.518 hours), the two halves of the curve look the same within reasonable error. It should be noted that the authors noticed an interesting dip in the lightcurve on the evening of 2012 February 21. Additional observations failed to confirm the irregularity. We plan to follow up at the next apparition.




(28704) 2000 GU91. This was a target of opportunity that passed through the same field as 4419 Allancook. Follow up observations were not attempted until May when the asteroid was too faint to achieve a reasonable signal-to-noise ratio. Given the incomplete data set, we have included a raw plot as well as a plot phased to a bimodal solution of 2.836 ± 0.072 h. The lightcurves are based on 40 data points, and the amplitude is measured to be 0.20 ± 0.05 magnitude.




Acknowledgments

Thanks to Brian Warner and Petr Pravec for their timely and useful advice. Thanks also to Marshall Cloyd for his encouragement and support of student research at the Phillips Academy Observatory.

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## LIGHTCURVE FOR NEA 2012 KP24

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CCD photometric observations were made of the near-Earth asteroid, 2012 KP24 during a close flyby in 2012 May. Analysis of more than 700 data points found a period of 0.041667 ± 0.000002 h, or 150.00 ± 0.01 seconds. The maximum amplitude of the asymmetric lightcurve was 0.86 ± 0.03 mag.

The near-Earth asteroid 2012 KP24 was discovered by the Catalina Sky Survey on 2012 May 24 (UT). Four days later, it made a close flyby of the Earth, coming to a distance of about 51,000 km (about 32,000 miles; less than 10 Earth radii). We observed the asteroid on the night of closest approach to support spectroscopic observations by finding the rotation period. The observations at PDO were made using a 0.35-m Schmidt-Cassegrain (SCT) using a Finger Lakes FLI-1001E CCD camera. The observations at CS3 used a 0.40-m SCT and SBIG STL-1001E. Initial exposure times at both observatories were 30 seconds but this produced significant trailing. The exposures were reduced to 10-15 seconds. All images were unfiltered. The data were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*, 2006; see Warner, 2007; Stephens, 2008).

The data were analyzed as they came in. It became quickly apparent that the period was very short, on the order of a few minutes, which was another, and actually, main reason for reducing the exposure times. When the exposure becomes a significant portion of the rotation period (> 0.185*P*), not only can lightcurve details be lost (shape information) but the true amplitude of the curve can be seriously under-estimated (Pravec *et al.*, 2000). Analysis of the combined data set found a period of 0.041667 ± 0.000002 h, or 150.00 seconds. The maximum amplitude was 0.86 ± 0.03 mag based on a 10$^{th}$-order Fourier solution. These results are consistent with those found by Polishook *et al.* (2012).

Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G, by National Science Foundation grant AST-1032896. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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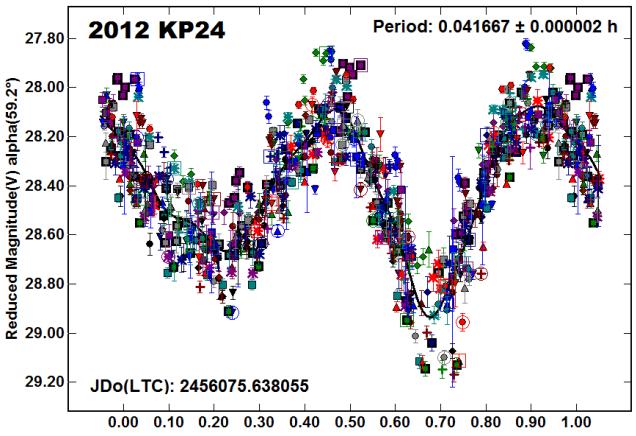


## ASTEROID LIGHTCURVE ANALYSIS AT RIVERLAND DINGO OBSERVATORY: 1394 ALGOA, 1660 WOOD, 8882 SAKAETAMURA, AND (15269) 1990 XF

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Lightcurves for four asteroids were obtained at Riverland Dingo Observatory (RDO) from 2012 January-June: 1394 Algoa, 1660 Wood, 8882 Sakaetamura, and (15269) 1990 XF.

The observations reported here were all obtained using a 0.41-m *f*/9 Ritchey-Chretien, SBIG STL-1001E CCD camera, and Johnson-Cousins V filter. All images were bias, dark and flat-field corrected. The image scale was 1.35 arc seconds per pixel. Differential photometry measurements were made in *MPO Canopus* (Warner, 2008) using V magnitudes for comparison stars extracted from the AAVSO Photometric All-Sky Survey Catalog (APASS; *http://www.aavso.org/download-apass-data*)

The four asteroids reported here were selected from the Collaborative Asteroid Lightcurve Link (CALL; Warner, 2011). A search of the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) did not reveal any previously reported results for asteroids 1660 Wood or (15269) 1990 XF. Previously or newly-reported results for 1394 Algoa and 8882 Sakaetamura are referenced below.

1394 Algoa is a main-belt asteroid discovered by Jackson in Johannesburg in 1936. A total of 442 data points were obtained over four nights during the period 2012 May 9-30, with average magnitude of 14.7 and average SNR of 121. The lightcurve shows a period of 2.768 ± 0.001 h and amplitude of 0.20 ± 0.01 mag. A submission by Klinglesmith (2012) on the CALL website reports a period of 2.768 ± 0.001 h and amplitude of 0.20 ± 0.05 mag.

1660 Wood is a main-belt asteroid discovered by Bruwer in Johannesburg in 1953. A total of 592 data points were obtained over seven nights during the period 2012 February 10-25, with average magnitude of 13.6 and average SNR of 225. The lightcurve shows a period of 6.8088 ± 0.0004 h and amplitude of 0.16 ± 0.01 mag.

8882 Sakaetamura is a main-belt asteroid discovered by Endate and Watanabe in Kitame in 1994. A total of 502 data points were obtained over four nights during the period 2012 January 1-19 with average magnitude of 15.6 and average SNR of 57. The lightcurve shows a period of 4.8742 ± 0.0002 h and amplitude of 0.37 ± 0.02 mag. The result is in agreement with one found by Warren (2012).

(15269) 1990 XF is a main-belt asteroid discovered by Kushida and Muramatsu in Yatsugatake in 1990. A total of 1304 data points were obtained over 12 nights during the period 2012 April 4 to June 10, with average magnitude of 15.4 and average SNR of 69. The lightcurve shows a period of 26.708 ± 0.001 h and amplitude of 0.62 ± 0.02 mag.

Acknowledgements

The measurements reported make use of the *AAVSO Photometric All-Sky Survey (APASS)* catalog, which is funded by the Robert Martin Ayers Sciences Fund.

Thanks to Darren Wallace of RDO and his collaborators at New Mexico Skies for maintaining the equipment in Australia and to Richard Miles and Peter Birtwhistle for sharing information via the British Astronomical Association's Asteroids and Remote Planets Section.

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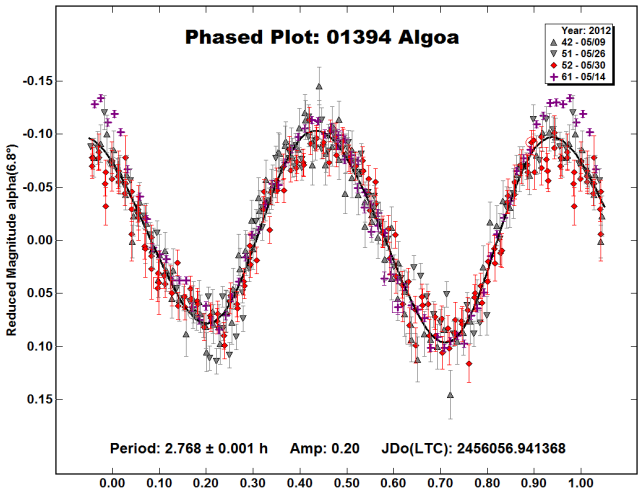


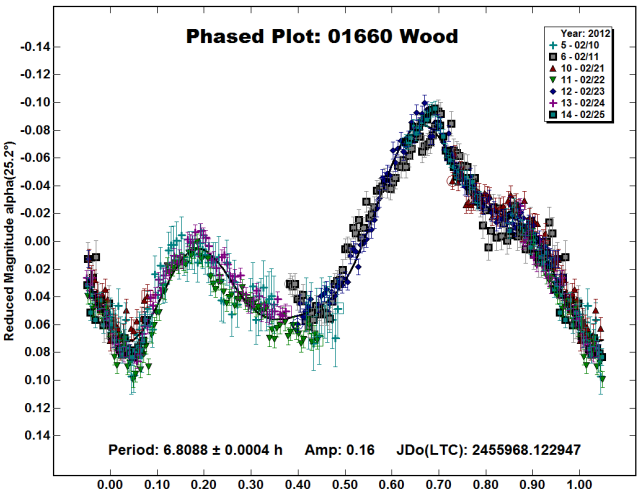


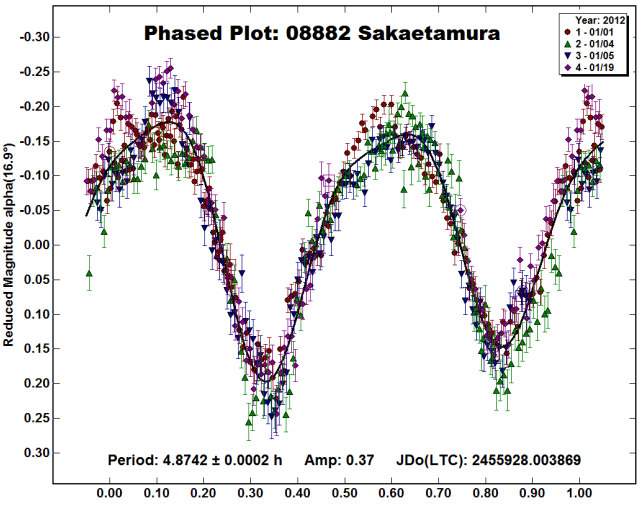


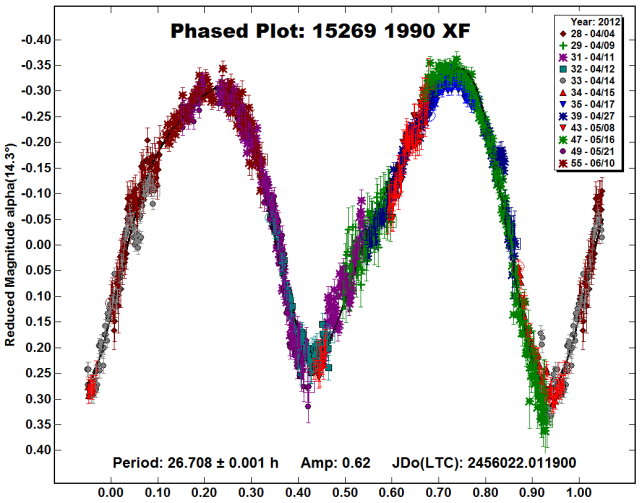


## LIGHTCURVE FOR 7958 LEAKEY: A NEW HUNGARIA BINARY

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Analysis of CCD photometric observations of the Hungaria asteroid 7958 Leakey made in 2012 reveals that the object is mostly likely a binary with a primary rotation period of 2.34843 ± 0.00006 h, A = 0.22 mag. The orbital period of the tidally-locked satellite is likely 50.29 ± 0.08 h, although it's possible that the period is 25.26 ± 0.04 h. The secondary lightcurve shows a bowing (amplitude) of about 0.05 mag, indicating that satellite has a projected a/b ratio of 2/1. Two possible mutual events (occultations/eclipses) were observed. From these, the estimated size ratio of the two bodies is Ds/Dp = 0.30 ± 0.03. Additional observations are needed to confirm these results.

The Hungaria asteroid was observed starting the middle of 2012 June at the Palmer Divide Observatory (PDO) using a 0.35-m Schmidt-Cassegrain (SCT) with an SBIG STL-1001E CCD camera. Analysis of the data after several observing runs indicated the possibility that the asteroid was a binary with a somewhat long orbital period, $P > 24$ hours. A request for assistance was made to the Center for Solar System Studies (CS3) when poor weather and other conditions prevented additional observations at PDO. The observations at CS3 used a 0.35-m SCT and SBIG ST-10 and were mostly at the end of June, which helped considerably by filling in missing sections of the secondary period. All images were unfiltered. The data were put onto an internal standard system

using V magnitudes derived from the APASS catalog (Henden *et al.*, 2012).

Warner used the dual period search feature in *MPO Canopus* to find the period of the primary ($P_1$ = 2.34843 ± 0.00006 h, $A$ = 0.22 mag). Two possible solutions were found for the secondary (orbital) period: 25.26 ± 0.04 h and 50.29 ± 0.08 h, both with a total amplitude (satellite rotation and events) of 0.12 mag. We adopted the longer period based on the following logic.

Keeping in mind that the secondary lightcurve is "diluted" by the light of the primary, then if the secondary is only 10% of the total light and it has an amplitude of 0.05 mag, the "undiluted" lightcurve would have an amplitude around 0.5 magnitude. This is out of the range of ambiguity for the number of extrema per rotation cycle. In this case, meaning that a bimodal lightcurve and its corresponding longer period are more likely. Additionally, in order to have events at only one phase and not at the opposite phase requires either a very strange geometry or an eccentric orbit. The unusual situation where only one event is seen is for a period where the rotation phase 0.5 around is not covered. The 25 h period is 100% covered, but with only one minimum. This is unlikely for the reasons given before. Therefore, the 50.29 h solution for the secondary period was adopted.

The overall amplitude of the secondary lightcurve indicates an approximate projected a/b ratio of 2/1 for the satellite. Two apparent mutual events (occultations or eclipses) were observed. From these, the estimated size ratio of the pair is Ds/Dp = 0.30 ± 0.03. Since only two events were observed, neither completely covered, these results are hardly definitive. Observations at future apparitions are strongly encouraged.

Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35G and by National Science Foundation grant AST-1032896. This research was made possible through the use of the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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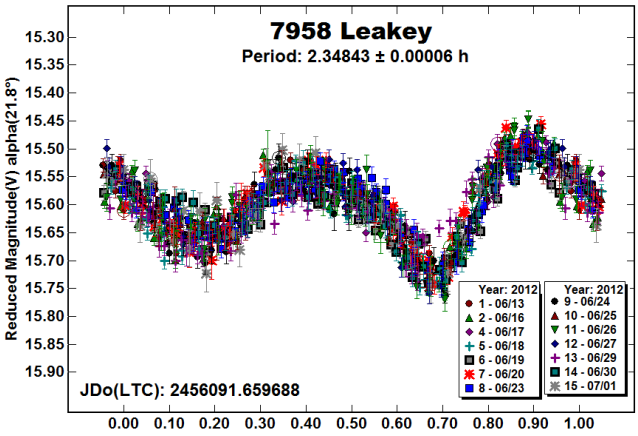


Figure 1. Lightcurve for 7958 Leakey due only to the rotation of the primary in a binary system.

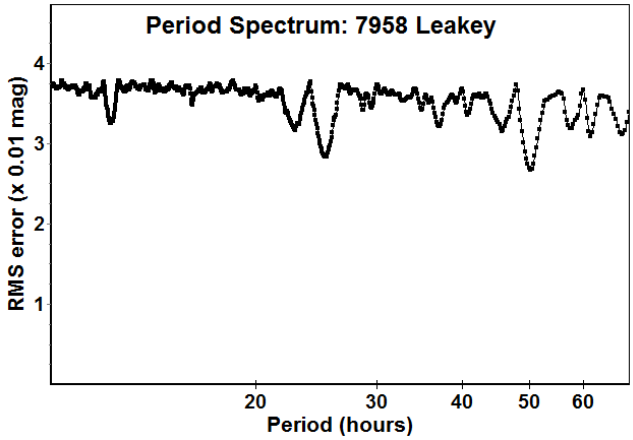


Figure 2. The period spectrum for 7958 Leakey after subtracting the rotation of the primary. The period of about 50 hours has the lowest RMS. A period near 25 h cannot be formally excluded but it is not likely. See the text for a discussion on why the longer period is considered correct.

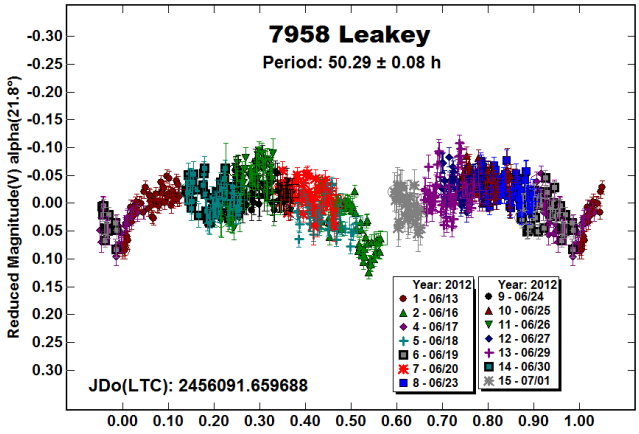


Figure 3. The lightcurve for the preferred secondary (orbital) period for 7958 Leakey after subtracting the rotation of the primary. In this case, the significant bowing is due to the rotation of an elongated satellite that is tidally-locked to the orbital period of 50.29 h. The sharp "dips" at about 0.0 and 0.5 rotation phase are most likely mutual events (occultation or eclipse).

## LIGHTCURVES FOR SHAPE MODELING: 852 WLADILENA, 1089 TAMA, AND 1180 RITA

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The folded lightcurves and synodic periods of 852 Wladilena, 1089 Tama, and 1180 Rita are reported. The data are used by Hanus et al. (2012) to derive the rotation axis and to construct a shape model by applying the inversion lightcurve technique.

The shapes of asteroids can be constructed by using inversion techniques when the asteroids are observed from different aspect angles and at different apparitions (Kaasalainen *et al.*, 2001). Josef Durech and Josef Hanus from the Astronomical Institute of the Charles University in Prague use archival data and new observations to model the shapes of asteroids and constrain their spin axis orientations (*http://astro.troja.mff.cuni.cz/projects/asteroids3D/web.php*). Three asteroids that were measured in the past by other observers were observed at the Wise Observatory and their lightcurves were used by Hanus *et al.* (2012) for shape modeling. This paper presents the lightcurves and the derived synodic rotation periods.

The observations were performed using the two telescopes of the Wise Observatory (code: 097, E 34:45:47, N 30:35:46): A 1-m Ritchey-Chrétien telescope and a 0.46-m Centurion telescope (Brosch *et al.*, 2008). At the *f*/7 focus, the 1-m telescope is equipped with a wide-field SITe CCD (field of view [FOV] of 34'x17', 4096x2048 pixels, 0.872" per pixel, binned 2x2). The 0.46-m telescope was equipped with an SBIG STL-6303E (FOV of 75'x55', 3072x2048 pixels, 1.47" per pixel, unbinned) at the *f*/2.8 prime focus. While a V filter was mounted on the 1-m telescope, the 0.46-m was used in white light with no filters (Clear). Exposure times were 30–180s, determined by the brightness and angular velocity of the asteroids. All images were taken with an auto-guider. The observational circumstances are summarized in Table I.

The images were reduced in a standard way. IRAF *phot* function was used for the photometric measurements with an aperture of four pixels. After measuring, the photometric values were calibrated to a differential magnitude level using local comparison stars. The brightness of these stars remained constant to ± 0.02 mag. The measurements of 1089 Tama from the 2006 apparition were also calibrated to a standard magnitude system by observing Landolt equatorial standards (Landolt, 1992). This usually adds an error of ~0.03 mag. and allows fitting the data to *H-G* system (Bowell *et al.*, 1989). Astrometric solutions were obtained using *PinPoint* (*www.dc3.com*) and the asteroids were identified in the MPC web database. Analysis for the lightcurve period and amplitude was done by the Fourier series analysis (Harris and Lupishko, 1989). See Polishook and Brosch (2009) for a complete description about reduction, measurements, calibration and analysis.

### Results

The lightcurves and synodic rotation periods of 852 Wladilena (Fig. 1), 1089 Tama (Fig. 2, 3), and 1180 Rita (Fig. 4) are reported. Reliability code is determined by the definitions that appeared in Warner *et al*. (2009). 1089 Tama was observed at four different apparitions (2006, 2008, 2009, and 2011), but here data are presented from only 2006 (Fig. 2) and 2009 (Fig. 3) when enough points were obtained to cover the entire lightcurve. The derived rotation periods of 852 Wladilena and 1089 Tama are similar to those appear in the literature (e.g., Kiss, 1999; Harris 1999; Behrend, 2006; Durech, 2009). The derived rotation period of 1180 Rita (9.605 ± 0.006 h) is different from the literature values, which range between 14.72 h (Gonano, 1991), 14.902 h (Dahlgren, 1998), and 20.496 h (Slyusarev, 2012), and is partially similar to the 9 h deduced by Binzel and Sauter (1992) from a partial measurement of the entire period. In order to test the reliability of these different periods, the obtained data points were folded to try to match the periods in the literature (Fig. 5). It is clear from the figure that none of the literature values match to the measurements. Therefore, it seems certain that the true rotation period of 1180 Rita is 9.605 ± 0.006 h.

A list of candidate asteroids for the inversion modeling appears at the end of this issue.

### Acknowledgement

The author is thankful to the AXA research grant. The collaboration with Dr. Durech and Mr. Hanus was very fruitful. I thank the Wise Observatory staff for their continuous support.

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| Asteroid | Scope | Filter | Date | Time span [hours] | N | r [AU] | Δ [AU] | α [Deg] | $L_{PAB}$ [Deg] | $B_{PAB}$ [Deg] |
|---|---|---|---|---|---|---|---|---|---|---|
| *(852) Wladilena* | C18 | C | Mar 10, 2010 | 2.7 | 94 | 2.84 | 1.9 | 8.56 | 164.2 | 19.2 |
| | C18 | C | Mar 11, 2010 | 2.12 | 74 | 2.83 | 1.9 | 8.66 | 164.2 | 19.1 |
| | C18 | C | Mar 13, 2010 | 1.83 | 56 | 2.83 | 1.9 | 8.92 | 164.2 | 19 |
| *(1089) Tama* | 1m | V | Oct 19, 2006 | 8.16 | 120 | 1.97 | 0.99 | 7.13 | 35.2 | -3.1 |
| | 1m | V | Oct 23, 2006 | 5.07 | 49 | 1.96 | 0.98 | 4.87 | 35.9 | -3 |
| | 1m | V | Nov 23, 2006 | 7.37 | 149 | 1.94 | 1.02 | 14.6 | 41.3 | -2.1 |
| | 1m | V | Nov 24, 2006 | 6.94 | 67 | 1.94 | 1.03 | 15.13 | 41.4 | -2.1 |
| | 1m | V | Nov 25, 2006 | 7.87 | 73 | 1.94 | 1.03 | 15.63 | 41.6 | -2 |
| | 1m | R | May 1, 2008 | 3.04 | 61 | 2.45 | 1.45 | 4.34 | 214.3 | 2.7 |
| | 1m | R | May 9, 2008 | 6.23 | 74 | 2.45 | 1.48 | 8.04 | 214.8 | 2.6 |
| | C18 | C | Oct 11, 2009 | 5.1 | 104 | 2.1 | 1.29 | 20.27 | 344.5 | -4.6 |
| | C18 | C | Oct 12, 2009 | 2.63 | 37 | 2.1 | 1.3 | 20.61 | 344.6 | -4.6 |
| | C18 | C | Oct 13, 2009 | 4.56 | 88 | 2.1 | 1.3 | 20.98 | 344.8 | -4.6 |
| | C18 | C | Oct 15, 2009 | 3.05 | 44 | 2.1 | 1.32 | 21.63 | 345.1 | -4.6 |
| | C18 | C | Oct 17, 2009 | 4.77 | 99 | 2.09 | 1.33 | 22.27 | 345.5 | -4.5 |
| | C18 | C | Oct 22, 2009 | 4.58 | 72 | 2.09 | 1.38 | 23.72 | 346.4 | -4.5 |
| | C18 | C | Oct 24, 2009 | 4.3 | 76 | 2.08 | 1.39 | 24.24 | 346.8 | -4.4 |
| | C18 | C | Nov 7, 2009 | 2.64 | 39 | 2.06 | 1.52 | 27.05 | 349.7 | -4.2 |
| | C18 | C | Nov 8, 2009 | 3.42 | 41 | 2.06 | 1.53 | 27.2 | 350 | -4.1 |
| | C18 | C | Nov 11, 2009 | 3.5 | 52 | 2.06 | 1.56 | 27.6 | 350.7 | -4.1 |
| | C18 | C | Nov 20, 2009 | 4.02 | 60 | 2.05 | 1.65 | 28.5 | 352.9 | -3.9 |
| | C18 | C | Nov 22, 2009 | 3.99 | 70 | 2.04 | 1.67 | 28.63 | 353.5 | -3.8 |
| | C18 | C | Dec 18, 2009 | 1.02 | 18 | 2.01 | 1.94 | 28.77 | 1.4 | -3.3 |
| | C18 | C | Dec 19, 2009 | 2.81 | 48 | 2.01 | 1.95 | 28.72 | 1.7 | -3.2 |
| | C18 | C | Dec 20, 2009 | 1.84 | 28 | 2.01 | 1.96 | 28.68 | 2.1 | -3.2 |
| | C18 | C | Apr 02, 2011 | 2.39 | 55 | 2.30 | 1.34 | 9.31 | 177.4 | 4.5 |
| *(1180) Rita* | C18 | C | Mar 19, 2010 | 1.25 | 33 | 4.23 | 3.25 | 2.27 | 176.9 | 8.2 |
| | C18 | C | Mar 20, 2010 | 2.21 | 57 | 4.23 | 3.25 | 2.34 | 176.9 | 8.2 |
| | C18 | C | Mar 21, 2010 | 3.06 | 82 | 4.23 | 3.25 | 2.45 | 176.9 | 8.2 |
| | C18 | C | Apr, 9, 2010 | 1.6 | 40 | 4.21 | 3.3 | 6.41 | 176.8 | 8.1 |

Table I: Observational circumstances. Legend: asteroid name, telescope, filter, observation date, nightly time span of the specific observation, the number of images obtained (N), the object's heliocentric (r) and geocentric distances (Δ), the phase angle (α), and the Phase Angle Bisector (PAB) ecliptic coordinates (LPAB, BPAB). The table includes data from 2008 and 2011 that are not plotted.

| Name | Period [hours] | Reliability code | Amplitude [mag] | H [mag] |
|---|---|---|---|---|
| *(852) Wladilena* | 4.608 ± 0.002 | 3 | 0.28 ± 0.01 | 9.9 |
| *(1089) Tama* | 16.464 ± 0.004 | 3 | 0.14 ± 0.03 | 11.7 |
| *(1180) Rita* | 9.605 ± 0.006 | 2 | 0.15 ± 0.03 | 9.14 |

Table II: Analysis results. Legend: asteroid name, rotation period, reliability code, amplitude, absolute magnitude H from the MPC website.


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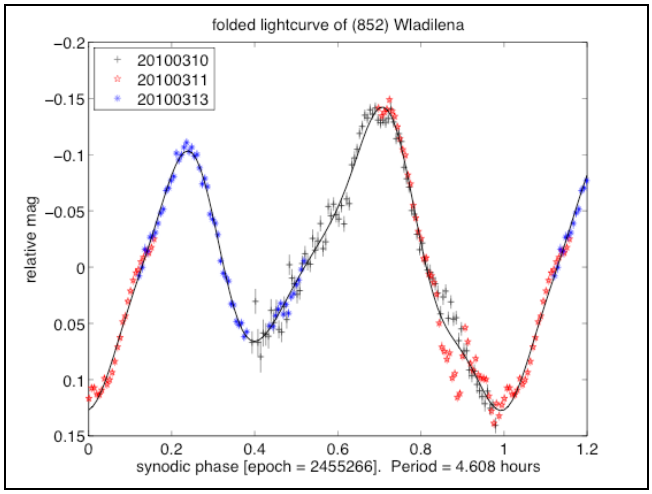


Figure 1. Lightcurve of 852 Wladilena based on P = 4.608 h.

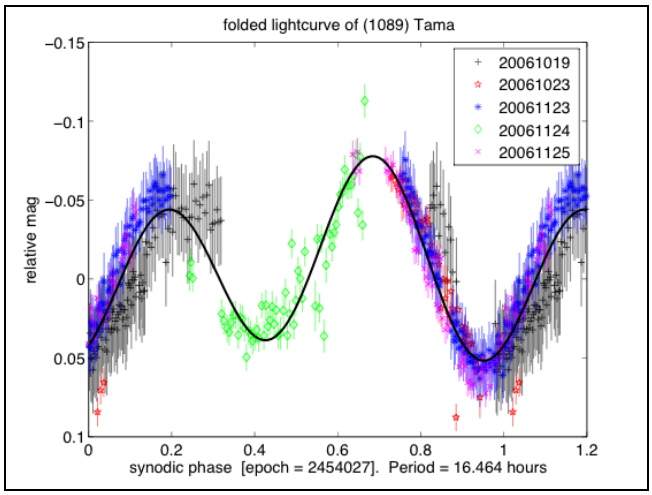


Figure 2. Lightcurve of 1089 Tama in 2006 based on *P* = 16.464 h.

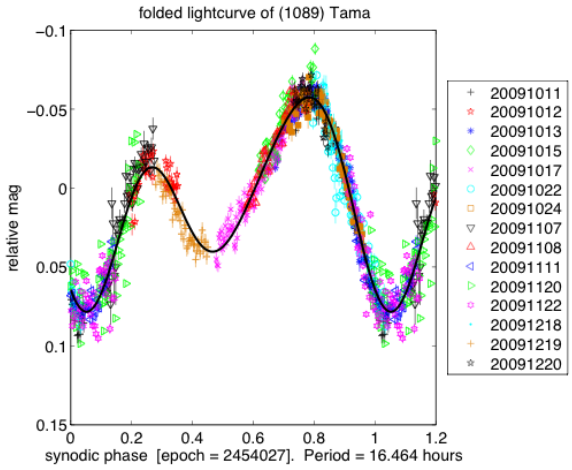


Figure 3. Lightcurve of 1089 Tama in 2009 based on *P* = 16.464 h.

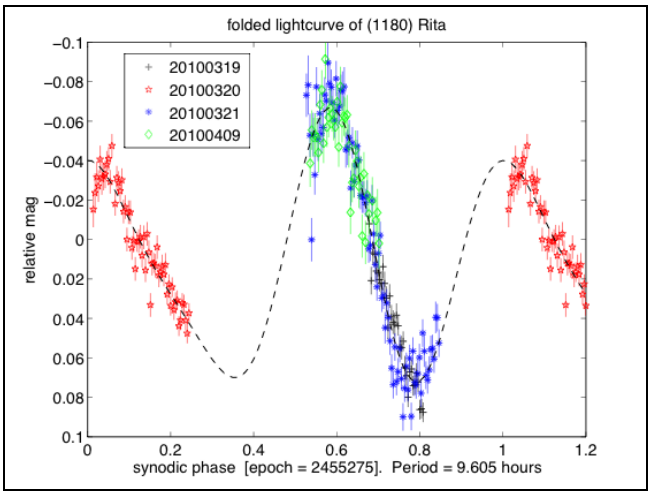


Figure 4. Lightcurve of 1180 Rita based on *P* = 9.605 h.

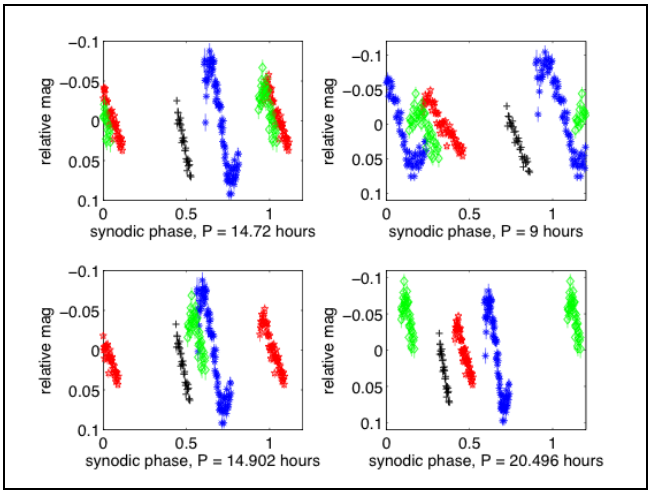


Figure 5. Lightcurve of 1180 Rita using data from 2010 but forced to previously-reported periods. Based on the poor fits, the new result of *P* = 9.605 h is considered highly reliable.

# ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2012 MARCH - JUNE

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Lightcurves for 34 asteroids, including a new Hungaria binary, were obtained at the Palmer Divide Observatory (PDO) from 2012 March to July: 1656 Suomi, 3169 Ostro, 3266 Bernardus, 4116 Elachi, 4483 Petofi, 4490 Bambery, 5968 Trauger, 6107 Osterbrock, 6354 Vangelis, 6517 Buzzi, 6670 Wallach, 7087 Lewotsky, (11304) 1993 DJ, (17129) 1999 JM78, (17590) 1995 CG, (20996) 1986 PB, (23482) 1991 LV, (24702) 1991 OR, (31182) 1997 YZ3, (31881) 2000 FL15, (42811) 1999 JN81, (47143) 1999 LL31, (48307) 2002 LP53, (49674) 1999 SB5, (51302) 2000 KY54, (51381) 2001 BG51, (51386) 2001 CN35, (74081) 1998 OU1, (79472) 1998 AX4, (88259) 2001 HJ7, (326732) 2003 HB6, 2011 WV134, 2012 AA11, and 2012 DO. The Hungaria asteroid (79472) 1998 AX2 showed what appeared to be mutual events (occultations/eclipses) in its lightcurve, likely indicating a satellite. Analysis of the data gives an orbital period of 25.95 ± 0.02 h and size ratio of Ds/Dp ~ 0.32 ± 0.03.

CCD photometric observations of 34 asteroids were made at the Palmer Divide Observatory (PDO) from 2012 March to July. See the introduction in Warner (2010a) 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) 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 $G = 0.15$ unless otherwise stated.

For the sake of brevity in the following discussions on specific asteroids, only some of the previously reported results are 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.

1656 Suomi. This Hungaria asteroid was previously worked by Stephens (2004), Brinsfield (2008), and by Warner (2009a), among others. The three found periods of about 2.59 h. The most recent results from PDO are in agreement with that period.

3169 Ostro. There are numerous reports in the LCDB for this Hungaria, e.g., Wisniewski (1991), Descamps (2007), Warner (2009a), and Hamanowa (2011). The period of 6.503 h reported here is in agreement with the earlier results.

3266 Bernardus. The author worked this Hungaria two times before (Warner, 2009b; Warner, 2011a). The period reported here is consistent with those earlier results.

4116 Elachi. This was the third time this asteroid was observed at PDO (Warner, 2006a; 2011a). All three results are in agreement.

4483 Petofi. Angeli (1996) reported a period of 4.480 h. Warner (2008; 2009b; 2011a) found a period of about 4.334 h. The latest results confirm the shorter period.

4490 Bambery. Three previous results from PDO (Warner, 2006b; 2009b; 2011b) confirm the period of 5.827 h reported here.

5968 Trauger. Warner (2006a) first reported a period of 7.560 h for this Hungaria. A second look at the same data (Warner, 2011a) found a period of 3.783 h. The asteroid was observed again in 2010 (Warner, 2011a), when a period of 6.341 h, $A = 0.30$ mag was found. Analysis of the 2012 PDO observations found 3.7879 h with an amplitude of 0.19 mag. The 2010 and 2012 data sets cannot be reconciled against one another and so the true period remains uncertain.

6354 Vangelis. Stephens (2003) found a period of 4.115 h based on two nights of observations separated by 11 days. The 2012 PDO observations consisted of two nights separated by 4 nights. Analysis found a period of 4.039 h. Stephens kindly lent his data where the period spectrum showed a solution of 4.039 h that was almost identical in RMS value to the 4.115 h solution. The period spectrum for the PDO data showed a possible solution at 4.125 h but the RMS was noticeably more than at 4.039 h. There was no solution near 4.115 h. In both cases, a third night, not so much removed from either of the existing two nights would have served to reduce or eliminate alias solutions.

6517 Buzzi. This was the third apparition this asteroid was observed at PDO. The results from the two earlier data sets (Warner, 2005; 2009a) are statistically identical the period of 8.648 h reported here.

6670 Wallach. Pletikosa *et al.* (2011) reported a period of 4.08 h. Analysis of the 2012 PDO data gives the same result.

7087 Lewotsky. Carbo *et al.* (2009) reported observing this Hungaria but unable to find a period. Warner (2011a) found a period of 5.15 h from data obtained in 2010. The analysis of the 2012 PDO data give 3.934 h with $A = 0.42$ mag. Since this seems to be a secure result given the amplitude, the 2010 data from PDO were rechecked. A number of solutions between 3 and 6 hours were found, all about equally the same RMS fit. The plot for 2010 included here shows the data forced to a solution to within 3.9-4.0 h. The fit is statistically as good as for the original solution at 5.15 h.

(11304) 1993 DJ. Warner (2009a) reported a period of 95.7 h. The result of 94.5 h reported here is reasonably consistent with that earlier result given the lack of coverage. The tumbling damping time for this asteroid (see Pravec *et al.*, 2005) is longer than the age of the Solar System. The sparse coverage does not allow saying one way or the other if the asteroid is tumbling.

(17129) 1999 JM78. Ditteon *et al.* (2011) reported a period of 6.2615 h. The PDO 2012 data analysis gives 6.2618 h. Originally, the analysis found 6.09 h. After consulting with Ditteon to see if their data would fit that period, it was ruled out.

| Number | Name | 2012 (mm/dd) | Pts | Phase | $L_{PAB}$ | $B_{PAB}$ | Period | P.E. | Amp | A.E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1656 | Suomi (H) | 06/02-06/20 | 512 | 22.0 20.0 | 274 | 34 | 2.5879 | 0.0002 | 0.11 | 0.01 |
| 3169 | Ostro (H) | 05/30-06/01 | 145 | 12.1 11.7 | 251 | 17 | 6.503 | 0.003 | 0.79 | 0.02 |
| 3266 | Bernardus (H) | 06/26-07/12 | 157 | 9.4 13.7 | 272 | 11 | 10.760 | 0.003 | 0.27 | 0.02 |
| 4116 | Elachi (H) | 04/10-04/24 | 418 | 11.0 13.7 | 206 | 15 | 38.143 | 0.005 | 1.02 | 0.02 |
| 4483 | Petofi (H) | 04/25-04/30 | 126 | 13.6 16.1 | | | 4.334 | 0.002 | 0.85 | 0.02 |
| 4490 | Bambery (H) | 06/23-06/25 | 181 | 16.1 15.6 | 282 | 23 | 5.827 | 0.002 | 1.00 | 0.02 |
| 5968 | Trauger (H) | 03/17-03/28 | 171 | 19.4 23.2 | 154 | -15 | 3.7879 | 0.0004 | 0.19 | 0.02 |
| 6107 | Osterbrock (H) | 05/28-05/31 | 127 | 26.0 26.2 | 233 | 33 | 2.372 | 0.002 | 0.09 | 0.01 |
| 6354 | Vangelis | 05/05-05/09 | 122 | 14.3 15.2 | 206 | 20 | 4.039 | 0.002 | 0.54 | 0.02 |
| 6517 | Buzzi (H) | 05/28-06/01 | 191 | 21.2 20.5 | 256 | 29 | 8.648 | 0.002 | 0.71 | 0.03 |
| 6670 | Wallach | 05/05-05/10 | 171 | 11.6 12.3 | 217 | 25 | 4.080 | 0.001 | 0.40 | 0.02 |
| 7087 | Lewotsky (H) | 05/30-06/02 | 101 | 11.9 13.5 | 233 | 8 | 3.934 | 0.002 | 0.42 | 0.02 |
| 11304 | 1993 DJ (H) | 03/23-04/09 | 443 | 21.0 20.5 20.8 | 198 | 29 | 94.5 | 0.2 | 1.0 | 0.1 |
| 17129 | 1999 JM78 | 05/05-06/02 | 209 | 12.9 9.2 9.5 | 245 | 19 | 6.2618 | 0.0003 | 0.51 | 0.02 |
| 17590 | 1995 CG (H) | 06/23-0713 | 216 | 21.0 23.3 | 267 | 27 | 16.10 | 0.01 | 0.18 | 0.02 |
| 20996 | 1986 PB (H) | 04/20-04/30 | 344 | 21.8 22.3 | 216 | 35 | 43.6 | 0.2 | 0.38 | 0.02 |
| 23482 | 1991 LV (H) | 06/26-07/13 | 153 | 20.5 17.0 | 300 | 22 | 3.1388 | 0.0002 | 0.27 | 0.02 |
| 24702 | 1991 OR (H) | 03/23-04/09 | 330 | 14.6 18.2 | 180 | 26 | 59.5 | 1.0 | 0.19 | 0.02 |
| 31182 | 1997 YZ3 (H) | 05/30-06/19 | 355 | 21.6 25.9 | 227 | 27 | 380 | 25 | 0.62 | 0.05 |
| 31881 | 2000 FL15 (H) | 04/23-04/28 | 128 | 15.0 13.8 | 226 | 14 | 4.16 | 0.01 | 0.21 | 0.03 |
| 42811 | 1999 JN81 (H) | 06/23-06/26 | 142 | 28.0 28.1 | 281 | 36 | 3.897 | 0.002 | 0.15 | 0.01 |
| 47143 | 1999 LL31 (H) | 04/20-04/22 | 113 | 19.2 19.0 | 224 | 32 | 3.32 | 0.01 | 0.31 | 0.02 |
| 48307 | 2002 LP53 | 05/09-05/10 | 82 | 6.2 | 232 | 18 | 3.79 | 0.05 | 0.34 | 0.03 |
| 49674 | 1999 SB5 (H) | 04/17-04/18 | 125 | 13.2 13.1 | 206 | 22 | 7.56 | 0.05 | 1.22 | 0.03 |
| 51302 | 2000 KY54 | 04/30-05/28 | 132 | 7.5 15.6 | 218 | 12 | 2.46 | 0.01 | 0.08 | 0.01 |
| 51381 | 2001 BG51 | 04/30-05/10 | 236 | 24.3 24.0 | 229 | 35 | 47.1 | 0.5 | 0.38 | 0.03 |
| 51386 | 2001 CN35 (H) | 03/25-04/09 | 213 | 8.9 6.9 8.9 | 190 | 9 | 48.0 | 0.2 | 0.36 | 0.03 |
| 74081 | 1998 OU1 (H) | 04/10-04/30 | 363 | 23.1 24.6 | 205 | 36 | 46.1 | 0.2 | 0.23 | 0.02 |
| 79472 | 1998 AX4 (H) | 03/17-04/09 | 573 | 20.2 22.0 | 178 | 34 | 2.8802[1] | 0.0002 | 0.21 | 0.02 |
| 88259 | 2001 HJ7 (H) | 06/09-06/12 | 136 | 12.4 13.9 | 245 | 12 | 4.175 | 0.005 | 0.15 | 0.02 |
| 326732 | 2003 HB6 | 06/12-06/20 | 146 | 24.1 29.7 | 250 | 16 | 9.436 | 0.004 | 0.19 | 0.01 |
| | 2011 WV134 | 06/02-06/11 | 183 | 27.4 18.9 | 262 | 17 | 10.105 | 0.003 | 0.23 | 0.02 |
| | 2012 AA11 | 03/29-04/10 | 279 | 58.9 28.8 | 158 183 | 15 3 | 14.19 | 0.01 | 0.72 | 0.03 |
| | 2012 DO | 04/17-04/25 | 377 | 17.4 19.5 | 216 | 11 | 38.7 | 0.5 | 0.24 | 0.02 |

[1] Rotation period of primary in a binary system.

Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. The phase angle (□) 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. LPAB and BPAB are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

(23482) 1991 LV. Analysis found a weak secondary period at around 13.8 hours. Removing this produced a significantly better RMS fit of the data to the 3.1388 h period reported here. However, the data were far from conclusive. Two plots are provided below: first is one after subtracting the secondary period and then one without subtraction. The hints of something unusual make this a prime target for detailed, high-precision observations in the future.

(42811) 1999 JN81. This Hungaria was observed in 2007 by Warner (2008). A period of 3.902 h was reported. The new results of 3.897 h are consistent with that earlier finding.

(79472) 1998 AX4. Several apparent "mutual events", occultations and/or eclipses due to a satellite, were observed. The effect of these were subtracted from the data using the dual period search in MPO Canopus, which found a period for the primary of 2.8802 ± 0.0002 h. The orbital period of the, presumably, tidally-locked satellite, was found to be 25.95 ± 0.02 h. The depths of the events were about equal, $A \sim 0.12$ mag. This gives the size ratio Ds/Dp ~ 0.32 ± 0.03.

(88259) 2001 HJ7. Pravec *et al.* (2010) found a period of 4.166 h. The best fit of the PDO data give 4.175 h, although they can be forced to the shorter period with only a very slight increase in the RMS value.

2011 WV134, 2012 AA11, and 2012 DO. These are near-Earth asteroids that were observed to help build the rotational statistics for this group of asteroids and for potential support of radar observations.

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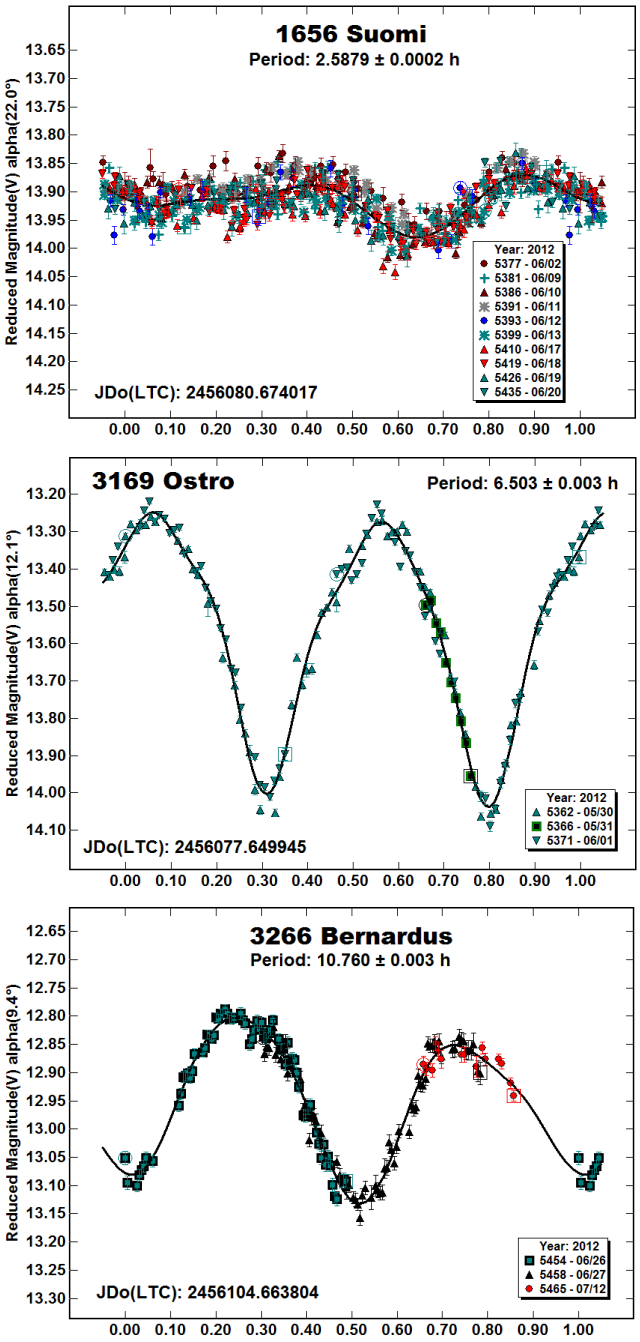
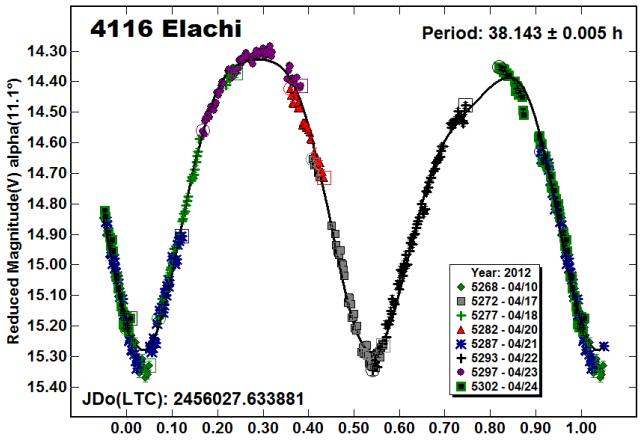
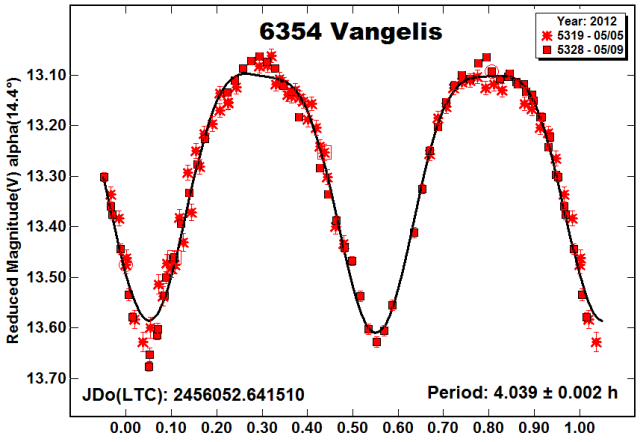
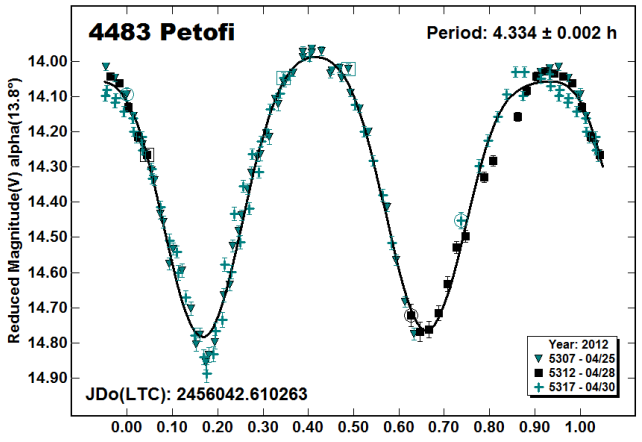
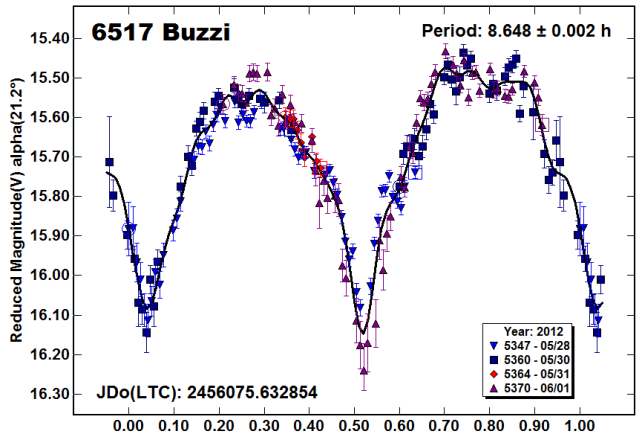
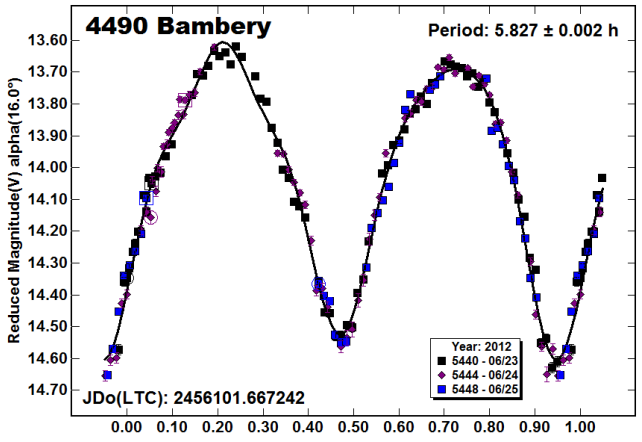


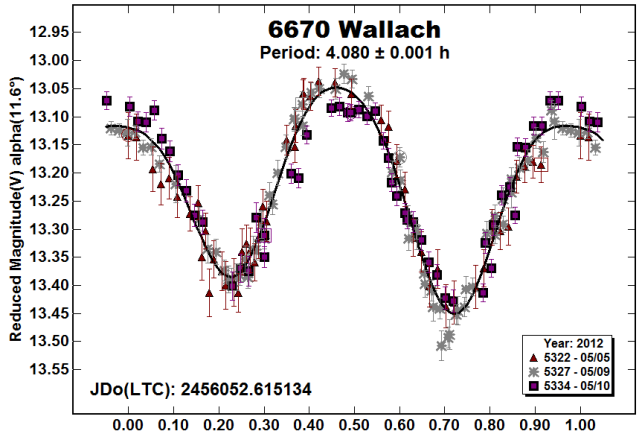

4116 Elachi
Period: 38.143 ± 0.005 h
Reduced Magnitude(V) alpha(11.1°)
Year: 2012
5268 - 04/10
5272 - 04/17
5277 - 04/18
5282 - 04/20
5287 - 04/21
5293 - 04/22
5297 - 04/23
5302 - 04/24
JDo(LTC): 2456027.633881

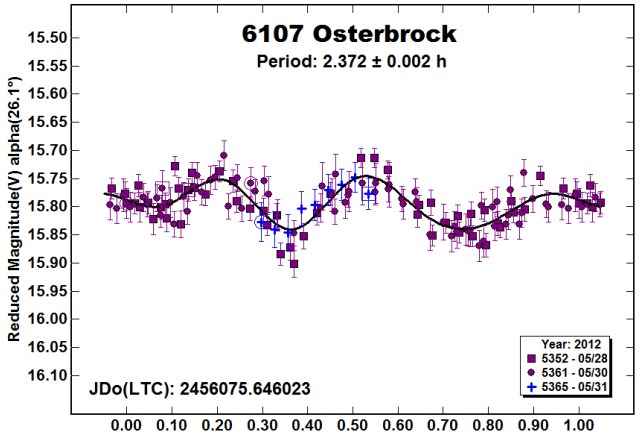

6354 Vangelis
Year: 2012
5319 - 05/05
5328 - 05/09
Reduced Magnitude(V) alpha(14.4°)
JDo(LTC): 2456052.641510
Period: 4.039 ± 0.002 h

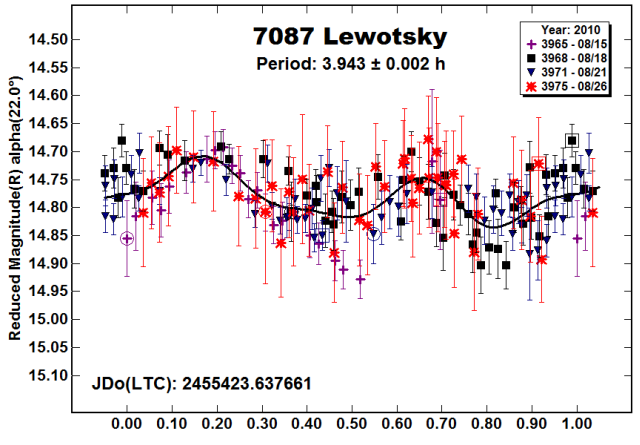

4483 Petofi
Period: 4.334 ± 0.002 h
Reduced Magnitude(V) alpha(13.8°)
Year: 2012
5307 - 04/25
5312 - 04/28
5317 - 04/30
JDo(LTC): 2456042.610263

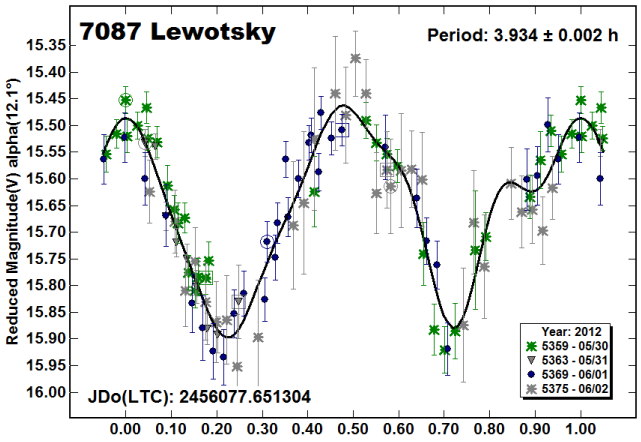

6517 Buzzi
Period: 8.648 ± 0.002 h
Reduced Magnitude(V) alpha(21.2°)
Year: 2012
5347 - 05/28
5360 - 05/30
5364 - 05/31
5370 - 06/01
JDo(LTC): 2456075.632854

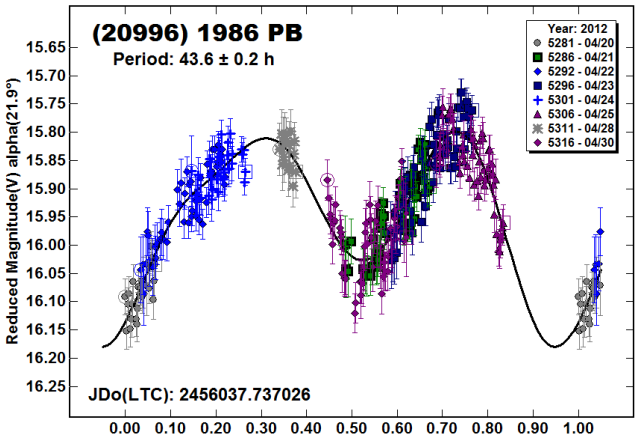

4490 Bambery
Period: 5.827 ± 0.002 h
Reduced Magnitude(V) alpha(16.0°)
Year: 2012
5440 - 06/23
5444 - 06/24
5448 - 06/25
JDo(LTC): 2456101.667242

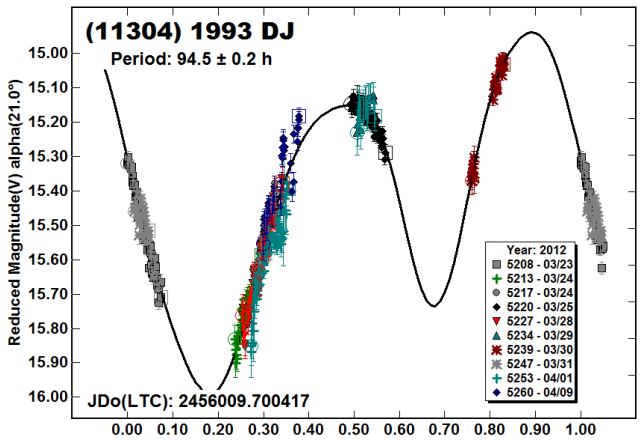

6670 Wallach
Period: 4.080 ± 0.001 h
Reduced Magnitude(V) alpha(11.6°)
Year: 2012
5322 - 05/05
5327 - 05/09
5334 - 05/10
JDo(LTC): 2456052.615134

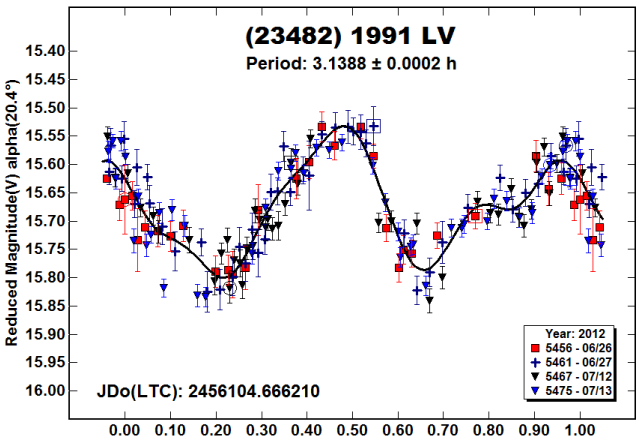

6107 Osterbrock
Period: 2.372 ± 0.002 h
Reduced Magnitude(V) alpha(26.1°)
Year: 2012
5352 - 05/28
5361 - 05/30
5365 - 05/31
JDo(LTC): 2456075.646023

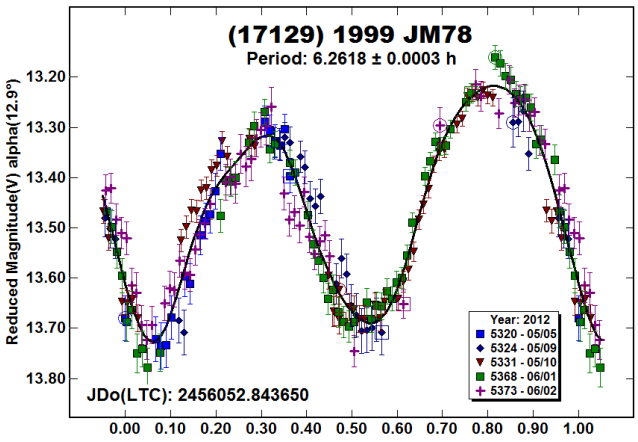

7087 Lewotsky
Period: 3.943 ± 0.002 h
Reduced Magnitude(R) alpha(22.0°)
Year: 2010
3965 - 08/15
3968 - 08/18
3971 - 08/21
3975 - 08/26
JDo(LTC): 2455423.637661

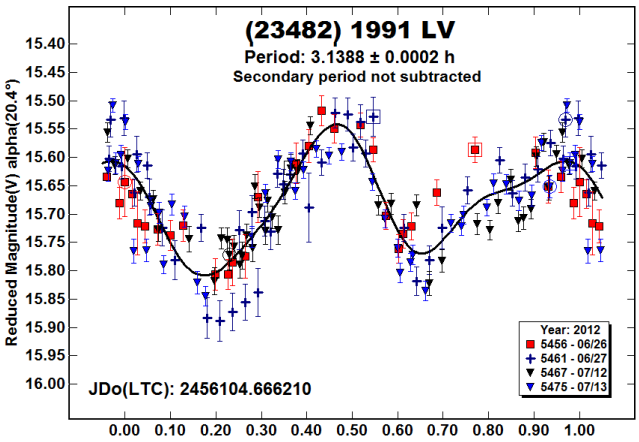

7087 Lewotsky
Period: 3.934 ± 0.002 h
Reduced Magnitude(V) alpha(12.1°)
JDo(LTC): 2456077.651304
Year: 2012
5359 - 05/30
5363 - 05/31
5369 - 06/01
5375 - 06/02

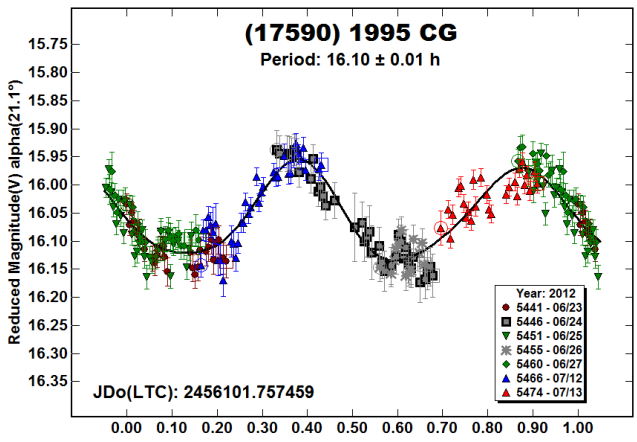

(20996) 1986 PB
Period: 43.6 ± 0.2 h
Reduced Magnitude(V) alpha(21.9°)
JDo(LTC): 2456037.737026
Year: 2012
5281 - 04/20
5286 - 04/21
5292 - 04/22
5296 - 04/23
5301 - 04/24
5306 - 04/25
5311 - 04/28
5316 - 04/30

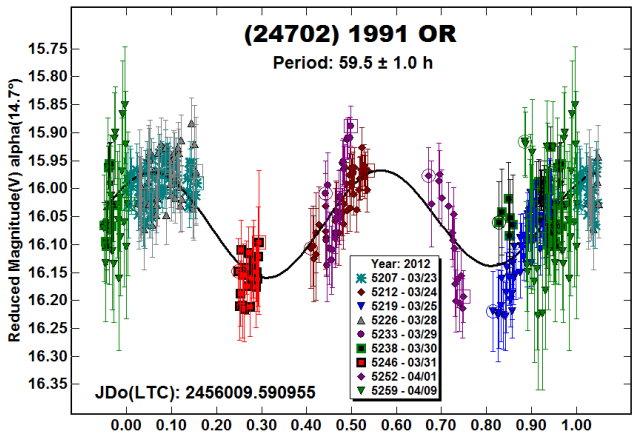

(11304) 1993 DJ
Period: 94.5 ± 0.2 h
Reduced Magnitude(V) alpha(21.0°)
JDo(LTC): 2456009.700417
Year: 2012
5208 - 03/23
5213 - 03/24
5217 - 03/24
5220 - 03/25
5227 - 03/28
5234 - 03/29
5239 - 03/30
5247 - 03/31
5253 - 04/01
5260 - 04/09

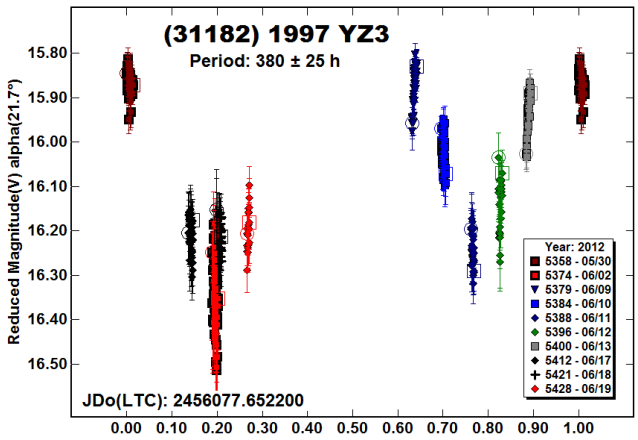

(23482) 1991 LV
Period: 3.1388 ± 0.0002 h
Reduced Magnitude(V) alpha(20.4°)
JDo(LTC): 2456104.666210
Year: 2012
5456 - 06/26
5461 - 06/27
5467 - 07/12
5475 - 07/13

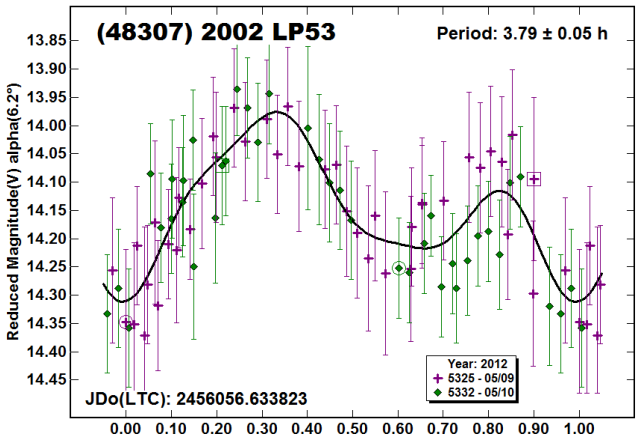

(17129) 1999 JM78
Period: 6.2618 ± 0.0003 h
Reduced Magnitude(V) alpha(12.9°)
JDo(LTC): 2456052.843650
Year: 2012
5320 - 05/05
5324 - 05/09
5331 - 05/10
5368 - 06/01
5373 - 06/02

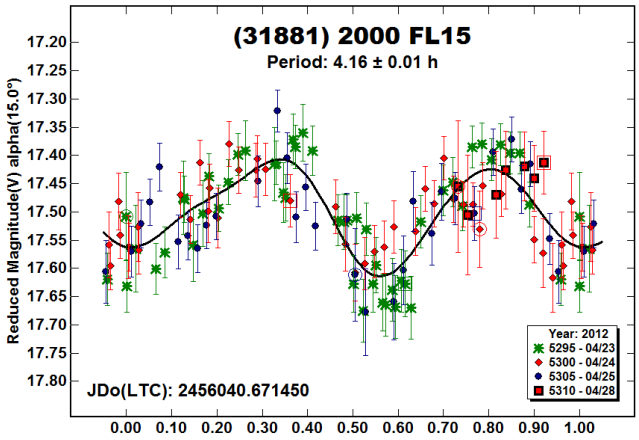

(23482) 1991 LV
Period: 3.1388 ± 0.0002 h
Secondary period not subtracted
Reduced Magnitude(V) alpha(20.4°)
JDo(LTC): 2456104.666210
Year: 2012
5456 - 06/26
5461 - 06/27
5467 - 07/12
5475 - 07/13

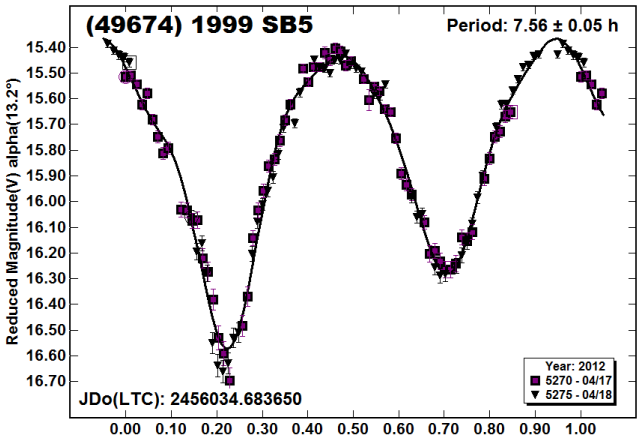

(17590) 1995 CG
Period: 16.10 ± 0.01 h
Reduced Magnitude(V) alpha(21.1°)
JDo(LTC): 2456101.757459
Year: 2012
5441 - 06/23
5446 - 06/24
5451 - 06/25
5455 - 06/26
5460 - 06/27
5466 - 07/12
5474 - 07/13

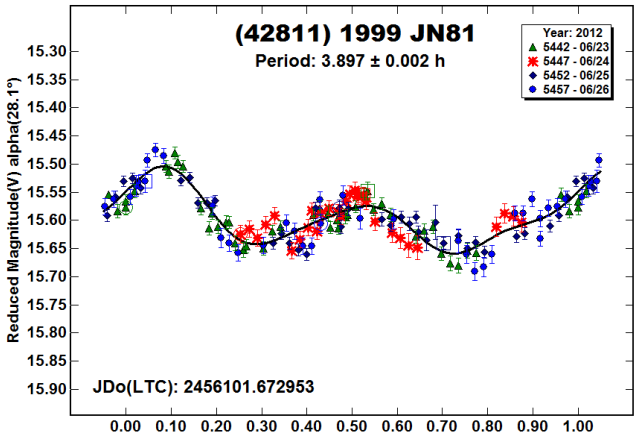

(24702) 1991 OR
Period: 59.5 ± 1.0 h
Reduced Magnitude(V) alpha(14.7°)
JDo(LTC): 2456009.590955
Year: 2012
5207 - 03/23
5212 - 03/24
5219 - 03/25
5226 - 03/28
5233 - 03/29
5238 - 03/30
5246 - 03/31
5252 - 04/01
5259 - 04/09

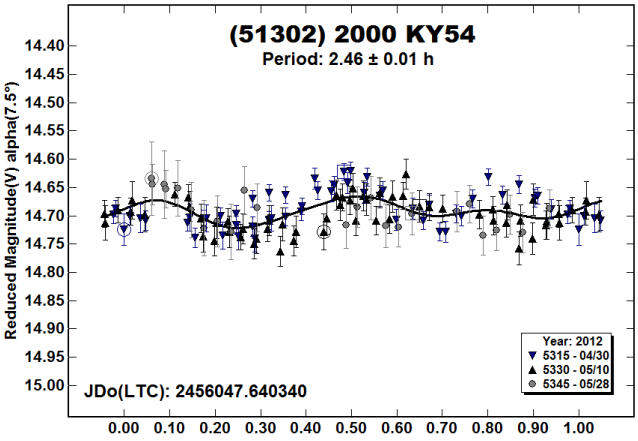

(31182) 1997 YZ3
Period: 380 ± 25 h
Reduced Magnitude(V) alpha(21.7°)
JDo(LTC): 2456077.652200
Year: 2012
5358 - 05/30
5374 - 06/02
5379 - 06/09
5384 - 06/10
5388 - 06/11
5396 - 06/12
5400 - 06/13
5412 - 06/17
5421 - 06/18
5428 - 06/19

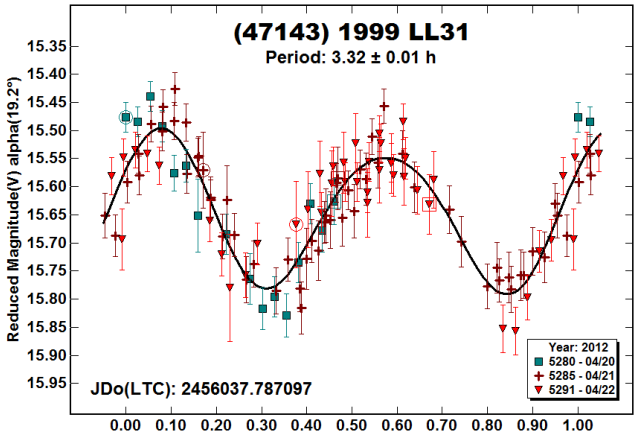

(48307) 2002 LP53
Period: 3.79 ± 0.05 h
Reduced Magnitude(V) alpha(6.2°)
JDo(LTC): 2456056.633823
Year: 2012
5325 - 05/09
5332 - 05/10

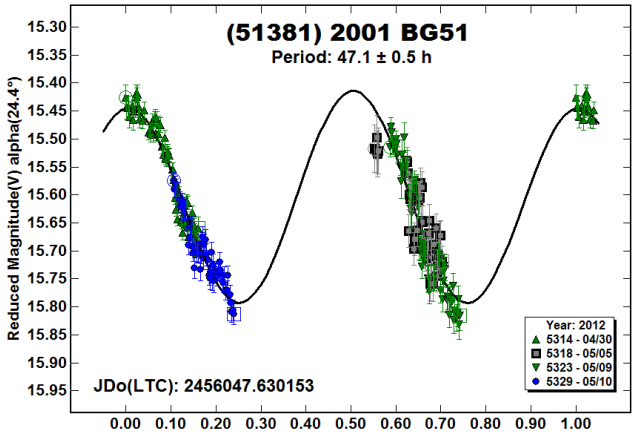

(31881) 2000 FL15
Period: 4.16 ± 0.01 h
Reduced Magnitude(V) alpha(15.0°)
JDo(LTC): 2456040.671450
Year: 2012
5295 - 04/23
5300 - 04/24
5305 - 04/25
5310 - 04/28

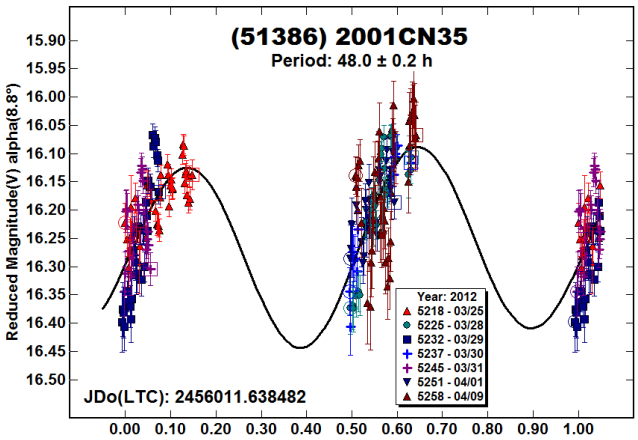

(49674) 1999 SB5
Period: 7.56 ± 0.05 h
Reduced Magnitude(V) alpha(13.2°)
JDo(LTC): 2456034.683650
Year: 2012
5270 - 04/17
5275 - 04/18

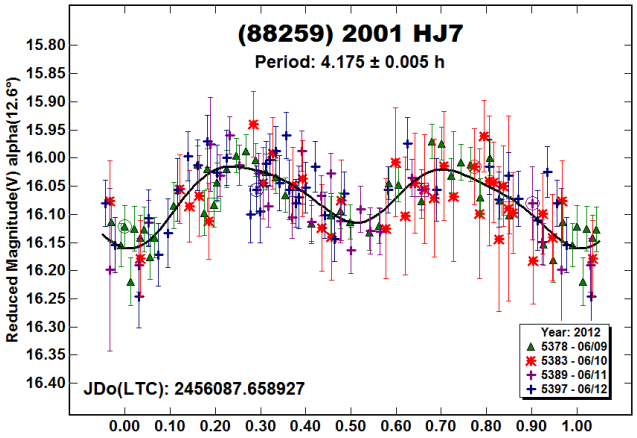

(42811) 1999 JN81
Period: 3.897 ± 0.002 h
Reduced Magnitude(V) alpha(28.1°)
JDo(LTC): 2456101.672953
Year: 2012
5442 - 06/23
5447 - 06/24
5452 - 06/25
5457 - 06/26

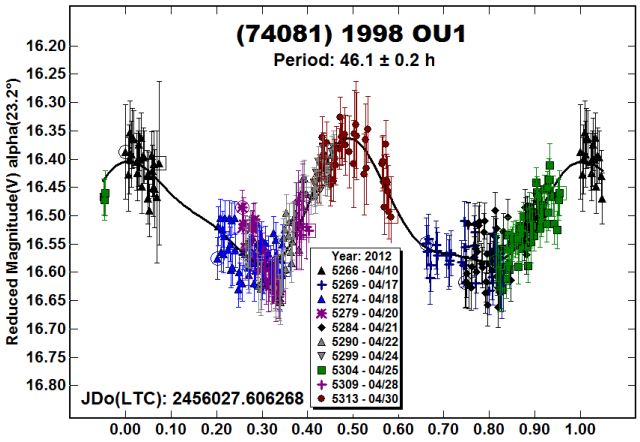

(51302) 2000 KY54
Period: 2.46 ± 0.01 h
Reduced Magnitude(V) alpha(7.5°)
JDo(LTC): 2456047.640340
Year: 2012
5315 - 04/30
5330 - 05/10
5345 - 05/28


(47143) 1999 LL31
Period: 3.32 ± 0.01 h
Reduced Magnitude(V) alpha(19.2°)
JDo(LTC): 2456037.787097
Year: 2012
5280 - 04/20
5285 - 04/21
5291 - 04/22


(51381) 2001 BG51
Period: 47.1 ± 0.5 h
Reduced Magnitude(V) alpha(24.4°)
JDo(LTC): 2456047.630153
Year: 2012
5314 - 04/30
5318 - 05/05
5323 - 05/09
5329 - 05/10


(51386) 2001CN35
Period: 48.0 ± 0.2 h
Reduced Magnitude(V) alpha(8.8°)
JDo(LTC): 2456011.638482
Year: 2012
5218 - 03/25
5225 - 03/28
5232 - 03/29
5237 - 03/30
5245 - 03/31
5251 - 04/01
5258 - 04/09


(88259) 2001 HJ7
Period: 4.175 ± 0.005 h
Reduced Magnitude(V) alpha(12.6°)
JDo(LTC): 2456087.658927
Year: 2012
5378 - 06/09
5383 - 06/10
5389 - 06/11
5397 - 06/12


(74081) 1998 OU1
Period: 46.1 ± 0.2 h
Reduced Magnitude(V) alpha(23.2°)
JDo(LTC): 2456027.606268
Year: 2012
5266 - 04/10
5269 - 04/17
5274 - 04/18
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5284 - 04/21
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5299 - 04/24
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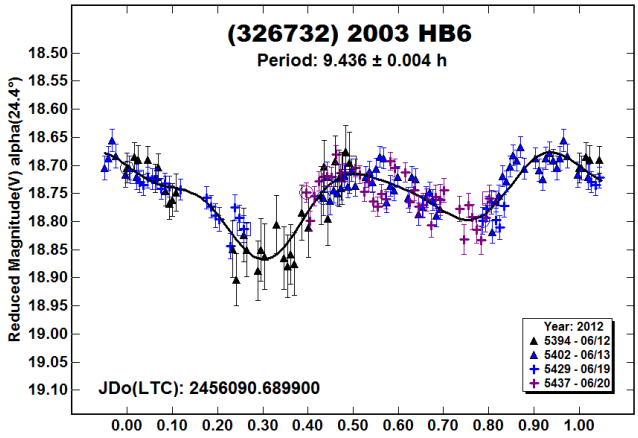
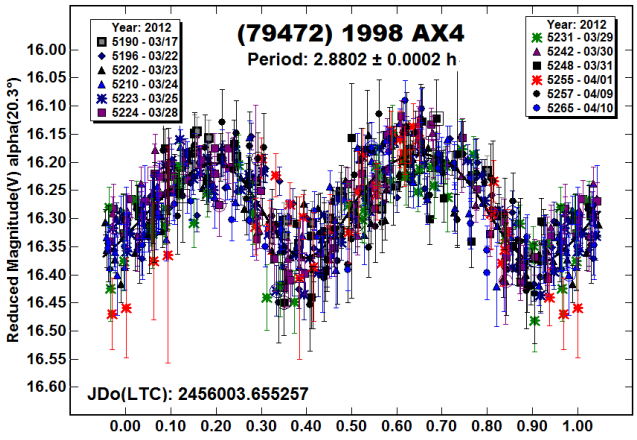
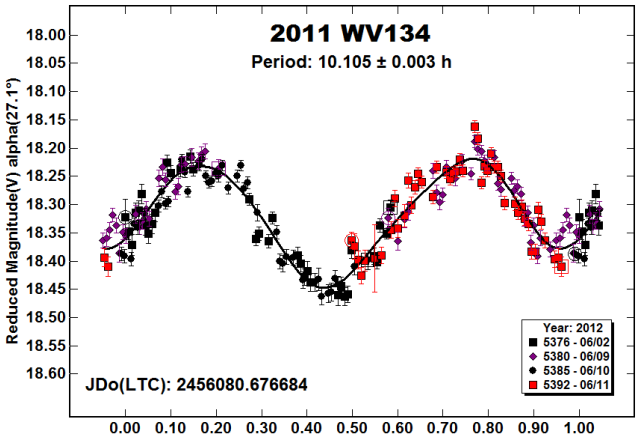
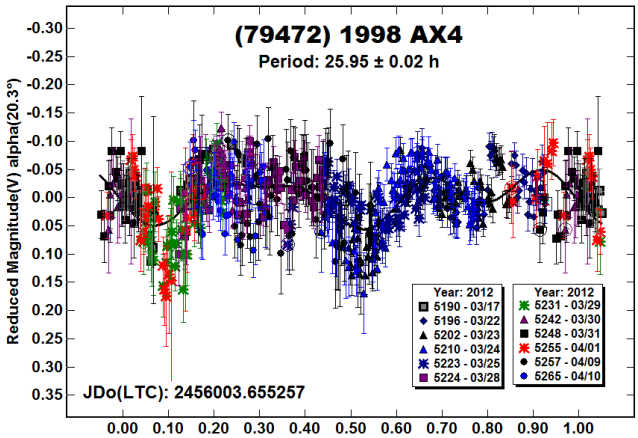
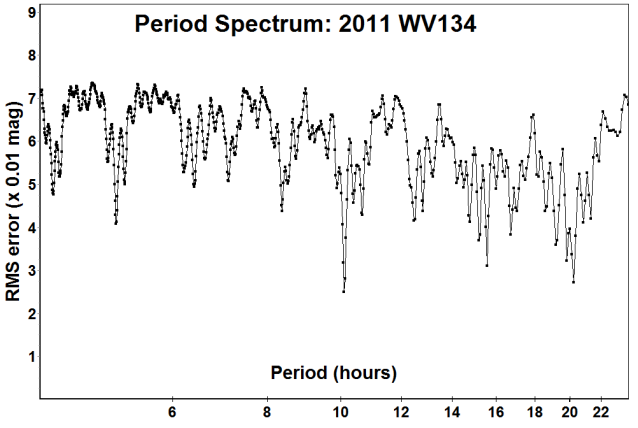
5313 - 04/30

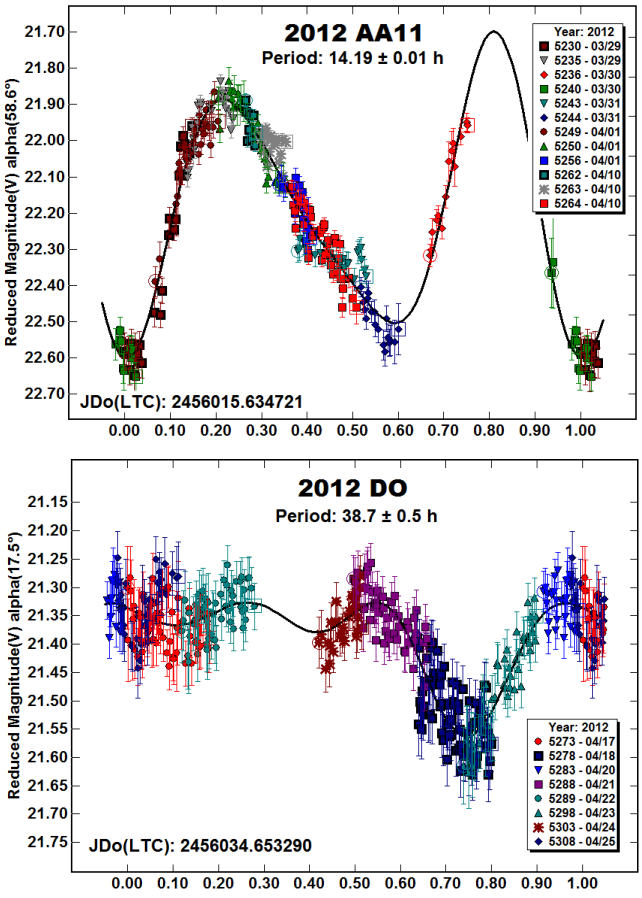

(326732) 2003 HB6
Period: 9.436 ± 0.004 h
Reduced Magnitude(V) alpha(24.4°)
JDo(LTC): 2456090.689900
Year: 2012
5394 - 06/12
5402 - 06/13
5429 - 06/19
5437 - 06/20


(79472) 1998 AX4
Period: 2.8802 ± 0.0002 h
Reduced Magnitude(V) alpha(20.3°)
JDo(LTC): 2456003.655257
Year: 2012
5190 - 03/17
5196 - 03/22
5202 - 03/23
5210 - 03/24
5223 - 03/25
5224 - 03/28
Year: 2012
5231 - 03/29
5242 - 03/30
5248 - 03/31
5255 - 04/01
5257 - 04/09
5265 - 04/10


2011 WV134
Period: 10.105 ± 0.003 h
Reduced Magnitude(V) alpha(27.1°)
JDo(LTC): 2456080.676684
Year: 2012
5376 - 06/02
5380 - 06/09
5385 - 06/10
5392 - 06/11


(79472) 1998 AX4
Period: 25.95 ± 0.02 h
Reduced Magnitude(V) alpha(20.3°)
JDo(LTC): 2456003.655257
Year: 2012
5190 - 03/17
5196 - 03/22
5202 - 03/23
5210 - 03/24
5223 - 03/25
5224 - 03/28
Year: 2012
5231 - 03/29
5242 - 03/30
5248 - 03/31
5255 - 04/01
5257 - 04/09
5265 - 04/10


Period Spectrum: 2011 WV134
RMS error (x 0.01 mag)
Period (hours)




## LIGHTCURVE FOR NEA 2012 LZ1

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(Received: 6 July)

Analysis of CCD photometric observations of the near-Earth asteroid 2012 LZ1 during a flyby in 2012 June found a synodic rotation period of 12.87 ± 0.01 h and amplitude A = 0.28 ± 0.03 mag. The data are being used to supplement analysis of radar and other optical observations obtained at the time.

The near-Earth asteroid 2012 LZ1 was discovered on 2012 June 11 by Rob McNaught at Siding Spring Observatory in Australia. Three days later, it made its closest approach to Earth (about 5.4 million km; roughly 14 times the lunar distance). Sky motion at that time was too extreme for useful photometry. The authors waited until June 16 to begin photometric observations to determine the rotation period of the asteroid. This information would supplement radar and other optical observations to determine physical characteristics of the asteroid. Table I gives basic observer and equipment information

| Observer | Observatory | Equipment |
|---|---|---|
| Warner | Palmer Divide | 0.35-m SCT, STL-1001E |
| Sherrod | Arkansas Sky | 0.51-m DK, ST-2000 XM |
| Bacci/Franco | San Marcello | 0.60-m Newt, Alta U6 |
| Pollock | PROMPT | 0.46-m SCT, Alta U47 |

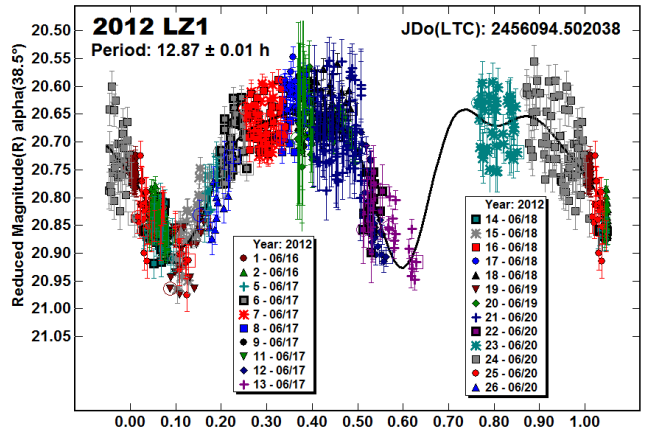
Table I. List of observers and equipment.

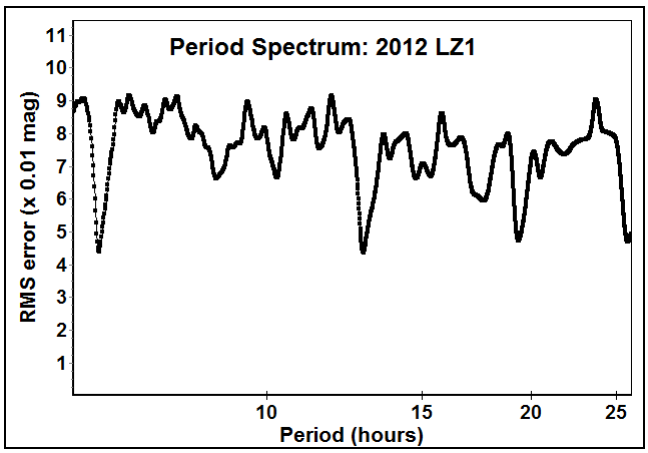
All images were unfiltered. The data from the several nights at Palmer Divide were put onto an internal standard system using V magnitudes derived from the 2MASS catalog (Skrutskie *et al.*,

2006; see Warner, 2007; Stephens, 2008). The remaining data were adjusted by moving zero points to provide the best RMS fit.

Warner used *MPO Canopus* to combine the data and do period analysis. The initial observations from the first night at Palmer Divide (June 17) indicated a very short period, on the order of 30 minutes. The same was determined from the first night of data from the PROMPT telescope. However, radar data analysis (Ellen Howell, private communications) indicated a much longer period, on the order of 10 hours. The images from Palmer Divide were re-measured, changing only to brighter comparison stars, to see if the revised data would produce different results. They did. The analysis of the combined data set found a period of 12.87 ± 0.01 h, consistent with the radar data analysis, with amplitude $A$ = 0.28 ± 0.03 mag.

The period spectrum shows that the solution is unambiguous. A plot using for the solution near 20 hours shows a complex curve with four maximums, which is highly unlikely.




Getting Fooled

The initial finding of a very short period from the first night of data demonstrates several important points. First, such provocative results need careful analysis and strong confirmation. Second, "never trust a computer." Just because the Fourier analysis found such a period does not mean that it's a valid solution. Harris *et al.* (2012) used data from two wide field surveys to show how the analysis can "latch onto" random noise and give false positives. If the amplitude of the lightcurve is low, as the initial data seemed to show, then it is much easier to be fooled into accepting an incorrect result. This example, and those in the Harris *et al.* paper, should serve as cautionary tales for all those doing lightcurve period analysis.

Acknowledgements

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## LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2012 OCTOBER-DECEMBER

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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 four lists of "targets of opportunity" for the period 2012 October-December. 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, "U" is the quality code of the lightcurve, and "α" is the solar phase angle. 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 < 14.5 at brightest during the period and have either no or poorly-constrained lightcurve parameters. A '(F)' after the name indicates that the asteroid is reaching one of its five brightest apparitions between the years 1995-2050.

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 ≤ 17.5 during any month in the current year, e.g., limiting the results by magnitude and declination.

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

In a general note, small objects with periods up to 4 hours or even longer are possible binaries. The odds 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. 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 |
|---|---|---|---|---|---|---|---|
| 1007 | Pawlowia (F) | 10 01.4 | 14.0 | +7 | 8.23 | 0.02 | 1 |
| 973 | Aralia | 10 01.6 | 14.2 | +11 | 7.29 | 0.25 | 2 |
| 673 | Edda | 10 02.2 | 13.9 | +6 | 14.92 | 0.12 | 2 |
| 537 | Pauly | 10 04.1 | 12.4 | -8 | 14.15 | 0.15-0.20 | 2+ |
| 876 | Scott | 10 04.4 | 14.5 | -6 | > 14. | 0.3 | 1 |
| 231 | Vindobona | 10 06.9 | 13.3 | +8 | 14.244 | 0.20-0.29 | 2+ |
| 2763 | Jeans | 10 07.3 | 13.8 | +12 | | | |
| 3385 | Bronnina | 10 07.3 | 14.5 | +6 | 2.996 | 0.25 | 2+ |
| 786 | Bredichina | 10 07.7 | 13.9 | -12 | 18.61 | 0.60 | 2+ |
| 960 | Birgit | 10 08.2 | 14.4 | +11 | 17.3558 | 0.25 | 1+ |
| 1604 | Tombaugh | 10 08.9 | 14.2 | +19 | 7.047 | 0.16-0.20 | 2+ |
| 597 | Bandusia (F) | 10 09.1 | 11.9 | -1 | 11.5 | 0.11 | 2 |
| 932 | Hooveria (F) | 10 12.9 | 12.3 | +9 | 39.1 | 0.22 | 2+ |
| 2890 | Vilyujsk (F) | 10 16.9 | 14.4 | +15 | 3.45 | 0.08 | 2 |
| 3478 | Fanale (F) | 10 17.0 | 13.9 | +2 | | | |
| 460 | Scania (F) | 10 17.3 | 13.4 | +10 | 9.56 | 0.05 | 2 |
| 279 | Thule | 10 18.5 | 14.4 | +8 | 15.962 | 0.04-0.10 | 2+ |
| 1051 | Merope | 10 19.2 | 14.5 | -4 | 27.2 | 0.20 | 2 |
| 1578 | Kirkwood | 10 20.7 | 14.5 | +10 | 17.9 | 0.22 | 2 |
| 863 | Benkoela | 10 22.5 | 14.2 | -22 | 7.03 | 0.05 | 2+ |
| 999 | Zachia (F) | 10 23.0 | 12.9 | +13 | 22.77 | 0.3 | 2 |
| 1137 | Raissa (F) | 10 23.2 | 13.0 | +6 | 37. | 0.34 | 1 |
| 903 | Nealley | 10 23.7 | 14.4 | -1 | 21.6 | 0.15 | 2 |
| 1694 | Kaiser (F) | 10 23.7 | 12.6 | +20 | 13.23 | 0.13-0.25 | 2+ |
| 1086 | Nata | 10 24.3 | 14.1 | +23 | 18.074 | 0.17 | 2 |
| 684 | Hildburg | 10 24.7 | 13.9 | +19 | 11.92 | 0.23 | 2 |
| 1264 | Letaba | 10 29.4 | 14.0 | +26 | 32.16 | 0.13 | 1 |
| 6991 | Chichibu | 10 29.8 | 14.5 | +3 | | | |
| 1056 | Azalea | 10 31.9 | 13.8 | +6 | 11.893 | 0.07-0.79 | 2+ |
| 5234 | Sechenov (F) | 11 01.6 | 14.5 | +20 | 12.067 | 0.22 | 1 |
| 562 | Salome | 11 04.9 | 13.9 | +8 | 6.3501 | 0.21-0.37 | 2 |
| 717 | Wisibada | 11 07.0 | 13.9 | +19 | | | |
| 748 | Simeisa | 11 12.1 | 13.5 | +20 | 11.919 | 0.22-0.36 | 2 |
| 897 | Lysistrata | 11 12.2 | 14.0 | +28 | 11.26 | 0.11 | 2 |
| 464 | Megaira | 11 12.4 | 12.5 | +5 | 12.726 | 0.08 | 2 |
| 1390 | Abastumani | 11 15.1 | 14.2 | +30 | 17.1 | 0.15 | 2 |
| 1135 | Colchis | 11 18.7 | 13.5 | +26 | 23.47 | 0.45 | 2 |
| 487 | Venetia (F) | 11 19.6 | 11.3 | +6 | 13.28 | 0.03-0.30 | 2 |
| 850 | Altona | 11 21.4 | 14.5 | +1 | 11.197 | 0.12 | 2 |
| 273 | Atropos | 11 21.6 | 14.3 | -10 | 23.928 | 0.60-0.65 | 2 |
| 4352 | Kyoto (F) | 11 21.6 | 13.9 | +17 | | | |
| 882 | Swetlana (F) | 11 21.8 | 13.4 | +23 | > 20. | 0.17 | 2- |
| 1064 | Aethusa | 11 23.0 | 14.2 | +30 | 8.621 | 0.18 | 2 |
| 783 | Nora | 11 23.3 | 14.5 | +6 | 34.4 | 0.08- 0.2 | 2 |
| 538 | Friederike | 11 23.9 | 13.3 | +11 | 27. | 0.12 | 1 |
| 738 | Alagasta | 11 26.4 | 14.3 | +16 | 17.83 | 0.20 | 2 |
| 227 | Philosophia | 11 26.8 | 14.5 | +33 | 18.048 | 0.06-0.20 | 2 |
| 4369 | Seifert | 11 27.3 | 14.3 | +39 | 30.3 | 0.28 | 2 |
| 964 | Subamara | 11 29.2 | 14.3 | +30 | 6.864 | 0.11 | 2 |
| 1066 | Lobelia | 11 29.7 | 14.5 | +31 | | | |
| 858 | El Djezair | 11 30.0 | 14.4 | +22 | 22.31 | 0.1 | 2 |
| 1549 | Mikko (F) | 11 30.6 | 14.2 | +19 | 11.49 | 0.03 | 1+ |
| 1605 | Milankovitch | 12 02.1 | 14.1 | +6 | 11.6 | 0.12 | 2 |
| 1166 | Sakuntala | 12 02.2 | 14.3 | +5 | 6.3 | 0.40 | 2 |
| 396 | Aeolia | 12 02.8 | 14.1 | +22 | 22.2 | 0.30 | 2- |
| 2052 | Tamriko | 12 04.4 | 14.2 | +13 | 7.462 | 0.11 | 2 |
| 845 | Naema | 12 07.5 | 14.3 | +33 | 20.892 | 0.16 | 2 |
| 1052 | Belgica (F) | 12 07.7 | 13.6 | +19 | | | |
| 891 | Gunhild | 12 09.2 | 13.7 | +13 | 7.93 | 0.18 | 2 |
| 906 | Repsolda | 12 09.3 | 13.4 | +34 | 15.36 | 0.20 | 2 |
| 644 | Cosima | 12 09.6 | 13.7 | +22 | 15.13 | 0.16 | 1 |
| 1197 | Rhodesia | 12 15.0 | 13.6 | +21 | 16.062 | 0.22-0.32 | 2 |
| 521 | Brixia (F) | 12 15.5 | 10.2 | +21 | 9.78 | 0.11 | 2- |
| 308 | Polyxo | 12 15.7 | 12.0 | +17 | 12.032 | 0.08-0.15 | 2+ |
| 392 | Wilhelmina | 12 25.3 | 13.6 | +3 | 17.96 | 0.04-0.70 | 2 |
| 987 | Wallia | 12 25.6 | 14.2 | +33 | 10.082 | 0.16-0.36 | 2 |
| 2034 | Bernoulli | 12 25.7 | 14.0 | +41 | | | |
| 1016 | Anitra | 12 26.1 | 13.8 | +35 | 5.93 | 0.30-0.50 | 2 |

Low Phase Angle Opportunities

| # | Name | Date | α | V | Dec | Period | Amp | U |
|---|---|---|---|---|---|---|---|---|
| 35 | Leukothea | 09 04.0 | 0.72 | 13.1 | -09 | 31.900 | 0.07-0.43 | 3 |
| 1346 | Gotha | 09 06.1 | 0.44 | 14.0 | -05 | 11.19 | 0.12 | 2 |
| 76 | Freia | 09 06.4 | 0.55 | 12.8 | -04 | 9.969 | 0.10-0.33 | 3 |
| 277 | Elvira | 09 08.3 | 0.65 | 13.1 | -04 | 29.69 | 0.34-0.59 | 3 |
| 601 | Nerthus | 09 09.6 | 0.44 | 13.3 | -04 | 13.59 | 0.29 | 3 |
| | 2010 GT12 | 09 10.8 | 0.20 | 7.0 | -04 | | | |
| 1332 | Marconia | 09 15.7 | 0.53 | 13.6 | -04 | | | |
| 658 | Asteria | 09 20.5 | 0.19 | 14.0 | -01 | 21.034 | 0.22-0.32 | 3 |
| 236 | Honoria | 09 20.8 | 0.86 | 10.7 | +01 | 12.333 | 0.05-0.18 | 3 |
| 313 | Chaldaea | 09 22.0 | 0.32 | 12.1 | -01 | 8.392 | 0.08-0.24 | 3 |
| 492 | Gismonda | 10 01.9 | 0.61 | 13.1 | +02 | 6.488 | 0.10 | 3 |
| 673 | Edda | 10 02.2 | 0.97 | 13.9 | +06 | 14.92 | 0.12 | 2 |
| 359 | Georgia | 10 03.3 | 0.37 | 11.4 | +05 | 5.537 | 0.15-0.54 | 3 |
| 1542 | Schalen | 10 04.0 | 0.57 | 13.9 | +06 | | | |
| 60 | Echo | 10 06.0 | 0.07 | 10.6 | +05 | 25.208 | 0.07-0.22 | 3 |
| 231 | Vindobona | 10 07.1 | 0.98 | 13.3 | +08 | 14.244 | 0.29 | 2+ |
| 85 | Io | 10 11.5 | 0.85 | 10.1 | +09 | 6.875 | 0.05-0.17 | 3 |
| 222 | Lucia | 10 12.7 | 0.81 | 13.7 | +05 | 7.80 | 0.25-0.33 | 3 |
| 932 | Hooveria | 10 12.8 | 0.53 | 12.4 | +09 | 39.1 | 0.22 | 2+ |
| 834 | Burnhamia | 10 15.8 | 0.57 | 13.9 | +07 | 13.875 | 0.15-0.22 | 3 |
| 460 | Scania | 10 17.3 | 0.17 | 13.4 | +10 | 9.56 | 0.05 | 2 |
| 32 | Pomona | 10 20.5 | 0.71 | 11.2 | +12 | 9.448 | 0.13-0.30 | 3 |
| 518 | Halawe | 10 21.0 | 0.35 | 13.3 | +10 | | | |
| 999 | Zachia | 10 23.1 | 0.77 | 13.3 | +13 | 22.77 | 0.3 | 2 |
| 73 | Klytia | 10 30.3 | 0.76 | 12.1 | +16 | 8.297 | 0.26-0.35 | 3 |
| 178 | Belisana | 10 30.6 | 0.32 | 12.4 | +13 | 12.323 | 0.12-0.26 | 3 |
| 499 | Venusia | 11 05.1 | 0.51 | 13.8 | +17 | 13.48 | 0.33 | 3 |
| 717 | Wisibada | 11 07.2 | 0.99 | 14.0 | +19 | | | |
| 91 | Aegina | 11 08.9 | 0.90 | 11.5 | +19 | 6.025 | 0.15 | 3 |
| 208 | Lacrimosa | 11 11.1 | 0.64 | 12.8 | +19 | 14.085 | 0.15-0.33 | 3 |
| 748 | Simeisa | 11 12.0 | 0.56 | 13.5 | +20 | 11.88 | 0.22 | 2 |
| 663 | Gerlinde | 11 19.7 | 0.65 | 13.7 | +18 | 10.251 | 0.19-0.35 | 3 |
| 184 | Dejopeja | 11 22.5 | 0.50 | 12.8 | +22 | 6.455 | 0.25-0.3 | 3 |
| 90 | Antiope | 11 27.8 | 0.11 | 12.7 | +21 | 16.509 | 0.08-0.90 | 3 |
| 3322 | Lidiya | 12 01.2 | 0.77 | 14.0 | +23 | | | |
| 24 | Themis | 12 02.0 | 0.21 | 11.0 | +23 | 8.374 | 0.09-0.14 | 3 |
| 352 | Gisela | 12 02.8 | 0.25 | 11.4 | +22 | 7.490 | 0.31-0.58 | 3 |
| 122 | Gerda | 12 04.5 | 0.71 | 12.2 | +20 | 10.685 | 0.11-0.26 | 3 |
| 197 | Arete | 12 09.5 | 0.35 | 12.8 | +22 | 6.6084 | 0.10-0.15 | 3 |
| 644 | Cosima | 12 09.6 | 0.42 | 13.7 | +22 | 15.13 | 0.16 | 1 |
| 1197 | Rhodesia | 12 14.8 | 0.95 | 13.6 | +21 | 16.062 | 0.22-0.32 | 2 |
| 43 | Ariadne | 12 17.0 | 0.03 | 11.0 | +23 | 5.762 | 0.08-0.66 | 3 |
| 1 | Ceres | 12 18.3 | 0.69 | 6.7 | +25 | 9.074170 | 0.02-0.06 | 3 |
| 21 | Lutetia | 12 23.1 | 0.35 | 10.5 | +24 | 8.1655 | 0.06-0.25 | 3 |
| 972 | Cohnia | 12 23.5 | 0.81 | 13.0 | +26 | 18.472 | 0.20-0.30 | 3 |
| 486 | Cremona | 12 27.0 | 0.17 | 13.7 | +24 | 65.15 | 0.80-1.00 | 3- |

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

| # | Name | Brightest Date | Mag | Dec | LCDB DATA Period | Amp | U |
|---|---|---|---|---|---|---|---|
| 51 | Nemausa | 09 02.2 | 10.4 | -04 | 7.783 | 0.10-0.25 | 3 |
| 76 | Freia | 09 06.5 | 12.7 | -04 | 9.969 | 0.10-0.33 | 3 |
| 638 | Moira | 09 17.0 | 14.0 | -12 | 9.875 | 0.31 | 3 |
| 366 | Vincentina | 09 20.7 | 12.6 | +02 | 15.5 | 0.08 | 1 |
| 522 | Helga | 09 29.1 | 13.6 | -03 | 8.129 | 0.17-0.30 | 3 |
| 120 | Lachesis | 10 16.9 | 12.3 | +16 | 46.551 | 0.14-0.22 | 3 |
| 381 | Myrrha | 10 26.8 | 13.2 | -04 | 6.572 | 0.36 | 3 |
| 704 | Interamnia | 11 14.9 | 9.8 | +38 | 8.727 | 0.03-0.11 | 3 |
| 914 | Palisana | 11 18.5 | 12.1 | +33 | 15.922 | 0.04-0.18 | 3 |
| 154 | Bertha | 12 14.3 | 12.4 | +45 | 22.30 | 0.04-0.20 | 2 |
| 308 | Polyxo | 12 15.7 | 12.0 | +17 | 12.032 | 0.08-0.15 | 2+ |
| 105 | Artemis | 12 31. | 12.8 | -13 | 37.15506 | 0.09-0.17 | 3 |
| 976 | Benjamina | 12 31. | 14.2 | +05 | 9.746 | 0.18 | 3- |
| 102 | Miriam | 12 31. | 13.3 | +12 | 23.613 | 0.04-0.14 | 3 |

Inversion Modeling Candidates

| # | Name | Brightest Date | Mag | Dec | LCDB Data Period | Amp | U |
|---|---|---|---|---|---|---|---|
| 770 | Bali | 09 04.5 | 13.1 | -14 | 5.9513 | 0.40-0.55 | 3 |
| 484 | Pittsburghia | 09 05.2 | 13.2 | -18 | 10.63 | 0.37 | 3 |
| 277 | Elvira | 09 08.3 | 13.1 | -04 | 29.69 | 0.34-0.59 | 3 |
| 601 | Nerthus | 09 09.6 | 13.3 | -04 | 13.59 | 0.29 | 3 |
| 1368 | Numidia | 09 11.8 | 14.1 | -16 | 3.64 | 0.35 | 3 |
| 787 | Moskva | 09 17.5 | 12.4 | +02 | 6.056 | 0.47-0.60 | 3 |
| 313 | Chaldaea | 09 22.0 | 12.1 | -01 | 8.392 | 0.08-0.24 | 3 |
| 733 | Mocia | 09 28.6 | 14.2 | +14 | 11.374 | 0.29 | 3 |
| 567 | Eleutheria | 09 28.7 | 14.0 | -07 | 7.71 | 0.26-0.50 | 3 |
| 2111 | Tselina | 10 09.5 | 14.1 | -01 | 6.563 | 0.17 | 3 |
| 226 | Weringia | 10 10.2 | 13.6 | -13 | 11.240 | 0.08-0.15 | 3- |
| 2332 | Kalm | 10 11.6 | 14.9 | -07 | 22.8 | 0.39 | 2 |
| 292 | Ludovica | 10 15.2 | 12.6 | +00 | 8.93 | 0.45 | 3 |
| 1245 | Calvinia | 10 16.4 | 13.3 | +06 | 4.84 | 0.37-0.63 | 3 |
| 550 | Senta | 10 23.6 | 12.3 | +26 | 20.555 | 0.3 | 3 |
| 692 | Hippodamia | 10 27.0 | 14.0 | -08 | 8.98 | 0.50 | 3 |
| 889 | Erynia | 10 27.5 | 13.0 | -02 | 9.89 | 0.67 | 3 |
| 312 | Pierretta | 10 28.6 | 13.0 | +20 | 10.282 | 0.32 | 3 |
| 502 | Sigune | 11 03.0 | 14.6 | -24 | 10.922 | 0.35-0.44 | 3 |
| 1002 | Olbersia | 11 06.2 | 14.6 | +31 | 10.244 | 0.38 | 3 |
| 782 | Montefiore | 11 17.4 | 13.8 | +15 | 4.08 | 0.43 | 3 |
| 809 | Lundia | 11 23.8 | 14.0 | +08 | 15.4142 | 0.18-1.12 | 3 |
| 1088 | Mitaka | 11 26.9 | 12.7 | +24 | 3.049 | 0.23-0.40 | 3 |
| 486 | Cremona | 12 27.1 | 13.6 | +24 | 65.15 | 0.80-1.00 | 3- |
| 934 | Thuringia | 12 31. | 13.5 | +40 | 8.166 | 0.52-0.66 | 3 |
| 299 | Thora | 12 31. | 14.1 | +21 | | | |
| 351 | Yrsa | 12 31. | 12.8 | +18 | 13.29 | 0.42 | 3 |
| 1350 | Rosselia | 12 31. | 14.6 | +20 | 8.140 | 0.53 | 3 |
| 187 | Lamberta | 12 31. | 12.3 | +31 | 10.670 | 0.23-0.32 | 3 |

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.

Some of the objects below are repeats from the previous issue of the *Minor Planet Bulletin* and those with opportunities extending into the next quarter may be featured again in the next issue of the MPB.

**1620 Geographos (2012 Sep-Nov, H = 16.8, PHA)**
The rotation period (5.22 h) and shape for this famous NEA are well-established. A good reason for observing this and any NEA under such circumstances is to build a data set that can be used to determine if the asteroid's spin rate is being changed by the YORP effect. This thermal process can cause an asteroid's spin rate to increase or decrease slowly, but perceptibly, over time. The strength of the YORP is dependent on many factors, but chief among them is distance from the Sun. Therefore, NEAs are the best candidates for checking on YORP. That all said, Durech *et al.* (2008, *Astron. Astrophys.* **489**, L25) have detected YORP spin-up for Geographos (0.0027 s/year!). However, more data can be used to confirm and/or refine those findings.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 09/10 | 15 46.8 | -28 04 | 0.45 | 0.98 | 16.6 | 80.6 | 73 | 146 | -0.36 | +21 |
| 09/20 | 17 05.2 | -25 51 | 0.45 | 1.03 | 16.5 | 74.0 | 80 | 28 | +0.20 | +9 |
| 09/30 | 18 15.3 | -21 32 | 0.48 | 1.08 | 16.6 | 67.1 | 87 | 92 | +1.00 | -2 |
| 10/10 | 19 13.1 | -16 31 | 0.54 | 1.14 | 16.7 | 61.2 | 91 | 161 | -0.34 | -12 |
| 10/20 | 19 59.9 | -11 44 | 0.61 | 1.19 | 17.0 | 56.4 | 93 | 31 | +0.27 | -20 |
| 10/30 | 20 38.6 | -07 30 | 0.70 | 1.25 | 17.2 | 52.7 | 93 | 88 | -1.00 | -27 |
| 11/09 | 21 11.9 | -03 51 | 0.80 | 1.30 | 17.5 | 49.7 | 92 | 158 | -0.30 | -33 |
| 11/19 | 21 41.5 | -00 39 | 0.90 | 1.34 | 17.8 | 47.3 | 91 | 22 | +0.33 | -37 |

**(68216) 2001 CV26 (2012 Sep-Oct, H = 16.2, PHA)**
The rotation period for 2001 CV26 is about 2.4 h. This and its size make it a potential binary candidate so higher-precision observations are encouraged. The estimated size is 1.2 km, or the approximate average of the diameters found by the WISE (Mainzer *et al.*, $p_V = 0.27$) and AKARI (Usui *et al.*, $p_V = 0.41$) surveys.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 09/20 | 20 30.3 | -62 57 | 0.27 | 1.12 | 15.8 | 58.7 | 108 | 69 | +0.20 | -35 |
| 09/25 | 20 08.5 | -59 09 | 0.25 | 1.09 | 15.7 | 62.9 | 104 | 43 | +0.74 | -33 |
| 09/30 | 19 51.3 | -54 25 | 0.23 | 1.07 | 15.7 | 67.6 | 100 | 81 | +1.00 | -30 |
| 10/05 | 19 37.9 | -48 45 | 0.22 | 1.04 | 15.6 | 72.7 | 95 | 131 | -0.79 | -27 |
| 10/10 | 19 27.0 | -42 07 | 0.20 | 1.02 | 15.6 | 78.3 | 90 | 149 | -0.34 | -24 |
| 10/15 | 19 17.8 | -34 29 | 0.19 | 1.00 | 15.7 | 84.3 | 85 | 90 | +0.00 | -20 |
| 10/20 | 19 09.3 | -25 53 | 0.18 | 0.98 | 15.8 | 90.6 | 79 | 18 | +0.27 | -15 |
| 10/25 | 19 00.9 | -16 31 | 0.18 | 0.96 | 15.9 | 96.9 | 73 | 52 | +0.79 | -9 |

**(137032) 1998 UO1 (2012 Oct-Nov, H = 16.6)**
This NEA has an estimated diameter of 1.4 km. The rotation period has been given as from 2.9 to 4.4 h. The amplitude has tended to be small, $A < 0.15$ mag, which can make finding an unambiguous period more difficult. However, those previous attempts were at solar phases angles < 35°. The amplitude of a lightcurve increases with phase angle, so it's possible that the amplitude this time around will be larger and help with period analysis.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/05 | 17 17.0 | -08 09 | 0.15 | 0.95 | 16.2 | 103.5 | 68 | 161 | -0.79 | +17 |
| 10/10 | 19 13.9 | +01 30 | 0.19 | 1.03 | 15.7 | 76.6 | 93 | 156 | -0.34 | -4 |
| 10/15 | 20 24.9 | +07 18 | 0.25 | 1.10 | 15.9 | 60.6 | 107 | 114 | +0.00 | -17 |
| 10/20 | 21 06.6 | +10 18 | 0.33 | 1.16 | 16.4 | 52.0 | 113 | 56 | +0.27 | -24 |
| 10/25 | 21 33.5 | +11 59 | 0.41 | 1.23 | 16.9 | 47.0 | 115 | 21 | +0.79 | -28 |
| 10/30 | 21 52.6 | +13 03 | 0.50 | 1.29 | 17.3 | 43.8 | 116 | 65 | -1.00 | -31 |
| 11/04 | 22 07.5 | +13 47 | 0.59 | 1.35 | 17.7 | 41.6 | 115 | 118 | -0.78 | -33 |
| 11/09 | 22 19.8 | +14 21 | 0.69 | 1.41 | 18.1 | 40.0 | 113 | 162 | -0.30 | -35 |

**(66146) 1998 TU3 (2012 Sep-Nov, H = 14.6, PHA)**

There is no lack of previous work on this NEA. The period is well established at 2.377 h. Here is another case where additional lightcurves are most beneficial for YORP and shape/spin axis modeling. There have been no reported indications of the asteroid being binary. However, its rotation rate and size make it good candidate.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 09/20 | 19 08.7 | -44 04 | 0.25 | 1.10 | 14.0 | 62.3 | 105 | 56 | +0.20 | -21 |
| 09/30 | 19 51.5 | -38 57 | 0.33 | 1.13 | 14.6 | 59.0 | 105 | 75 | +1.00 | -28 |
| 10/10 | 20 20.3 | -34 56 | 0.41 | 1.15 | 15.0 | 57.9 | 102 | 159 | -0.34 | -32 |
| 10/20 | 20 43.6 | -31 34 | 0.48 | 1.17 | 15.4 | 57.8 | 98 | 39 | +0.27 | -37 |
| 10/30 | 21 04.4 | -28 35 | 0.56 | 1.17 | 15.8 | 58.1 | 93 | 89 | -1.00 | -40 |
| 11/09 | 21 23.9 | -25 48 | 0.63 | 1.16 | 16.0 | 58.7 | 88 | 151 | -0.30 | -44 |
| 11/19 | 21 42.9 | -23 07 | 0.69 | 1.14 | 16.2 | 59.5 | 83 | 19 | +0.33 | -47 |
| 11/29 | 22 01.5 | -20 28 | 0.74 | 1.11 | 16.3 | 60.6 | 78 | 106 | -1.00 | -51 |

**(136993) 1998 ST49 (2012 Sep-Oct, H = 17.6)**

Galad (2007) reported a period of 2.3 h for this NEA. The diameter is a little under a kilometer.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 09/20 | 01 26.8 | -35 23 | 0.29 | 1.24 | 16.8 | 32.1 | 139 | 121 | +0.20 | -79 |
| 09/25 | 01 17.6 | -34 14 | 0.24 | 1.20 | 16.3 | 31.4 | 141 | 71 | +0.74 | -81 |
| 09/30 | 01 03.1 | -31 55 | 0.20 | 1.17 | 15.7 | 30.2 | 144 | 40 | +1.00 | -85 |
| 10/05 | 00 40.4 | -27 21 | 0.15 | 1.13 | 15.0 | 28.1 | 148 | 71 | -0.79 | -88 |
| 10/10 | 00 04.0 | -18 01 | 0.11 | 1.10 | 14.2 | 25.8 | 151 | 128 | -0.34 | -76 |
| 10/15 | 23 04.4 | +01 10 | 0.08 | 1.06 | 13.6 | 32.3 | 145 | 152 | +0.00 | -52 |
| 10/20 | 21 31.7 | +29 27 | 0.08 | 1.03 | 14.1 | 56.9 | 119 | 72 | +0.27 | -16 |
| 10/25 | 19 39.9 | +47 52 | 0.10 | 1.01 | 15.3 | 78.6 | 96 | 64 | +0.79 | +12 |

**(163364) 2002 OD20 (2012 Oct-Nov, H = 18.8, PHA)**

There are no entries in the lightcurve database (LCDB, Warner *et al.*) for 2002 OD20. The estimated size is 0.5 km. This is fainter than we normally include but it's a rare opportunity to observe this PHA.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/20 | 03 24.0 | +25 36 | 0.67 | 1.61 | 19.9 | 17.4 | 151 | 145 | +0.27 | -26 |
| 10/25 | 03 17.4 | +25 15 | 0.63 | 1.59 | 19.6 | 14.0 | 157 | 76 | +0.79 | -27 |
| 10/30 | 03 09.1 | +24 43 | 0.60 | 1.57 | 19.3 | 10.2 | 164 | 14 | -1.00 | -28 |
| 11/04 | 02 59.5 | +23 59 | 0.57 | 1.55 | 19.0 | 6.4 | 170 | 50 | -0.78 | -30 |
| 11/09 | 02 48.8 | +23 03 | 0.54 | 1.53 | 18.8 | 4.2 | 173 | 114 | -0.30 | -32 |
| 11/14 | 02 37.5 | +21 56 | 0.52 | 1.51 | 18.8 | 6.6 | 170 | 169 | +0.00 | -35 |
| 11/19 | 02 26.1 | +20 38 | 0.51 | 1.48 | 18.9 | 11.3 | 163 | 93 | +0.33 | -37 |
| 11/24 | 02 15.1 | +19 15 | 0.50 | 1.46 | 19.0 | 16.3 | 155 | 26 | +0.82 | -39 |

**(144411) 2004 EW9 (2012 Sep-Nov, H = 16.6)**

Pravec *et al.* (2004) found a period of 49.94 h for this asteroid along with an amplitude at least 0.9 magnitude. The estimated size is 1.4 km. Given the long period, this a target best suited to a campaign among several observers at different longitudes.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 09/20 | 03 06.8 | +49 22 | 0.36 | 1.20 | 16.6 | 50.0 | 114 | 149 | +0.20 | -8 |
| 09/30 | 02 40.3 | +47 23 | 0.39 | 1.27 | 16.6 | 39.1 | 127 | 52 | +1.00 | -12 |
| 10/10 | 02 14.0 | +44 13 | 0.42 | 1.35 | 16.7 | 28.9 | 139 | 83 | -0.34 | -16 |
| 10/20 | 01 51.6 | +40 07 | 0.47 | 1.43 | 16.8 | 20.3 | 150 | 125 | +0.27 | -21 |
| 10/30 | 01 35.7 | +35 42 | 0.54 | 1.50 | 17.0 | 15.5 | 156 | 22 | -1.00 | -26 |
| 11/09 | 01 26.6 | +31 36 | 0.63 | 1.58 | 17.4 | 15.5 | 155 | 128 | -0.30 | -31 |
| 11/19 | 01 23.3 | +28 10 | 0.73 | 1.66 | 18.0 | 18.4 | 148 | 82 | +0.33 | -34 |
| 11/29 | 01 24.7 | +25 31 | 0.86 | 1.73 | 18.5 | 21.7 | 140 | 45 | -1.00 | -37 |

**3200 Phaethon (2012 Oct-Nov, H = 14.6, PHA)**

This is a relatively large target among this quarter's offerings: about 5 km. It makes the closest approach to the Sun of all the named asteroids, only 0.14 AU, and its orbit resembles more one of a comet. However, there have been no obvious cometary signs observed over the years. This object is considered to be the parent body of the Geminid meteor shower. The rotation period is about 3.6 h.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/01 | 03 36.7 | +45 11 | 1.41 | 2.12 | 18.1 | 23.8 | 121 | 48 | -0.99 | -8 |
| 10/06 | 03 25.3 | +45 19 | 1.38 | 2.14 | 18.0 | 21.8 | 127 | 32 | -0.71 | -10 |
| 10/11 | 03 12.3 | +45 15 | 1.36 | 2.17 | 17.9 | 19.7 | 133 | 84 | -0.24 | -11 |
| 10/16 | 02 58.2 | +44 55 | 1.34 | 2.19 | 17.9 | 17.5 | 139 | 145 | +0.00 | -12 |
| 10/21 | 02 43.4 | +44 19 | 1.33 | 2.21 | 17.8 | 15.3 | 144 | 122 | +0.38 | -14 |
| 10/26 | 02 28.3 | +43 26 | 1.32 | 2.23 | 17.7 | 13.4 | 149 | 61 | +0.86 | -16 |
| 10/31 | 02 13.6 | +42 16 | 1.33 | 2.25 | 17.7 | 12.0 | 152 | 27 | -0.99 | -18 |
| 11/05 | 01 59.7 | +40 53 | 1.34 | 2.27 | 17.7 | 11.3 | 153 | 72 | -0.69 | -20 |

**(214869) 2007 PA8 (2012 Oct and 2012 Jan, H = 16.2, PHA)**

2007 PA8 is an NEA with an estimated diameter of 1.6 km. There are no entries in the LCDB. This asteroid has two good apparitions in late 2012 and early 2013, the gap being when the asteroid gets too close to the Sun in 2012 November-December. An ephemeris for before and after conjunction are included below.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/01 | 00 54.5 | -01 52 | 0.25 | 1.25 | 14.3 | 6.4 | 172 | 12 | -0.99 | -65 |
| 10/06 | 00 59.8 | -03 02 | 0.21 | 1.21 | 13.9 | 7.2 | 171 | 65 | -0.71 | -66 |
| 10/11 | 01 07.1 | -04 35 | 0.18 | 1.17 | 13.5 | 9.9 | 168 | 123 | -0.24 | -67 |
| 10/16 | 01 18.2 | -06 39 | 0.14 | 1.13 | 13.1 | 13.7 | 164 | 158 | +0.00 | -69 |
| 10/21 | 01 36.2 | -09 36 | 0.11 | 1.10 | 12.6 | 18.4 | 160 | 96 | +0.38 | -70 |
| 10/26 | 02 09.0 | -14 11 | 0.08 | 1.07 | 12.1 | 24.7 | 153 | 45 | +0.86 | -68 |
| 10/31 | 03 17.5 | -21 36 | 0.06 | 1.04 | 11.6 | 36.3 | 142 | 40 | -0.99 | -56 |
| 11/05 | 05 44.4 | -29 17 | 0.04 | 1.01 | 11.7 | 60.8 | 117 | 53 | -0.69 | -27 |
| | | | | | | | | | | |
| 01/01 | 12 09.1 | -04 14 | 0.30 | 1.06 | 16.2 | 66.7 | 97 | 43 | -0.88 | +57 |
| 01/06 | 12 10.8 | -03 43 | 0.32 | 1.09 | 16.2 | 61.6 | 102 | 22 | -0.41 | +58 |
| 01/11 | 12 11.2 | -03 06 | 0.34 | 1.13 | 16.3 | 56.4 | 107 | 96 | -0.01 | +58 |
| 01/16 | 12 10.0 | -02 23 | 0.35 | 1.17 | 16.3 | 51.1 | 113 | 168 | +0.22 | +59 |
| 01/21 | 12 07.2 | -01 32 | 0.37 | 1.21 | 16.3 | 45.8 | 119 | 129 | +0.69 | +59 |
| 01/26 | 12 03.1 | -00 35 | 0.38 | 1.25 | 16.3 | 40.3 | 125 | 68 | +0.99 | +60 |
| 01/31 | 11 57.6 | +00 29 | 0.40 | 1.29 | 16.3 | 34.8 | 132 | 5 | -0.85 | +60 |
| 02/05 | 11 51.1 | +01 38 | 0.42 | 1.33 | 16.3 | 29.2 | 139 | 68 | -0.34 | +61 |

**2006 VB14 (2012 Dec, H = 18.6)**

The rotation period for this 0.6 km NEA has yet to be determined. It will be moving across the sky fairly rapidly, so numerous shorter exposures to "beat down the noise" may be required. Fortunately for Northern Hemisphere observers, it's fairly bright the first part of December.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/01 | 05 37.5 | +65 11 | 0.14 | 1.09 | 15.9 | 39.7 | 135 | 46 | -0.95 | +17 |
| 12/06 | 03 52.7 | +52 28 | 0.11 | 1.08 | 15.2 | 28.8 | 148 | 91 | -0.57 | -1 |
| 12/11 | 02 49.0 | +31 15 | 0.11 | 1.08 | 15.1 | 29.8 | 147 | 166 | -0.08 | -25 |
| 12/16 | 02 14.0 | +10 10 | 0.12 | 1.07 | 15.8 | 44.7 | 130 | 94 | +0.10 | -48 |
| 12/21 | 01 54.2 | -04 49 | 0.15 | 1.05 | 16.6 | 58.2 | 114 | 25 | +0.58 | -63 |
| 12/26 | 01 42.4 | -14 26 | 0.18 | 1.04 | 17.3 | 67.6 | 103 | 53 | +0.95 | -73 |
| 12/31 | 01 35.0 | -20 44 | 0.22 | 1.02 | 17.8 | 74.1 | 93 | 109 | -0.94 | -78 |
| 01/05 | 01 30.1 | -25 07 | 0.26 | 1.00 | 18.3 | 78.9 | 86 | 145 | -0.52 | -81 |

**(33342) 1998 WT24 (2012 Nov-Dec, H = 17.9)**

Based on LCDB entries, the last period determination (3.69 h) was based on observations in 2001, more than a decade ago. That's because favorable apparitions are rare. The next "highly favorable" one is not until 2015 December (V ~ 11.3) and the one after that is 2029, so work this one now if possible. The estimated diameter is 400 meters.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/15 | 09 51.4 | +08 30 | 0.33 | 1.02 | 18.1 | 75.6 | 86 | 101 | +0.02 | +44 |
| 11/20 | 10 09.2 | +08 10 | 0.30 | 1.02 | 18.0 | 76.3 | 87 | 169 | +0.44 | +47 |
| 11/25 | 10 29.9 | +07 46 | 0.27 | 1.01 | 17.8 | 77.6 | 87 | 132 | +0.89 | +51 |
| 11/30 | 10 54.4 | +07 15 | 0.25 | 1.00 | 17.7 | 79.6 | 86 | 79 | -0.98 | +56 |
| 12/05 | 11 23.7 | +06 32 | 0.23 | 0.99 | 17.5 | 82.8 | 84 | 27 | -0.67 | +61 |
| 12/10 | 11 59.1 | +05 31 | 0.21 | 0.97 | 17.5 | 87.3 | 81 | 34 | -0.16 | +65 |
| 12/15 | 12 41.6 | +04 07 | 0.19 | 0.95 | 17.5 | 93.5 | 75 | 98 | +0.04 | +67 |
| 12/20 | 13 31.1 | +02 14 | 0.18 | 0.93 | 17.7 | 101.1 | 69 | 151 | +0.48 | +63 |

**(203471) 2002 AU4 (2012 Dec, H = 18.7)**

Here is a good opportunity to get a phase curve for an asteroid. The phase angle changes dramatically during the apparition and reaches a minimum of 8.5°. For best estimates of H-G, it would better if the phase angle was at least < 3°, but this may be "good enough." There are no entries in the LCDB for the 0.5 km NEA.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/05 | 09 47.9 | -35 51 | 0.15 | 0.99 | 17.7 | 83.3 | 88 | 45 | -0.67 | +14 |
| 12/10 | 09 10.6 | -29 56 | 0.13 | 1.02 | 17.0 | 71.5 | 101 | 67 | -0.16 | +12 |
| 12/15 | 08 25.7 | -20 51 | 0.11 | 1.04 | 16.2 | 56.0 | 119 | 137 | +0.04 | +10 |
| 12/20 | 07 35.0 | -08 11 | 0.10 | 1.06 | 15.6 | 36.7 | 140 | 119 | +0.48 | +6 |
| 12/25 | 06 43.8 | +05 58 | 0.11 | 1.08 | 15.1 | 17.0 | 161 | 47 | +0.90 | +1 |
| 12/30 | 05 58.3 | +17 58 | 0.12 | 1.10 | 15.1 | 9.3 | 170 | 26 | -0.98 | -3 |
| 01/04 | 05 22.0 | +26 21 | 0.14 | 1.12 | 15.9 | 19.5 | 158 | 98 | -0.62 | -6 |
| 01/09 | 04 55.2 | +31 47 | 0.17 | 1.13 | 16.6 | 28.8 | 146 | 168 | -0.11 | -7 |

**1994 XD (2012 Nov-Dec, H = 19.1, PHA, Binary)**

Radar observations in 2005 (Benner *et al.*) determined that this NEA is a binary. The primary size was estimated at 600 meters with a lower bound size of 150 meters for the secondary. This implies mutual event depths of about 0.07 mag, if total. These should be observable in higher-precision data.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/25 | 11 45.7 | -41 46 | 0.06 | 0.96 | 17.7 | 119.4 | 58 | 143 | +0.89 | +19 |
| 11/30 | 07 46.2 | -13 59 | 0.06 | 1.02 | 15.1 | 57.9 | 119 | 48 | -0.98 | +5 |
| 12/05 | 06 15.3 | +06 25 | 0.10 | 1.08 | 15.4 | 24.3 | 153 | 50 | -0.67 | -5 |
| 12/10 | 05 40.5 | +13 59 | 0.16 | 1.14 | 16.0 | 10.1 | 168 | 125 | -0.16 | -9 |
| 12/15 | 05 22.9 | +17 33 | 0.21 | 1.20 | 16.6 | 4.9 | 174 | 155 | +0.04 | -10 |
| 12/20 | 05 12.9 | +19 35 | 0.28 | 1.26 | 17.4 | 7.8 | 170 | 83 | +0.48 | -11 |
| 12/25 | 05 07.0 | +20 53 | 0.34 | 1.32 | 18.1 | 11.8 | 164 | 21 | +0.90 | -12 |
| 12/30 | 05 03.7 | +21 47 | 0.41 | 1.37 | 18.7 | 15.3 | 158 | 39 | -0.98 | -12 |

**2062 Aten (2012 Nov-Dec, H = 16.8)**

This namesake for the Aten NEA group (semi-major axis < 1.0 AU) has only one period determination in the LCDB: 40.8 h (Mottola *et al.*, 1995). This apparition could provide an excellent opportunity for a campaign involving observers at different longitudes to confirm and/or refine those results.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/01 | 05 45.8 | -55 08 | 0.34 | 1.10 | 16.9 | 63.6 | 99 | 78 | -0.96 | -31 |
| 11/11 | 05 06.0 | -54 16 | 0.32 | 1.11 | 16.7 | 59.7 | 104 | 96 | -0.12 | -37 |
| 11/21 | 04 21.7 | -50 57 | 0.31 | 1.13 | 16.6 | 56.1 | 109 | 87 | +0.55 | -44 |
| 12/01 | 03 41.1 | -44 35 | 0.30 | 1.14 | 16.4 | 53.2 | 113 | 74 | -0.95 | -52 |
| 12/11 | 03 10.3 | -35 24 | 0.30 | 1.14 | 16.4 | 51.5 | 115 | 127 | -0.08 | -59 |
| 12/21 | 02 50.9 | -24 26 | 0.31 | 1.14 | 16.4 | 51.7 | 114 | 47 | +0.58 | -63 |
| 12/31 | 02 41.4 | -13 03 | 0.32 | 1.14 | 16.6 | 53.5 | 111 | 92 | -0.94 | -61 |
| 01/10 | 02 39.5 | -02 22 | 0.35 | 1.13 | 16.9 | 56.4 | 106 | 131 | -0.05 | -54 |

**3908 Nyx (2012 Nov-Dec, H = 17.4)**

The LCDB lists a rotation period of 4.426 h along with shape and spin axis models based on lightcurve inversion and/or radar. As mentioned before, new lightcurve observations can be used to study YORP as well as help analysis using new radar data. Go to *echo.jpl.nasa.gov/asteroids/benner.etal.2002.**nyx**.pdf* to download a paper by *Benner et al.* showing the derived shape.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/01 | 20 34.1 | -12 49 | 0.35 | 1.05 | 17.6 | 71.4 | 89 | 115 | -0.96 | -28 |
| 11/11 | 21 17.4 | -10 10 | 0.33 | 1.04 | 17.5 | 71.6 | 90 | 130 | -0.12 | -37 |
| 11/21 | 22 08.1 | -06 31 | 0.32 | 1.05 | 17.4 | 69.7 | 93 | 2 | +0.55 | -46 |
| 12/01 | 23 04.7 | -01 57 | 0.31 | 1.07 | 17.3 | 65.7 | 97 | 109 | -0.95 | -54 |
| 12/11 | 00 04.0 | +03 04 | 0.33 | 1.10 | 17.2 | 60.3 | 103 | 136 | -0.08 | -58 |
| 12/21 | 01 01.8 | +07 50 | 0.36 | 1.15 | 17.4 | 54.8 | 108 | 9 | +0.58 | -55 |
| 12/31 | 01 54.7 | +11 49 | 0.41 | 1.19 | 17.6 | 50.2 | 111 | 98 | -0.94 | -48 |
| 01/10 | 02 41.2 | +14 52 | 0.48 | 1.25 | 17.9 | 46.6 | 113 | 138 | -0.05 | -40 |

**(137924) 2000 BD19 (2012 Dec – 2013 Jan, H = 17.1)**

What makes this NEA particularly interesting is that has among the smallest perihelion distances of any numbered asteroid and also has one of largest aphelion distances among the Atens (the orbital eccentricity is almost 0.9). The estimated diameter is 1 km. There are no entries in the LCDB.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/01 | 13 40.7 | +31 08 | 0.56 | 0.92 | 18.5 | 79.3 | 67 | 96 | -0.95 | +79 |
| 12/11 | 13 28.1 | +42 55 | 0.52 | 1.06 | 18.3 | 66.9 | 84 | 64 | -0.08 | +73 |
| 12/21 | 13 02.2 | +56 26 | 0.50 | 1.19 | 18.1 | 54.6 | 101 | 116 | +0.58 | +61 |
| 12/31 | 11 48.2 | +70 00 | 0.51 | 1.29 | 17.9 | 43.2 | 116 | 64 | -0.94 | +46 |
| 01/10 | 08 25.5 | +75 59 | 0.55 | 1.38 | 18.1 | 35.6 | 125 | 121 | -0.05 | +32 |
| 01/20 | 05 50.2 | +69 31 | 0.63 | 1.45 | 18.4 | 33.1 | 126 | 61 | +0.60 | +20 |
| 01/30 | 05 03.9 | +61 07 | 0.74 | 1.51 | 18.9 | 33.8 | 121 | 86 | -0.92 | +12 |
| 02/09 | 04 51.9 | +54 19 | 0.88 | 1.56 | 19.3 | 35.3 | 114 | 124 | -0.02 | +6 |

**(153958) 2002 AM31 (2012 Nov-Dec, H = 18.1, PHA)**

There are no lightcurve parameters in the LCDB for 2002 AM31, an NEA with estimated size of 0.7 km. The asteroid made a close flyby in July. It becomes a photometry target the final two months of the year, when it might be possible for those with larger instruments (1-meter or so) to get a good rotation period.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/01 | 07 02.5 | +08 45 | 0.41 | 1.21 | 18.5 | 49.5 | 112 | 45 | -0.96 | +6 |
| 11/11 | 06 53.1 | +08 46 | 0.42 | 1.27 | 18.4 | 40.1 | 124 | 84 | -0.12 | +4 |
| 11/21 | 06 37.4 | +09 13 | 0.43 | 1.34 | 18.3 | 29.9 | 137 | 126 | +0.55 | +1 |
| 12/01 | 06 17.2 | +10 05 | 0.46 | 1.41 | 18.2 | 19.5 | 152 | 10 | -0.95 | -3 |
| 12/11 | 05 55.6 | +11 16 | 0.50 | 1.47 | 18.2 | 10.3 | 164 | 135 | -0.08 | -7 |
| 12/21 | 05 36.3 | +12 36 | 0.56 | 1.54 | 18.4 | 7.6 | 168 | 77 | +0.58 | -10 |
| 12/31 | 05 22.0 | +13 57 | 0.64 | 1.60 | 19.0 | 12.7 | 159 | 47 | -0.94 | -13 |
| 01/10 | 05 13.3 | +15 15 | 0.74 | 1.66 | 19.6 | 18.2 | 148 | 172 | -0.05 | -14 |

**2003 UC20 (2012 Nov-Dec, H = 18.7, PHA)**

2003 UC20 is an NEA with an estimated effective diameter of 0.7 km. There are no entries in the LCDB for the asteroid.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/20 | 08 47.7 | -01 17 | 0.19 | 1.04 | 16.9 | 67.5 | 102 | 166 | +0.44 | +25 |
| 11/25 | 08 50.6 | -04 41 | 0.17 | 1.04 | 16.6 | 65.8 | 105 | 112 | +0.89 | +24 |
| 11/30 | 08 52.8 | -08 48 | 0.15 | 1.04 | 16.3 | 64.6 | 108 | 58 | -0.98 | +22 |
| 12/05 | 08 53.9 | -13 58 | 0.13 | 1.04 | 16.0 | 63.9 | 109 | 25 | -0.67 | +19 |
| 12/10 | 08 53.6 | -20 39 | 0.11 | 1.03 | 15.6 | 64.2 | 110 | 71 | -0.16 | +15 |
| 12/15 | 08 51.1 | -29 34 | 0.09 | 1.02 | 15.3 | 66.5 | 109 | 126 | +0.04 | +9 |
| 12/20 | 08 44.6 | -41 40 | 0.08 | 1.01 | 15.1 | 71.9 | 104 | 125 | +0.48 | +1 |
| 12/25 | 08 28.6 | -57 39 | 0.07 | 0.99 | 15.1 | 81.7 | 94 | 98 | +0.90 | -11 |

**4179 Toutatis (2012 Jul-Sep, H = 15.3, PHA, NPA)**

This 2.6 km NEA is one of the prime examples of a "tumbler", an asteroid in non-principal axis rotation (see Pravec *et al.*, 2005). The lightcurve will be anything from regular and so don't expect it to repeat itself. The two periods (rotation and precession) are 178 and 130 h. The amplitude has ranged from 0.15 to 1.0 mag or more.

The asteroid has a close approach in December (0.046 AU), when it will be as bright as V ~ 10.4. It was a good photometric target earlier this year. Comparisons between any lightcurves obtained at

that time and during the December apparition could be very interesting. As noted in this article in 39-3, the wide range of phase angles might allow finding a good phase curve (G). However, the complex lightcurve of a tumbler may make it hard to determine a good average magnitude value for a given night.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/01 | 21 37.5 | -18 34 | 0.09 | 0.96 | 13.9 | 103.3 | 72 | 134 | -0.95 | -45 |
| 12/11 | 00 45.1 | -02 45 | 0.05 | 1.00 | 11.2 | 67.5 | 110 | 143 | -0.08 | -66 |
| 12/21 | 04 48.3 | +18 47 | 0.08 | 1.06 | 10.8 | 15.5 | 163 | 65 | +0.58 | -17 |
| 12/31 | 06 03.9 | +21 55 | 0.14 | 1.12 | 11.9 | 7.6 | 171 | 38 | -0.94 | +0 |
| 01/10 | 06 32.1 | +22 32 | 0.22 | 1.20 | 13.1 | 10.1 | 168 | 167 | -0.05 | +6 |
| 01/20 | 06 47.5 | +22 43 | 0.31 | 1.28 | 14.2 | 14.4 | 161 | 60 | +0.60 | +9 |
| 01/30 | 06 59.1 | +22 42 | 0.41 | 1.37 | 15.1 | 18.7 | 154 | 60 | -0.92 | +12 |
| 02/09 | 07 09.9 | +22 34 | 0.53 | 1.45 | 15.9 | 22.4 | 146 | 163 | -0.02 | +14 |

**2010 BB (2012 Dec – 2013 Jan, H = 20.0, PHA)**

This small (0.3 km) NEA has no entries in the LCDB. The observing window extends into 2013 January, assuming good photometry can still be obtained at V ~ 18.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/20 | 20 22.7 | +20 09 | 0.06 | 0.95 | 18.8 | 119.8 | 57 | 51 | +0.48 | -10 |
| 12/23 | 21 24.0 | +20 49 | 0.06 | 0.96 | 18.0 | 111.4 | 65 | 65 | +0.76 | -21 |
| 12/26 | 22 34.8 | +19 46 | 0.06 | 0.97 | 17.3 | 101.1 | 76 | 81 | +0.95 | -33 |
| 12/29 | 23 43.8 | +16 57 | 0.06 | 0.98 | 17.0 | 90.7 | 86 | 101 | -1.00 | -43 |
| 01/01 | 00 41.3 | +13 23 | 0.06 | 0.99 | 16.9 | 82.1 | 94 | 126 | -0.88 | -49 |
| 01/04 | 01 25.0 | +10 03 | 0.07 | 1.00 | 17.0 | 76.0 | 100 | 156 | -0.62 | -52 |
| 01/07 | 01 57.6 | +07 20 | 0.08 | 1.01 | 17.2 | 72.0 | 103 | 168 | -0.30 | -52 |
| 01/10 | 02 22.3 | +05 13 | 0.10 | 1.01 | 17.4 | 69.5 | 105 | 131 | -0.05 | -51 |

**(52762) 1998 MT24 (2012 Dec, H = 14.6)**

Pravec et al. (1998) reported a period of 12.07 h for this asteroid. This begs for a collaboration among at least two observers who are well-separated in longitude. Pravec et al. (2012) report a size of 6.7 km based on an assumed albedo of 0.05, which was based on their derived value of $G = 0.0$, implying a dark asteroid.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/01 | 10 13.4 | +37 15 | 1.06 | 1.64 | 17.3 | 35.4 | 106 | 53 | -0.95 | +55 |
| 12/06 | 10 22.0 | +36 06 | 0.97 | 1.59 | 17.1 | 36.0 | 109 | 32 | -0.57 | +57 |
| 12/11 | 10 30.3 | +34 45 | 0.88 | 1.54 | 16.9 | 36.5 | 111 | 81 | -0.08 | +59 |
| 12/16 | 10 38.3 | +33 10 | 0.80 | 1.50 | 16.6 | 37.0 | 114 | 142 | +0.10 | +61 |
| 12/21 | 10 46.0 | +31 16 | 0.71 | 1.45 | 16.3 | 37.5 | 116 | 135 | +0.58 | +62 |
| 12/26 | 10 53.4 | +28 55 | 0.63 | 1.40 | 15.9 | 37.9 | 119 | 86 | +0.95 | +64 |
| 12/31 | 11 00.6 | +25 55 | 0.55 | 1.35 | 15.6 | 38.2 | 122 | 36 | -0.94 | +65 |
| 01/05 | 11 07.6 | +22 00 | 0.47 | 1.31 | 15.2 | 38.6 | 124 | 38 | -0.52 | +66 |

**2002 AY1 (2012 Dec, H = 20.9, PHA)**

There are no entries in the LCDB for this NEA of about 0.2 km size. The semi-major axis is only 0.78 AU. With an orbital eccentricity of 0.44, the asteroid distance from the Sun ranges from about 0.44 to 1.12 AU, or almost entirely within the Earth's orbit.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/20 | 11 40.1 | +59 54 | 0.19 | 1.07 | 19.5 | 58.7 | 112 | 118 | +0.48 | +55 |
| 12/23 | 11 39.5 | +61 56 | 0.16 | 1.06 | 19.1 | 58.2 | 114 | 99 | +0.76 | +53 |
| 12/26 | 11 36.3 | +64 51 | 0.14 | 1.05 | 18.6 | 57.7 | 116 | 79 | +0.95 | +50 |
| 12/29 | 11 27.3 | +69 19 | 0.11 | 1.04 | 18.1 | 57.3 | 117 | 64 | -1.00 | +46 |
| 01/01 | 10 54.4 | +76 44 | 0.08 | 1.02 | 17.4 | 57.4 | 119 | 68 | -0.88 | +38 |
| 01/04 | 04 22.7 | +84 04 | 0.06 | 1.01 | 16.7 | 59.9 | 117 | 96 | -0.62 | +23 |
| 01/07 | 00 54.9 | +54 37 | 0.04 | 0.99 | 16.3 | 72.1 | 106 | 137 | -0.30 | -8 |
| 01/10 | 00 31.0 | +12 31 | 0.04 | 0.98 | 17.3 | 95.0 | 82 | 107 | -0.05 | -50 |

**(99942) Apophis (2012 Dec – 2013 Feb, H = 19.3, PHA)**

This is probably the most famous and debated NEA of recent times. The rotation period for the 400 meter NEA is about 30.4 h, based on observations in 2005 analyzed by Behrend. Again, such a period is best confirmed and refined by several observers at multiple longitudes, in this case, those south of the equator.

| DATE | RA | Dec | ED | SD | V | α | SE | ME | MP | GB |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/10 | 11 38.1 | -26 13 | 0.11 | 0.96 | 17.9 | 99.9 | 74 | 34 | -0.16 | +34 |
| 12/20 | 10 56.7 | -27 13 | 0.10 | 0.99 | 17.2 | 83.1 | 91 | 153 | +0.48 | +29 |
| 12/30 | 10 09.4 | -27 11 | 0.10 | 1.02 | 16.6 | 66.5 | 108 | 55 | -0.98 | +23 |
| 01/09 | 09 13.6 | -24 52 | 0.10 | 1.04 | 16.1 | 50.0 | 126 | 98 | -0.11 | +16 |
| 01/19 | 08 16.0 | -19 16 | 0.10 | 1.06 | 15.8 | 36.3 | 140 | 101 | +0.50 | +9 |
| 01/29 | 07 29.7 | -11 32 | 0.11 | 1.08 | 16.0 | 31.6 | 145 | 42 | -0.96 | +3 |
| 02/08 | 07 00.4 | -03 55 | 0.13 | 1.09 | 16.5 | 36.3 | 139 | 158 | -0.07 | +0 |
| 02/18 | 06 46.7 | +02 23 | 0.16 | 1.10 | 17.1 | 43.8 | 130 | 45 | +0.52 | +0 |

## INDEX TO VOLUME 39

Melton, E., Carver, S., Harris, A., Karnemaat, R., Klaasse, M., and Ditteon, R. "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2011 November–December" 131–133.

Moravec, P., Cochren, J., Gerhardt, M., Harris, A., Karnemaat, R., Melton, E., Stolze, K., West, J., and Ditteon, R. "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2012 January–April" 213–216.

Odden, C., French, J., and Briggs, J. "Lightcurve Analysis for Four Asteroids" 236–238.

Odden, C., Martinez, L., Klinglesmith, D., and Warren, C. "Lightcurve Analysis of 3080 Moisseiev" 93.

Odden, C. and McDonald, D. "Lightcurve Analysis for 3017 Petrovic" 104–105.

Oey, J. "Lightcurve Analysis of Asteroids Observed in 2011 from Leura and Kingsgrove Observatories" 145–147.

Oey, J. "Period Determination of 617 Patroclus" 106–107.

Oey, J. and Alvarez, E.M. "Period Determination for 1660 Wood" 147–148.

Oey, J., Colazo, C., Mazzone, F., and Chapman, A. "Lightcurve Analysis of 918 Itha and 2008 Konstitutsiya" 1–2. Erratum 89.

Oey, J., Pilcher, F., Benishek, V., Higgins, D., and Pravec, P. "Photometric Analysis of the Very Long Period and Tumbling Asteroid 1278 Kenya" 86–88.

Owings, L.E. "Lightcurves for 2567 Elba, 2573 Hannu Olavi, 2731 Cucula, 4930 Rephiltim, 6952 Niccolo, and 7750 McEwen" 22–23.

Pilcher, F. "140 Siwa – A Problematic Asteroid" 134–135.

Pilcher, F. "General Report of Position Observations by the ALPO Minor Planets Section for the Year 2011" 167–169.

Pilcher, F. "Minor Planets at Unusually Favorable Elongations in 2012" 9–11.

Pilcher, F. "Rotation Period Determinations for 31 Euphrosyne, 65 Cybele, 154 Bertha, 177 Irma, 200 Dynamene, 724 Hapag, 880 Herba, and 1470 Carla" 57–60.

Pilcher, F. "Rotation Period Determinations for 46 Hestia, 223 Rosa, 225 Henrietta, 266 Aline, 750 Oskar, and 765 Mattiaca" 171–173.

Pilcher, F. "Rotation Period Determinations for 47 Aglaja, 252 Clementia, 611 Valeria, 627 Charis, and 756 Lilliana" 220–222.

Pilcher, F., Benishek, V., Briggs, J.W., Ferrero, A., Klinglesmith, D.A. III, and Warren, C.A. "Eight Months of Lightcurves of 1036 Ganymed" 141–144.

Pilcher, F., Benishek, V., Delos, S., Barker, T., Ahrendts, G., Hamanowa, H., Hamanowa, H., and Higgins, D. "Rotation Period Determination for 180 Garumna: A Triumph of Global Collaboration" 46.

Pilcher, F., Briggs, J.W., Franco, L., Inasaridze, R.Y., Krugly, Y.N., Molotov, I.E., Klinglesmith, D.A. III, Pollock, J., and Pravec, P. "Rotation Period Determination for 5143 Heracles" 148–151.

Pilcher, F., Delos, S., Ahrendts, G., and Barker, T. "Rotation Period Determination for 247 Eukrate" 204.

Pilcher F. and Durech, J. "A Request to Post Your Lightcurve Inversion Models" 213.

Pilcher, F., Durkee, R.I., and Martinez, L. "Rotation Period Determination for 668 Dora" 11.

Pilcher, F., Ferrero, A., Hamanowa, H., and Hamanowa, H. "Rotation Period Determination for 203 Pompeja – Another Triumph of Global Collaboration" 99.

Pilcher, F., Ferrero, A., Inasaridze, R.Y., Krugly, Y.N., Molotov, I.E., Oey, J., Strabla, L.P., Quadri, U., and Girelli, R. "Rotation Period Determination for 801 Helwerthia" 222–225.

Pilcher, F., Ferrero, A., and Oey, J. "Rotation Period Determination for 482 Petrina" 228–229.

Pilcher, F. and Ruthroff, J.C. "Rotation Period Determination for 185 Eunike" 13.

Polishook, D. "Lightcurves for Shape Modeling: 852 Wladilena, 1089 Tama, and 1180 Rita" 242–244.

Polishook, D. "Lightcurves and Spin Periods of Near-Earth Asteroids, The Wise Observatory, 2005–2010" 187–192.

Polishook, D. "Lightcurves and Spin Periods from the Wise Observatory – October 2011" 88–89.

Ruthroff, J.C. "Lightcurve Analysis of 1786 Raahe and 4729 Mikhailmil'" 39.

Schmidt, R.E. "The Rotational Period of 328 Gudrun" 109.

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

Slivan, S.M. "Epoch Data in Sidereal Period Determination. I. Initial Constraint from Closest Epochs" 204–206.

Stephens, R.D. "Asteroids Observed from GMARS and Santana Observatories"
"2011 July–September" 11–12.
"2011 October –December" 80–81.
"2012 January–March" 181–183.

Stephens, R.D. "Asteroids Observed from Santana, CS3 and GMARS Observatories: 2012 April–June" 226–228.

Stephens, R.D., French, L.M. and Wasserman, L.H. "A Deep Main-belt Asteroid Survey" 193–195.

Stephens, R.D., and Warner, B.D. "Lightcurve for 205 Martha" 233–234.

Stephens, R.D., Warner, B.D., Megna, R., and Coley, D. "A Shape Model of the Main-belt Asteroid 27 Euterpe" 2–5.

Strabla, L, Quadri, U., and Girelli, R. "Lightcurve Analysis for Eight Minor Planets at Bassano Bresciano Observatory" 177–179.

## IN THIS ISSUE

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

| Number | Name | EP | Page |
|---|---|---|---|
| 47 | Hestia | 18 | 220 |
| 161 | Athor | 32 | 234 |
| 205 | Martha | 31 | 233 |
| 225 | Henrietta | 11 | 213 |
| 247 | Eukrate | 2 | 204 |
| 252 | Clementina | 18 | 220 |
| 412 | Elisabetha | 24 | 226 |
| 482 | Petrina | 26 | 228 |
| 611 | Valeria | 18 | 220 |
| 627 | Charis | 18 | 220 |
| 648 | Pippa | 11 | 213 |
| 756 | Lilliana | 18 | 220 |
| 801 | Helwerthia | 20 | 222 |
| 852 | Wladilena | 40 | 242 |
| 862 | Franzia | 11 | 213 |
| 1055 | Tynka | 24 | 226 |
| 1089 | Tama | 40 | 242 |
| 1090 | Sumida | 29 | 231 |
| 1180 | Rita | 40 | 242 |
| 1311 | Knopfia | 11 | 213 |
| 1394 | Algoa | 37 | 239 |
| 1424 | Sundmania | 24 | 226 |
| 1428 | Mombasa | 24 | 226 |
| 1656 | Suomi | 43 | 245 |
| 1660 | Wood | 37 | 239 |
| 1714 | Sy | 11 | 213 |
| 1985 | Hopmann | 11 | 213 |
| 2074 | Shoemaker | 23 | 225 |
| 2145 | Blaauw | 11 | 213 |
| 2234 | Schmadel | 11 | 213 |
| 2423 | Ibarruri | 7 | 209 |
| 2464 | Nordenskiold | 11 | 213 |
| 2550 | Houssay | 11 | 213 |
| 2698 | Azerbajdzhan | 11 | 213 |
| 2903 | Zhuhai | 11 | 213 |
| 2927 | Alamosa | 34 | 236 |
| 3169 | Ostro | 43 | 245 |
| 3266 | Bernardus | 43 | 245 |
| 3397 | Leyla | 10 | 212 |
| 3493 | Stepanov | 24 | 226 |
| 3810 | Aoraki | 11 | 213 |
| 3968 | Koptelov | 11 | 213 |
| 4116 | Elachi | 43 | 245 |
| 4419 | Allancook | 34 | 236 |
| 4483 | Petofi | 43 | 245 |
| 4490 | Bambery | 43 | 245 |
| 4790 | Petrpravec | 11 | 213 |
| 4892 | Chrispollas | 11 | 213 |
| 4950 | House | 11 | 213 |
| 5374 | Hokutosei | 11 | 213 |
| 5374 | Hokutosei | 34 | 236 |
| 5477 | Holmes | 28 | 230 |
| 5968 | Trauger | 43 | 245 |
| 6107 | Osterbrock | 43 | 245 |
| 6254 | 1993 UM3 | 24 | 226 |
| 6321 | Namuratakao | 11 | 213 |
| 6354 | Vangelis | 43 | 245 |
| 6517 | Buzzi | 43 | 245 |
| 6574 | Gvishiani | 11 | 213 |
| 6670 | Wallach | 43 | 245 |
| 6972 | Helvetius | 11 | 213 |
| 7036 | 1995 BH3 | 11 | 213 |
| 7087 | Lewotsky | 43 | 245 |
| 7758 | Poulanderson | 30 | 232 |
| 7958 | Leakey | 38 | 240 |
| 8077 | Hoyle | 1 | 203 |
| 8345 | Ulmerspatz | 5 | 207 |
| 8345 | Ulmerspatz | 7 | 209 |
| 8882 | Sakaetamura | 4 | 206 |
| 8882 | Sakaetamura | 37 | 239 |
| 11304 | 1993 DJ | 43 | 245 |
| 15269 | 1990 XF | 11 | 213 |
| 15269 | 1990 XF | 37 | 239 |
| 17129 | 1999 JM78 | 43 | 245 |
| 17590 | 1995 CG | 43 | 245 |
| 19774 | 2000 OS51 | 11 | 213 |
| 20996 | 1986 PB | 43 | 245 |
| 21976 | 1999 XV2 | 11 | 213 |
| 23482 | 1991 LV | 43 | 245 |
| 24702 | 1991 OR | 43 | 245 |
| 30185 | 2000 GT95 | 11 | 213 |
| 30432 | 2000 LM20 | 11 | 213 |
| 31182 | 1997 YZ3 | 43 | 245 |
| 31881 | 2000 FL15 | 43 | 245 |
| 33736 | 1999 NY36 | 24 | 226 |
| 42811 | 1999 JN81 | 43 | 245 |
| 44443 | 1998 UY19 | 11 | 213 |
| 47035 | 1998 WS | 14 | 216 |
| 47143 | 1999 LL31 | 43 | 245 |
| 48307 | 2002 LP53 | 43 | 245 |
| 49674 | 1999 SB5 | 43 | 245 |
| 51302 | 2000 KY54 | 43 | 245 |
| 51381 | 2001 BG51 | 43 | 245 |
| 51386 | 2001 ON35 | 43 | 245 |
| 74081 | 1998 OU1 | 43 | 245 |
| 79472 | 1998 AX4 | 43 | 245 |
| 83574 | 2000 GU91 | 34 | 236 |
| 88259 | 2001 HJ7 | 43 | 245 |
| 326732 | 2003 HB6 | 43 | 245 |
| | 2011 WV134 | 43 | 245 |
| | 2012 AA11 | 43 | 245 |
| | 2012 DO | 43 | 245 |
| | 2012 KP24 | 36 | 238 |
| | 2012 LZ1 | 50 | 252 |

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