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67.

PHOTOMETRIC OBSERVATION AND LIGHTCURVE ANALYSIS OF (24445) 2000 PM8

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Photometric observations of NEO (24445) 2000 PM8 were made over three nights in September 2013. A synodic period $P = (6.81 \pm 0.03)$ h was derived from these data.

ROTAT (Remote Observatory Theoretical Astrophysics Tübingen) is a 60 cm remotely operated telescope, located on the OHP site (Observatoire de Haute-Provence) at Haute-Provence (France), about 100 km north-east of Marseille. ROTAT was formerly located and operated in Tübingen, Dept. for Theoretical Astrophysics, University of Tübingen.

Image acquisition was made with a SBIG STL-1100M CCD camera attached to the $f/3.2$ Newtonian focus of the ROTAT telescope, resulting in a pixelscale of 1.94 arcs/px (with 2x2 binning). No filters were used. Exposure times were 50, 45 and 35 seconds for the three nights: 2013 Sept. 19, 20 and 25. It should be noted that during the last night the nearby moon was interfering the observation and that the SNR in that night was about half of the SNR of the two previous nights.

All images were measured using *Astrometrica*, i.e. PSF-based all-sky photometry. Dark images obtained in the same night and a masterflat image were applied. The UCAC4 star catalog was used for the reduction.

Near-Earth Asteroid (24445) 2000 PM8 belongs to the Amor orbital class with an Earth MOID of 0.08173 AU. Given an absolute magnitude $H = 14.6$ and an assumed albedo for a C or S type asteroid, 0.04 and 0.20 respectively, a diameter range of 3.6 –

8.1 km is derived. The object was also observed on 2013 Sept. 25 with the Arecibo radar telescope (<http://www.naic.edu/~pradar/>).

Lightcurve analysis

The lightcurve analysis was carried out with *Peranso*. Originally intended for variable stars, *Peranso* also supports the FALC method by A.W. Harris (Harris et al., 1989). This method was used, though a second analysis was also performed using the ANOVA period analysis method, which confirmed the result obtained with the FALC algorithm. The three observation sets were aligned (zero-point-adjustment) by subtracting the average magnitude of each set from the observations of that night. A period $P = 6.81\text{h} \pm 0.03\text{h}$ was found for (24445) 2000 PM8, which is in agreement with a value of $P = 6.811\text{h}$ found by Warner (2013).

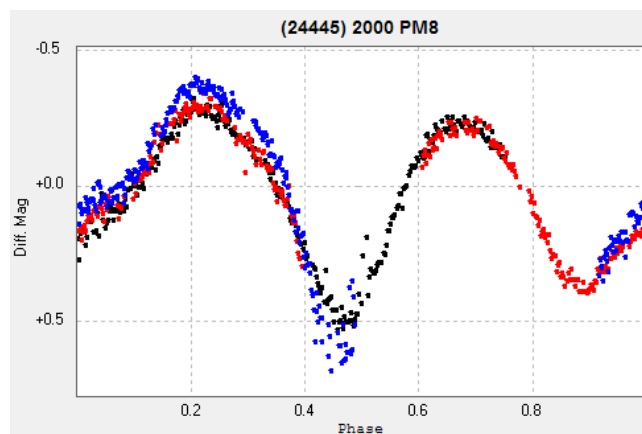


Fig. 1: Phased plot: 2013 Sept. 19 (black), 20 (red), 25 (blue)

Acknowledgements

We would like to thank Dr. Dieter Husar (Hamburg) and Prof. Dr. Hanns Ruder (Tübingen), chairmen of “Stiftung Interaktive Astronomie und Astrophysik”, for granting us access to the ROTAT facilities and their friendly support.

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THE LIGHTCURVE OF 3753 CRUITHNE

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A calibrated lightcurve was obtained for 3753 Cruithne during an observing campaign at the Spacewatch 1.8 meter telescope between August and October of 2012. Analysis indicates a rotation period of 27.30990 ± 0.00015 hours and an amplitude of 0.67 ± 0.01 magnitudes. Insufficient small angle phase coverage was observed for spin axis orientation.

An Aten of some note, 3753 Cruithne's interesting horseshoe orbit is in a 1:1 orbital resonance with Earth, making for an easily accessible spacecraft target. It also has an appreciable size for a near-Earth asteroid, having an absolute magnitude of $H=15.6$. The albedo and diameter have been determined by NEOWISE (Mainzer *et al.* 2012). The Asteroid Lightcurve Database (Warner *et al.* 2013) indicates that Cruithne has a period of 27.4 hours, which is based on 1995 observations presented in Erikson *et al.* (2000). Given the incomplete coverage of those observations over a whole rotational cycle, that value was estimated to be uncertain by 30% in the JPL Small-Body Database Browser (2013).

Observations. The Spacewatch Project performed an observing campaign to obtain a better value for this rotation period over 29 nights between 2012 August 10 and 2012 October 23, observing Cruithne low in the east each morning. During the campaign, Cruithne's distance from the Earth varied from 1.127 AU to 0.461 AU. The phase angle was quite high and varied substantially, from 44.6° to 76.3° . This led to a brightening from $V=18.4$ to 16.6 over the course of the campaign. The rate of motion varied by more than a factor of three which caused some later exposures to be trailed. Additionally the motion of the asteroid carried it into the galactic plane. Despite the short observing windows at low elevation, effort was made to observe as long a series as possible during every sitting so that the measured slope of the lightcurve would help constrain the solution.

All observations were made with the f/2.7 Spacewatch 1.8 meter telescope. The camera was a Finger Lakes Instruments ProLine Model PL3041-LC with a 2Kx2K Fairchild 3041 thinned, back illuminated, broad band antireflection coated CCD. The system is filtered with a Schott OG-515, yielding an effective bandpass of 515-950 nm (approximately V+R+I). MaximDL was used to perform basic image calibration with dark, flat-field and fringe frames. In all cases, high signal-to-noise measurements were made with the exposure time being 120 seconds for most observations before October 6 and decreasing to 60 seconds for most images thereafter as the asteroid became brighter. Time calibration for each session was performed by using ntp at the telescopes.

Data Reduction. Object catalogs were created for each image using the most recent version SExtractor package of Bertin and

Arnouts (1996) while astrometry was performed using Bertin's SCAMP program (Bertin 2010). A custom set of analysis tasks were written to allow images displayed in the SAOImage ds9 to access the object catalogs so that measurements of both astrometric position and magnitude could be collected by clicking on the objects as they were identified by blinking.

As Cruithne was not in regions covered by SDSS directly, observations suited for formal absolute photometric calibration were also performed each night using the deep catalogs of Osmer *et al.* (1998), which itself has been supplemented with additional magnitudes from SDSS DR7 (Abazajian, *et al.* 2009). The photometry was stable, the night to night variations of the zero point varied by only 0.04 magnitudes in the worst case. As Cruithne was rather low in the east each night, the airmasses remained relatively high: between 1.43 and 2.32. Due to a lack of a second bandpass, only a generic reddening term could be used. Additionally, the asteroid moved deeper into the galactic plane, so the increasing star densities caused a growing fraction of observations to be lost to crowding.

On each night, Cruithne was measured in all images along with two check stars that were used for internal photometric consistency measurements. Relatively stringent criteria were placed on each measurement. In general, if another star of appreciable magnitude was visible within 10 arcseconds of Cruithne's position, the observation was rejected. This did not help in all cases, however, because fainter stars and the wings of occasionally brighter stars are still present. Each night's photometry was examined and if the check stars varied by more than 0.05 magnitudes over the duration of the observations observations observations were removed from consideration. In practice, this resulted in the full removal of August 13 and truncation of the observing sessions on August 10 and October 6. In all cases, the observing logs had also made note about degraded weather conditions.

Light travel time corrections were manually calculated before the fit using an ephemeris generated by the Minor Planet Center on August 3. Weather conditions were variable at times.

In the end, 718 observations passed the quality control measures.

Analysis: Lightcurve analysis was primarily performed using Harris's original FALC code from Harris *et al.* (1989) as well as an independent check determination (and JD of zero phase determination) using Peranso Version 2.50 (Husar 2006). Given the numerous effects on the photometry, the original FALC program was preferred because it kept each night to night zero point as a free parameter.

The primary result of the period determination is presented in Figure 1. While FALC used independent zero point determinations, Peranso did not and instead used the photometry calibration directly. Persanso returned a very similar period (to within seconds but we adopt the FALC period preferentially because of the possibility of photometric calibration, distance and phase errors in the raw magnitudes over the wide duration of the campaign. The photometric errors relative to the final lightcurve are presented in Figure 2.

We conclude that Cruithne has a 27.30990 ± 0.00015 hour period and an amplitude of 0.67 ± 0.01 magnitudes. Our results are in good agreement with that of Erikson *et al.* (2000) but sample the asteroid lightcurve over the entire cycle.

Future Studies: Low phase angle observations of Cruithne will be needed for a pole determination. More observations at other phase angles are also needed.

Acknowledgements

This campaign was suggested by Amy Mainzer, PI of NEOWISE at JPL. Spacewatch is supported by NASA's NEO Observation Program, the Brinson Foundation of Chicago, IL, the estates of R. L. Waland and R. S. Vail, and other private donations. Extensive use was made of the IAU's Minor Planet Center web services. In addition to support from Spacewatch, Larsen would like to acknowledge support from the USNA Kinnear Fellowship over Summer 2013 and the Spacewatch Project at the University of Arizona during Fall of 2013.

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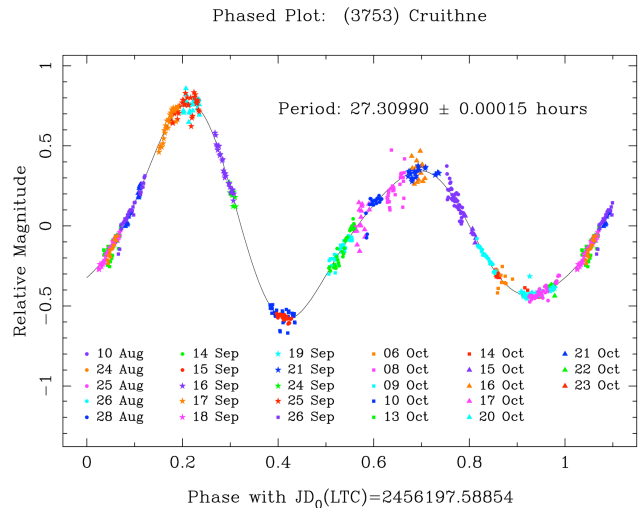


Figure 1: The phased plot of the observations, showing the 4th order period from FALC and first date of zero phase in the campaign.

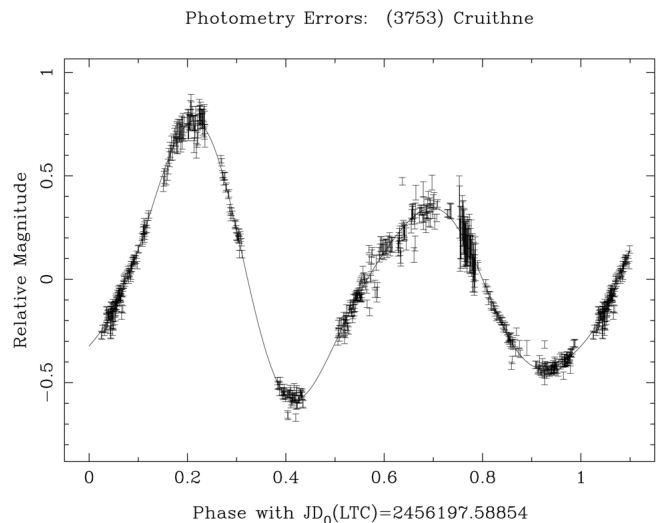


Figure 2: Comparison of internal photometric uncertainties to the best-fit lightcurve.

CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar 2013 are encouraged to report them to this author on or before 2014 April 1. This will be the deadline for receipt of reports which can be included in the "General Report of Position Observations for 2013," to be published in *MPB* Vol. 41, No. 3.

ROTATION PERIOD DETERMINATION FOR 870 MANTO

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(Received: 18 November)

A consortium of observers from Australia, Europe, North and South America have collaborated to find for 870 Manto a rotation period of 122.30 ± 0.01 hours, amplitude 0.80 ± 0.05 mag. There is no evidence of tumbling.

The only previous attempt to find a rotation period for 870 Manto is by Harris et al. (1992) who merely stated a period >24 hours without providing a lightcurve. When several sessions by first author Pilcher suggested a long and possibly Earth commensurate period, he requested collaboration which the other authors kindly provided.

Equipment, telescope and CCD, respectively, utilized by the several observers are as follows: Eduardo Alvarez, 0.3 m f/6.9 SCT, QSI 516wsg; Andrea Ferrero, 0.3 m f/8 RC, SBIG ST9; Daniel Klinglesmith and Angelica Vargas 0.35 m SCT, SBIG ST 10 and STL-1001E; Julian Oey, 0.35 m f/5.9 SCT, SBIG ST - 8XME; Frederick Pilcher, 0.35 m SCT, SBIG STL-1001E.

A total of 37 sessions obtained in the interval 2013 Aug. 8 - Oct. 22 are included in this analysis. *MPO Canopus* software was used by all observers to measure the images photometrically, construct lightcurves, and share data. This software includes a Comparison Star Selector which enables calibration stars with near solar colors to be selected from the MPOSC3 or APASS catalogs. The software also further adjusts asteroid magnitudes measured from these stars for the variation caused by changing heliocentric and geocentric distances and phase angle with an assumed phase factor $G = 0.15$. The magnitudes obtained from these procedure are utilized without further adjustment in the lightcurve of Figure 1. In this lightcurve slopes of corresponding phases are parallel, or nearly so, but the magnitudes themselves show misfits up to 0.2 and sometimes larger. These we attribute mostly to errors in the catalog magnitudes. The next step was to adjust the instrumental magnitudes of one session at a time through several hundred steps until a best fit is obtained, shown in Figure 2. This represents a lightcurve of the object, averaged over the full range of phase angles 25 degrees to 6.5 degrees and back to 19 degrees included in the observations. A good fit to a period 122.30 ± 0.01 hours,

amplitude 0.80 ± 0.05 magnitudes is obtained. There is no indication of tumbling.

The observing cadence by FP and EA 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 their observations, they have been binned in sets of five points with a maximum of ten minutes between points.

Acknowledgement

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

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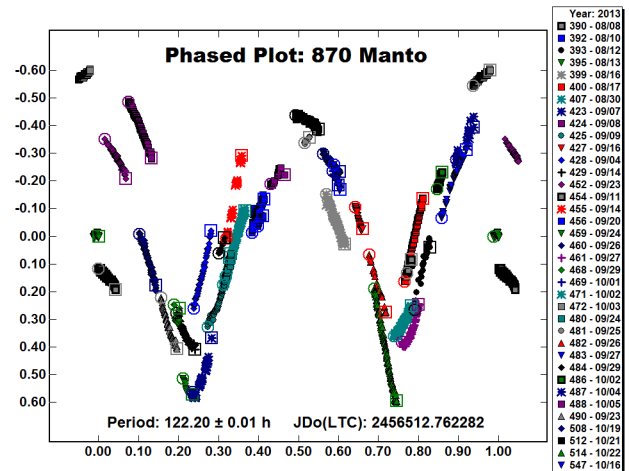


Figure 1. Lightcurve of 870 Manto based on catalog star magnitudes.

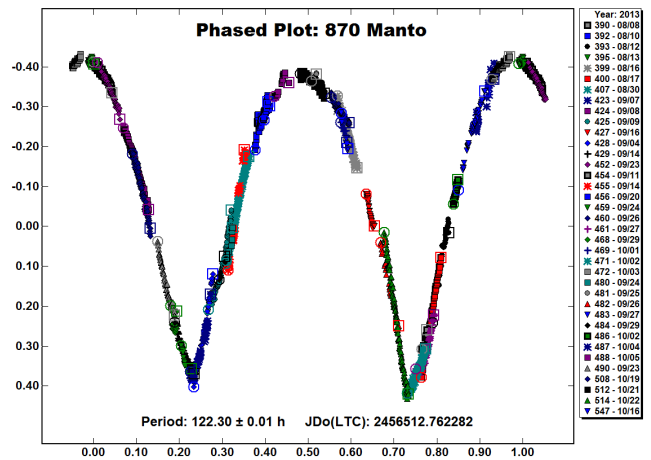


Figure 2. Lightcurve of 870 Manto with instrumental magnitudes of sessions adjusted to best fit.

ROTATION PERIOD AND H-G PARAMETERS OF 641 AGNES

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(Received: 21 November)

The synodic rotation period and amplitude have been found for 641 Agnes 178.0 ± 0.1 hours, 0.55 ± 0.05 magnitudes. The absolute magnitude and the opposition parameter are $H = 12.64 \pm 0.05$, $G = 0.16 \pm 0.03$. The V-R color index was determined to be 0.50 ± 0.05 . Both the color index and G value are compatible with a medium albedo asteroid. The diameter is estimated to be $D = 9 \pm 2$ km.

Observations by Pilcher have been made at the Organ Mesa Observatory with a 35.4 cm Meade LX200 GPS S-C and SBIG STL 1001-E CCD, unguided, clear filter, 60 second exposures. Those by Franco are with a 20 cm Meade LX200 S-C, SBIG ST7XME CCD, V and R filter, 600 second exposures. Observations by Martinez are with a Celestron CPC 1100 28 cm Schmidt-Cassegrain, SBIG ST8XME CCD, clear filter, 40 to 75 second exposures. Photometric measurement, data sharing, and lightcurve construction are with *MPO Canopus* software (Warner, 2013). To reduce the number of points on the lightcurve and make it easier to read data points have been binned in sets of 5 with maximum time difference 10 minutes.

Warner et al. (2013) state only one previous period measurement of 641 Agnes by Lagerkvist (1978), a very uncertain 8.9 hours. We have obtained sessions on 27 nights 2013 Aug. 31 - Oct. 31 and find a synodic rotation period of 178.0 ± 0.1 hours, amplitude 0.55 magnitudes, provides a good fit to a lightcurve with about 95% phase coverage (Figure 1). Each night includes only a small part of the total amplitude. Adjacent or overlapping segments do not have identical slopes and do not allow an excellent fit. Therefore we consider the error in amplitude to be at least 0.05 magnitudes.

For each session the comparison stars were selected with near-solar color indexes and were calibrated to the R magnitude system using the method described by Dymock and Miles (2009) and CMC-14 catalogue by using Vizier Service (2013). The Sloan r' magnitudes in this catalog were converted to Johnson-Cousins R magnitudes by $R = r' - 0.22$. Even with these magnitudes many sessions required instrumental magnitude adjustments as large as 0.2 magnitudes for the best fitting lightcurve which we publish here.

The V and R band session of the October 16 allowed us to determine the color index of $V-R = 0.50 \pm 0.05$.

The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. For each

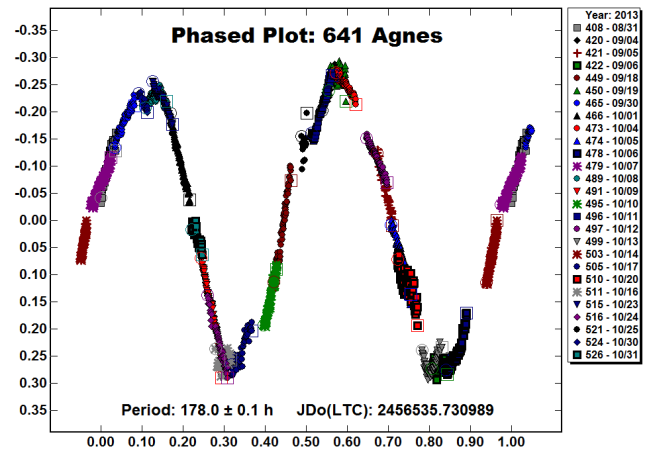


Figure 1.

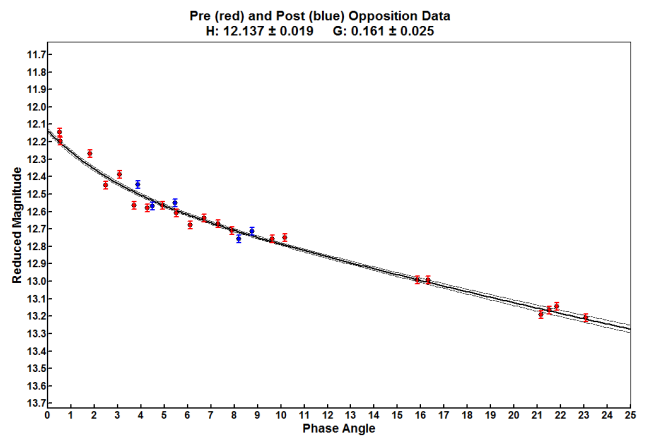


Figure 2.

lightcurve the R mag was measured removing the rotational effects, using a Fourier fit model (Buchheim, 2010). We have achieved $H_R = 12.14 \pm 0.02$ mag and $G = 0.16 \pm 0.03$ (Figure 2) that we convert to $H_V = 12.64 \pm 0.05$ mag, adding the V-R color index value. Both the color index (V-R) and G value are compatible with a medium albedo asteroid (Shevchenko and Lupishko, 1998). For the S-type asteroid, the geometric albedo is $p_V = 0.20 \pm 0.07$ (Shevchenko and Lupishko, 1998). With these values we can estimate the diameter $D = 9 \pm 2$ km, using the formula by Pravec and Harris (2007):

$$D_{(km)} = \frac{1329}{\sqrt{p_V}} 10^{-0.2H_V}$$

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LIGHTCURVE ANALYSIS OF MAIN-BELT BINARY SYSTEM 3905 DOPPLER

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Photometric observations of the main-belt asteroid 3905 Doppler over eight nights in 2013 revealed for the first time that it is a synchronous binary system. A synodic period of 50.8 ± 0.1 hours was derived from the data.

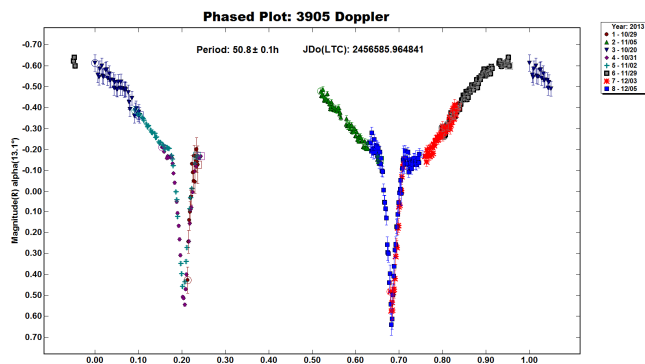
The main-belt asteroid 3905 Doppler was discovered on 1984 August 28 by Czech astronomer Antonin Mrkos. It was named after Austrian physicist Christian Andreas Doppler, who proposed that the measured frequency of a wave depends on the relative motion between the observer and source of emission. There are no prior period determinations for Doppler in the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009; Warner, 2013). Doppler's orbit has an eccentricity of 0.258 and time-averaged mean orbital radius of 2.644 AU. It has an orbital period of 4.09 years, perihelion distance of 1.9 AU, and an inclination of 14.2° with respect to the ecliptic (JPL).

The asteroid was selected for observation due to consistently low zenith distances and no previously published period. In addition, it reached opposition on 2013 November 1, which was about the middle of the college semester in which the project took place.

The observations were made over the Internet using a robotic telescope in Spain (*iTelescope.net*; $2^\circ 19'$ west, $39^\circ 09'$ north; elevation 1650 m). The asteroid was observed using a 0.43-m PlaneWave CDK telescope and CCD camera with a Kodak Enhanced KAI-11000M chip (4008x2745, 9x9 micron pixels). All images were taken using a Baader UV/IR Luminance filter, which has a cutoff frequency of 420 nm at the lower limit and 680 nm at the upper limit. The camera was binned 1x1 with an exposure time of 300 seconds. Data were collected on four nights from 2013 October 20 through November 02, although a significant portion of the data collected on 2013 October 23 had to be discarded due to elongation as a result of guider error. The data collected on October 20 are noisier relative to other nights due to the moon's presence in the sky. Fourier analysis of calibrated images was carried out using *MPO Canopus* (Warner, 2013b).

We collaborated with Lorenzo Franco, who observed Doppler from Rome, Italy. He collected data over five nights from 2013 October 29 to December 05 using a 0.2-m Meade LX-200 Schmidt-Cassegrain telescope coupled to an SBIG ST7-XME CCD camera.

Preliminary analysis of the combined data set suggests that Doppler is a synchronous binary system with a period of 50.8 ± 0.1 hours. This is evidenced by the sharp attenuations in the lightcurve which are preceded and followed by less-steep attenuations on either side of maximum light.



Eight nights of observation of 3905 Doppler phased to an orbital period of 50.8 ± 0.1 hours.

Acknowledgments

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ROTATIONAL PERIOD DETERMINATION FOR 3632 GRACHEVKA

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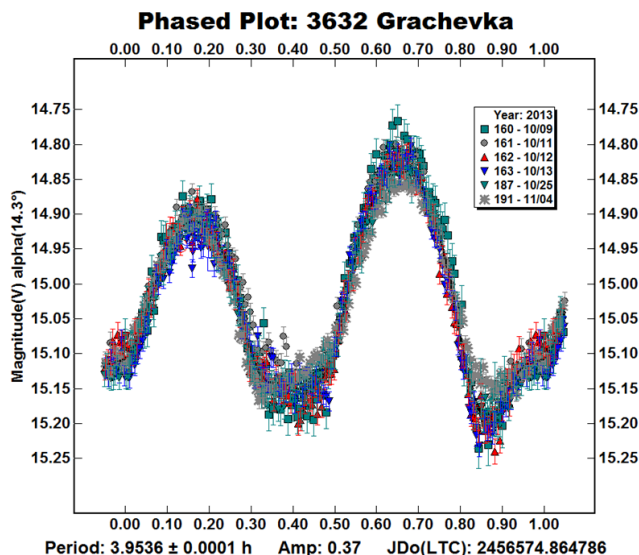
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CCD photometric observations for main-belt asteroid 3632 Grachevka was made from 2013 October 9 through 25. The resulting lightcurve was found to have a synodic period of 3.9536 ± 0.0001 hours and amplitude 0.37 ± 0.01 mag.

The main-belt minor planet 3632 Grachevka was discovered in 1976 by N.S. Chernykh at Nauchnyj and named after a village in the Lipetsk region of Russia, the birthplace of the discoverer's parents (Schmadel, 2003).

Observations of the asteroid at the Lenomiya Observatory were conducted with a Celestron CPC1100 0.28-m Schmidt-Cassegrain with a focal length of 1.943 m, and a ratio of $f/6.3$ using a focal reducer. This was coupled to a Santa Barbara Instruments Group ST-8XME working at -13° C and binned 2×2 . This gave an effective array of 765×510 of 18-micron per pixels and 1.92 arcseconds per pixel. The images were unfiltered and guided. All exposures were 60 s. The images were dark and flat field corrected. After flat field correction, the images were aligned before being measured with *MPO Canopus* (Bdw Publishing) with a differential photometry technique.

Data merging and period analysis were also done with *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris (Harris *et al.*, 1989). Analysis of the combined data set with 833 points found a best fit synodic period of 3.954 ± 0.001 hours and amplitude 0.39 ± 0.01 mag. A search of the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) and other sources did not reveal any previously reported lightcurve results for 3632 Grachevka.



Acknowledgments

The author wishes to express gratitude to Frederick Pilcher and Brian Warner for their support and helpful suggestions on the *MPO Canopus* software.

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NEW PHOTOMETRIC OBSERVATIONS OF 279 THULE

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Photometric observations of 279 Thule reported for the first time here have not solved its enigmatic rotation period. Lightcurves of 279 Thule obtained in 2008, showing an amplitude of 0.06 magnitudes, provide equally good fits to rotation periods of 7.970 hours and 15.960 hours. Lightcurves obtained in 2013 November have an amplitude of only 0.02 magnitudes with small dips in the period spectrum at 15.85 hours and 19.10 hours. The amplitude-aspect method is utilized to find a rotational pole within 15 degrees of celestial longitude 70 degrees, latitude 0 degrees, or longitude 250 degrees, latitude 0 degrees.

Minor planet 279 Thule is the only large asteroid in a stable 4:3 resonance with Jupiter with a small eccentricity small inclination orbit. Oppositions occur at nearly uniform intervals separated by about 13.5 months and celestial longitudes of about 45 degrees. The magnitude at opposition is always near 14.5. The minimum possible distance from Earth is about 3.24 AU. This makes disk resolved imagery by adaptive optics or radar studies especially difficult, and the only practical means to study its properties is by photometry.

Observations near several previous oppositions have all yielded inconclusive results. The period, amplitude, and celestial longitude of each of these follow, listed in chronological sequence. Zappala *et al.* (1989) 7.44 h, 0.06 mag, 5 deg; Sauppe *et al.* (2007), no period found, 0.14 mag, 157 deg; Behrend (2008), 5.75 h, 0.06 mag, 200 deg; Pravec (2008), 11.942 h, 0.04 mag, 200 deg. Warner *et al.* (2010) published lightcurves phased to both 7.979 h and 15.962 h with amplitude 0.10 mag at celestial longitude 245 deg. The 15.962 hour bimodal lightcurve with a slight asymmetry has a somewhat better fit than the 7.979 hour monomodal

lightcurve. The Asteroid Lightcurve Data File (Warner et al., 2013) states 15.962 hours as the most likely, but not secure, period.

This paper reports additional observations by the author from 2008 but not previously published, and from 2013. These have been made at the Organ Mesa Observatory with a 35.4 cm Meade LX200 GPS S-C and SBIG STL-1001E CCD, 60 second exposures, clear filter, unguided. To reduce the number of data points on the lightcurves and make them easier to read data points have been binned in sets of 3 with maximum time difference 5 minutes.

Observations on 5 nights 2008 March 27 - May 3 near celestial longitude 200 degrees provide equally good fit to both a monomodal lightcurve phased to 7.970 ± 0.002 hours and a bimodal lightcurve phased to 15.960 ± 0.005 hours, with amplitude 0.06 ± 0.02 magnitudes.

From observations on 4 consecutive nights 2013 Nov. 8 - 11 near celestial longitude 70 degrees a very small amplitude only 0.02 ± 0.01 magnitudes was found. A period spectrum between 7 and 22 hours shows small dips near 15.85 hours and 19.10 hours, and lightcurves phased to both of these periods are presented. The 19.10 hour lightcurve has a slightly smaller rms residual, but especially near phase 0.00 there is a distinct misfit between sessions. The 15.85 hour lightcurve on the other hand shows no significant misfits. The shorter period is therefore slightly favored, but cannot be considered secure. It must be recognized that due to the short interval of observation and very small amplitude the errors in these periods are likely greater than their formal errors, probably ± 0.1 hours or even greater.

The observations of both 2008 and 2013 are consistent with the 15.962 hour value favored in the Asteroid Lightcurve Data Base (Warner et al. 2013). But they are insufficient to establish this value definitively.

The wide range of celestial longitudes of the several investigations, and the extremely small amplitude noted in 2013 November, enable application of the amplitude-aspect method to determine a rotational pole position within 15 degrees of celestial longitude 70 degrees, latitude 0 degrees, or alternately longitude 250 degrees, latitude 0 degrees.

Future work. The next opposition in 2015 January will occur almost exactly opposite in the sky from the 2010 July opposition observed by Warner et al. (2010) and one can anticipate an amplitude near 0.10 magnitude. The opposition in 2016 February/March is expected to occur at near equatorial aspect with nearly the maximum amplitude possible, likely near the 0.14 magnitudes reported by Sauppe et al. (2007) at almost the same position in the sky. Observers take note, and please place 279 Thule on your schedule for 2016 February/March. These months represent the best opportunity for many years to come to resolve definitively the rotation period of 279 Thule.

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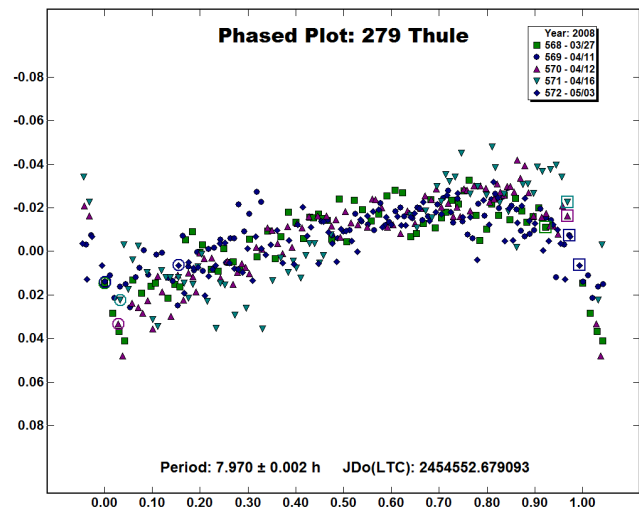


Figure 1. Year 2008 observations of 279 Thule phased to a 7.970 hour period.

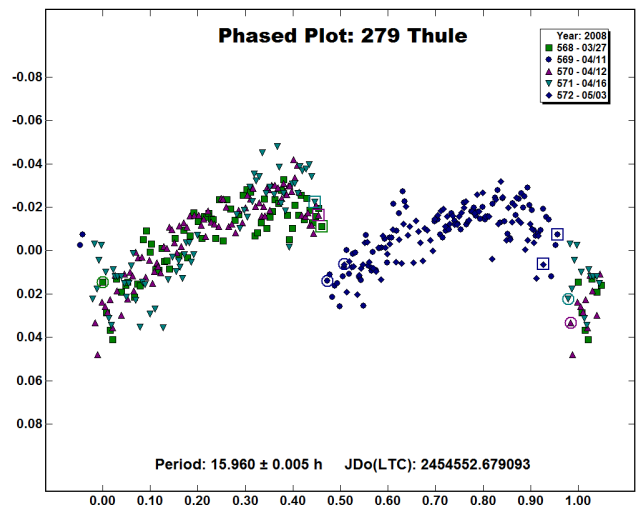


Figure 2. Year 2008 observations of 279 Thule phased to a 15.960 hour period.

**LIGHTCURVE ANALYSIS OF THE
NEAR-EARTH ASTEROID (138095) 2000 DK79**

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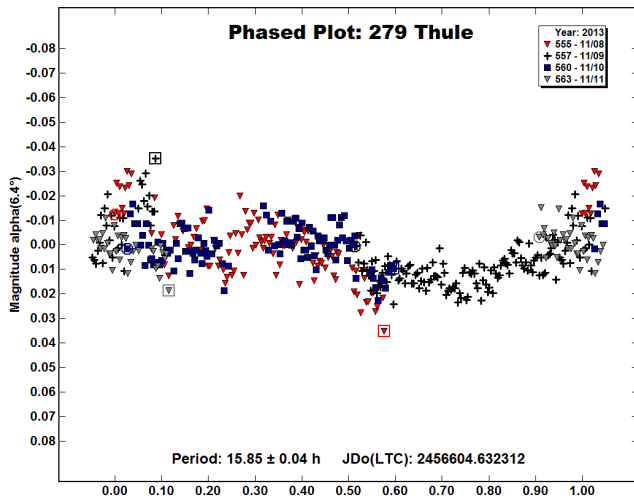


Figure 3. Year 2013 observations of 279 Thule phased to a 15.85 hour period.

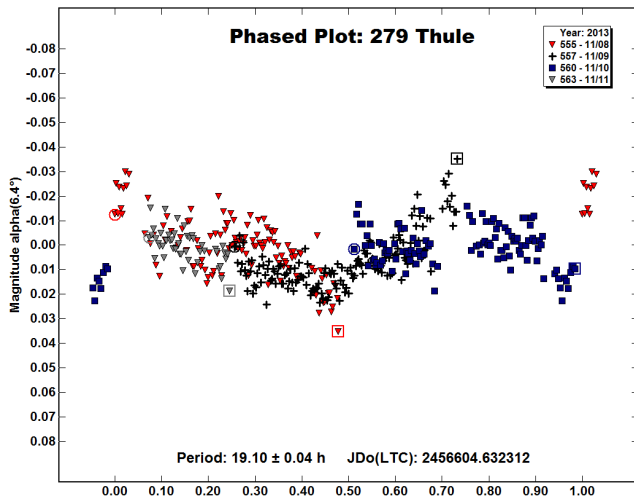


Figure 4. Year 2013 observations of 279 Thule phased to a 19.10 hour period.

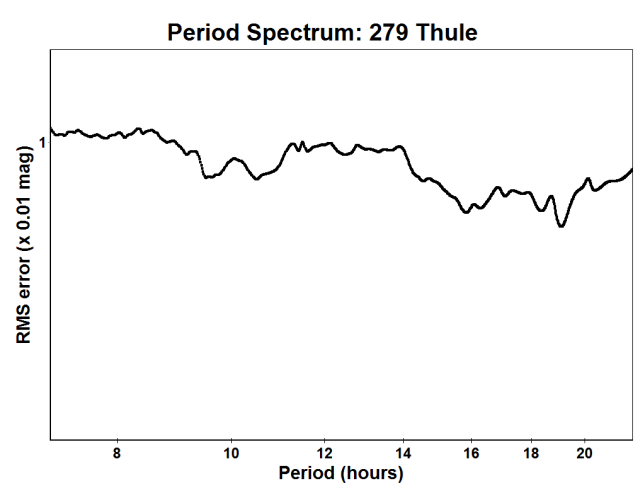


Figure 5. Period spectrum of year 2013 observations of 279 Thule.

Initial analysis of CCD photometry observations in 2013 November from two stations in California made of the near-Earth asteroid (138095) 2000 DK79 found a synodic rotation period of 5.19 h, or 4.62 rotations per Earth day. It was only after adding data from a station on the East Coast of the United States that the more accurate period of 4.243 h (5.62 rotations) was found. This case points to the value of collaborative efforts in asteroid photometry, even when the period is well less than 24 hours.

The near-Earth asteroid (NEA) (138095) 2000 DK79 was reported to be a binary asteroid as a result of radar observations (Mike Nolan, private communications). CCD photometry of the asteroid was requested to support those radar results and to provide additional data for modeling. Initial observations were made by Warner on 2013 November 17 and 18. Mechanical problems prevented further work, at which time Stephens started observing the asteroid. Pray joined the effort when it became apparent that data from a different location would be required to resolve aliases in the period analysis. Tables I and II list the observers, equipment used, and the dates that each person made observations.

OBS	Telescope	Camera
Warner	0.50-m f/8.1 Ritchey-Chretien	STL-1001E
Stephens	0.35-m f/10 Schmidt-Cass	STL-1001E
Pray	0.50-m f/4.0 Newtonian	ST-10XME

Table I. List of observers and equipment.

Obs	Dates (2013 Nov)	Sessions
Warner (CS3)	17 18	1 2 3 4 5 6
Stephens (CS3)	19 21	7 8 11 12
Pray (SLM)	21	9 10

Table II. Dates of observation for each observer. The Sessions column gives the session numbers shown in the lightcurve legend.

Image processing and measurement were done using *MPO Canopus* (Bdw Publishing). Master flats and darks were applied to the science frames prior to measurements. The *MPO Canopus* export data sets from each observer were collected by Stephens for period analysis, also in *MPO Canopus*, which incorporates the FALC Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

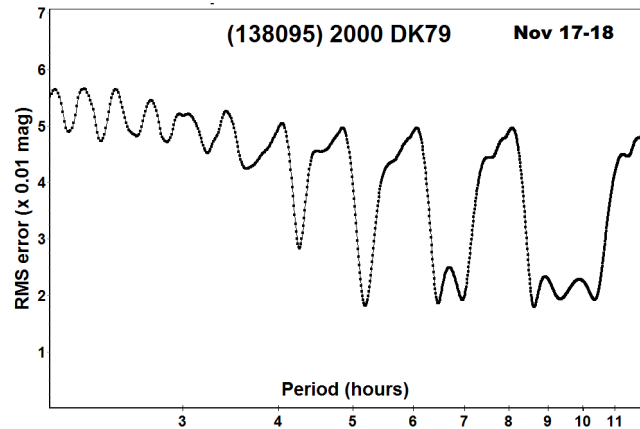
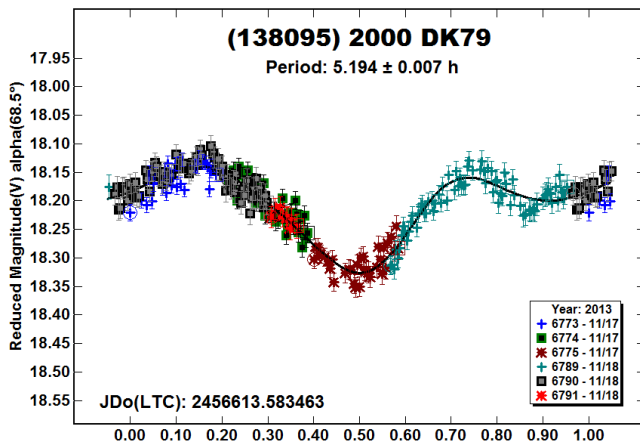
Conversion to an internal standard system with approximately ± 0.05 mag zero point precision was accomplished using the Comp

Star Selector in *MPO Canopus* and the MPOSC3 catalog provided with that software. The magnitudes in the MPOSC3 are based on the 2MASS catalog converted to the BVRcIc system using formulae developed by Warner (2007c).

In the lightcurve plots presented below, the “Reduced Magnitude” is Johnson V corrected to unity distance by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, i.e., $\alpha(68.5^\circ)$, using $G = 0.15$. The horizontal axis is the rotation phase, ranging from -0.05 to 1.05 .

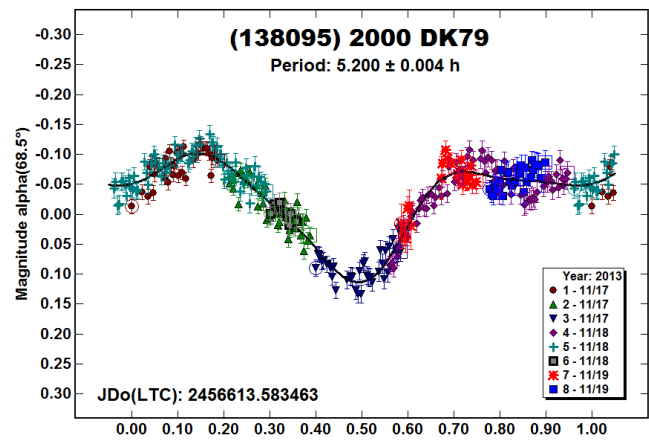
A Progression of Progress

After the first two nights of observations on 2013 Nov 17 and 18 by Warner, lightcurve analysis favored a period of 5.1 h, as shown in the period spectrum below. This was adopted as the working period despite the somewhat unusual shape of the curve with markedly different minimums.

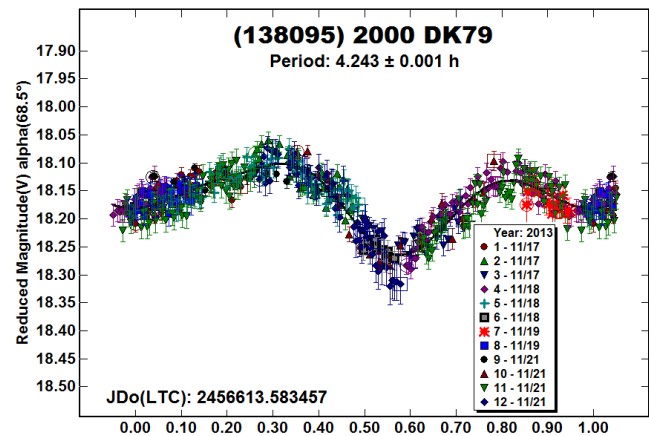
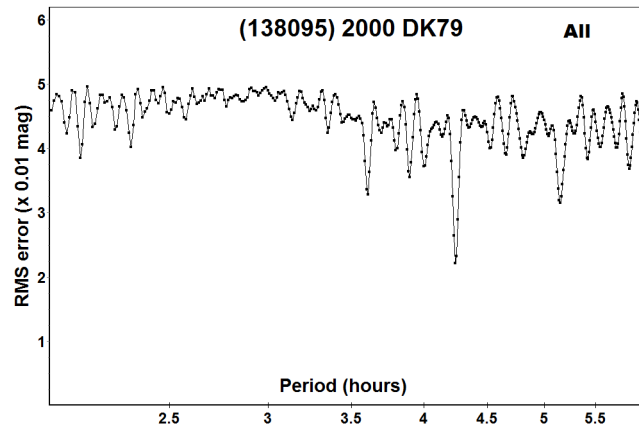


Mechanical problems prevented additional observations by Warner, so Stephens imaged the asteroid from his location, about 20 meters from Warner’s telescopes. His data from Nov 19 were somewhat sparse due to passing clouds. However, they still fit with a period of about 5.2 h, as shown in the plot below.

The period of 5.2 h represents 4.62 rotations per 24 hours. However, the period spectrum started to show a period near 4.2 h might also be possible. The difference between the two periods amounted to almost exactly 1 rotation difference over 24 hours.



At this point, Pray – who is located on the East Coast of the United States – was contacted to see if he might be able to observe the asteroid. If he and Stephens could observe on the same night, there would be nearly continuous coverage over an extended time and so help resolve which rotational alias was correct. They were able to do this on Nov 21.



As shown in the period spectrum, this additional, extended run proved to be an “alias buster”, clearly favoring a period of 4.243 hours and producing a more plausible lightcurve shape.

Had the asteroid been more favorably positioned in the sky and so allowed longer runs, this aliasing problem probably would not have occurred because the runs from each night would have covered more than a complete cycle. As it was, the asteroid was far enough west that it could not be followed by a single station to get extended coverage. By combining the runs from two well-

separated locations, the raw data covered significantly more than a single rotation and broke the alias logjam.

This shows that rotational alias issues are not reserved for objects with periods near 1/4, 1/3, 1/2, or 1/1 of an Earth day, but can also include those with shorter periods. The secret is being able to cover enough of a single rotation (or more than one rotation) in a single run, be it from one or multiple stations. Put another way, if the length of single data run is just short of or about equal to the derived period, a rotational alias is a real possibility and should be carefully addressed during period analysis.

Acknowledgements

The purchase of the FLI-1001E CCD camera used for some observations by Stephens at the CS3 site was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society. Funding for Warner was provided by NASA grant NNX13AP56G and National Science Foundation Grant AST-1210099. Operations at Sugarloaf Mountain Observatory were supported by 2007 and 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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ROTATION PERIOD OF 983 GUNILA

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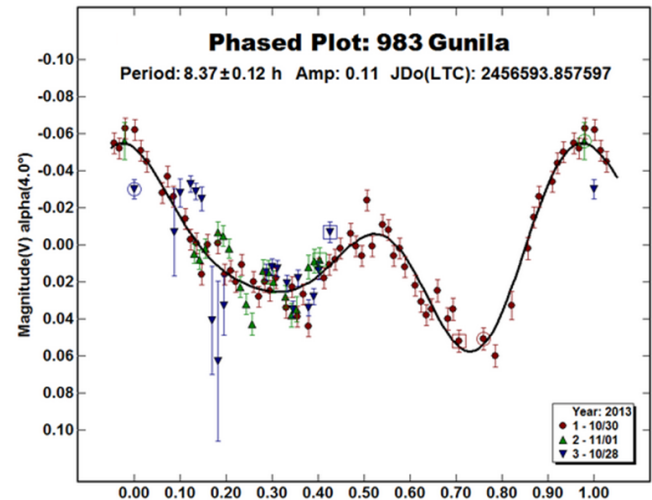
For the ASTR315 class at University of Maryland, we present a lightcurve analysis for 983 Gunila. The asteroid was observed on three nights from 2013 Oct 19 to Nov 1 using iTelescope's T7 Telescope in Nerpio, Spain. After the analysis of the lightcurve, we found a rotation period of 8.37 ± 0.12 h.

The main-belt asteroid 983 Gunila was discovered at the Heidelberg-Königstuhl State Observatory in Heidelberg, Germany, on 1922 July 30 by Karl Wilhelm Reinmuth. The orbital period for the asteroid 5.616 years (Von Heeren, 2013). A query of the asteroid lightcurve database (LCDB; Warner *et al.*, 2009; Warner, 2013a) yielded no prior reported results for the rotation period of 983 Gunila.

Observations at the Nerpio Observatory (MPC I89) were made using the 0.43-m T7 telescope. The telescope was accessed over the Internet through *itelescope.net*. All images were taken through the luminance filter for 300 s with 1x1 binning. Photometric and

rotation period analysis were done using *MPO Canopus* (Warner, 2013b) which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989).

The asteroid was observed for three nights from 2013 October 19 to November 1. The plot shows our results of $P = 8.37 \pm 0.12$ h, $A = 0.11 \pm 0.01$ mag.



The lightcurve of 983 Gunila with a period of 8.37 ± 0.12 h and an amplitude of 0.11 ± 0.01 mag.

Acknowledgements

We gratefully acknowledge the University of Maryland Astronomy Department for funding our observations for the semester. We would also like to thank *itelescope.net* for the use of their telescopes to study our asteroid.

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ROTATION PERIOD FOR 5110 BELGIRATE

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We present an updated rotation period for asteroid 5110 Belgirate, which we observed using the *iTelescope.net* T7 telescope in Nerpio, Spain, on 2013 October 24, 27, and November 3. The previously reported period is 11.04 hours with no uncertainty and based on fragmentary data. Through our observations and analysis, we found a period of 8.26 ± 0.02 h.

The main-belt asteroid 5110 Belgirate was mentioned in the *Minor Planet Bulletin* as a favorable asteroid for study during its apparition of 2013 October and November (Warner *et al.*, 2013). The CALL web site revealed no other current observers (Warner, 2013). A prior analysis for 5110 Belgirate was made in 2006 by Raoul Behrend of Observatoire de Geneve. He found a period of 11.04 h, but it was given little confidence since it was based on fragmentary lightcurves.

We observed 5110 Belgirate using a 0.43-m Planewave CDK telescope with an SBIG STL-11000M CCD. The telescope was operated over the Internet through *iTelescope.net*. It is located near Nerpio, Spain, at $39^\circ 09'$ north, $2^\circ 19'$ west. All images were taken with a standard luminance filter and were bias, dark, and flat-field corrected. Weather conditions proved fairly good during observation times.

Photometric reductions and lightcurve analysis were accomplished using differential aperture photometry with *MPO Canopus* (Warner, 2012). We found that the most likely rotation period is 8.26 ± 0.02 h. The majority of our observational data were from the nights of 2013 October 27 and November 3. The night of October 24th yielded only 10 data points, which were a challenge to include in a differential lightcurve. When plotting only the October 27 and November 3 data, we found a period of 8.91 h. However, with all three nights of data, we achieved a better fit than with only two nights.

Acknowledgements

We greatly appreciate the opportunity provided to us by the Astronomy Department at the University of Maryland. We also acknowledge *itelescope.net* and their staff for their support and use of their instruments.

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Phased Plot: 5110 Belgirate

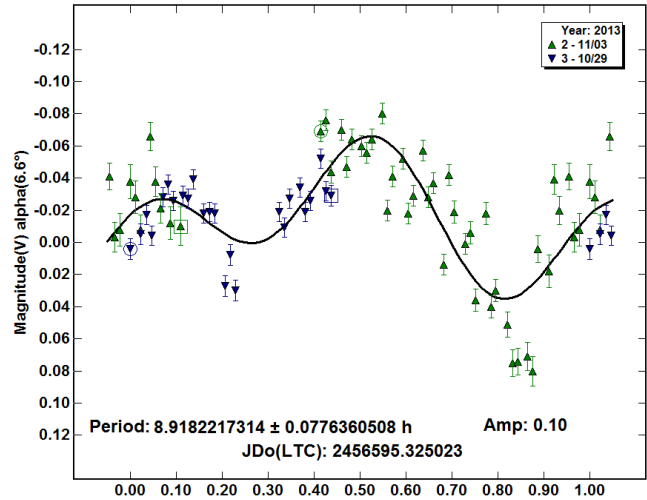


Figure 1. The lightcurve for 5110 Belgirate, using only data from the nights of 2013 Oct. 29 and Nov 03.

Phased Plot: 5110 Belgirate

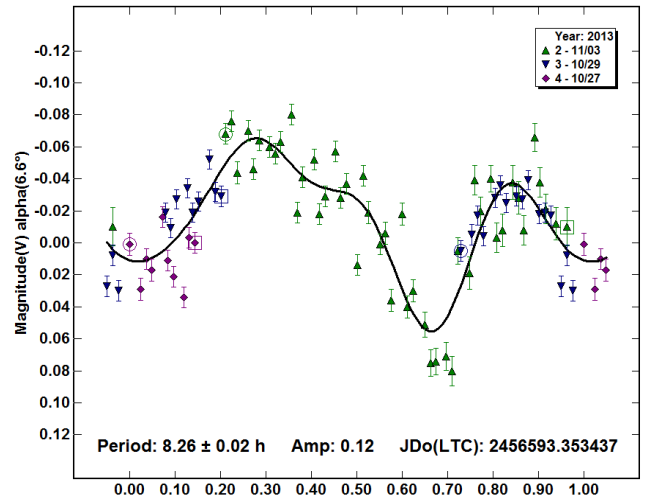


Figure 2. The lightcurve for 5110 Belgirate, using data from the nights of 2013 Oct. 29, 27 and Nov 03

ROTATION PERIOD OF ASTEROID 4727 RAVEL

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The results of photometric observations of the main-belt asteroid 4727 Ravel (1979 UD1) from 2013 August 13-16 at the Maidanak Astronomical Observatory of the Ulugh Beg Astronomical Institute (UBAI), Uzbekistan Academy of Sciences are presented. During the period of observations, the lightcurve amplitude was 0.32 ± 0.05 mag and the synodic rotation period was 0.185 ± 0.009 days (4.44 ± 0.22 h).

The main-belt asteroid 4727 Ravel was discovered on 1979 October 24 by F. Borngen at Karl Schwarzschild Observatory, Tautenburg, Germany (MPC: 033). It is named after the French composer Maurice Ravel (1875-1937), who is a significant representative of impressionism in music. The orbital period is 4.93 years. Since there is no reference to this object in the minor planet lightcurve database (LCDB; Warner *et al.*, 2009), we report our observation results of this asteroid here.

All observational data reported here were obtained by the Maidanak observatory's 60-cm Zeiss-600 telescope. We used an FLI IMG1001E CCD camera (1Kx1K) with the resolution of 0.67 arcsec/pixel, FOV of 10.7×10.7 arcmin, and Bessel R-filter. The temperature of the camera was set to -30°C . Image acquisition was done with *MaxIm DL*. All images were reduced with master bias, dark, and flat frames. Calibration frames were created using *IRAF* (Image Reduction and Analysis Facility). Instrumental star magnitudes were also obtained using *IRAF*, with the zero point set to mag = 25.

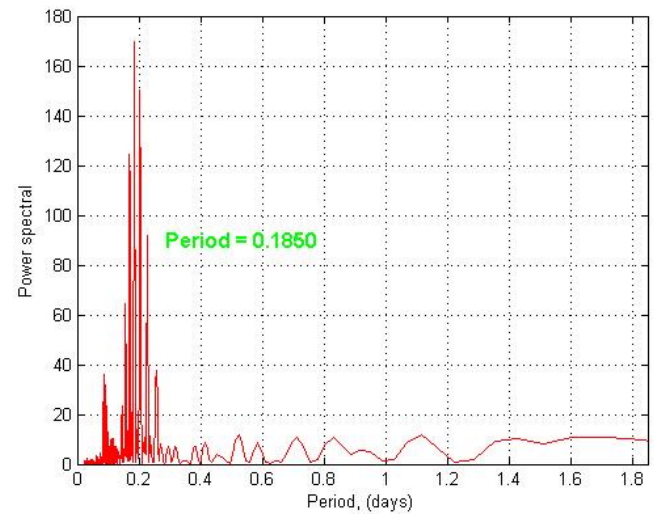
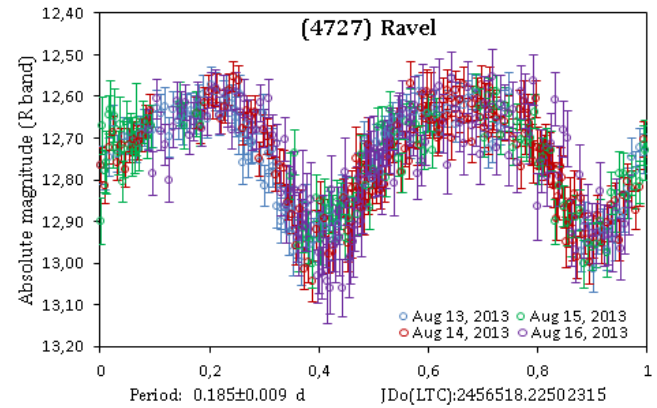
The asteroid's magnitudes were corrected for atmospheric extinction and nightly zero point. To determine the extinction coefficient, we used Landolt photometric standard stars SA113-233, SA113-239, SA113-241, SA113-337, SA113-339, and SA113-342 (Landolt, 1992). We observed 4727 Ravel three times during one night (about 2.5 hours before culmination, 0.5 hours around culmination, and 2.5 hours after culmination). The R-filter extinction coefficient and zero point correction were found to be 0.1115 mag/airmass and 4.33 mag, respectively.

We used LS periodogram (Scargle J.D., 1982) for period analysis of the photometric data. We also used two other software packages: *Period04* (Lenz and Breger 2005) and *cyclocode* developed by B. Dermawan. All programs found the same synodic rotation period, within errors, of 0.185 ± 0.009 day (4.44 ± 0.22 h). The amplitude of lightcurve was 0.32 ± 0.05 mag.

Acknowledgements

We gratefully acknowledge the support of the "Committee for coordination of science and technology development under Cabinet of Ministers of Uzbekistan" (grant No. F2-FA-F026) for

organization of observations at the Maidanak Observatory. We also appreciate B. Dermawan, Bandung Institute of Technology, Faculty of Mathematics and Natural Sciences, who made and published the *cyclocode* program for period analysis. We used his code to confirm the results obtained with our own script and using *Period04*.



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ROTATIONAL PERIOD AND POST OPPOSITION H_R-G PARAMETERS DETERMINATION FOR 3250 MARTEBO

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Photometric measurements for asteroid 3250 Martebo were performed during its 2013 favorable opposition. The synodic rotation period was found to be 9.495 ± 0.001 h, the lightcurve amplitude was 0.52 ± 0.04 mag, the absolute magnitude was $H_R = 10.841 \pm 0.025$ mag, and the slope parameter was $G = 0.101 \pm 0.033$. These lead to an estimated diameter of $D = 31 \pm 4$ km.

3250 Martebo is a small main-belt asteroid discovered in 1979 by C. Lagerkvist at Mount Stromlo (US). It appeared on the CALL web site (<http://www.MinorPlanet.info/call.html>) as an asteroid photometry opportunity due to it reaching a favorable apparition in 2013 and having no defined lightcurve parameters.

Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) in 2013 from October 22 (shortly after opposition) to December 24. The telescope was a 0.3-m Meade LX-200R reduced to $f/6.9$. The CCD imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536x1024 array of 9-micron pixels and 23x16 arcminute field-of-view. The exposures increased from 90 to 240 seconds as the asteroid faded past-opposition (see Table I). 2x2 binning was used, yielding an image scale of 1.77 arcseconds per pixel. The camera was set to -10° C and off-axis guided by means of an SX Lodestar camera and *PHD Guiding* (Stark Labs) software. Image acquisition was done with *MaxIm DL5* (Diffraction Limited). The computer was synchronized with atomic clock time via Internet NTP servers at the beginning of each session.

All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.3.16 with a differential photometry technique. The data were light-time corrected. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors according to recommendations by Warner (2007) and Stephens (2008). Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

More than 58 hours of effective observation and about 1,370 data points were required in order to solve the lightcurve (Figure 1). Over the span of observations, the phase angle varied from 1.8° to 20.2° , the phase angle bisector ecliptic longitude from 24.6° to 29.8° , and the phase angle bisector ecliptic latitude from -0.2° to -2.9° . The rotation period for 3250 Martebo was determined to be 9.495 ± 0.001 h along with a peak-to-peak amplitude of 0.52 ± 0.04 mag. The lightcurve showed a typical bimodal shape, with the maxima virtually identical in magnitude and the minima differing by only a small – although noticeable – amount. No clear evidence of tumbling or binary companion was seen in the lightcurve.

The absolute *R*-band magnitude (H_R) and slope parameter (G) were found using the H-G Calculator tool of *MPO Canopus*, which is based on the FAZ algorithm developed by Alan Harris (1989). Thirteen post-opposition data were used (Table I), all of them

Sess	Date	Span	Exp	Phase	R mag
188	10/22	5.1	90	1.79	14.40–14.86
189	10/23	5.0	90	2.22	14.47–14.98
190	10/25	3.6	105	3.09	14.49–14.85
191	10/28	5.1	120	4.39	14.60–15.11
193	11/05	6.0	150	7.71	14.82–15.44
194	11/06	5.4	150	8.16	14.89–15.59
195	11/22	4.8	180	13.76	15.22–15.82
196	11/23	5.0	180	14.06	15.29–15.75
198	12/01	4.4	240	16.24	15.46–16.05
199	12/04	4.2	240	16.94	15.45–15.97
200	12/21	3.1	240	19.82	15.67–16.33
201	12/22	3.4	240	19.94	15.83–16.60
202	12/24	3.0	240	20.15	15.91–16.62

Table I. Observing circumstances. All dates are in 2013. The imaging intervals (Span) are expressed in hours and the exposure times (Exp) are in seconds.

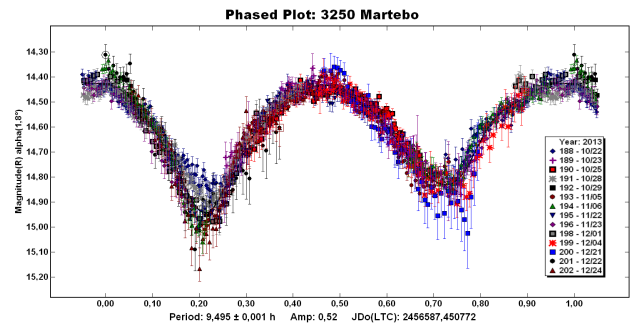


Figure 1. Composite lightcurve of 3250 Martebo.

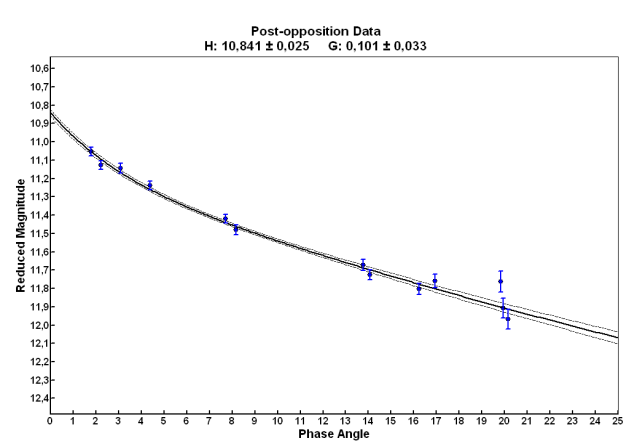


Figure 2. H-G plot in *R*-band magnitude for 3250 Martebo.

representing the maximum of the curve for each observing session. The absolute *R*-band magnitude was determined to be 10.841 ± 0.025 mag and the slope parameter 0.101 ± 0.033 (Figure 2). Such a low G parameter is typical of low albedo asteroids (Lagerkvist and Magnusson, 1990).

Assuming a taxonomic class C, the geometric albedo on the Johnson *V* band becomes $p_V = 0.06 \pm 0.02$ and the color index $V-R = 0.38 \pm 0.05$ (Shevchenko and Lupishko, 1998), which makes the absolute magnitude $H_V = 11.22 \pm 0.06$. By using the formula by Pravec and Harris (2007) for the asteroid diameter (D) in kilometers:

$$D = \frac{1329}{\sqrt{p_V}} 10^{-0.2H}$$

this gives an estimated diameter of $D = 31 \pm 4$ km.

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ROTATION PERIOD DETERMINATION FOR 67 ASIA

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New photometric observations of 67 Asia indicate a synodic rotation period of 15.853 ± 0.001 hours with amplitude 0.22 ± 0.02 magnitudes.

Previous rotation period determinations are by Harris and Young (1980), 15.89 hours; Armstrong, Nellermeoe, and Reitzler (1996), 15.89 hours; and Ditteon and Hawkins (2007), 15.90 hours. Of these by far the most comprehensive is Harris and Young (1980). They obtained approximately 6 hours of data each night for 8 consecutive nights 1978 July 25 - Aug. 1. Lightcurves on consecutive nights looked very different while those on alternate nights looked the same. These results they interpreted as representing a period near 16 hours with the usual bimodal lightcurve, with observations on consecutive nights occurring at intervals of 1.5 rotational cycles, and approximately 3/4 phase coverage. Periods near 8 hours with monomodal lightcurve and near 24 hours with trimodal lightcurve are completely ruled out because in both cases lightcurves on consecutive nights would be separated by an integer number of cycles and would look the same. An alternative interpretation, which was not considered by Harris and Young (1980), is that the period is near 32 hours with a quadrimodal lightcurve the two halves of which look the same. This interpretation would require a shape model symmetric over a 180 degree rotation, highly unlikely for a real asteroid but not absolutely impossible.

Observations to obtain the data used in this paper were made at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. All exposures were 30 seconds, unguided, with a clear filter. Photometric measurement and lightcurve construction are with *MPO Canopus* software. To reduce the number of points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes between points in each bin.

New observations were made with three goals, first to resolve the near 16 hour versus 32 hour ambiguity, second to provide additional data for lightcurve inversion modeling, and third to further refine the 15.89 hour period reported by Harris and Young (1980). To obtain full phase coverage for lightcurves phased to both near 16 hours and 32 hours it is necessary to have sessions of at least 8 hours each night. Four consecutive nights will provide full phase coverage for both of these periods. Or, if any of these four nights is missed due to weather or other circumstance, the same part of the 32 hour lightcurve will be covered 4, or if necessary, 8 nights after the missed session. Four such sessions were obtained near 12 degrees phase angle 2013 Nov. 26-29. Five additional sessions 2013 Dec. 23 - 2014 Jan. 2 at phase angle between 3 and 5 degrees also provide full phase coverage for a trial period near 32 hours.

Separate lightcurves for an assumed period near 16 hours with bimodal lightcurve are drawn for the Nov. 26-29 data, Dec. 23-Jan. 2 data, and for the entire data set. A rotation period 15.853 ± 0.001 hours with amplitude 0.22 ± 0.01 magnitudes provides a good fit to the composite lightcurve. This period I interpret as the most accurate yet obtained. Inspection of the composite lightcurve shows that the shape of lightcurve changed significantly between 12 degrees and 3 degrees phase angle. For each of the short interval data sets lightcurves separated by 2, 6, or 10 nights looks identical within photometric accuracy of the equipment.

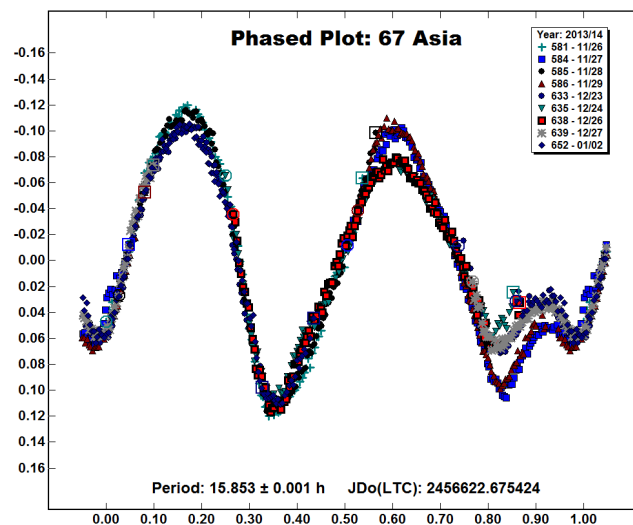
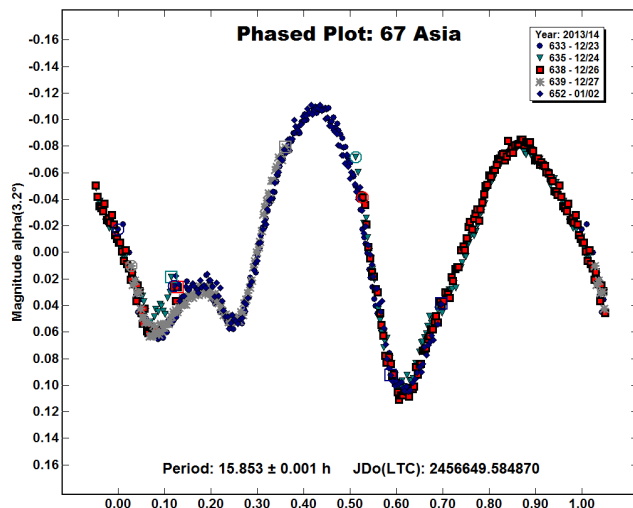
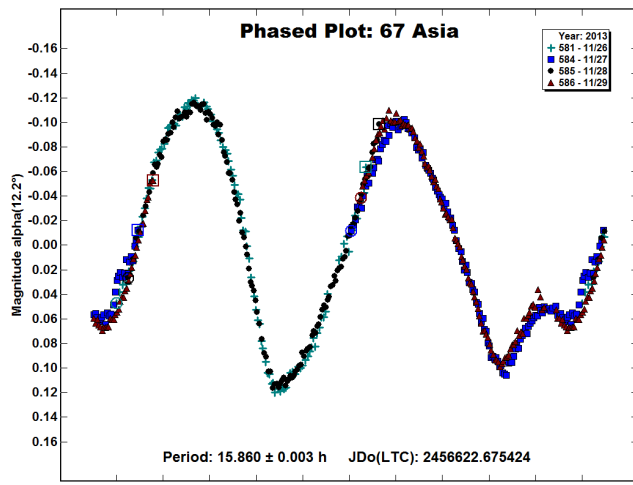
Therefore for a suggested period slightly less than 32 hours the two halves of the lightcurve look identical for three different observational geometries. The probability that a shape model could be symmetric over a 180 degree rotation in all three geometries becomes exceedingly small indeed. I conclude that a period slightly less than 32 hours may be confidently rejected, and that the 15.853 hour period found in this study may be considered secure.

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ASTEROID OBSERVATIONS AT THE ETS CORN CAMPUS OBSERVATORY

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(Received: 13 January)

We observed eight asteroids to determine their synodic rotation periods. Two were Mars-crossing and six were main-belt asteroids.

Observations of asteroid lightcurves were obtained at the Etscorn Campus Observatory (ECO, 2014). We used three Celestron 0.35-m Schmidt-Cassegrain (SCT) telescopes on Software Bisque Paramount ME mounts (SB, 2013). Two of the telescopes used SBIG STL-1001E CCD cameras that have 1024x1024 24-micron pixels. The combination gave a 22x22 arcmin field-of-view with a scale of 1.25 arcsec/pixel. The third C-14 used an SBIG ST-10XME with an Optec 0.5x focal reducer. The ST-10XME was binned 2x2, providing an image of 1092x736 13.6-micron pixels. This combination produced a field-of-view of 20x16 minutes and 1.28 arcsec/pixel scale.

The asteroid images were obtained through either an R or clear filter. Exposure times varied between 3 and 5 minutes depending on the brightness of the object. Each evening a series of 11 dome flats was obtained and combined into a master flat with a median filter. The telescopes were controlled with Software Bisque's TheSky6 (SB, 2014) and the CCDs were controlled with CCDsoft V5 (SB, 2014). The images were dark subtracted and flat field corrected using image processing tools within *MPO Canopus* version 10.4.1.9 (Warner, 2014). The multi-night data sets for each asteroid were combined with the FALC routine (Harris *et al.*, 1989) within *MPO Canopus* to provide synodic periods.

The information about asteroid discovery dates and names comes from the JPL small bodies database (JPL, 2014). LCDB refers to the asteroid lightcurve database (Warner *et al.*, 2009; on-line updates at <http://www.MinorPlanet.info/lightcurvedatabase.html>).

1420 Radcliffe is a main-belt asteroid discovered 1931 Sep 14 by K. Reinmuth at Heidelberg. It is also known as 1931 RJ, 1931 TF, 1935 OM, 1963, and 1963 VB. We observed it on six nights from 2013 Nov 06 through Dec 04. We obtained a synodic period of 4.792 ± 0.002 h and an amplitude of 0.20 ± 0.10 mag. It has a simple bimodal lightcurve.

3737 Beckman is a Mars-crossing asteroid discovered 1983 Aug 08 by E. F. Helin at Mt. Palomar. It is also known as 1983 PA. We observed it on five nights from 2013 Nov 10 through 19, in part because it was suggested as an inversion model candidate by Warner *et al.* (2013). We obtained a synodic period of 3.130 ± 0.002 h and an amplitude of 0.27 ± 0.10 mag assuming a simple bimodal lightcurve. It was observed by Wisniewski (1987) for two nights. He found a period of 3.124 h. The phase angle bisector longitude (PABL) and latitude (PABB) for his observations on 1987 Dec 22 and 23 were 96.2° and -7.9° . The values for our observations varied between 12° and 35° for longitude and 29.6° and 35° for latitude.

4943 Lac d'Orient is a main-belt asteroid discovered 1987 Jul 27 by E. W. Elst at Haute Provence. It is also known as 1987 OQ and 1979 XR1. We observed it on seven nights between 2013 Sep 04 and Nov 09. We obtained a synodic period of 11.809 ± 0.001 h and an amplitude of 0.56 ± 0.15 mag. Its bimodal lightcurve has unequal minimums.

5431 Maxinehelin is a main-belt asteroid discovered 1988 Jun 19 by E. F. Helin at Mt. Palomar. It is also known as 1988 MB, 1985 YB, and 1986 AT. We observed it on six nights between 2013 Aug 27 and Oct 09. We found a synodic period of 4.888 ± 0.001 h with an amplitude of 0.18 ± 0.10 mag. Pravec *et al.* (2013) reported a period of 5.1951 h. Their observations were obtained on 2013 Jul 07 and have a PABL and PABB of 329.5° and 15.6° (LCDB). The solar bisector angles for our observations varied between 337.9° and 344.4° for PABL and 27.3° and 31.4° for PABB.

6041 Juterkilian is a Mars-crossing asteroid discovered 1990 May 21 by E.F. Helin at Mt. Palomar. It is also known as 1990 KL and 1990 KV3. We observed it on four nights between 2013 Jul 31 and Aug 23. Due to the lack of complete coverage, we can only estimate the synodic period to be 13.57 ± 0.03 h with an amplitude of 1.17 ± 0.20 mag.

16197 Bluepeter is a main-belt asteroid discovered 2000 Jan 07 by the Lowell Observatory Near-Earth Object Search (LONEOS) at Anderson Mesa Station. It is also known as 2000 AA243, 1949 OH, 1979 MX4, and 1999 AD23. We observed it on twelve nights between 2013 Sep 05 and Nov 19. We obtained a synodic period of 2.708 ± 0.001 h and an amplitude of 0.25 ± 0.20 mag.

20210 1997 GQ7 is a main-belt asteroid discovered 1997 Apr 02 by LINEAR at Lincoln Labs, Socorro, NM. It is also known as 1985 UA4 and 1992 FC. We observed it for five nights between 2013 Nov 27 and Dec 07. We found a synodic period of 10.326 ± 0.001 h and an amplitude of 0.21 ± 0.05 mag.

32856 1992 SA25 is a main-belt asteroid discovered 1992 Sep 30 by H. E. Holt at Mt. Palomar. It is also known as 2000 LW11. We observed it for five nights between 2013 Sep 04 and 24. We found a synodic period of 13.507 ± 0.001 h and an amplitude of 0.40 ± 0.10 mag.

Acknowledgments

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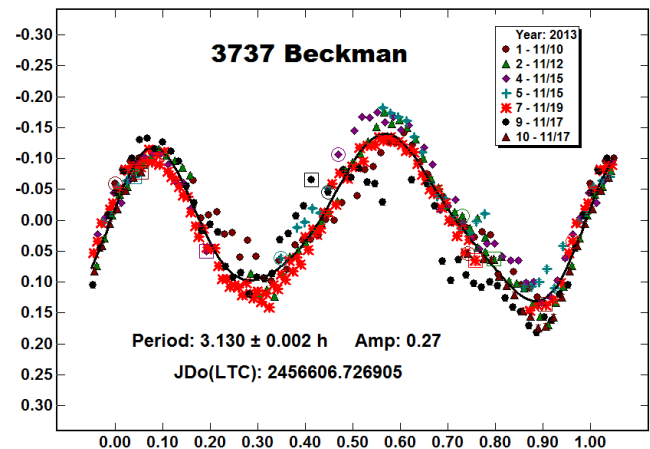
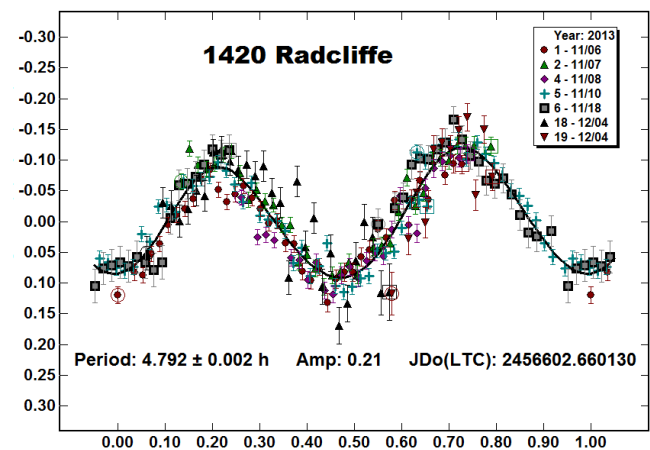
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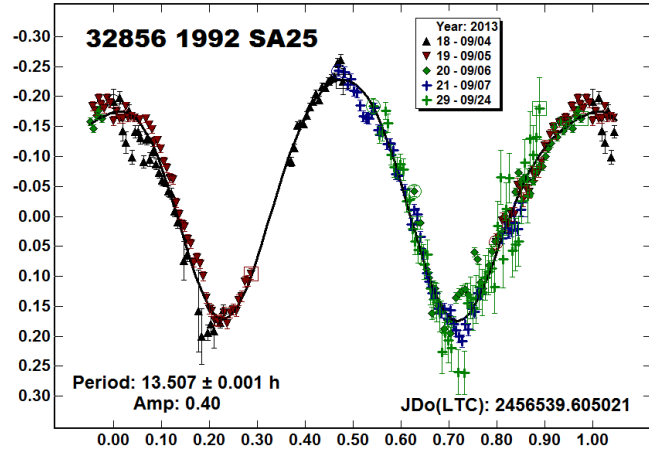
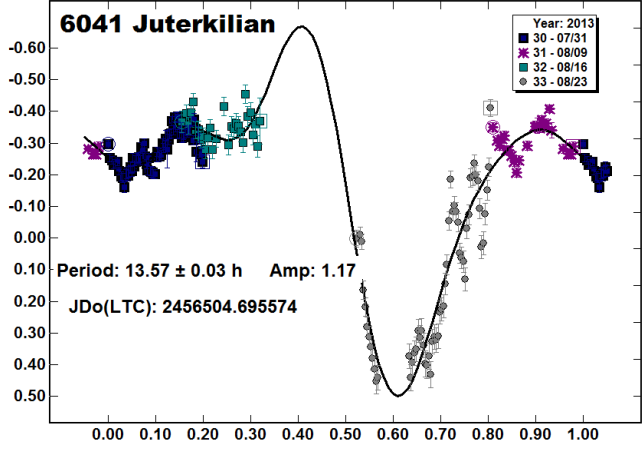
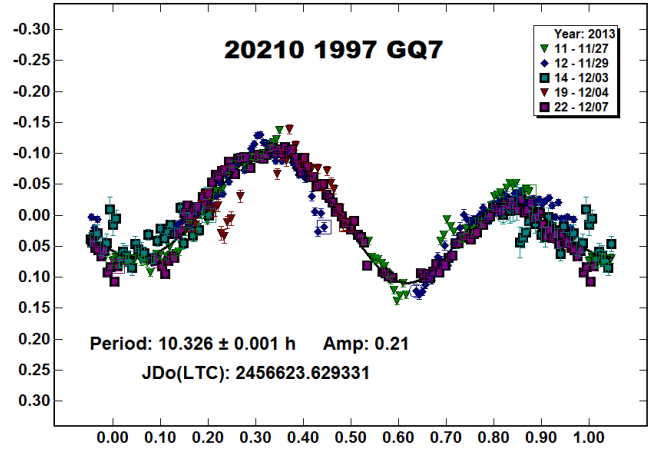
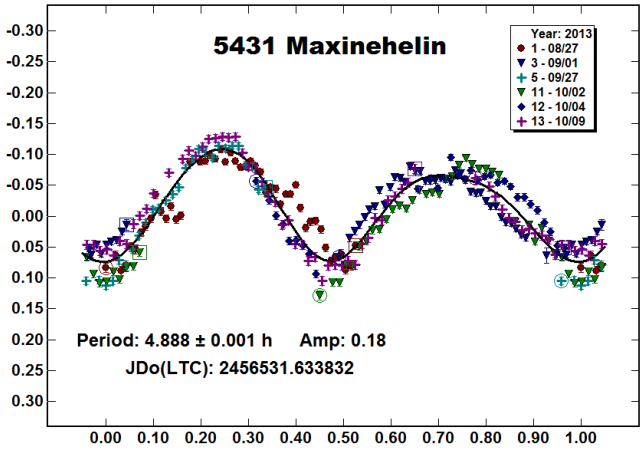
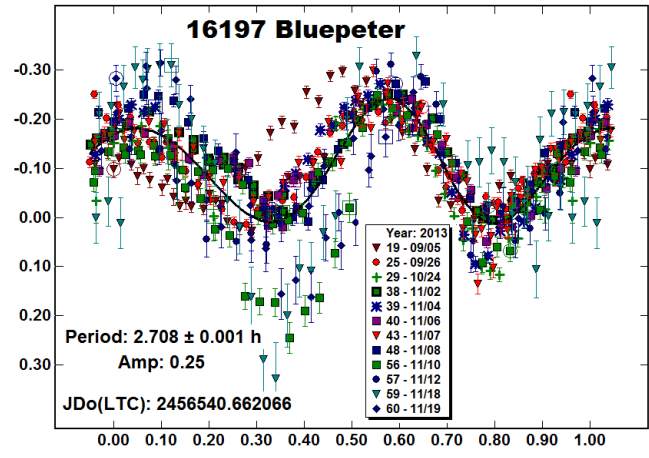
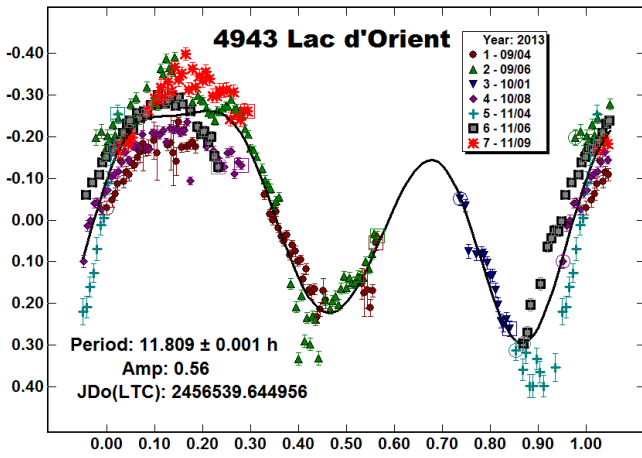
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LIGHTCURVE ANALYSIS OF 3182 SHIMANTO AND 3263 BLIGH

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Photometric observations of main-belt asteroids 3182 Shimanto and 3263 Bligh were made at the Eurac Observatory in 2013. For 3182 Shimanto, a synodic rotation period of $P = 2.9950 \pm 0.0001$ h and amplitude of $A = 0.26 \pm 0.05$ mag were found. The synodic period of 3263 Bligh was determined to be $P = 3.193 \pm 0.001$ h with an amplitude $A = 0.16 \pm 0.05$ mag. The V-R color index for both asteroids was also measured and the H-G parameters found for 3263 Bligh, resulting in an estimated diameter of $D = 15 \pm 3$ km.

CCD photometry observations of two main-belt asteroids were made at the Eurac Observatory (C62; Bolzano, Italy) in 2013. In both cases, a 0.30-m reflector, reduced to $f/4.0$, and QHY9 CCD camera were used to obtain the images. Before each session, the computer clock was synchronized with atomic clock time using Internet NTP servers. All images were calibrated with dark and flat-field frames. Image measurements using differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012). Images were taken with Johnson V and Cousins R filters so that the color index of the asteroid could be determined. The V and R band frames were acquired using an alternating sequence, i.e., VR VR VR, to help remove effects of variations due to rotation.

3182 Shimanto. This main-belt asteroid was reported as a lightcurve photometry opportunity for 2013 July on the MinorPlanet.info web site (http://www.minorplanet.info/PHP/call_OppLCDBQuery.php). The derived synodic period was $P = 2.9950 \pm 0.0001$ h (Fig. 1) with an amplitude of $A = 0.26 \pm 0.05$ mag.

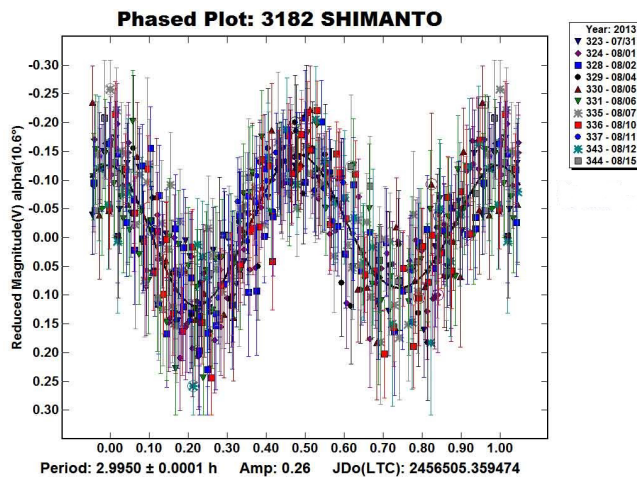


Figure 1. The lightcurve of 3182 Shimanto with a period of 2.9950 ± 0.0001 h and an amplitude of 0.26 ± 0.05 mag.

The color index was found to be $V-R = 0.43 \pm 0.04$ mag (mean of 40 values). This value is typical of an M-type asteroid (Shevchenko and Lupishko, 1998).

3263 Bligh. Bligh was reported as a lightcurve photometry opportunity for 2013 November on the MinorPlanet.info web site. The derived synodic period was $P = 3.193 \pm 0.001$ h (Fig. 2) with an amplitude of $A = 0.16 \pm 0.05$ mag. A color index of $V-R = 0.38 \pm 0.03$ mag (mean of 35 values) was found. This value is typical of a C-type asteroid (Shevchenko and Lupishko, 1998).

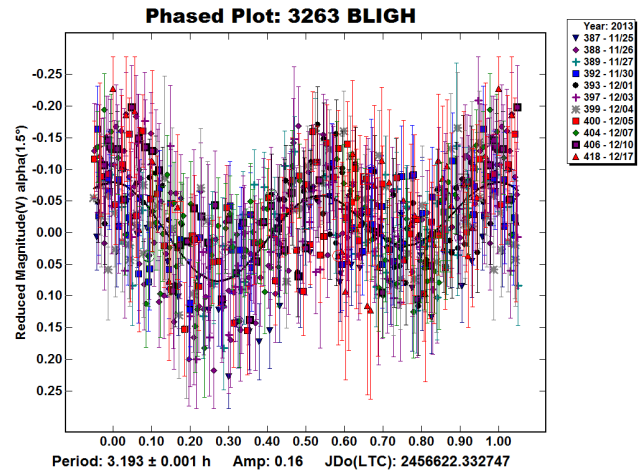


Figure 2. The lightcurve of 3263 Bligh with a period of 3.193 ± 0.001 h and an amplitude of 0.16 ± 0.05 mag.

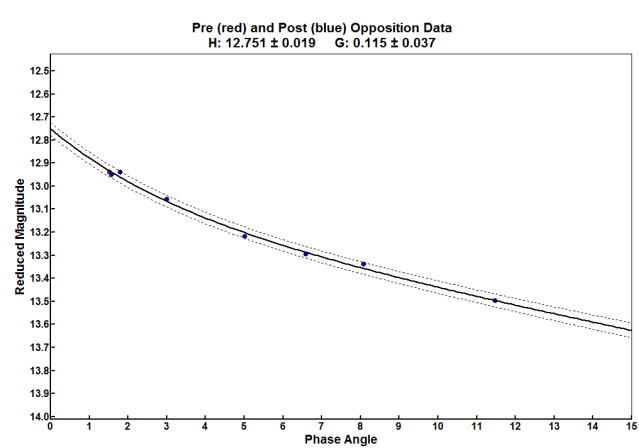


Figure 3. Visual reduced magnitude vs. phase angle for $H = 12.75 \pm 0.02$ mag and slope parameter $G = 0.11 \pm 0.04$

Assuming C-type, the geometric albedo is $p_v = 0.06 \pm 0.04$ (Shevchenko and Lupishko, 1998). The absolute magnitude (H) and slope parameter (G) were found using the H-G Calculator function of *MPO Canopus*. Eight values, using the maximum values of the lightcurve, were obtained pre- and post-opposition. The calculator reported $H = 12.75 \pm 0.02$ mag and $G = 0.11 \pm 0.04$ (Fig. 3).

From this, we can estimate a diameter of $D = 15 \pm 3$ km using the expression (Pravec and Harris, 2007):

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

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SHAPING A 3-D MODEL OF ASTEROID 1825 KLARE

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This study is part of an undergraduate research project and a continuation of the works done by Dr. Maurice Clark, who coordinated with the lead author in the findings. Observations were done on multiple nights by several observers within a ten year period, mostly in 2003 and 2013. Preston Gott Observatory at Texas Tech University is the last location where the observations were conducted.

The intention was to study the methods of photometry as a final project by Krueng for an observational astronomy course conducted by Dr. Maurice Clark at Texas Tech University. The asteroid 1825 Klare was chosen to be the object of the study. Dr. Clark, who has been in the field for more than a decade, guided Krueng in an attempt to construct a three-dimensional model of the asteroid. Since 2003, various observers made observations of the main-belt asteroid 1825 Klare. In 2003 and 2004, Dr. Clark and Don Pray independently conducted observations and derived lightcurves and periods (Clark, 2006; Pray, 2005). The latest lightcurve data were obtained in 2013 from observations done by the authors. *MPO Canopus* was used to analyze the data and derive the period and *MPO LCInvert* was used to convert the combined lightcurve data into the model shape.

Observations and Data

The observations are summarized in Table 1. Each row represents a single set of data by individual observer. The final row is the

Year	Date Range mm/dd	Solar Long.	Observatory	Sess	Per (h)	Error (h)	Amp (mag)	Error (mag)	Observer
2003/2004	12/27-01/01	~97°	Carbuncle Hill	5	4.744	0.009	0.75	0.02	Pray
2003/2004	12/28-01/11	~97°	Rosemary Hill ¹	3	4.7429	0.0003	0.9	0.1	Clark
2013	04/04-05/09	~140°	Preston Gott ²	8	4.7421	0.00004	0.77	0.1	Krueng, Clark
03,04,13	Multiple	-	Multiple	15	4.74235	0.00001	-	-	Multiple

¹ Rosemary Hill Observatory (Minor Planet Observatory code 831) is owned by the University of Florida, Gainesville, and is located near Bronson, Florida at an elevation of 51 m. The main instrument at Rosemary Hill is a 0.76-m Tinsley reflector. For these observations, the instrument was used at its f/5 Newtonian focus with an SBIG ST-7E CCD camera.

² The Preston Gott Observatory is the main astronomical facility of the Texas Tech University. Located about 20 km north of Lubbock, TX, the main instrument is a 0.5-m f/6.8 Dall-Kirkam Cassegrain. An SBIG STL-1001E CCD was used with this telescope.

combined observations from all observers. One session from the second set of observations (row two) was eliminated due to a large amount of noise that affected the modeling. Figures 1-4 show the results of lightcurve data from those observations. The table includes the date range of the observations along with the location and the name of the observer. The asteroid's heliocentric longitude as well as its period and amplitude (with errors) are also included.

Analysis

Using *LCInvert*, the lightcurve data of asteroid 1825 Klare from 2003, 2004, and 2013 were analysed to generate a possible synodic period and then further analysis was undertaken to derive the sidereal period.

The next step was to analyse the data to derive possible pole positions. The software generates 360 possible solutions using discrete, fixed longitude-latitude pairs while allowing the sidereal period to "float" (Clark, 2011). Figure 5 shows the result after the period is applied in the pole search. Dark blue indicates the lower values of log(chi-square) in the range of solutions. The plot colors progress towards bright red with increasing log(chi-square) with the highest value indicated by maroon (dark red) (Clark 2011).

Figure 5 shows a general solution near $\lambda = 200^\circ$, $\beta = +70^\circ$. A large dark blue area means a weak solution; therefore an attempt to find a refined solution is difficult. There is no other obvious solution in positive or negative λ and β directions. However, distinct non-dark blue areas indicate a wide range of positions where the poles are *not* located. This means the shape can be partially distinguished though poorly constrained.

Using the solution as a starting point to run the search again – this time allowing the longitude/latitude and sidereal period to float, the intermediate solution was then refined to two possible solutions. Figures 6 and 7 show the models for the final result.

Both solutions, (200°, +70°, 4.74233003 h) and (20°, +80°, 4.74233042 h), indicate prograde rotation. The error for the poles is $\pm 10^\circ$ while the period solutions have errors on the order of 2-3 units in the last decimal place. Given the low orbital inclination ($\sim 4^\circ$) and the nature of the lightcurve inversion process, it is common to find a double solution with the two usually differing by 180° in longitude (Clark 2011).

Since there are only slight differences between both solutions and the observed lightcurves, neither solution is preferred. Therefore, more observations are needed in the future to determine which, if either, of these solutions is correct. Figures 8-11 show examples of the model fits and the observed lightcurves. Figures 13 and 14 shows the 3-D model of the asteroid derived from the first solution. Figures 15 and 16 show the 3-D model of the asteroid derived from the second solution.

Conclusions

The initial involvement in photometry is a step up for the author in the field of astrophysics and through the shaping of three-dimensional of asteroid 1825 Klare, the author further implemented the use of photometry.

From this first attempt at converting the asteroid’s lightcurves into a 3-D model, it is clear that there is a need for additional data and analysis. This will be an ongoing project as more data are acquired. The asteroid will be at opposition in 2014 May but at -24° . Therefore, it may be necessary to enlist the aid of Southern Hemisphere observers. Besides the data used here, there were others, mainly from the year 2007. These data would have been very helpful for this study. However, we were not able to communicate with the other observers and so obtain their data.

Acknowledgements

Krueng wishes to express his utmost gratitude to Dr. Maurice Clark, who has been instrumental in every step of the way in guiding Krueng, from gathering data to writing this paper, and had great patience while showing the author the experience of professional astronomy. Dr. Clark’s kindness and efforts will be remembered for years to come. Further thanks to Don Pray who provided crucial data for this work.

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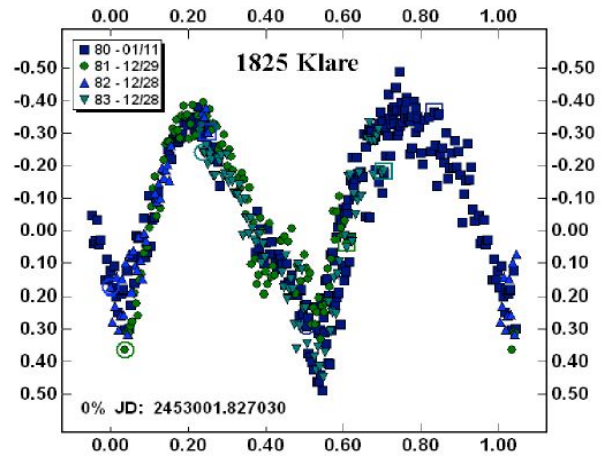


Figure 2: 2003/2004 lightcurve by Maurice Clark

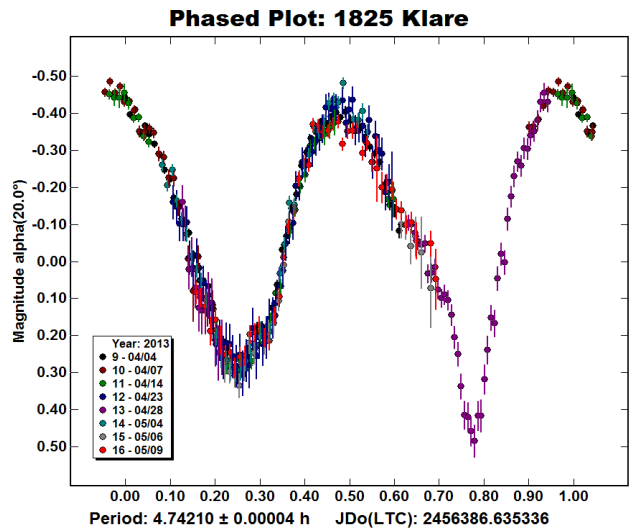


Figure 3: 2013 lightcurve by Mahfuz Krueng and Dr. Maurice Clark

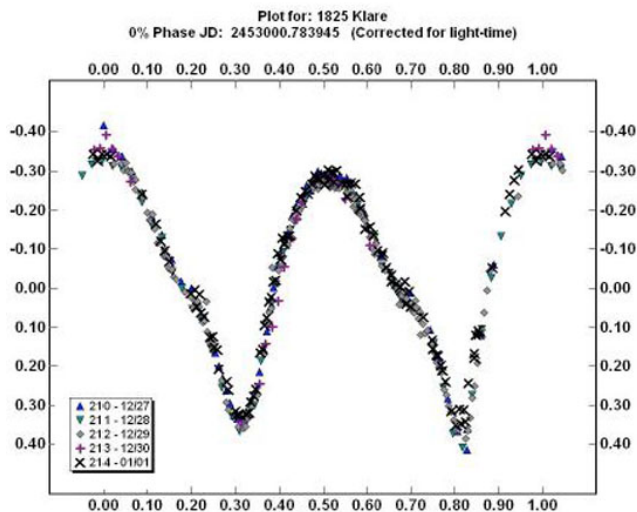


Figure 1: 2003/2004 lightcurve by Don Pray

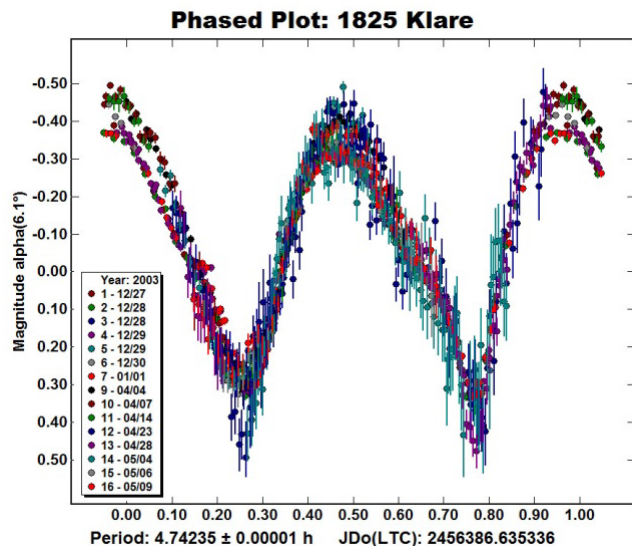


Figure 4: 2003-2013 lightcurve (multiple)

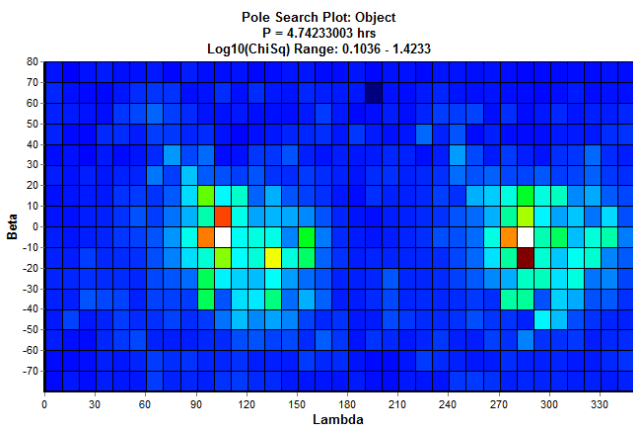


Figure 5. Plot of the log (chi-square) values for 1825 Klare. Dark blue represents the lowest chi-square value.

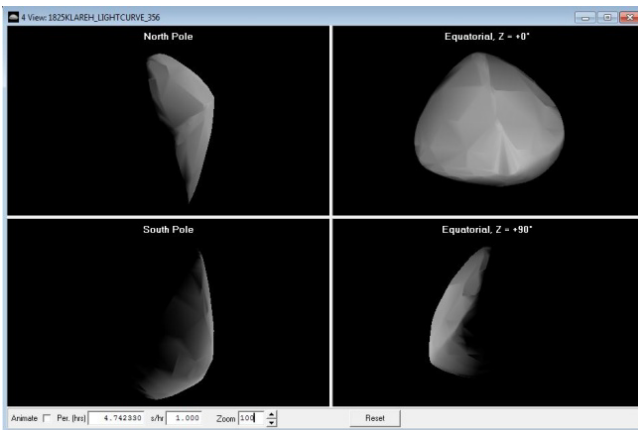


Figure 6: 3-D model of 1825 Klare for solution $\lambda = 200^\circ$, $\beta = +70^\circ$, period = 4.74233003 h

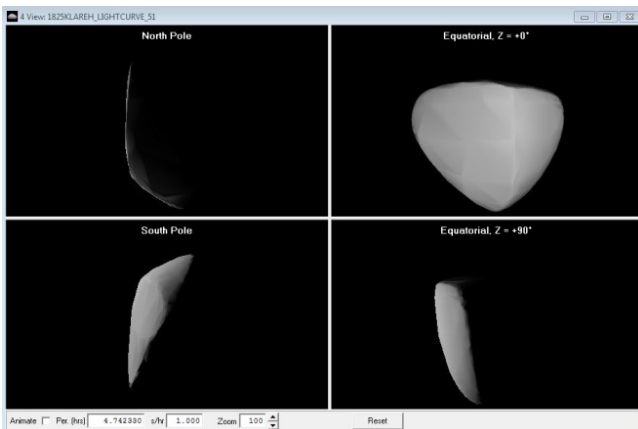


Figure 7: 3-D model of 1825 Klare for solution $\lambda = 20^\circ$, $\beta = +80^\circ$, period = 4.74233042 h

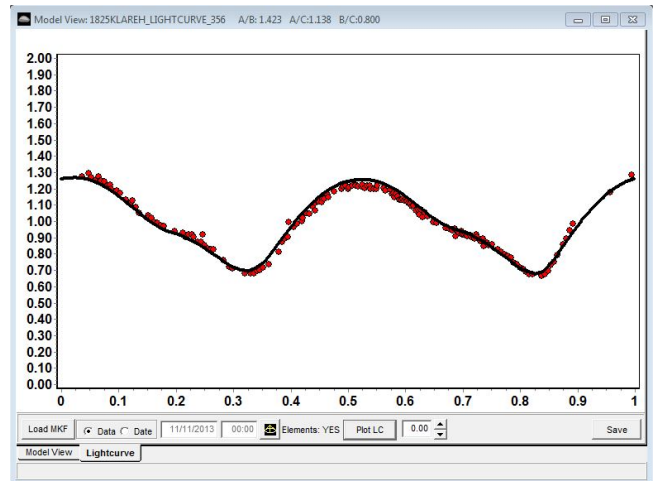


Figure 8: Correspondence between model and observed lightcurve of 1825 Klare $\lambda = 200^\circ$, $\beta = +70^\circ$, period = 4.74233003 h. December 29, 2003.

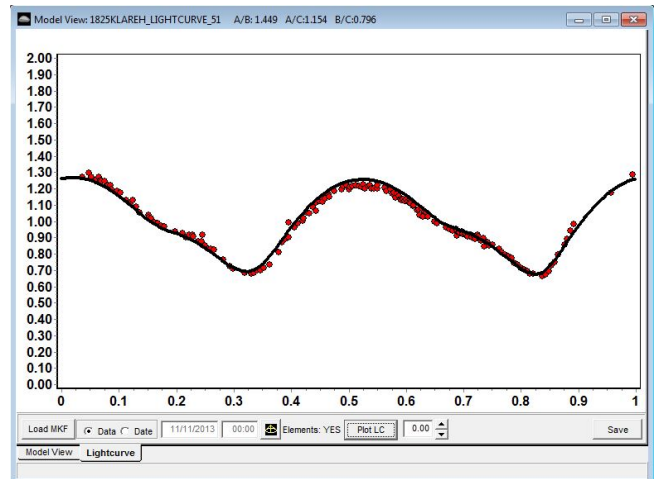


Figure 9: Correspondence between model and observed lightcurve of 1825 Klare $\lambda = 20^\circ$, $\beta = +80^\circ$, period = 4.74233042 h. December 29, 2003.

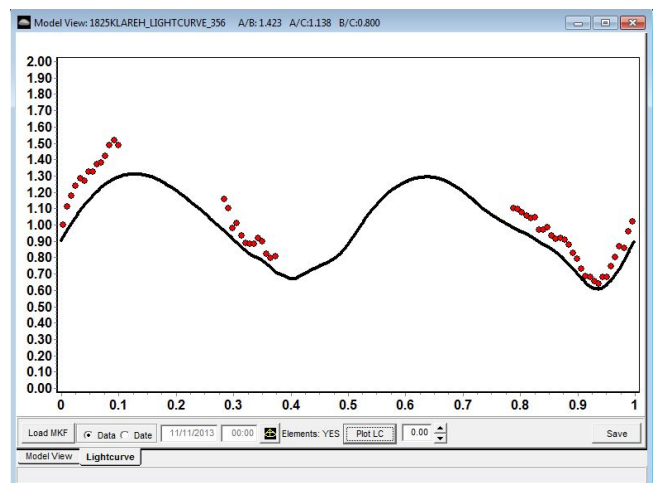


Figure 10: Correspondence between model and observed lightcurve of 1825 Klare $\lambda = 200^\circ$, $\beta = +70^\circ$ period = 4.74233003 h. April 23, 2013.

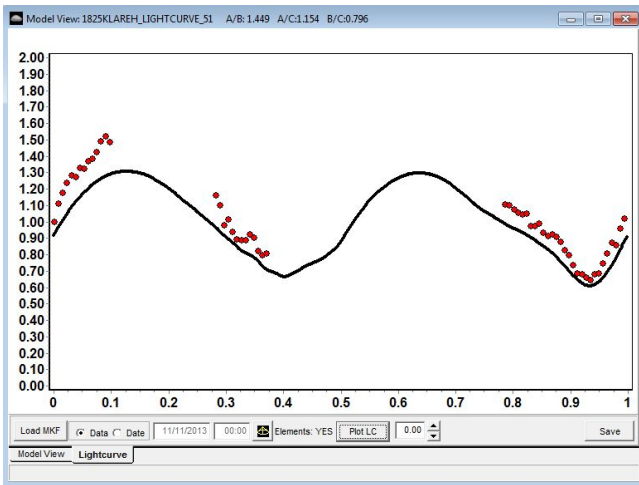


Figure 11: Correspondence between model and observed lightcurve of 1825 Klare $\lambda = 20^\circ$, $\beta = +80^\circ$, period = 4.74233042 h. April 23, 2013.

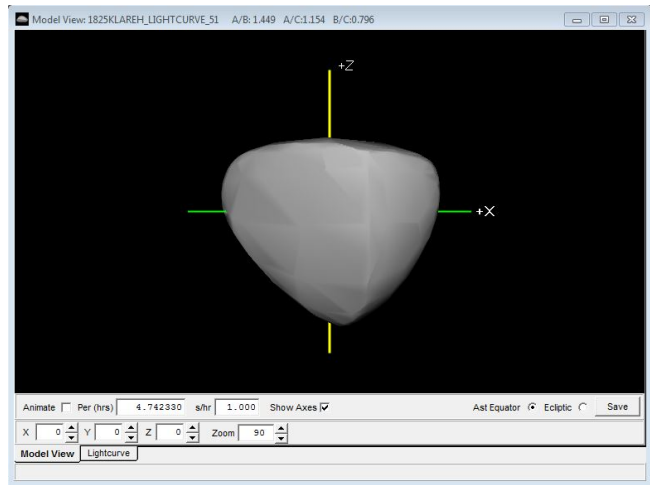


Figure 14: 3-D model $\lambda = 20^\circ$, $\beta = +80^\circ$, period = 4.74233042 h.

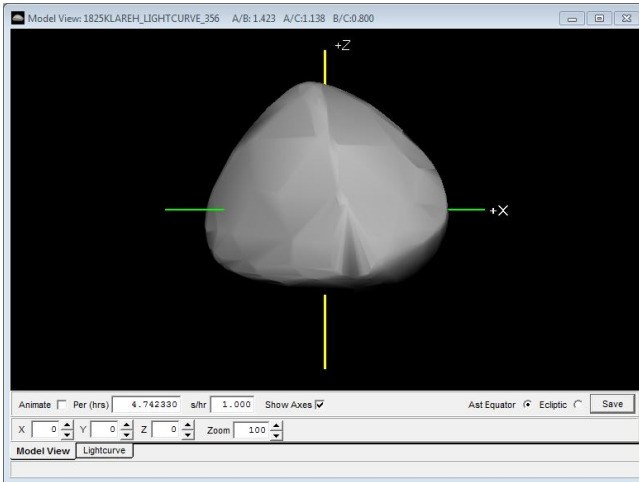


Figure 12: 3-D model $\lambda = 200^\circ$, $\beta = +70^\circ$, period = 4.74233003 h.

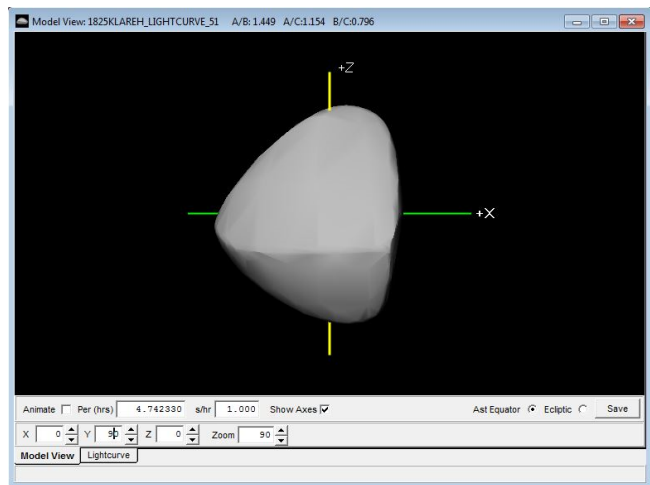


Figure 15: 3-D model $\lambda = 20^\circ$, $\beta = +80^\circ$, period = 4.74233042 h. Figure 15 is a 90° clockwise rotation along the y-axis of Figure 14.

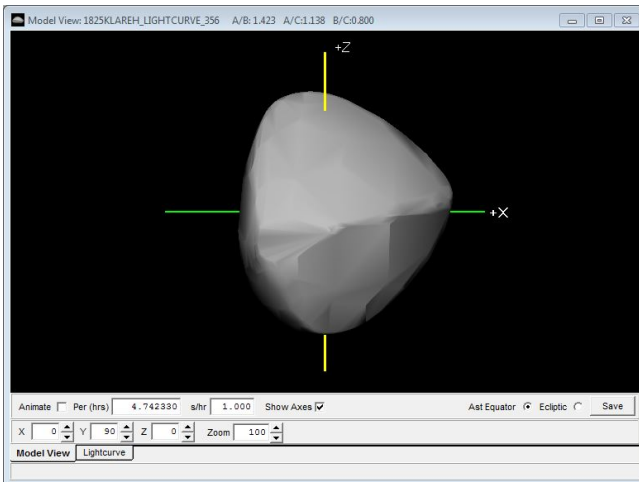


Figure 13: 3-D model $\lambda = 200^\circ$, $\beta = +70^\circ$ period = 4.74233003 h. Figure 13 is a 90° clockwise rotation along the y-axis of Figure 12.

AN ASTROMETRIC MASS ESTIMATE FOR 476 HEDWIG

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By applying the astrometric mass determination technique, a value of $M = (6.2 \pm 2.7) 10^{-13}$ solar masses has been obtained for asteroid 476 Hedwig.

Since the first determination of Vesta's mass by Hertz (1966), individual values for about 60 asteroids have been calculated so far by dynamical methods, some of them derived from the motion of their satellites rather than from perturbations on other asteroids, or planets like Mars. Overviews concerning latest mass determinations are given, for example, by Hilton (2002) and Baer (2010).

476 Hedwig. This asteroid was discovered on 1901 August 17 by the Italian astronomer Luigi Carnera at Heidelberg. It is a main-belt asteroid ($a = 2.65$ AU, $e = 0.07$). A rotation period of 27.33 h and an amplitude maximum of 0.13 mag was measured by Schober and Schroll (1985). No other lightcurve data were found in the literature or in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). The spectral type is given as P (Tholen scheme) and as X (SMASSII scheme). Different size measurements are reported in the literature or databases. IRAS / SIMPS found a mean diameter $D = 116.76 \pm 2.6$ km (Tedesco *et al.*, 2002); the AcuA (Asteroid catalog using AKARI; Usui *et al.*, 2011) value is $D = 111.06 \pm 1.54$ km; and for WISE / NEOWISE (Masiero *et al.*, 2012) a preliminary value of $D = 138.59 \pm 0.97$ km is given. Since the WISE / NEOWISE value was obtained from observations during the so-called post-cryo phase, it should be emphasized that the formal error given in the catalog data does not include a typical $\sim 20\%$ systematic error in diameter (Masiero *et al.*, 2012). On 2000 Nov. 11, an occultation of HIP 103334 was successfully observed in Germany. The ellipse fit to the six timing chords gives a projected profile size of $a \times b = 129.7 \pm 1.7$ km \times 76.7 ± 2.4 km (Frappa, 2000). This would imply a lower mean diameter limit of about 107 km, if we assume a regular shaped ellipsoid.

(187901) 2000 SB317. 2000 SB317 was discovered on 2000 Sep 30 by LINEAR at Socorro (MPC 704). No further physical data are found in the literature or databases. From the absolute magnitude $H = 15.6$ and mean geometric albedo $p_V = 0.1$, a diameter $D = 3.2$ km can be estimated using the known formula

$$D(\text{km}) = \frac{1329}{\sqrt{p}} 10^{-0.2H}.$$

The search for suitable test asteroids was done by numerical integration of all numbered asteroids (using orbital elements from the astorb.dat file: <ftp://ftp.lowell.edu/pub/elgb/astorb.dat.gz>) over their observational arc span and looking for close encounters with the perturbing asteroid, i.e. 476 Hedwig.

Asteroid	Mass / M_S	Asteroid	Mass / M_S
1 Ceres	4.757E-10	(16) Psyche	1.140E-11
2 Pallas	1.010E-10	(31) Euphrosyne	2.920E-11
3 Juno	1.440E-11	(52) Europa	1.139E-11
4 Vesta	1.300E-10	(511) Davida	1.896E-11
10 Hygiea	4.358E-11	(704) Interamnia	1.950E-11
15 Eunomia	1.597E-11	(476) Hedwig	TBD

Table I. Perturbing asteroids and their masses in units of the Solar Mass (Baer and Chesley 2011) used in the dynamical model.

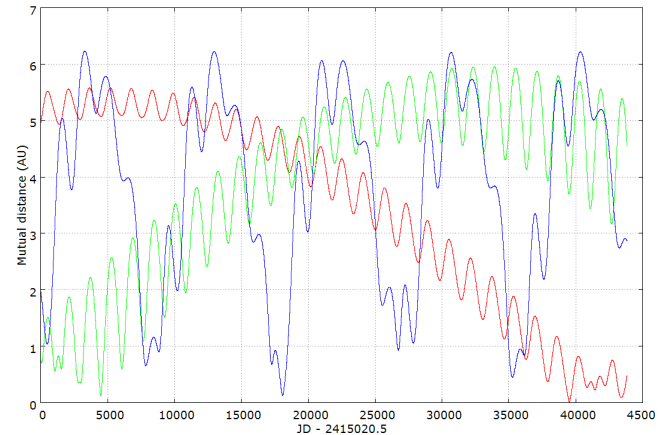


Figure 1. Mutual distance in AU between test asteroid (187901) 2000 SB317 and 476 Hedwig (red), 15 Eunomia (green), and 704 Interamnia (blue) over the period 1900-2020.

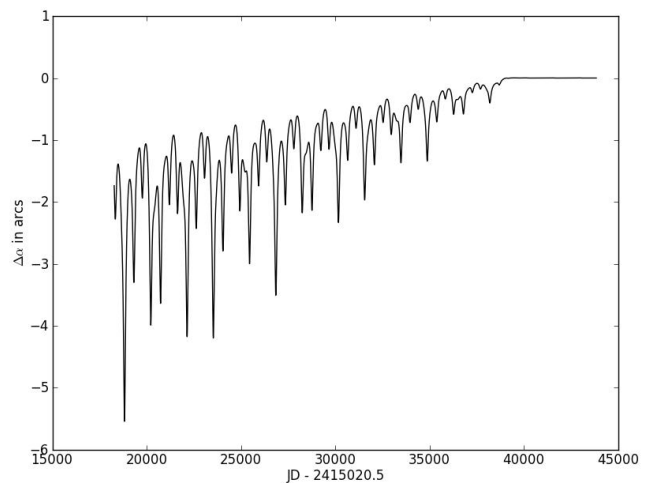


Figure 2. Differences in the ephemeris right ascension of the test asteroid caused by 476 Hedwig's perturbations for the period 1950-2020.

As an approximation for the change in mean motion Δn of the perturbed asteroid, the parameter (Galád and Gray, 2002)

$$P = \frac{D^3}{r \cdot v},$$

has been used to select the “strongest” encounters among the resulting list of events. D is the mean diameter in km of the perturbing asteroid, r the minimum distance in km, and v the relative velocity in km/s during the encounter.

Both asteroids had a close encounter on 2008 March 13.74, with a mutual distance of $d = 0.008$ AU and a relative velocity of 1.8 km/s. This encounter was the strongest in terms of parameter P of all found events. Since the diameter (and, therefore, mass) of 2000 SB317 is significantly smaller than for Hedwig, it is a suitable test asteroid to measure the gravitational forces caused by Hedwig during this deflection event. The test asteroid was checked for any encounter closer than $d = 0.2$ AU to the 11 perturbing asteroids of the dynamical model (Table I). As can be seen in Figure 1, that was the case for 15 Eunomia in 1912 and 704 Interamnia in 1949, but in both cases the minimal distance was larger than 0.1 AU.

Dynamical Model and Mathematical Procedure

Numerical integration was carried out using an n-body program developed by the author. The integrator is a multi-step, variable order, predictor-corrector (PECE) method with self-adjusting step size (Shampine and Gordon, 1975). Perturbations by the major planets Mercury–Neptune (masses and state vectors from JPL DE421 ephemeris) and 11 asteroids (Table I) were taken into account, as well as relativistic effects according to the Schwarzschild metric in isotropic coordinates (Sitarski, 1983).

The mass of 476 Hedwig was determined by means of a least-squares fit of the solve-for parameters to the observations by solving the system of linear equations

$$P\Delta E + Q\Delta M = R,$$

where $P = \partial(\alpha, \delta) / \partial E$ is the matrix of partial derivatives of the observed coordinates (α, δ) with respect to the six initial values E_1, \dots, E_6 (position and velocity) of the test asteroid. $Q = \partial(\alpha, \delta) / \partial M$ is the matrix of partial derivatives of the observed coordinates of the test asteroid with respect to the perturbing mass M and R is the matrix depending on the (O-C) residuals in coordinates of the test asteroid. $\Delta E = (\Delta E_1, \dots, \Delta E_6)$ are the corrections to the six initial values of the test asteroid and ΔM is the correction to the mass of the perturbing body. The partial derivatives P, Q were not computed by numerical variation, but rather by integrating a set of seven differential equations together with the equations of motion of the test asteroid (Sitarski, 1971).

Data, Results, and Discussion

A total of 176 astrometric observations covering the period 2000 Sep 06 until 2013 Sep 02 were available for the test asteroid. About 1/3 of the data covered the time before the encounter. Since almost all observations were reduced using USNO star catalogs (one night used the 2MASS catalog), no a-priori catalog debiasing was applied to the observations. During the iterative differential orbit correction process, observations with a residual larger than $2.5 \times \text{RMS}$ were gradually rejected. One night from one observatory was rejected manually because of systematic errors in RA. In the end, 152 observations (in RA and DEC) over 13 oppositions were considered in the final run. The RMS value of the orbit fit for the test asteroid is 0.34 arcsec. The resulting final mass value for 476 Hedwig is $(6.2 \pm 2.7) 10^{-13}$ solar masses. Figure 2 shows the ephemeris differences in the geocentric right ascension α in the sense (without–with) perturbations by the asteroid. The calculated bulk density is 1.48 ± 0.10 g/cm³ when using the IRAS diameter $D = 116.76 \pm 2.6$ km and 1.72 ± 0.07 g/cm³ when using the AcuA diameter $D = 111.06 \pm 1.54$ km. If a grain density of 2.12 g/cm³ is assumed for a P-type asteroid (Consolmagno *et al.*, 2008), these bulk densities yield a bulk porosity of 30% (IRAS diameter) and 19% (AcuA diameter).

Conclusion

A mass of $M = (6.2 \pm 2.7) 10^{-13}$ solar masses for 476 Hedwig was estimated from the analysis of the motion of the test asteroid (187901) 2000 SB317. This appears to be first individual mass estimate for 476 Hedwig. While the formal error is $\sim 45\%$, this result gives at least an order of magnitude for the mass of the asteroid.

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**ASTEROIDS OBSERVED FROM CS3:
2013 OCTOBER - DECEMBER**

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Results from CCD photometric observations are reported for eleven asteroids. These data were obtained from the Center for Solar System Studies (CS3) during 2013 October to December.

The Center for Solar System Studies (CS3, MPC U81) started operations in late 2012. Its participants have a history of studying asteroid families such as Jovian Trojans, Hungarias or NEOs. When program members of targeted families are not observable such as near the Full Moon, brighter alternative targets are selected to provide data for future shape model studies.

All images were made with a 0.4-m or 0.35-m SCT with a FLI-1001e or a SBIG STL-1001E CCD camera. They were unbinned with no filter and had Master flats and darks applied to the science frames prior to measurement. Measurements were made using MPO Canopus, which employs differential aperture photometry to produce the raw data. Period analysis was done using MPO Canopus, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989). Night-to-night calibration of the data (generally $< \pm 0.05$ mag) was done using field stars converted to approximate Cousins R magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in MPO Canopus was used to limit the comparison stars to near solar color.

540 Rosamunde. This Flora-region asteroid has been well characterized over the years. Wisniewski (1997) observed Rosamunde on three nights in 1989 and obtained a period of 9.336 h. Behrend (2013) reported periods observed in 2005 and 2009 of 9.3495 h and 9.342 h. Kryszczyńska (2012) observed it over five apparitions reporting a synodic period of 9.351 h. Durech (2009) reported a shape model and a sidereal period of 9.34778 h. This synodic period of 9.351 h is in good agreement with those earlier findings.

567 Eleutheria. This asteroid has been observed a number of times. Pilcher (2010) observed it over five nights in April and May 2010 reported a period of 7.718 h. Ruthroff (2010) also observed it on four nights in April 2010 reporting a period of 7.71 h. The results obtained on this opposition are in good agreement with those previously reported rotational periods.

607 Jenny. Brian Warner observed this asteroid in 2002 and 2007. His 2007 observations resulted in a rotational period of 8.524 h (Warner 2003). Upon re-measuring the 2002 images, he revised that rotational period to be 8.526 h (Warner 2011). Pierre Antonini (Behrend 2013) observed Jenny in 2007 finding a period of 8.5221 h. The period found this year is in good agreement with those results.

734 Benda. This asteroid was observed by Rene Roy for three nights in March 2004 (Behrend 2013) who reported the rotational period to be 7.11 h. Buchheim (2009) observed it on 10 nights in October 2007 reporting a period of 7.106 h. This result is in good agreement with those works.

804 Hispania. Hispania has been observed numerous times over the years. Harris and Young (Harris 1983) found a period of 14.851 h, Axel Martin (Behrend 2013) found a period of 14.844 h, and the author (Stephens 2004) found a period of 14.845 h. The rotational period found this year is in good agreement with those previous results.

989 Schwassmannia. Federico Manzini (Behrend 2013) observed this object on four nights in October 2004 reporting a period of 4.58 h. The scatter in the data was nearly the reported amplitude. At this opposition, each night of data was several hours long and showed no sign of an extrema. The asteroid could only be followed for a few nights, but the best fit of the data is to a period of 120.3 h. As a test, the half period was plotted which has a single modal period of 60.28 h.

1003 Lilofee. Rene Roy (Behrend 2013) observed Lilofee over three nights in February 2009 reporting a period of 8.255 h. This work is in good agreement with that finding.

1125 China. Menzies (2009) observed 1125 China for six nights in February 2009 reporting a period of 5.367 h. The lightcurve obtained at this opposition, although being for only a single night, is a close match to the previously reported period.

5489 Oberkochen. Caspari (2009) observed this asteroid over eight nights in August and September 2008 reporting a period of 5.6247 h. The period found at this opposition agrees with that result.

(6634) 1987 KB. Laurent Bernasconi (Behrend 2013) observed this asteroid on two nights in October 2002 reporting a period of 4.492 h. There was substantial scatter in the observations and the resulting phased lightcurve is asymmetric. The data observed at this opposition could not be phased to the 4.492 h period.

9950 ESA. Warner (2013) observed this Near Earth Object in August 2013 reporting a period of 6.712 h (private communication). In the 3 months between observational sets, the asteroid went from Phase Angle 56 to 6 and the L_{PAB} changed from 356 to 69. These two datasets are a good start towards an eventual

Number	Name	2013 (mm/dd)	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
540	Rosamunde	09/21 - 09/27	358	21.4, 22.4	311	6	9.351	0.001	0.59	0.02
567	Eleutheria	11/16 - 11/17	539	6.4, 5.7	71	2	7.717	0.003	0.31	0.02
607	Jenny	12/12 - 12/15	506	4.4, 3.2	91	4	8.521	0.002	0.25	0.02
734	Benda	10/17 - 10/18	348	13.1, 12.8	58	5	7.110	0.003	0.32	0.02
804	Hispania	11/14 - 11/21	516	9.2, 8.1	64	19	14.899	0.002	0.08	0.02
989	Schwassmannia	09/19 - 09/27	776	18.1, 14.9	23	15	120.3	1	0.39	0.05
1003	Lilofee	10/16 - 10/18	433	10.5, 9.8	48	-2	8.250	0.001	0.54	0.02
1125	China	10/20 - 10/20	158	13.5	58	-2	5.45	0.02	0.62	0.03
5489	Oberkochen	12/12 - 12/15	456	5.4, 4	90	-5	5.628	0.002	0.51	0.02
6634	1987 KB	10/19 - 10/21	395	8.9, 9.4	18	11	5.333	0.003	0.23	0.02
9950	ESA	11/25 - 11/28	206	7.3, 4.4	69	4	6.707	0.002	0.44	0.02

shape model.

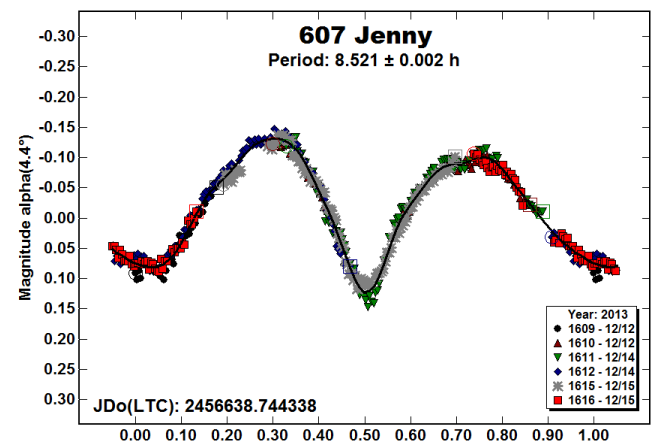
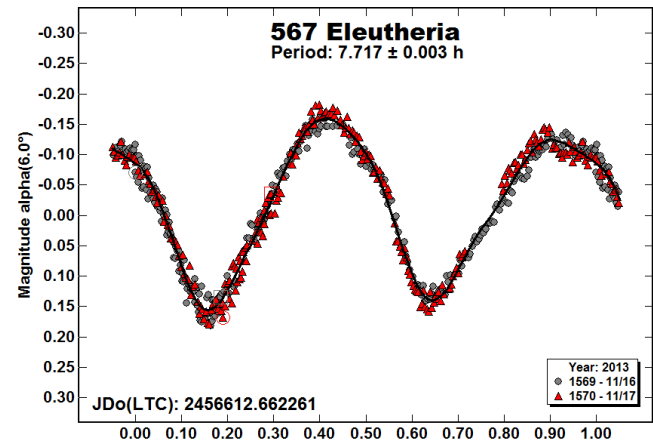
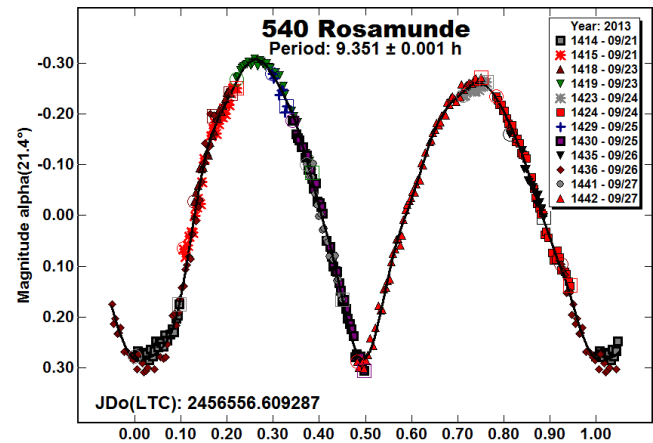
Acknowledgements

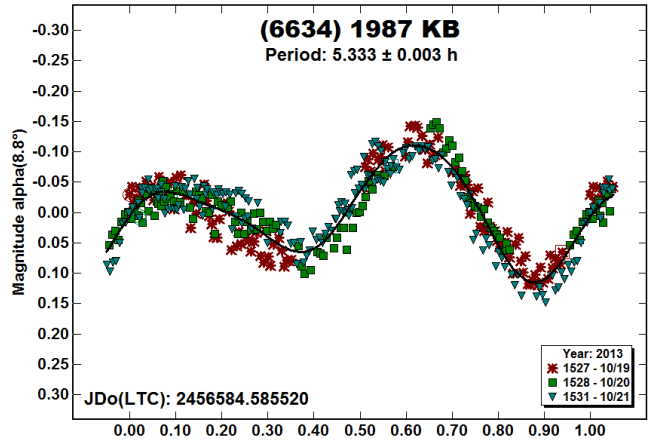
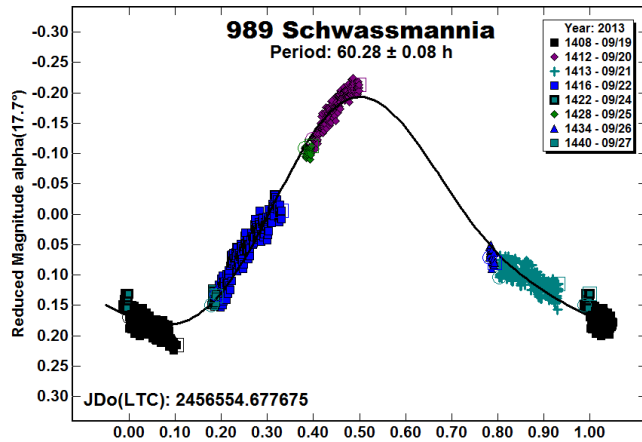
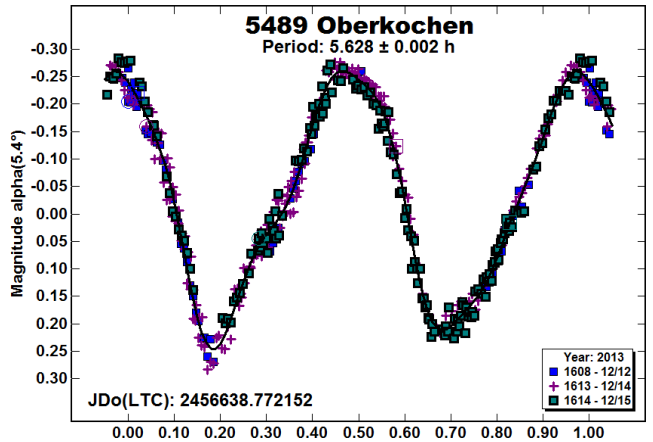
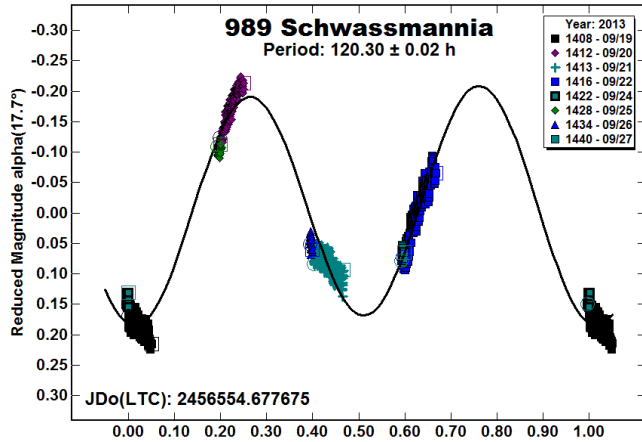
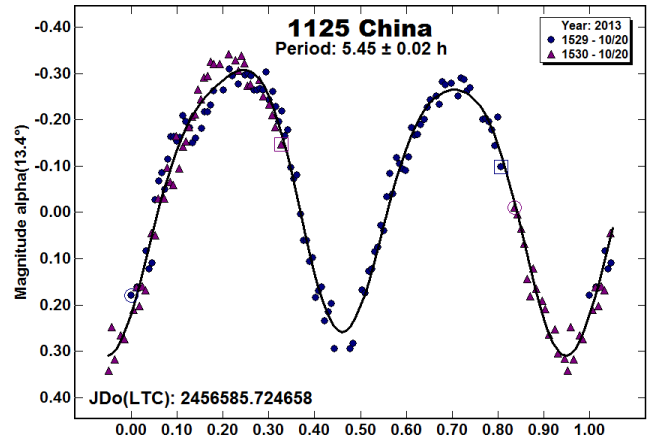
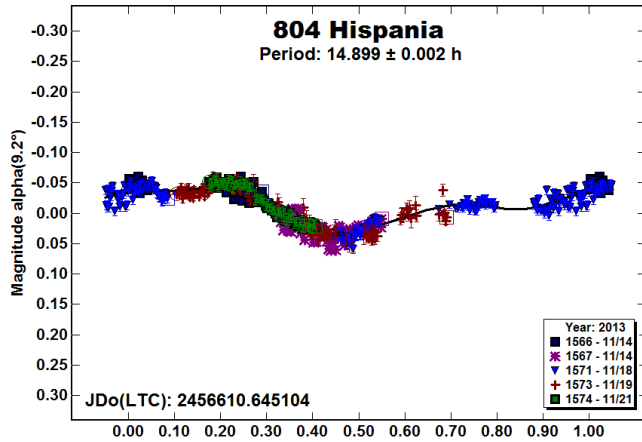
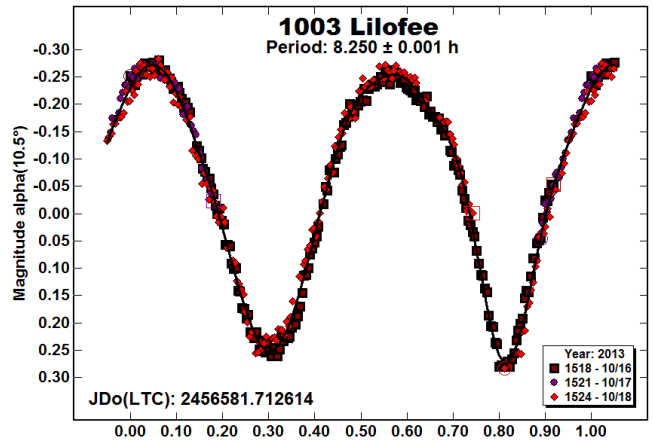
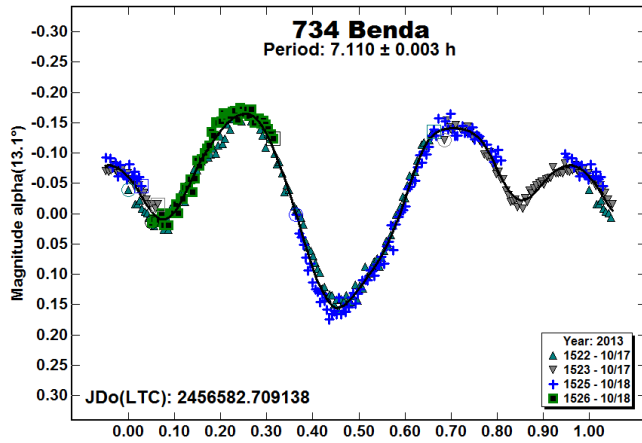
This research was supported by National Science Foundation grant AST-1212115 and by NASA grant NNX13AP56G. The purchase of the FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society.

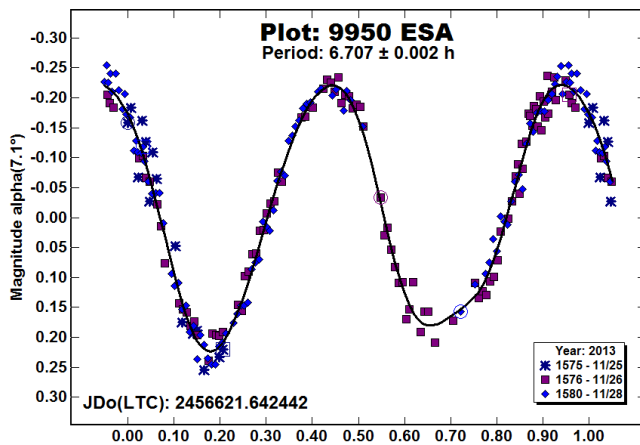
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AT THE SCAEAN GATES: OBSERVATIONS JOVIAN TROJAN ASTEROIDS, JULY - DECEMBER 2013

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Earlier in 2013 we reported rotational periods for two dozen Jupiter Trojan asteroids. Here we present lightcurves for 24 additional Trojans obtained from the Center for Solar System Studies and Cerro Tololo Inter-American Observatory from July to December 2013.

The Jovian Trojan asteroids formed further from the Sun than main belt asteroids and their composition and collisional history appears to be different. They are found in orbits near the stable L4 and L5 Lagrange points of Jupiter's orbit. As yet, the rotation properties of Trojan asteroids are poorly known relative to those of main-belt asteroids, due to the lower albedo and greater distance of the Trojans. As of 18 December 2013, 151 rotational periods are contained in the Lightcurve Database (Warner 2013). Here we report lightcurve data for 24 Trojans. Most are in the 25 – 50 km diameter size range.

Observations at CS3 (Center for Solar System Studies, MPC U81) were made by Stephens and Coley with three telescopes, either 0.4-m or 0.35-m SCTs, using a SBIG STL-1001E CCD Cameras, a FLI-1001e CCD camera, or a SBIG ST-9e CCD camera. All images were 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 *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989).

Observations at CTIO (Cerro Tololo Inter-American Observation, MPC 807) were made with the CTIO 0.9-m telescope. All images taken at CTIO were unbinned; R filters were used. Data and period analysis was done using *MPO Canopus*.

The results are summarized in Table 1. Night-to-night calibration of the data (generally $< \pm 0.05$ mag) was done using field stars converted to approximate Cousins R magnitudes based on 2MASS J-K colors (Warner 2007 and Stephens 2008) or using the APASS (AAVSO Photometric All-Sky Survey Release 7). Diameters (Dia) are from the WISE/NEOWISE database (Grav 2012).

2241 Alcaathous. We previously observed this Trojan (French 2011) finding a period of 7.690 h. Mottola *et al.* (2011) found a period of 7.687 h from 1991 observations. These results are in good agreement with those previously reported results.

3451 Mentor. This Trojan has been observed several times over the years by Mottola *et al.* (2011), Duffard *et al.* (2008), Behrend (2013), Sauppe *et al.* (2007) and the authors (French *et al.* 2011). Most of the reported periods range between 7.675 h and 7.73 h. We observed Mentor at this opposition in order to accumulate data for an eventual shape-model. Our 2013 result of 7.68 h is in good agreement with those prior results.

4867 Polites. We observed Polites in 2010 from Cerro Tololo Inter-American Observatory (French *et al.* 2011). The sparse lightcurve we obtained had an amplitude of 0.09 magnitudes and suggested a period of 9.21 hours assuming a bimodal shape. However, when the amplitude is less than 0.10 magnitudes Harris (2013) has shown that single modal and trimodal shapes are also possible. The denser dataset obtained this year has an amplitude of 0.23 mag. This period of 11.24 h is bimodal and is a 4:5 alias of our previously reported period.

5120 Bitias. Mottola *et al.* (2011) observed this Trojan in 1993 finding a period of 11.582 h. The period derived from our denser dataset is a 3:4 alias of that result.

(7352) 1994 CO. With a period of 648 h, this is the second slowest rotating Jovian Trojan asteroid yet found. It was followed for two complete rotations and features in the resulting lightcurve do not repeat for the second rotation. This is suggestive that the asteroid is tumbling, not surprising since the dampening time would approximate the age of the solar system (Pravec *et al.* 2005).

(15502) 1999 NV27. We previously observed this asteroid in 2012 finding a period of 15.03 h and an amplitude of 0.26 mag. over three nights. We observed it again at this opposition to gather data for an eventual shape model and were able to follow it for 12 nights. The resulting period of 15.09 h is in good agreement with our previous results.

(15977) 1998 MA11. We observed this asteroid for three nights and found that the amplitude never varied by more than 0.02 mag. Although the plot is phased to 11.17 h for demonstration purposes, the lack of change in amplitude is insufficient for us to confidently determine a rotational period since the lightcurve can have a single or multiple extrema. We encourage observations of this Trojan at a future opposition.

Name	Dates	Obs	Obs.	Tele.	Dia	PA	L _{PAB}	B _{PAB}	Per	PE	Amp	AE
1870 Glaukos	10/04 - 10/09	RDS CD	CTIO	0.9-m	48	5, 4	34	-4	5.986	0.003	0.42	0.02
1871 Astyanax	10/10 - 10/11	RDS CD	CTIO	0.9-m	28	3	3	-6	6.52	0.02	0.13	0.03
2241 Alcahous	07/29 - 08/08	RDS	CS3	0.35-m	114	10	19	17	7.695	.002	0.25	0.03
3451 Mentor	10/19 - 10/22	DRC	CS3	0.35-m	126	8, 7	59	-23	7.68	0.01	0.13	0.02
4707 Khryses	09/25 - 09/26	RDS	CS3	0.4-m	38	10	47	8	6.87	0.01	0.39	0.03
4867 Polites	08/03 - 09/04	DRC	CS3	0.35-m	57	11, 10	35	23	11.24	0.01	0.23	0.03
5120 Bitias	08/13 - 08/19	RDS	CS3	0.35-m	48	12, 11	40	25	15.21	0.02	0.32	0.03
7352 1994 CO	09/13 - 11/06	RDS DRC	CS3	0.40-3		2, 6	20	-8	648	3		
11089 1994 CS8	09/07 - 09/12	RDS	CS3	0.35-m	37	4, 3	2	-7	7.72	0.01	0.40	0.02
11887 Echemmon	11/06 - 11/09	RDS	CS3	0.35-m	31	2, 3	41	10	8.47	0.01	0.17	0.03
15502 1999 NV27	07/31 - 08/11	RDS	CS3	0.4-m	53	11, 10	16	16	15.09	0.01	0.15	0.03
15977 1998 MA11	08/28 - 09/02	RDS	CS3	0.35-m	44	7	11	7	Undet			
17171 1999 NB38	08/13 - 09/05	RDS	CS3	0.4-m	41	12, 11	39	25	64.79	0.04	0.66	0.05
17365 1978 VF11	09/28 - 10/03	RDS	CS3	0.4-m	45	8, 7	44	7	12.634	0.004	0.73	0.03
17492 Hippasos	11/29 - 12/10	RDS	CS3	0.35-m	54	3, 4	66	-13	17.75	0.01	0.21	0.02
18137 2000 OU30	10/02 - 10/30	RDS CD	CTIO CS3	0.9-m 0.4-m	34	2, 7	359	5	49.36	0.02	0.35	0.03
22180 2000 YZ	08/04 - 08/11	RDS	CS3	0.35-m	40	12, 11	25	24	19.40	0.01	0.04	0.02
24448 2000 QE42	10/08 - 10/10	RDS CD	CTIO	0.9-m	31*	1, 2	14	-6	8.33	0.01	0.20	0.02
24451 2000 QS104	11/07 - 14	RDS	CS3	0.40-m	41	2	44	7	17.18	0.03	0.17	0.02
30705 Idaios	09/04 - 10/24	RDS	CS3	0.4-m	45	7, 1, 3	17	-4	15.736	0.001	0.22	0.03
32496 2000 WX182	10/31 - 11/28	RDS DRC	CS3	0.4-m	48	5 - 1	61	-4	23.34	0.01	0.19	0.03
32615 2001 QU277	10/05 - 10/08	RDS CD	CTIO	0.9-m	36	5 - 6	353	-19	6.712	0.004	0.36	0.03
51958 2001 QJ256	10/07 - 10/15	RDS CD	CTIO, CS3	0.9-m 0.4-m	27	0, 2	12	-1	16.79	0.03	0.30	0.05
76867 2000 YM5	09/13 - 09/16	RDS	CS3	0.4-m	43	8, 7	39	-8	9.13	0.01	0.31	0.02

Table 1: Table of observations

(17365) 1978 VF11. This asteroid had a previously reported rotational period of 12.672 h (Mann 2007). Our period of 12.634 h is in good agreement with that finding.

(22180) 2000 YZ. We observed this Trojan in 2011 finding a period of 19.40 h and an amplitude of 0.50 mag. This year, we found the amplitude to be 0.04 magnitudes, essentially flat. These data alone are not sufficient to determine a rotational period. They are consistent with the 2011 results.

(24451) 2000 QS104. We observed this Trojan in 2012 determining a period of 40.7 h assuming a bimodal shape to the

lightcurve. However, we were not satisfied with the results because the amplitude was only 0.03 magnitudes and the 2012 lightcurve could have a single extremum or a more complex shape. We observed it again at this opposition to resolve the ambiguity. This year the amplitude was 0.17 magnitude and shows a bimodal structure when phased to 17.18 h.

Period Analysis

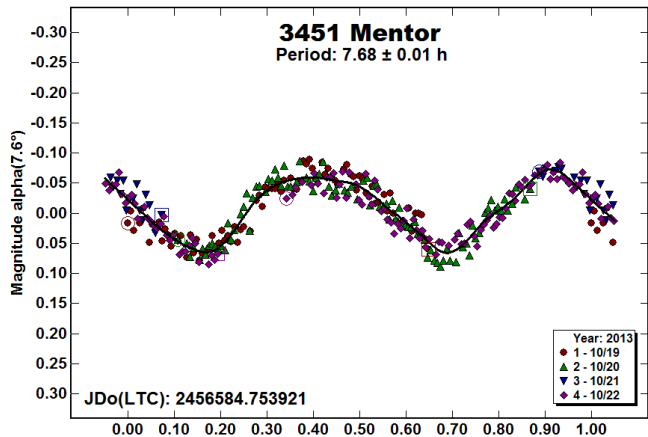
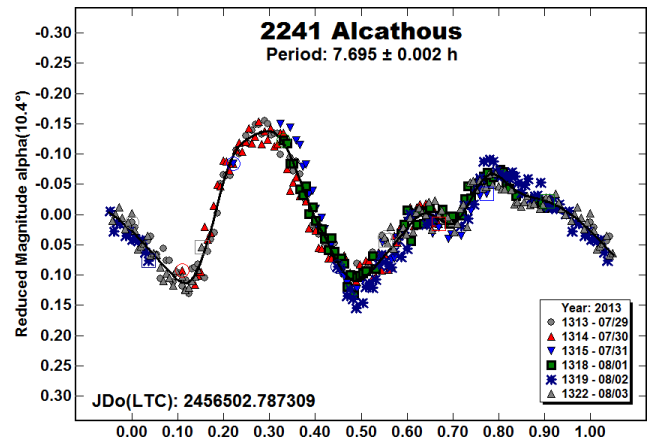
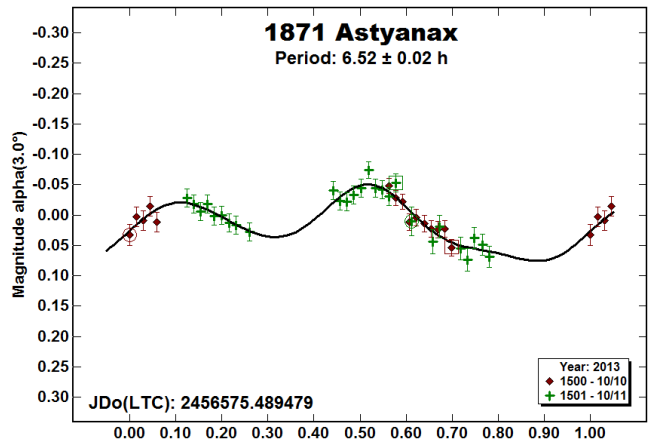
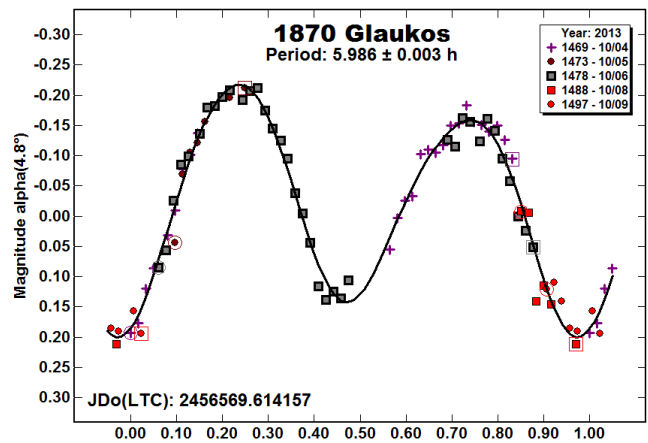
To avoid observation bias, asteroids were followed even if they appeared to be a long period.

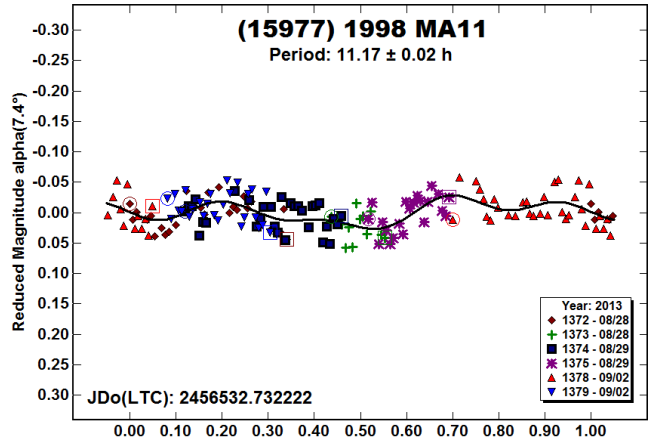
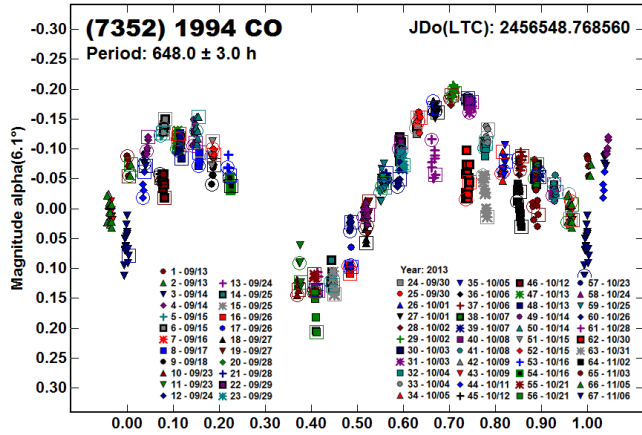
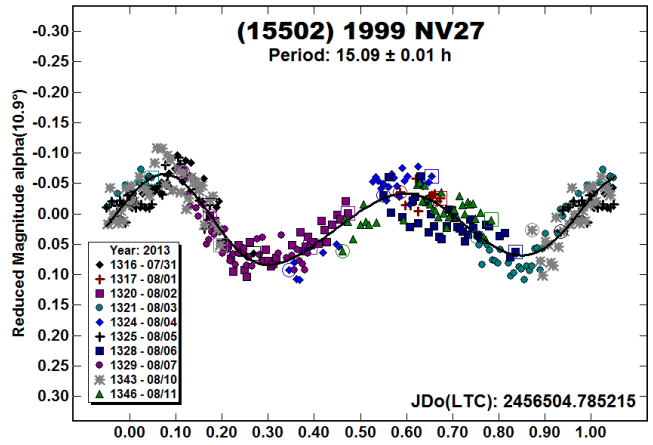
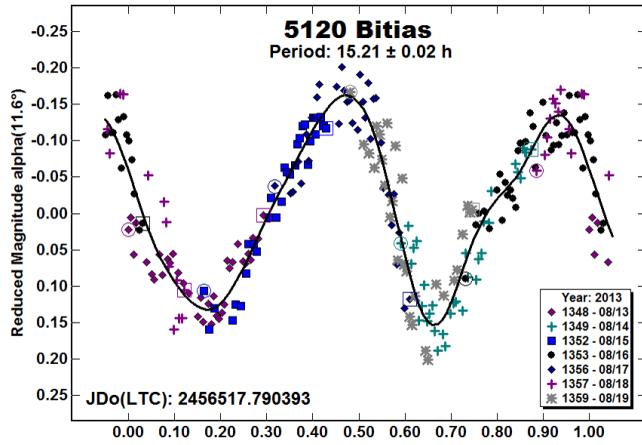
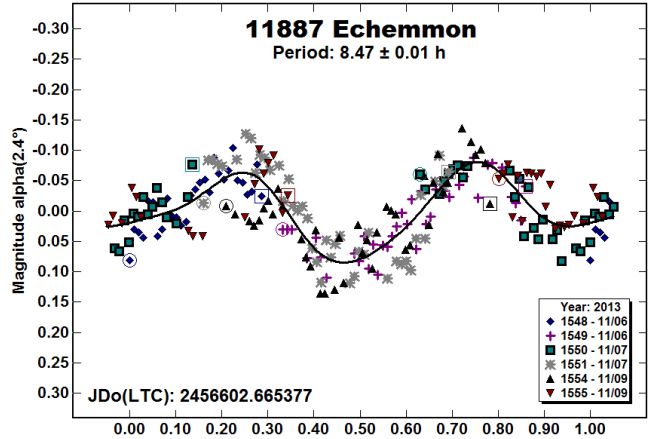
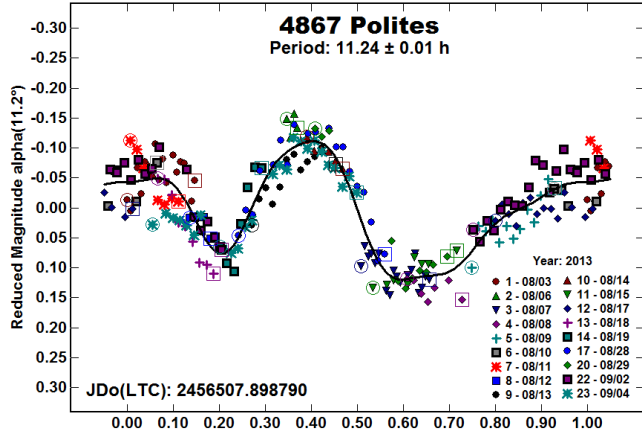
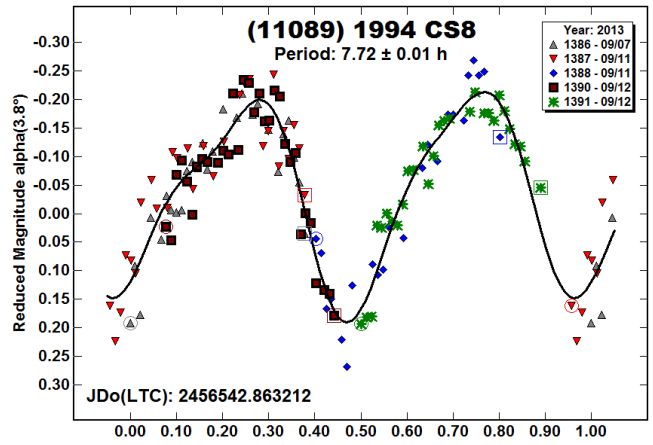
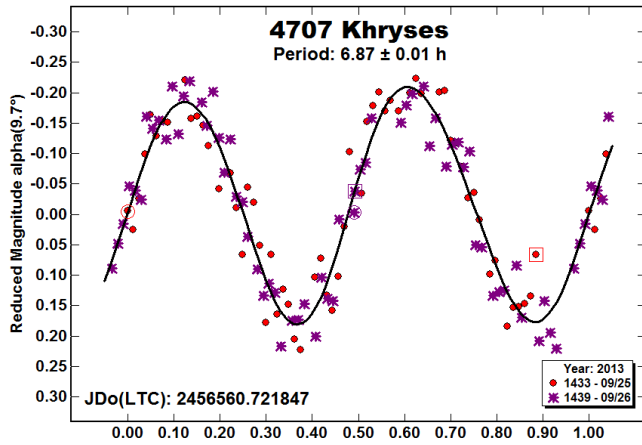
Acknowledgements

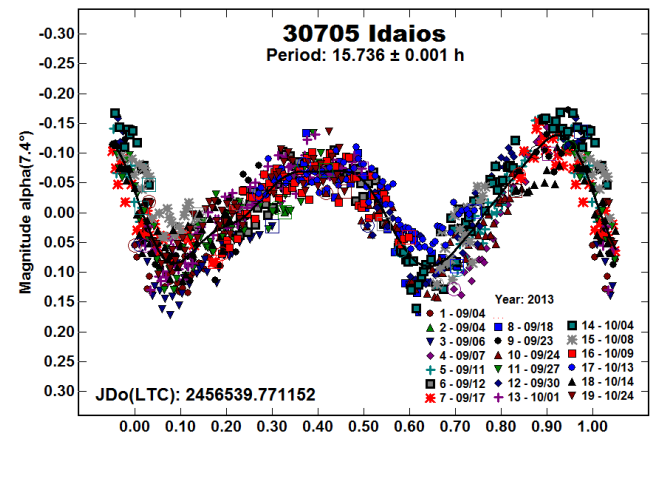
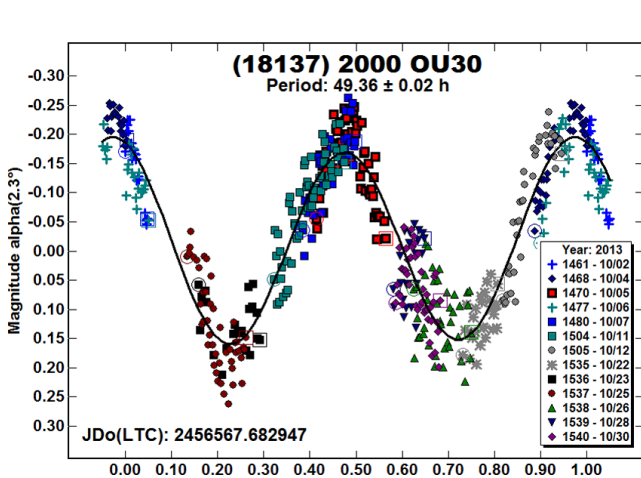
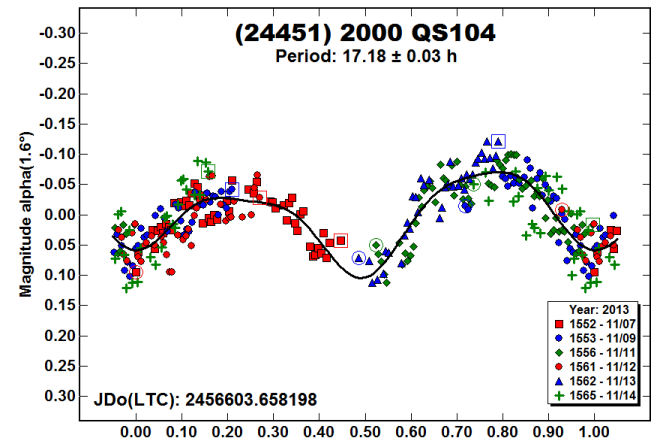
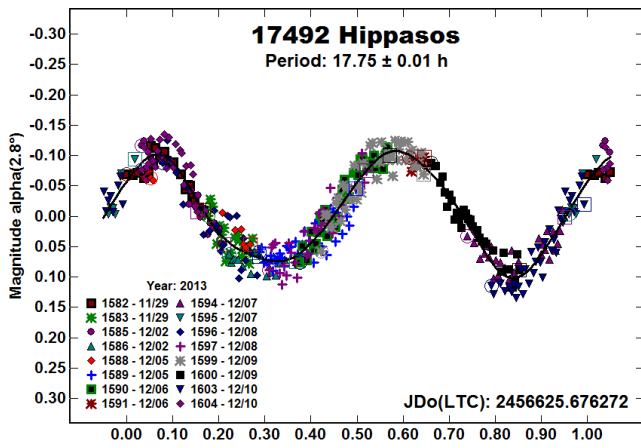
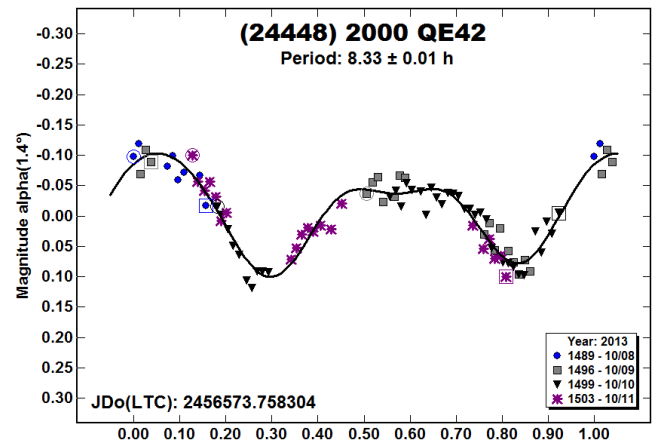
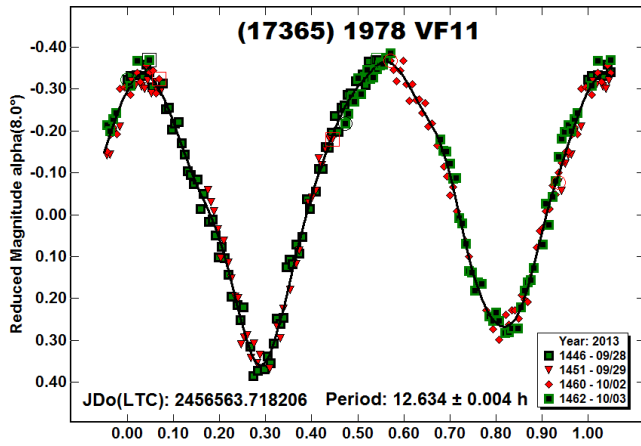
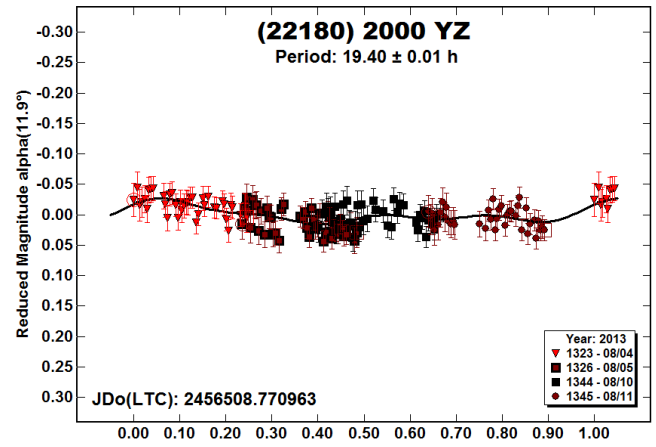
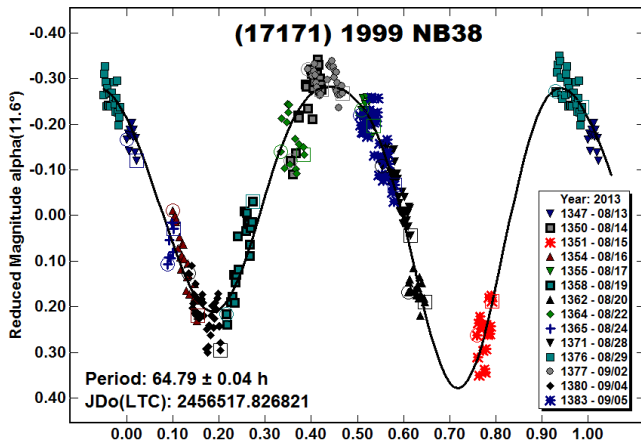
French, Stephens and Davitt were visiting astronomers at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory, operated by the Association of Universities for Research in Astronomy, under contract with the National Science Foundation. The Cerro Tololo 0.9-m telescope is operated by the SMARTS Consortium. This research was supported by National Science Foundation grant AST-1212115. The purchase of the FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society.

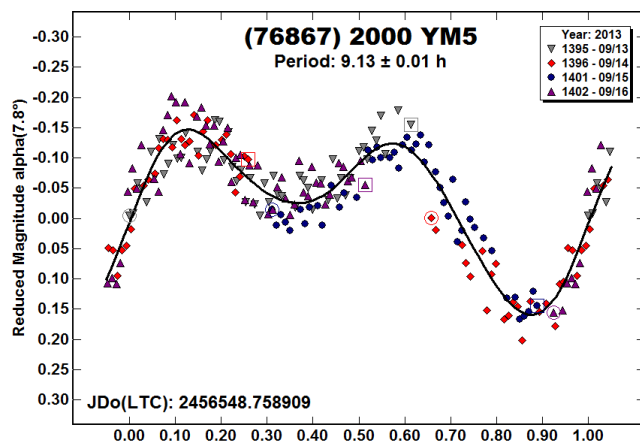
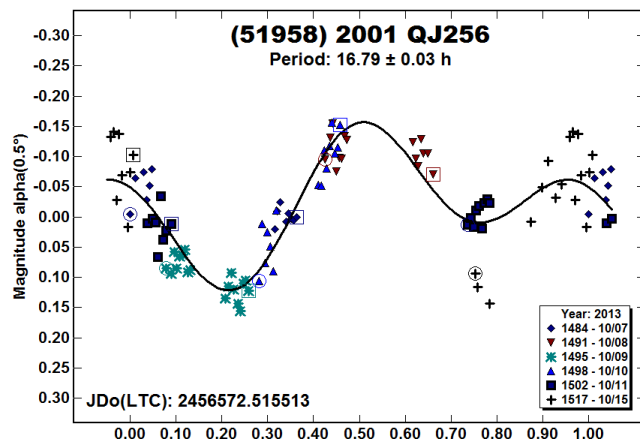
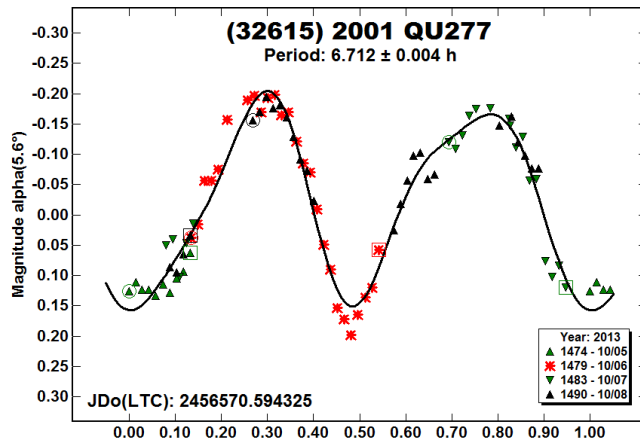
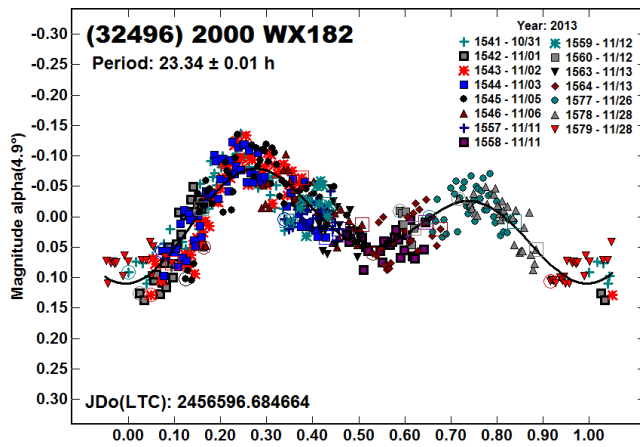
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ASTEROID PHOTOMETRY FROM THE PRESTON GOTT OBSERVATORY

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Rotation period and lightcurve amplitude results for five asteroids are presented based on measurements obtained at the Preston Gott Observatory during mid-2013.

The Preston Gott Observatory is the main astronomical facility of the Texas Tech University. Located about 20 km north of Lubbock, TX, the main instrument is a 0.5-m $f/6.8$ Dall-Kirkam Cassegrain. An SBIG STL-1001E CCD camera was used with this telescope. All images were unfiltered and were reduced with dark frames and sky flats. For the most part, the asteroids were chosen from a list generated on the CALL website. Image analysis was accomplished using differential aperture photometry with *MPO Canopus*. Period analysis was also done in *MPO Canopus*, which implements the algorithm developed by Alan Harris (Harris *et al.*, 1989). Differential magnitudes were calculated using reference stars from the USNO-A 2.0 catalog and the UCAC2 catalog.

Results are summarized in the table and the lightcurve plots are presented at the end of the paper. The data and curves are presented without additional comment except where circumstances warrant. Column 3 of the table gives the range of dates of observations and column 4 gives the number of nights on which observations were undertaken.

(12920) 1998 VM15. Observations of this asteroid were made on 10 nights with the derived period being 12.886 hours. The observations indicated that the two minima were very unequal although the maxima were similar.

(16141) 1999 XT127. This asteroid was observed on one night when it was in the field of another asteroid I was studying. Despite having one night of data, a complete lightcurve was obtained.

(85118) 1971 UU. Observations of this asteroid were made on four nights. Although the complete lightcurve was not observed, sufficient data were obtained to derive a period of 10.098 h with a large amplitude of 1.12 mag. The two maxima were unequal.

(125742) 2001 XT117. This asteroid was extremely difficult to analyze despite having worked it on 11 different nights. The lightcurve has a large amplitude, in excess of one magnitude. Despite this, no reliable period could be determined. The best result indicated a period of just over 60 hours. However, some of the sessions did not match properly. This result is reported as a guide for future observers. Much more work remains to be done on this asteroid, most probably as an international collaboration.

Acknowledgments

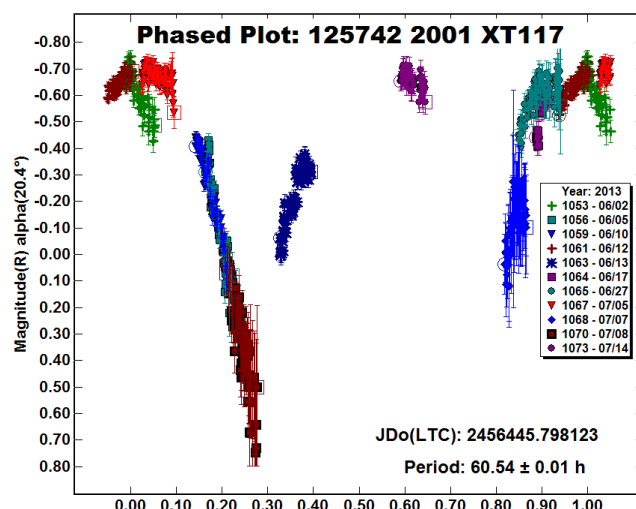
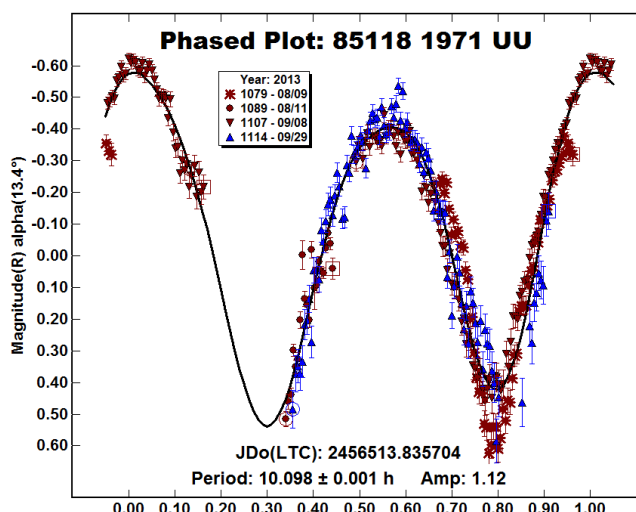
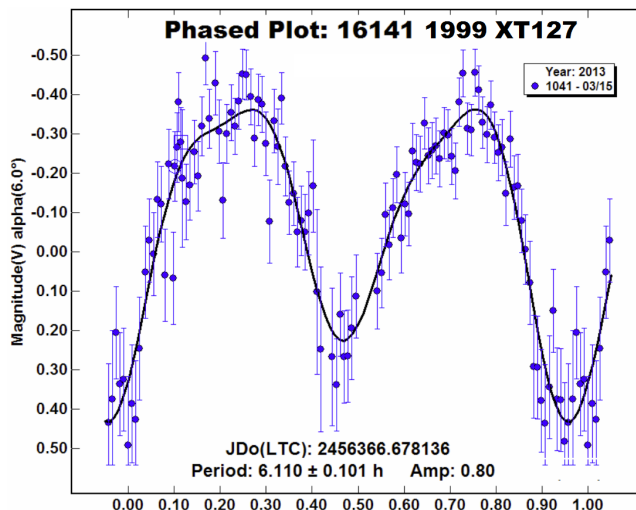
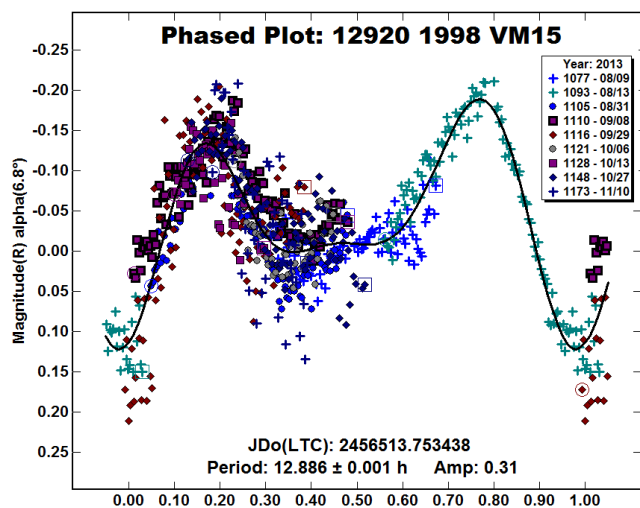
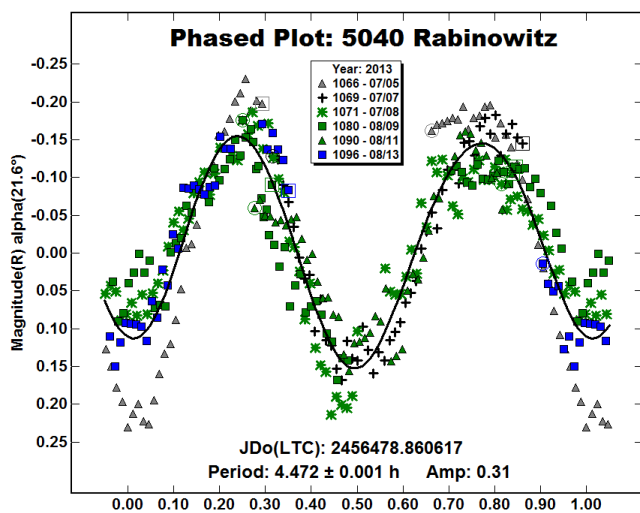
I would like to thank Brian Warner for all of his work with the program *MPO Canopus* and for his efforts in maintaining the CALL website.

Number	Name	Date Range 2013 mm/dd	Sess	Per (h)	P.E. (h)	Amp (mag)	A.E. (mag)
5040	Rabinowitz	07/05-08/18	9	4.472	0.001	0.31	0.02
12920	1998 VM15	08/09-11/10	10	12.886	0.001	0.31	0.03
16141	1999 XT127	03/15	1	6.11	0.101	0.80	0.02
85118	1971 UU	08/09-09/29	4	10.098	0.001	1.12	0.04
125742	2001 XT117	06/02-07/14	11	60.54	0.01	1.5	0.05

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Warner, B.D. (2013). Collaborative Asteroid Lightcurve Link website. <http://www.minorplanet.info/call.html>



**ASTEROID LIGHTCURVE ANALYSIS AT
CS3-PALMER DIVIDE STATION:
2013 SEPTEMBER-DECEMBER**

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Lightcurves for 31 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2013 September through December. The majority of the objects were members of the Hungaria group/family. In many cases, the observations were follow-up to previous apparitions to check for the possibility of undiscovered satellites or to provide additional data for spin axis and shape modeling. Three Hungaria asteroids, 4440 Tchantches, 6602 Gilclark, and 7173 Sepkoski, are *possible* binary candidates while (69406) 1995 SX48 is a *probable* binary candidate. The inner main-belt asteroid (119744) 2001 YN42 may be a rare example of a binary with a relatively short period superimposed on a large amplitude secondary period on the order of hundreds of hours.

CCD photometric observations of 31 asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 September through December. Table I gives a listing of the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

Desig	Telescope	Camera
PDS-1-12N	0.30-m f/6.3 Schmidt-Cass	ST-9XE
PDS-1-14S	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
PDS-2-14N	0.35-m f/9.1 Schmidt-Cass	STL-1001E
PDS-2-14S	0.35-m f/9.1 Schmidt-Cass	STL-1001E
PDS-20	0.50-m f/8.1 Ritchey-Chretien	FLI-1001E

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

All lightcurve observations were made with no filter (a clear filter can result in a 0.1-0.3 magnitude loss) and were guided on a field star, resulting in some cases in a trailed image for the asteroid. The exposures varied depending on the asteroid's brightness and sky motion.

Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes are usually taken from the MPOSC3 catalog, which is based on the 2MASS catalog (<http://www.ipac.caltech.edu/2mass>) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007b). When possible, magnitudes are taken from the APASS catalog (Henden *et al.*, 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ± 0.05 magnitude or better, but on occasion are as large as 0.1 mag. This reasonably good consistency is critical to analysis of long

period and/or tumbling asteroids. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.*, 1989).

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

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

Individual Results

64 Angelina. This middle main-belt asteroid was observed in support of radar observations and modeling by Michael Shepard. The period had been well-established beforehand (e.g., Behrend, 2005; Durech *et al.*, 2011). The CS3-PDS data led to a result of $P = 8.75$ h, in near perfect agreement with those earlier results.

2254 Requiem. This appears to be the first reported period for Requiem, a member of the Flora group.

3169 Ostro. The period of this Hungaria asteroid has been reported numerous times in the literature (e.g., Behrend, 2009; Warner, 2009c; 2012b) at about 6.5 h. The reported amplitude has ranged from 0.42 to 1.2 mag. Analysis of the 2013 PDS observations found $P = 6.509$ h and $A = 0.62$ mag.

3823 Yorii. This is an outer main-belt asteroid with an estimated diameter of 14.6 km. No previous entries in the LCDB were found.

4031 Mueller. The 2013 apparition was the third one at which the author observed this Hungaria (Warner, 2009b; 2012a). The period of 2.943 h is in agreement with those earlier findings.

4440 Tchantches. The author observed this asteroid on three previous occasions (Warner, 2006; 2011; Warner and Higgins, 2009). The previous results as well as those from 2013 (the first plot below) give $P \sim 2.79$ h with an amplitude range of 0.21-0.34 mag. These make the asteroid a good candidate for being binary. A review of data from the previous apparitions found that the 2005 data set showed signs of a satellite in the form of "mutual events" (occultations and/or eclipses) that show as attenuations in the principal lightcurve.

The "No Sub" plot for the asteroid shows the data without subtracting any effect due to the supposed satellite. Compare this to the "P1" plot, where those effects have been removed. The "P2" plot shows the data after subtracting the primary. There is a general up-bow trend in the curve, which is often seen with an elongated satellite that is tidally-locked to its orbital period. There are also indications of the mutual events. Overall, however, these are very weak signs and so the asteroid should be considered at best a

Number	Name	2013		Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
		mm/dd	Pts							
64	Angelina	12/13-12/15	1843	3.8, 4.7	74	1	8.75	0.01	0.22	0.02
2254	Requiem	11/17-11/18	317	12.2, 12.7	36	6	4.430	0.001	0.22	0.02
3169	Ostro	12/09-12/14	401	13.7, 10.2	95	-5	6.509	0.001	0.62	0.02
3823	Yorii	10/03-10/09	230	13.9, 12.2	46	-6	6.669	0.005	0.26	0.02
4031	Mueller	12/02-12/08	88	33.2, 33.2	358	7	2.943	0.001	0.19	0.02
4440	Tchantches	10/21-10/27	578	19.8, 18.6	44	28	2.7886	0.0002	0.28	0.02
4440	Tchantches	09/27-11/02 ⁵					2.7884*	0.0001	0.31	0.02
5175	Ables	09/25-09/29	206	27.0, 26.2	56	5	2.798	0.001	0.09	0.01
6249	Jennifer	12/21-12/23	202	33.9, 34.1	34	-6	4.958	0.005	0.49	0.02
6602	Gilclark	12/26-12/30	101	34.1, 34.2	29	25	4.569*	0.002	0.39	0.02
7087	Lewotsky	09/29-10/03	212	22.4, 20.9	44	5	3.941	0.001	0.29	0.02
7087	Lewotsky	12/27-12/30	172	27.1, 27.9	50	-10	3.941	0.001	0.51	0.02
7087	Lewotsky	08/15-08/26 ¹⁰	142				3.942	0.002	0.16	0.02
7173	Sepkoski	10/04-10/24	662	24.3, 15.7	51	13	2.5006*	0.0002	0.11	0.02
7505	Furusho	12/21-12/22	356	7.4, 6.8	102	2	4.140	0.005	0.52	0.02
9068	1993 OD	11/18-11/26	336	28.6, 25.7	79	27	3.407	0.001	0.20	0.02
9873	1992 GH	11/15-11/17	355	31.1, 31.1	131	18	2.926	0.003	0.34	0.03
11833	Dixon	11/07-11/13	277	13.4, 9.7	65	1	3.594	0.001	0.20	0.03
11941	Archinal	12/02-12/08	156	10.2, 6.7	86	3	2.718	0.001	0.18	0.02
11976	Josephthurn	12/15-12/22	319	18.6, 18.3	93	27	3.535	0.001	0.15	0.02
11976	Josephthurn	04/22-04/30 ⁹	102				3.534	0.002	0.10	0.01
12369	Pirandello	10/03-10/09	318	16.1, 14.0	45	-6	3.504	0.003	0.07	0.01
21321	1997 AN2	09/29-10/02	209	5.1, 4.2	12	6	13.92	0.03	0.11	0.01
24077	1999 TD233	12/31-12/31	956	5.1, 0.0, 4.2	0	0	30.86	0.01	0.70	0.05
30856	1991 XE	12/24-12/26	155	31.7, 32.0	42	-14	5.358	0.002	1.23	0.03
31173	1997 XF1	11/28-12/25	753	18.4, 27.8	44	8	122.8	0.5	0.67	0.03
49667	1999 OM2	12/13-12/15	251	14.3, 13.3	104	2	3.487	0.002	0.46	0.02
49675	1999 SW27	11/15-11/17	158	11.1, 10.4	60	14	4.998	0.004	0.42	0.03
69406	1995 SX48	12/26-12/31	330	18.9, 16.0	123	3	4.486*	0.001	0.15	0.03
82060	2000 WX8	11/13-11/17	315	17.7, 17.2	55	24	2.764	0.001	0.20	0.02
86192	1999 SV1	12/21-12/25	224	0.0, 10.8	84	-9	7.172	0.004	0.23	0.02
119744	2001 YN42	09/06-10/02	834	16.8, 4.3	11	6	7.24*	0.01	0.05	0.01
120578	1995 QV12	09/29-10/22	401	5.1, 4.0, 10.5	12	6	72.4	0.5	0.51	0.05
134549	1999 RN154	10/05-10/25	312	3.9, 11.7	13	7	124.	10.	0.55	0.05

Table II. Observing circumstances. * Solution is for a primary of a binary asteroid (see text). Dates with superscripts <90 are from the year 2000 plus the superscript value. Superscripts >90 are 1900 plus the value. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

possible, not probable, binary that warrants careful observations at future apparitions.

5175 Ables. Warner (2011a) reported a period of 2.798 h for this Hungaria. Analysis of the 2013 data found the same result.

6249 Jennifer. This asteroid has been observed several times before by the author (see Warner, 2014). Follow-up observations were made in late 2013, when the phase angle and phase angle bisector had changed significantly, to help with spin axis modeling. For reference, the previously published lightcurve from 2013 September ($A = 0.10$ mag) is shown as well as the one from December ($A = 0.39$ mag).

6602 Gilclark. Previous observations by the author (Warner, 2009a; 2012a) found a period of 4.574 h. The results from 2013 were in good agreement, $P = 4.5686$ h. This asteroid also showed weak indications of a satellite via shallow mutual events and a slight bowing of the secondary period. It should be considered a *possible* binary, not *probable*, and – like 4440 above – should be carefully monitored at future apparitions.

7087 Lewostksy. This Hungaria was observed by Carbo (2009) who reported only an amplitude of 0.25 mag. Observations by the author (Warner, 2011a) found a period of 5.15 h. Observations in 2012 (Warner, 2012b) updated the period to 3.934 h. The asteroid was observed at CS3 on two occasions during the 2013 apparition, first in late September ($P = 3.941$ h, $A = 0.29$ mag; first plot below)

and again in late December ($P = 3.942$ h, $A = 0.51$ mag; second plot below). The three most recent results prompted a visit to the original data from 2010. New analysis was able to fit those data to $P = 3.934$ h. Given the low amplitude, relatively noisy data, and the fact that each session was at least three days removed from any other, the small discrepancy should not come as a surprise and the results can be considered the same for statistical studies.

7173 Sepkoski. Previous results for this Hungaria include Warner (2011a, $P = 2.50$ h) and Han (2013, $P = 2.44$ h). Analysis of the data from the 2013 observations at CS3 found $P = 2.5006$ h, $A = 0.11$ mag. This asteroid also showed weak signs of mutual events. The difference between the “No Sub” and “P1” plots below shows little difference given the overall scatter in the lightcurve. The “P2” plot indicates a possible orbital period for a tidally-locked satellite of $P_{ORB} = 12.75$ h, mostly based on a supposed event at about 0.0 orbital phase. Here again, this should be considered only a *possible* binary and the asteroid be given priority at future apparitions.

7505 Furusho. This Mars-crosser was observed in 2000 by Stephens (2001), who reported $P = 4.14$ h, and by Szekely (2005), who reported the same period. The observations at CS3 led to a result of $P = 4.140$ h.

(9068) 1993 OD. Previous results for this Hungaria include Warner (2009a, $P = 3.405$ h) and Galad *et al.* (2010, $P = 3.4074$ h). The result from the 2013 apparition was $P = 3.407$ h.

(9873) 1992 GH. The author observed this Hungaria on three occasions prior to 2013 (Warner, 2007a; 2009a; 2012a). Sauppe *et al.* (2007) also reported observations. In all cases, the period was close to 2.92 h, which is the same result based on of the 2013 observations at CS3.

11833 Dixon. The results from the 2013 apparition appear to be the first to be reported for this Hungaria member.

11941 Archinal. Li *et al.* (2013) reported a period of 2.717 h for this Hungaria. The results from the 2013 campaign at CS3 are nearly identical, $P = 2.718$ h.

11976 Josephthurn. Analysis of the data from 2013 obtained at CS3 found $P = 3.535$ h (first plot below), nearly identical to the one found earlier by the author (Warner, 2011c), and somewhat the same one of $P = 3.50$ h obtained in 2009 (Warner, 2009d). The original data from 2009 were re-examined, which lead to a revised value of $P = 3.534$ h (second plot).

12369 Pirandello. There were no previous results in the LCDB for this Flora member.

(21321) 1997 AN2. Also a Flora member, there were no previous entries in the LCDB for this asteroid.

(24077) 1999 TD233. There is little doubt that this Hungaria is in non-principal axis rotation, or *tumbling*. Analysis by Petr Pravec, Astronomical Institute, Czech Republic (private communications), found two *possible* periods of about 30.86 and 33.13 h. The plots below show the entire data set forced to these two periods and are for instructive purposes only. These could easily be linear combinations of the two true periods ($1/f_1$ and $1/f_2$) or integral multiples of one or both. Even with observations from multiple locations that are well-separated in longitude, obtaining the actual periods would be very difficult. In such cases, it must be sufficient to determine that the asteroid is tumbling, the degree it is doing so, and approximate solutions. For a detailed discussion on the analysis and mechanisms of tumbling, see Pravec *et al.* (2005).

(30856) 1991 XE. The 2013 apparition was the fourth time this Hungaria had been observed by the author (Warner, 2007a; 2010b; 2012a). All four results found a period within 0.01 h of $P = 3.56$ h.

(31173) 1997 XF1. The long period of 123 hours and the size of this Hungaria ($D \sim 2.7$ km) favor it being in a tumbling state, i.e., that its damping time was greater than the age of the Solar System (see Pravec *et al.*, 2005). However, there were no obvious indications of this, e.g., a session “leaning the wrong way” and not being able to fit a reasonable single period even with zero point offsets. There were no previous entries in the LCDB.

(49667) 1999 OM2. Warner *et al.* (2011) observed this Hungaria in 2010 and reported a period of 3.48608 h. The 2013 data analysis found $P = 3.487$ h, in good agreement with those earlier results.

(49675) 1999 SW27. The results from the 2013 campaign of $P = 4.998$ h are in good agreement with the author’s earlier finding (Warner, 2011a; $P = 4.994$ h).

(69406) 1995 SX48. This Hungaria has a reported period of 2.2431 h (Warner and Stephens, 2011). However, the double period of about 4.48 h could not be formally excluded. Analysis of the 2013 data from CS3 found that the longer period, $P = 4.486$ h, is the correct one, the data providing a very poor fit to the shorter period.

Furthermore, the data showed signs of mutual events due to a satellite. The period spectrum for the secondary period shows several nearly equal solutions. The “P2” plot shows the data after subtracting the primary rotation and fit to a period of 16.11 h. This makes a good case for a satellite, having events at 0.0 and 0.5 orbital phase. The attenuation of about 0.04 mag gives a lower limit of $D_s/D_p \geq 0.19 \pm 0.02$. Had the events been flat-bottomed, indicating a total event, then this value would have been the actual effective diameter ratio of the satellite to primary. This can be considered a *probable* binary, maybe even confirmed.

(82060) 2000 WX8. Warner (2011a) observed this Hungaria in 2010, reporting a period of 2.7631 h. The period of 2.764 h found from the 2013 data is in good agreement.

(86192) 1999 SV1. The result of $P = 7.172$ h found from the 2013 observations (plot “P1B”) is in good, but not perfect, agreement with the author’s earlier result of $P = 7.167$ h (third plot in set). However, as seen in the period spectrum for the 2013 data (plot “2013: P1”), a monomodal solution with a half period of about 3.85 h is nearly as valid. The deciding factor for adopting the longer period was the asymmetry of the 2010 lightcurve at the longer period and that the data forced to the half period give a very poor fit. Given the 7.1-hour period and time span within each data set, the two periods are statistically the same. There were faint indications of a secondary period in the 2013 and so the asteroid should be monitored carefully at future apparitions.

(119744) 2001 YN42. Jacobsen and Scheeres (2011) reasoned that one evolutionary path for binary asteroids would result in a system that had a primary with a long period (due to conservation of energy) and a widely-spaced satellite with a relatively short rotation period and an orbital period that is probably very long. Furthermore, the orbital period would probably not be synchronized with either rotation period. The chances of seeing occultations and/or eclipses in such a system would be exceedingly remote. Two systems discovered by the author, 8026 Johnmckay (Hungaria; Warner, 2011b) and (218144) 2002 RL66 (Mars-crosser; Warner, 2010a) show such photometric traits, including the lack of mutual events. (119744) 2001 YN42 (inner main belt) appears to be the third example of this type of system. All three objects have estimated effective diameters of about 3 km or less.

The “P1” plot below (due to the putative primary) shows the large amplitude, long period component, the period being about 625 hours and the amplitude 0.52 mag. It is impossible to see the effects of the other period in this plot. However, if that long period is subtracted from the data, a reasonably good “secondary” period of 7.24 hours is found, as shown in the “P2” period spectrum. The “P2” lightcurve shows a low amplitude (0.05 mag) bimodal solution with a period of 7.24 h, which does not have a half or integral multiple equal to the long period.

As with the two previous cases, the amplitude of the shorter period lightcurve is low, making it difficult to state with certainty that it is does not have observational or systematic origins or is simply an artifact of the Fourier analysis. However, “three is a crowd” and given that such a system is considered not only theoretically possible but likely, it is not as easy to dismiss the results as when there were only one or two examples.

(120578) 1995 QV12. This outer main-belt object was a *target of opportunity*, i.e., in the same field as a targeted asteroid. There were no previous entries in the LCDB. Given the incomplete coverage of the lightcurve, the period of 72.4 h cannot be considered definitive.

(134549) 1999 RN154. There were no previous entries in the LCDB for this Flora member. It was also a *target of opportunity*. Some of the individual sessions seem to be “leaning the wrong way”, which may be an indication that the asteroid is tumbling. The period is much greater than one corresponding to a damping time equal to the age of the Solar System, so tumbling would not be unexpected. See Pravec *et al.* (2005) for a thorough discussion of tumbling asteroids.

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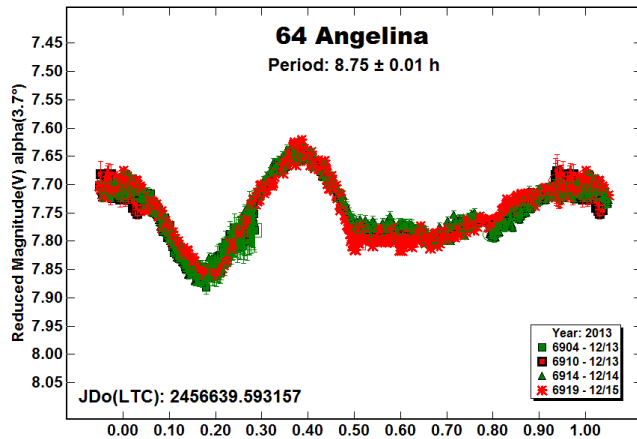
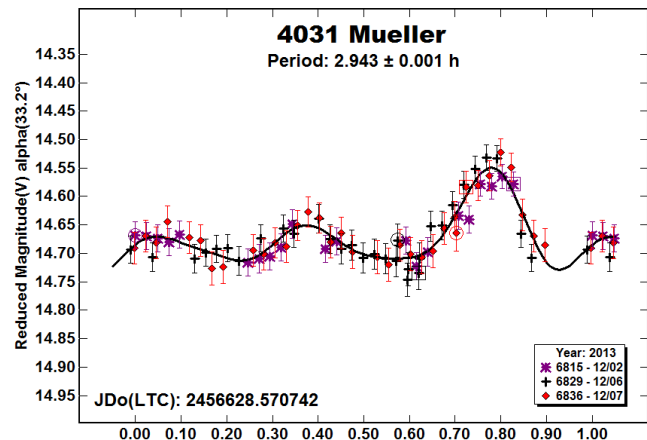
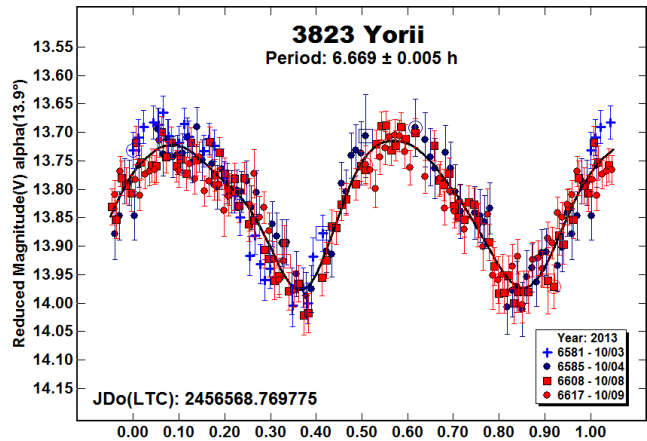
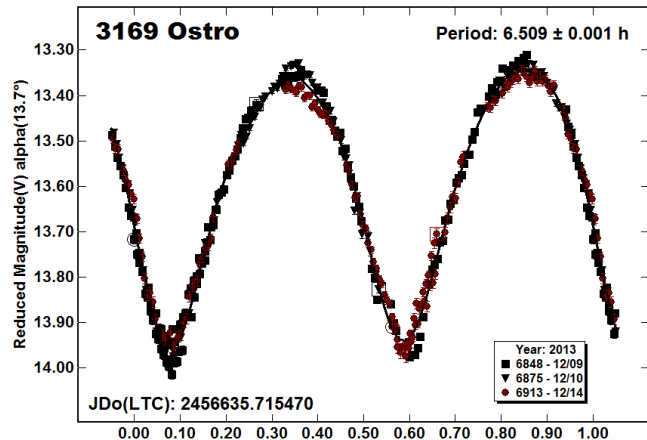
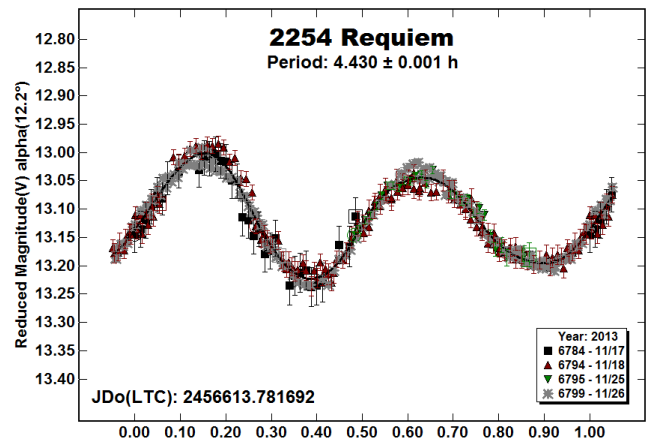
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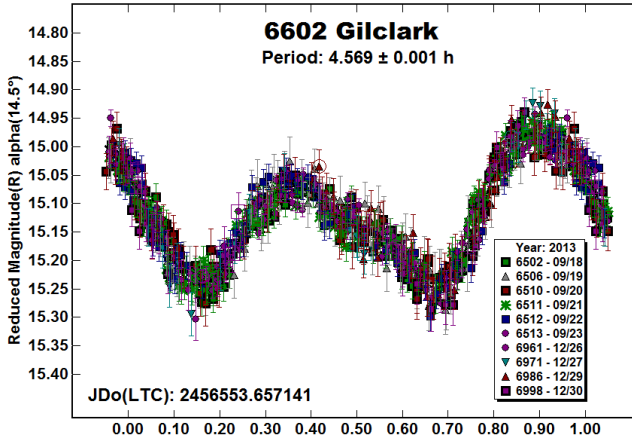
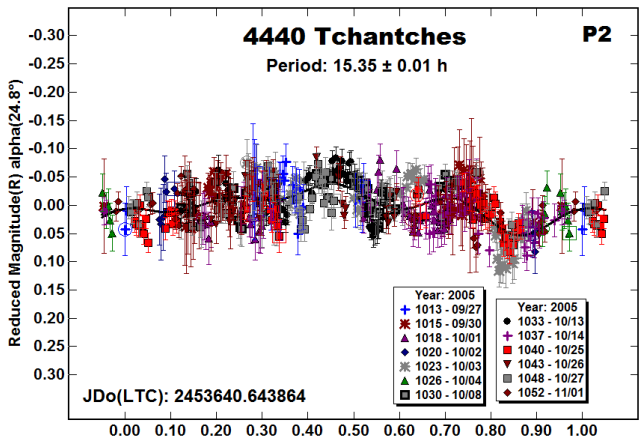
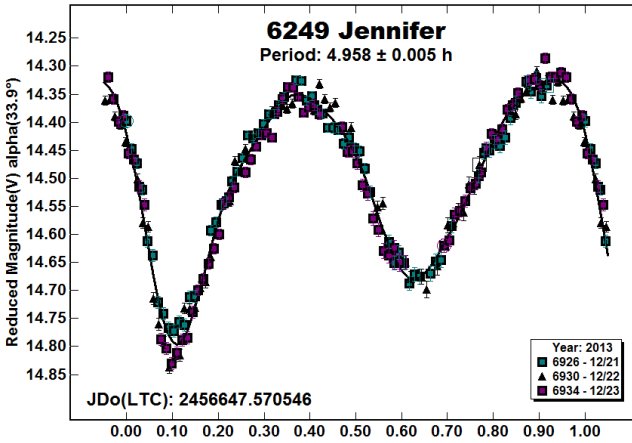
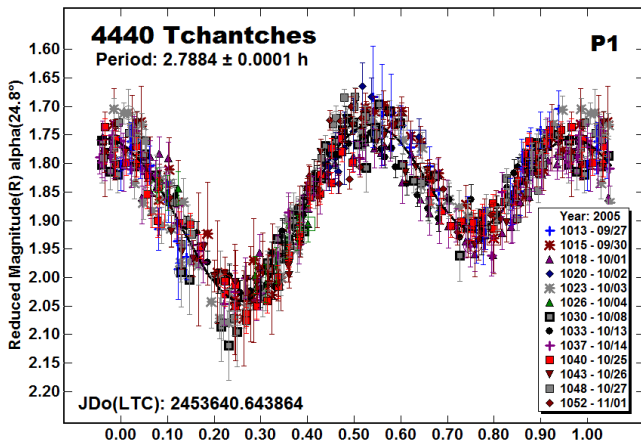
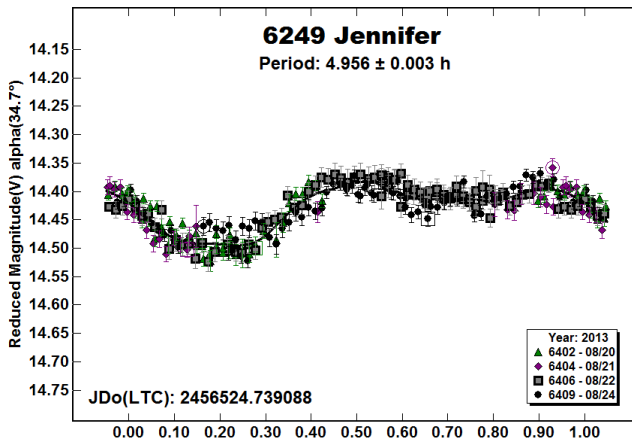
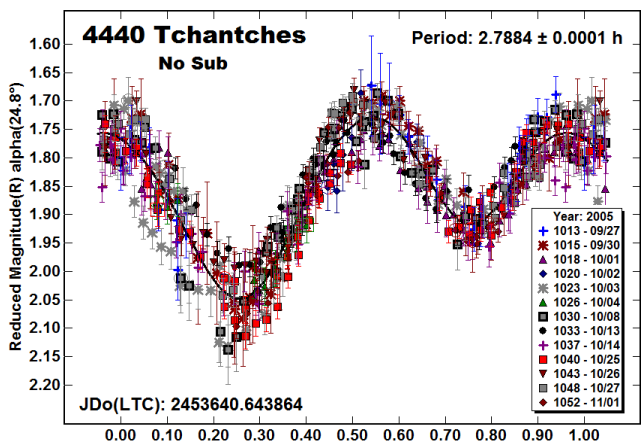
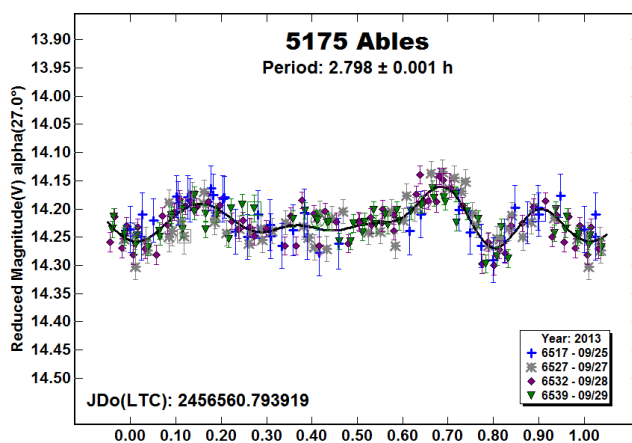
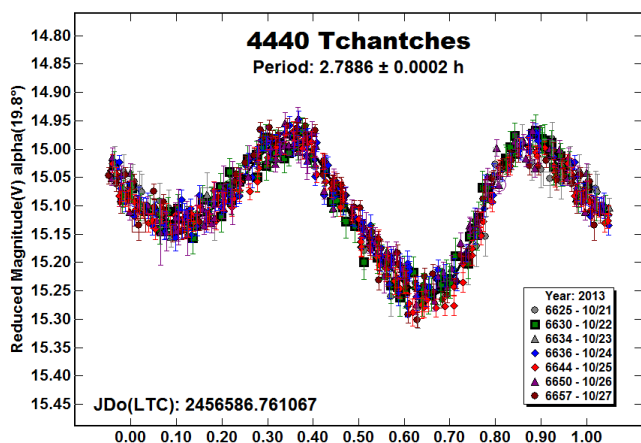
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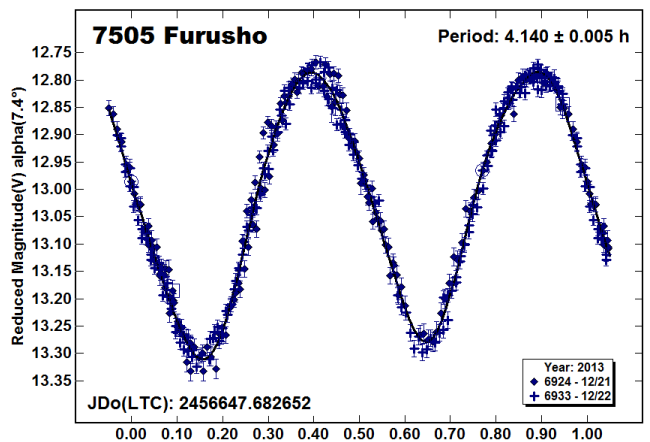
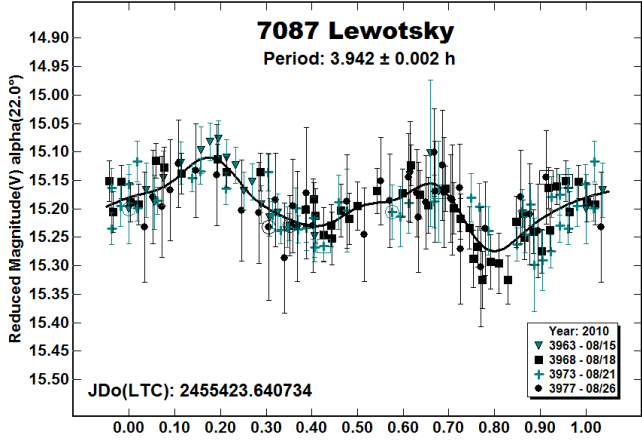
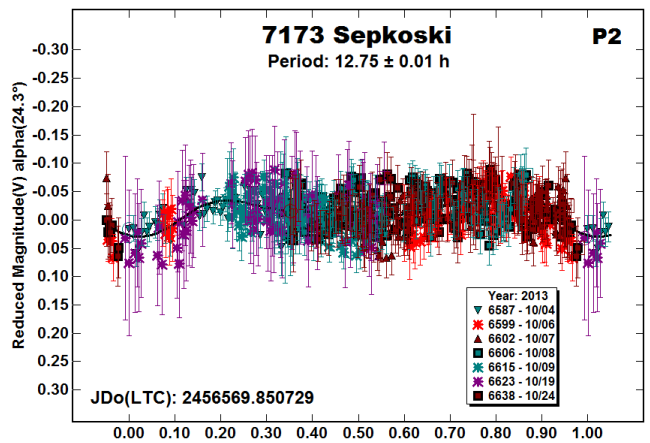
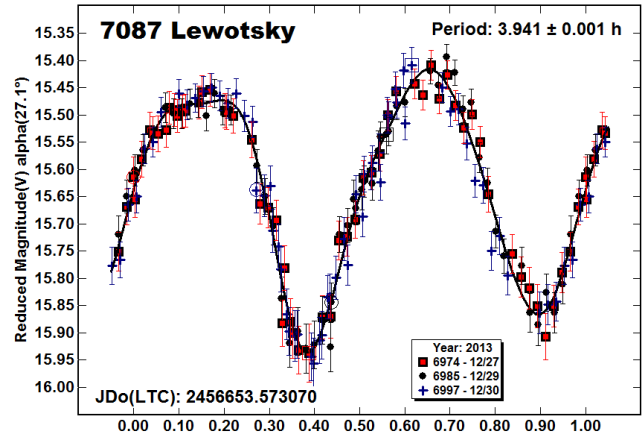
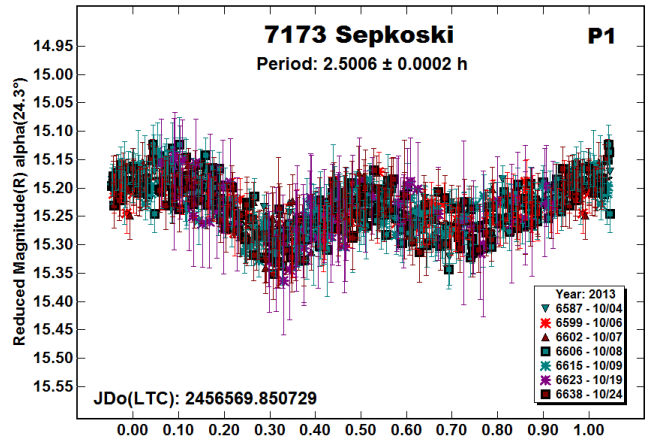
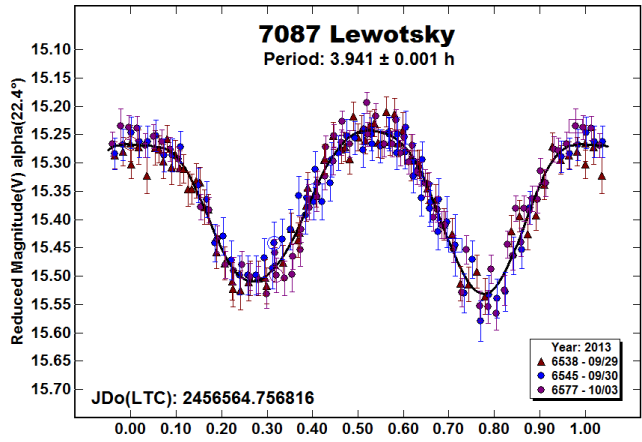
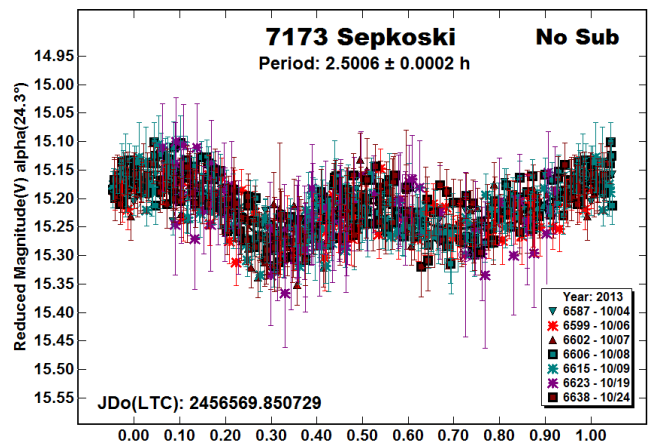
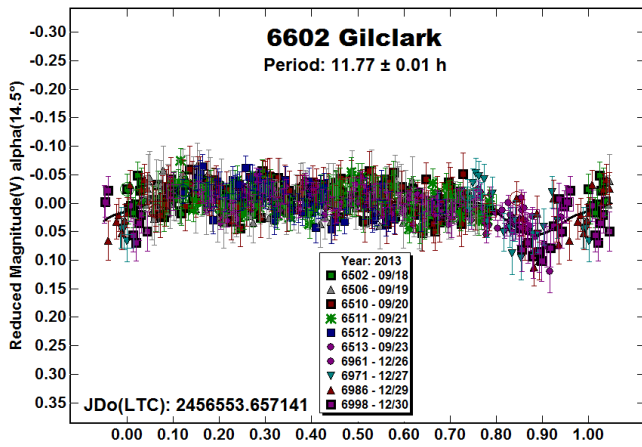
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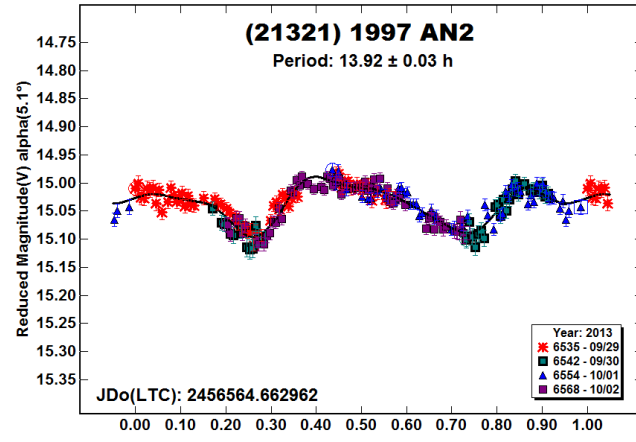
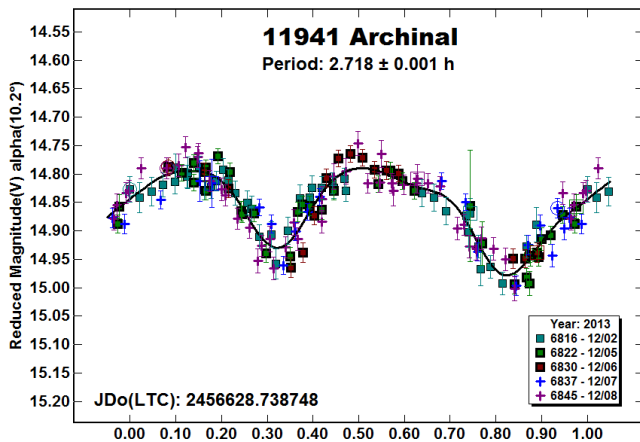
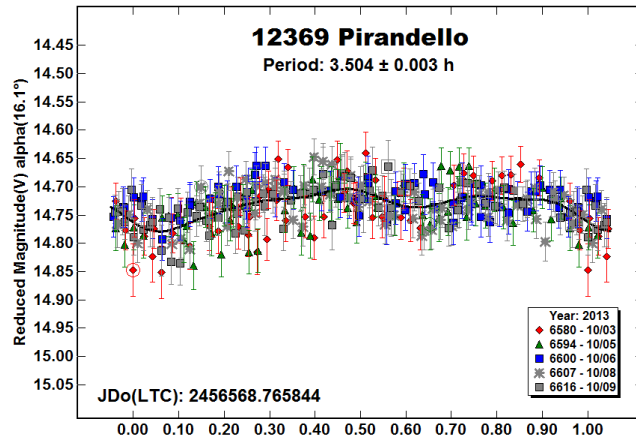
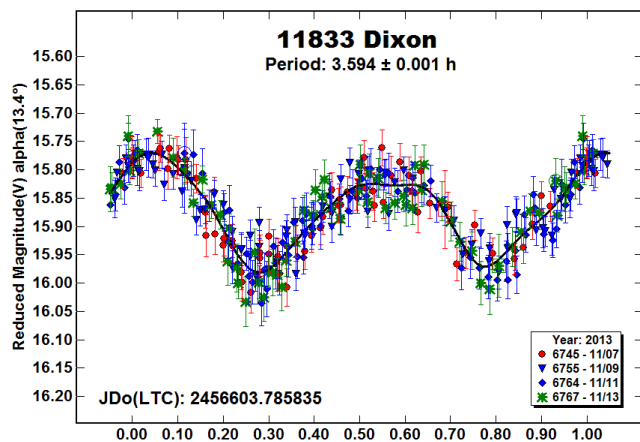
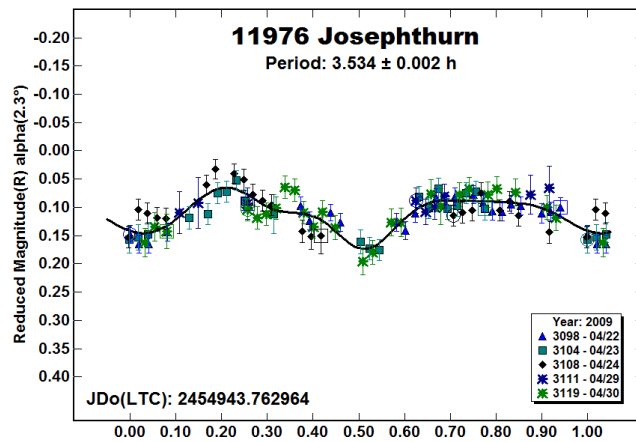
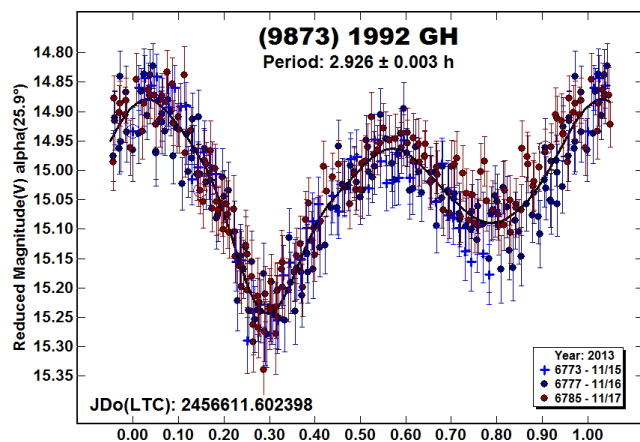
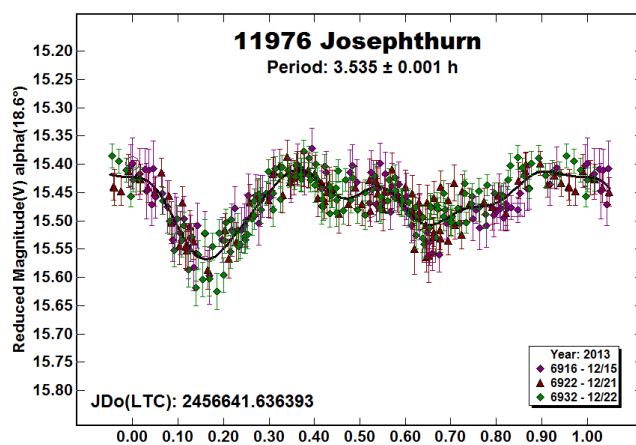
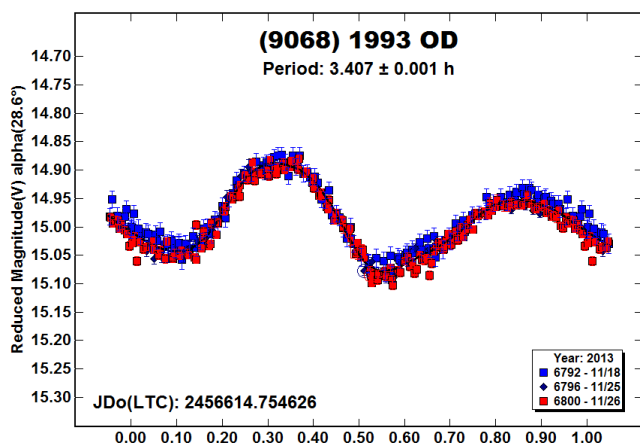
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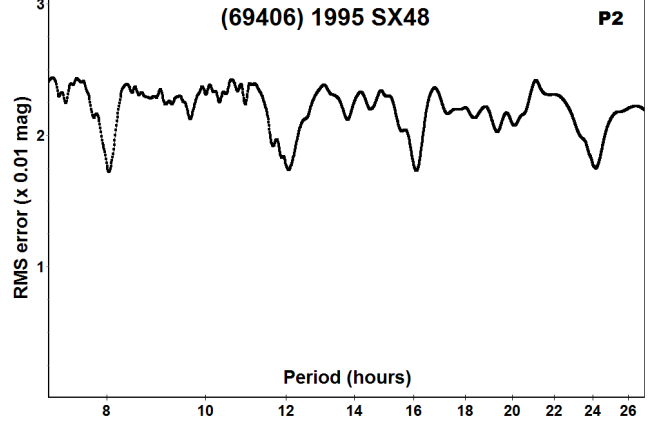
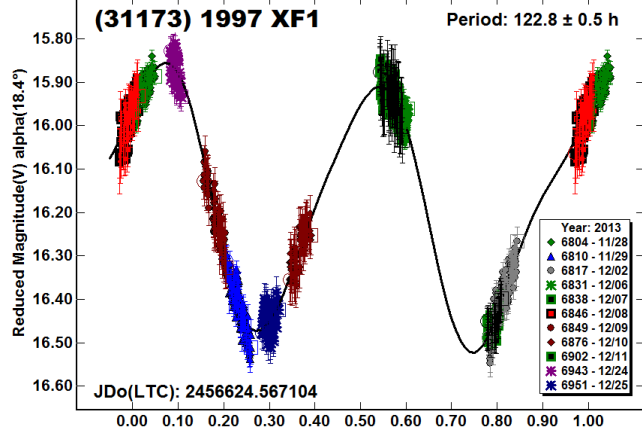
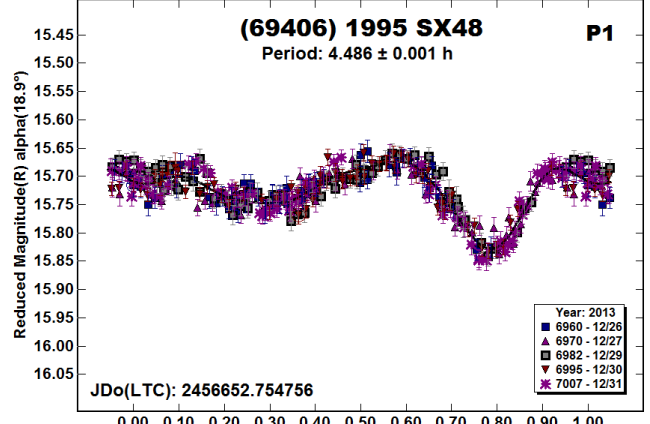
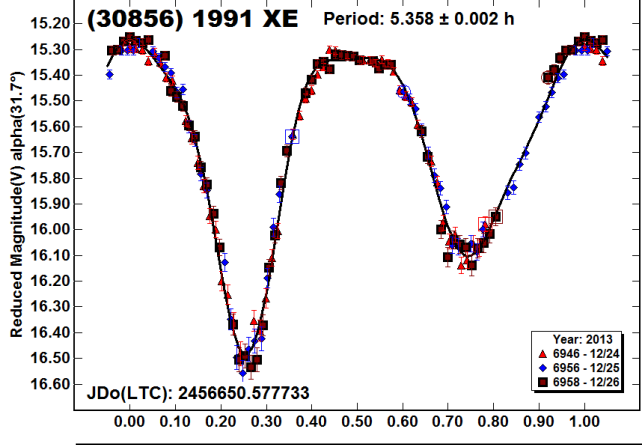
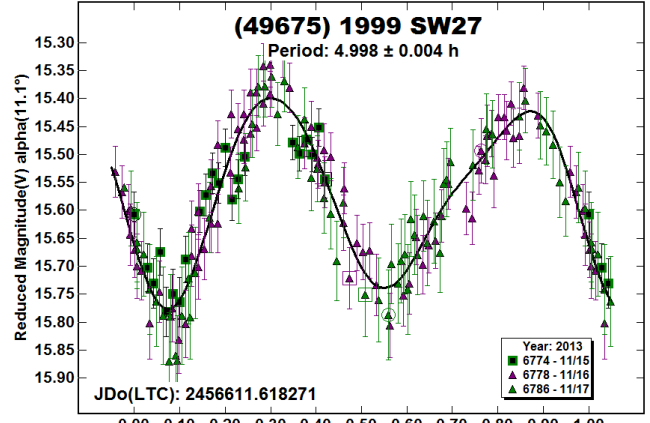
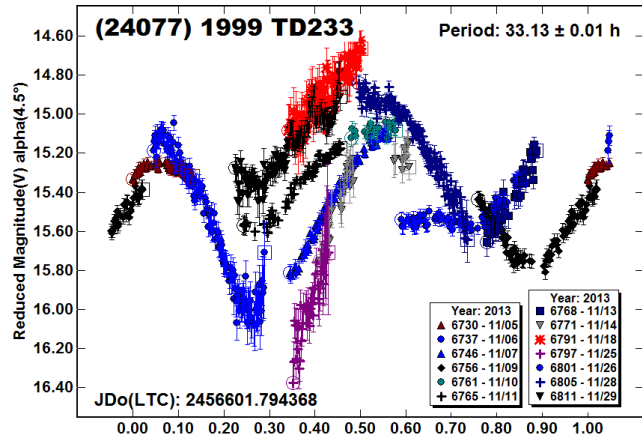
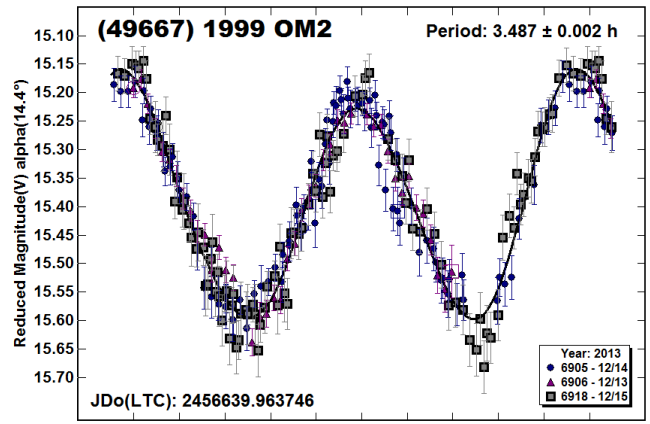
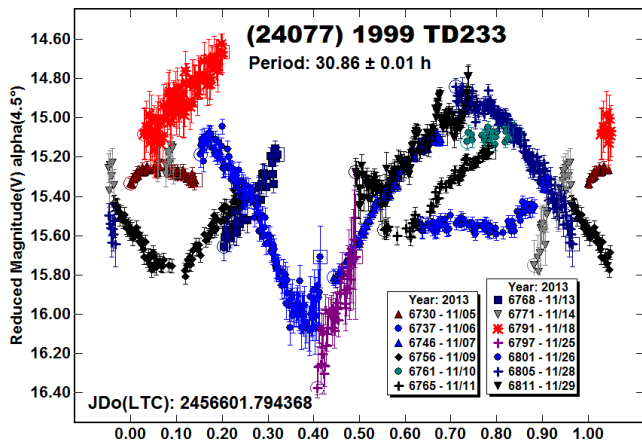
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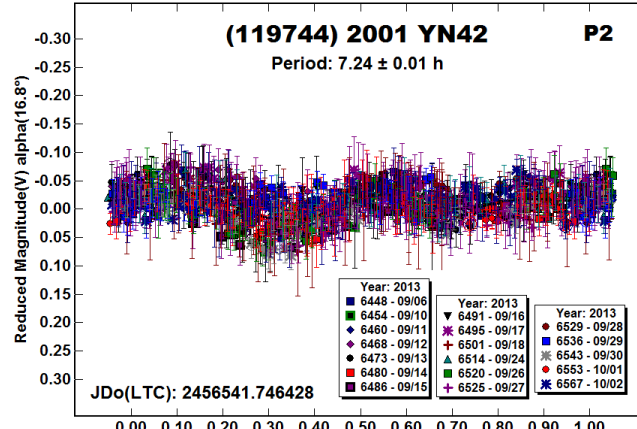
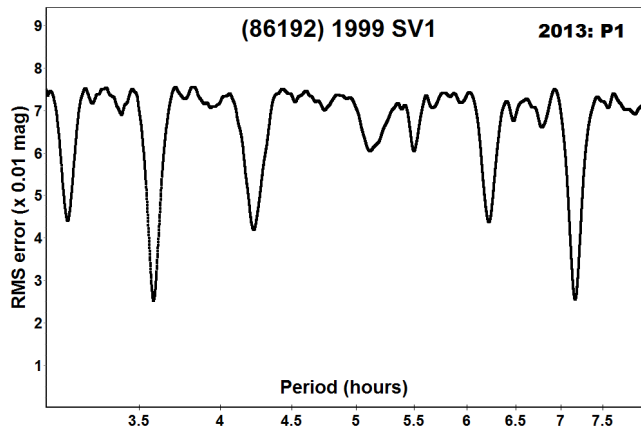
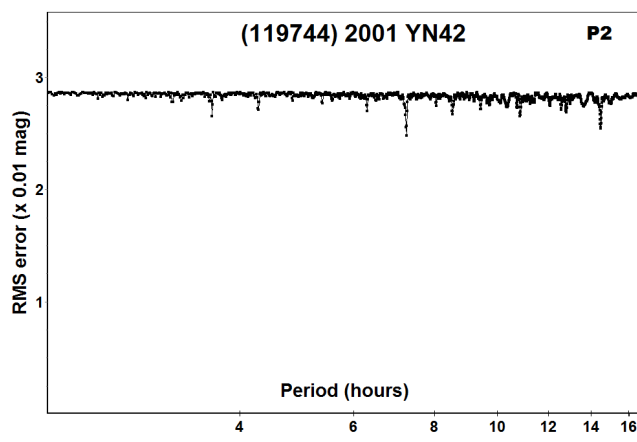
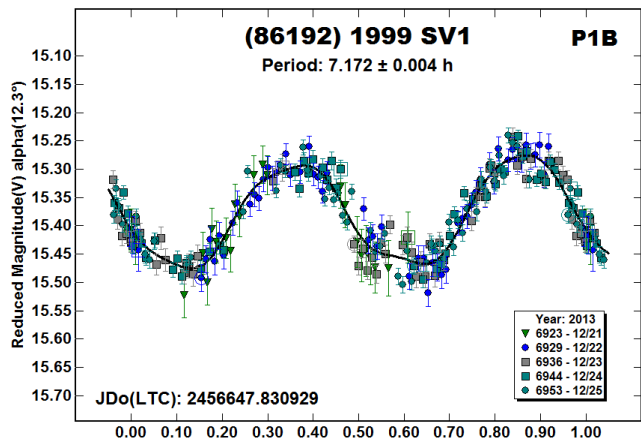
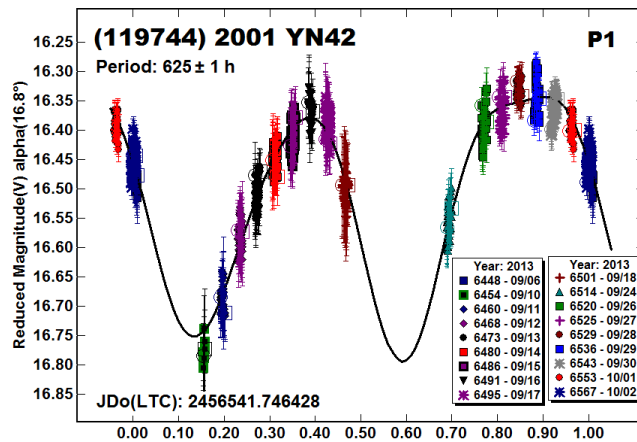
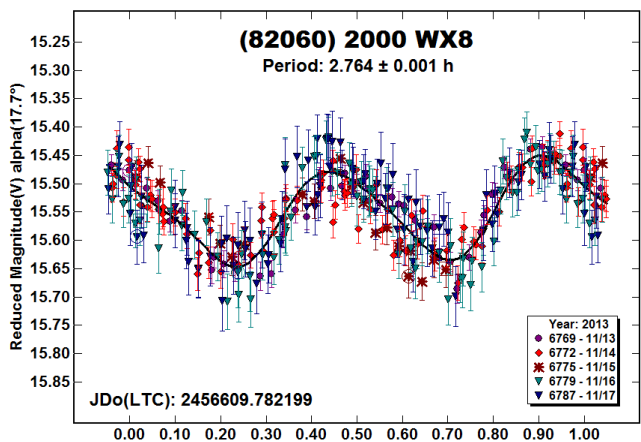
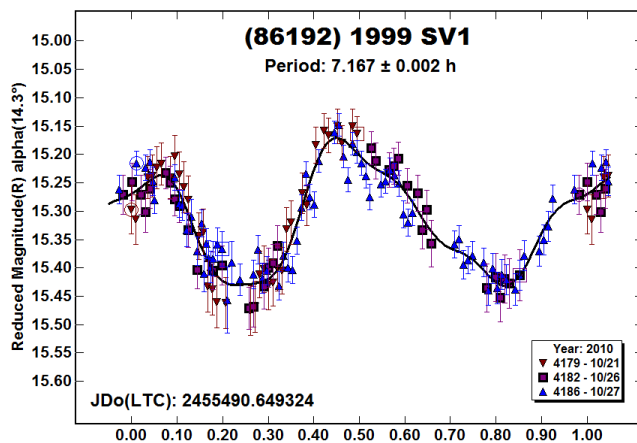
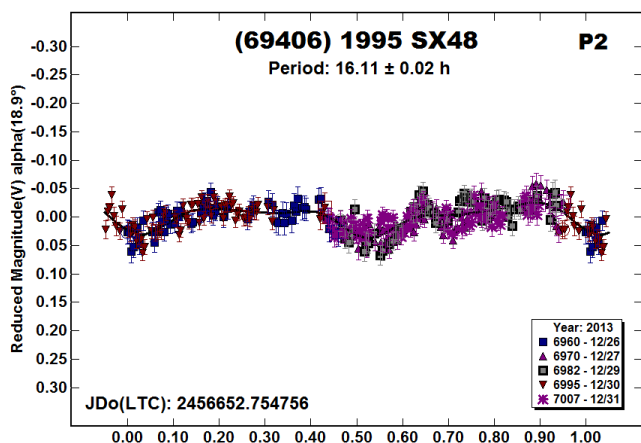


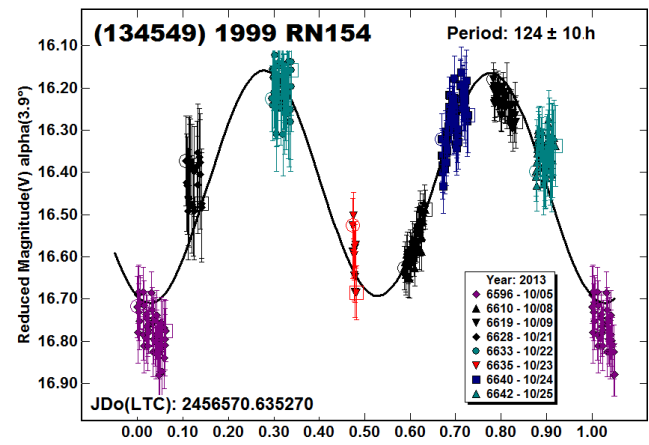
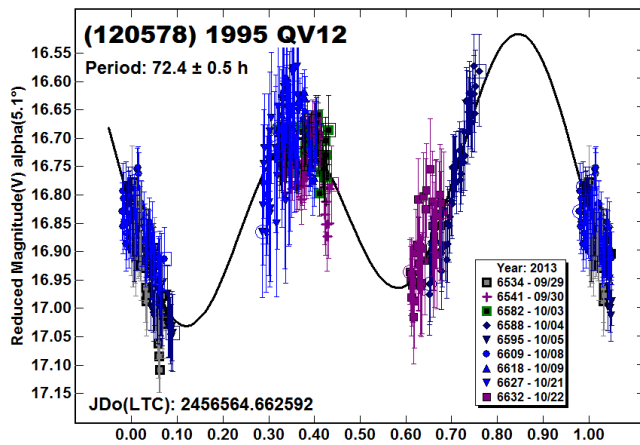












ROTATION PERIODS OF 3618 KUPRIN AND 3896 PORDENONE

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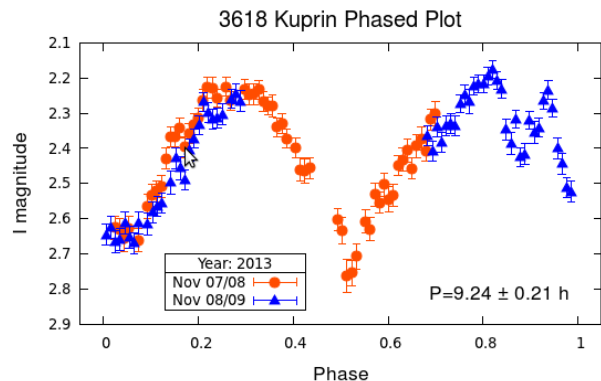
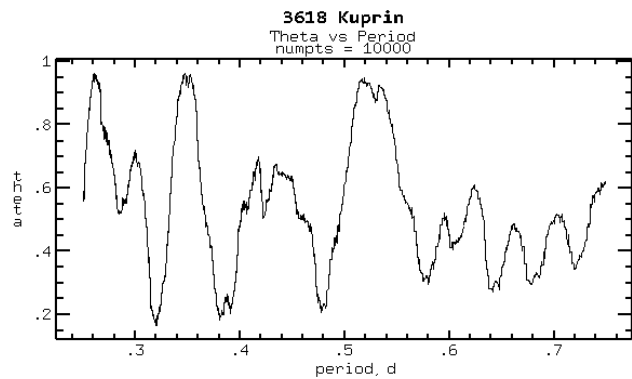
Photometric observations of two main-belt asteroids were obtained in 2013 November. Lightcurve analysis of 3618 Kuprin found a synodic rotation period of 9.24 ± 0.21 h with an amplitude of 0.56 ± 0.04 mag. Further studies of this object are necessary. For 3896 Pordenone, we found a synodic period of 3.995 ± 0.010 h and an amplitude of 0.37 ± 0.04 mag

A field near the ecliptic was imaged on two consecutive nights (2013 Nov 07 and 08) at the Bulgarian National Astronomical Observatory (NAO Rozhen, $41^{\circ}42'N$ $24^{\circ}44'E$) as a part of an ultracool dwarf monitoring program. A total of 134 frames in standard I filter were obtained with the 50/70-cm Schmidt telescope ($f/3.44$) and an FLI PL-16803 CCD camera. The duration of each exposure was 300 s. Asteroids 3618 Kuprin and 3896 Pordenone were identified in the field using the Minor Planet Center's MPChecker. Two reference stars were used to calculate differential magnitudes of both minor planets. The aperture was set at 4 arcseconds which yielded a final error in the range of 0.02–0.03 mag. All image processing was done using *IRAF* (*Image Reduction and Analysis Facility*).

3618 Kuprin. As of 2013 January, there was no lightcurve or rotation period information for this object in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). Our data are insufficient to determine the period with a high level of confidence. The *IRAF pdm* procedure, which was run within a trial period range from 0.25 to 0.75 d, showed three possible periods: ~ 0.32 d, ~ 0.38 d and

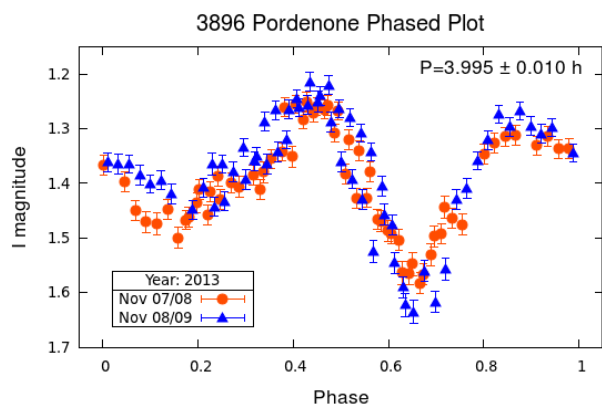
~ 0.48 d. We suggest a synodic period corresponding to $P = 9.24 \pm 0.21$ h with an amplitude $A = 0.56 \pm 0.04$ mag since this is the only option that accepts the two 4σ lightcurve features at phase ~ 0.9 (on the phased plot) as a local minimum followed by a local maximum rather than data noise.

3618 Kuprin was in opposition in 2013 November and the next closer approach is not until 2018. However, considering the high amplitude of the object, we encourage a more thorough photometric investigation.



3896 Pordenone. A rotation period of 4.009 h obtained by Higgins in 2007 and a maximum amplitude $A = 0.28$ mag are listed in the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009). Hanuš *et al.* (2013) found a sidereal period of 4.0037 h. Using the Phase Dispersion Minimization (PDM) technique (Stellingwerf, 1978) we obtained $P = 3.995 \pm 0.010$ h, which is in agreement with the

previous studies. However, we derived a higher amplitude ($A = 0.37 \pm 0.04$ mag).



Acknowledgements

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NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2013 SEPTEMBER-DECEMBER

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Lightcurves for 36 near-Earth asteroids (NEAs) were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2013 September-December.

CCD photometric observations of 36 near-Earth asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 September through December. Table I gives a listing of the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

Desig	Telescope	Camera
PDS-1-12N	0.30-m f/6.3 Schmidt-Cass	ST-9XE
PDS-1-14S	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
PDS-2-14N	0.35-m f/9.1 Schmidt-Cass	STL-1001E
PDS-2-14S	0.35-m f/9.1 Schmidt-Cass	STL-1001E
PDS-20	0.50-m f/8.1 Ritchey-Chretien	FLI-1001E

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

All lightcurve observations were made with no filter (a clear filter can result in a 0.1-0.3 magnitude loss) and were guided on a field star, resulting in some cases in a trailed image for the asteroid. The

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exposure varied depending on the asteroid's brightness and sky motion.

Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes are usually taken from the MPOSC3 catalog, which is based on the 2MASS catalog (<http://www.ipac.caltech.edu/2mass>) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). When possible, magnitudes are taken from the APASS catalog (Henden *et al.*, 2009) since these are derived directly from reductions based on Landolt standard fields. Using either catalog, the nightly zero points have been found to be consistent to about ± 0.05 magnitude or better, but on occasion are as large as 0.1 mag. This reasonably good consistency is critical to analysis of long period and/or tumbling asteroids. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.*, 1989).

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

For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.* 2009). The on-line version at <http://www.minorplanet.info/lightcurvedatabase.html> allows direct queries that can be filtered a number of ways and the results saved to a text file. A set of text files of the main LCDB

Number	Name	2013		Phase	L _{PAB}	B _{PAB}	Period	P.E.	Amp	A.E.
		mm/dd	Pts							
4450	Pan	09/25-10/01	580	16.0,10.9	12	10	56.48	0.02	0.64	0.02
6063	Jason	10/03-11/03	1887	27.5,25.2,36.5	46	-10	51.7	0.5	0.11	0.02
10115	1992 SK	11/03-11/06	168	12.9,14.2	36	14	7.323	0.005	0.50	0.02
17511	1992 QN	11/01-11/03	202	12.4,13.8	30	11	5.985	0.005	0.79	0.03
18109	2000 NG11	12/24-12/26	209	21.6,20.2	119	1	4.255	0.005	0.89	0.03
52760	1998 ML14	12/05-12/15	210	23.0,12.4	95	5	14.28	0.01	0.15	0.02
53435	1999 VM40	12/09-12/13	240	39.7,37.7	115	20	5.186	0.002	0.32	0.02
65733	1993 PC	10/06-10/06	49	12.7,12.7	3	5	4.28	0.03	0.73	0.02
65733	1993 PC	10/19-10/25	126	30.8,39.0	120	6	4.184	0.001	0.97	0.03
88710	2001 SL9	09/25-10/03	368	21.7,14.5	13	14	2.4013	0.0004	0.12	0.02
142781	2002 UM11	10/26-10/30	294	23.1,19.8	42	19	6.81	0.03	0.03	0.01
163696	2003 EB50	12/21-12/31	1088	62.4,54.5	44	8	27.2	0.1	0.73	0.03
249595	1997 GH28	12/27-01/01	290	37.1,35.0	126	15	19.74	0.05	1.20	0.03
251346	2007 SJ	11/03-11/06	268	21.6,23.3	38	19	2.718	0.002	0.14	0.02
262623	2006 WY2	12/23-12/26	329	16.7,11.8	104	-3	16.3	0.2	0.14	0.02
	1997 WQ23	11/28-11/29	303	29.9,29.3	47	1	14.6	0.1	0.54	0.03
	2003 WX25	10/28-10/31	257	9.4,6.8	43	-1	5.118	0.005	0.22	0.02
	2006 CT	12/27-01/02	457	41.7,26.4	118	1	16.69	0.02	0.80	0.03
	2006 HU30	11/05-11/17	428	16.5,11.7,15.3	53	7	47.6	0.3	0.20	0.02
	2010 SL13	12/11-12/15	130	31.1,30.5	102	-9	7.79	0.02	0.20	0.02
	2010 CL19	12/05-12/08	489	47.0,42.1	45	-2	3.1597	0.0005	0.39	0.03
	2010 XZ67	12/26-01/01	949	26.7,8.1	91	6	15.05	0.02	0.24	0.05
	2011 CQ4	12/27-01/02	304	30.7,38.6	68	-1	128.	3.	0.19	0.02
	2013 VJ2	11/07-11/07	208	11.7,11.7	52	-1	3.8	0.2	0.22	0.03
	2013 YL2	01/01-01/01	962	30.0,30.0	114	-8	2.97	0.01	0.96	0.05
	2013 UR3	11/18-12/08	565	27.9,38.4	40	4	11.08	0.01	0.08	0.01
	2013 XA4	12/21-12/23	206	7.0,8.5	87	4	3.57	0.05	0.15	0.03
	2013 UH5	10/31-11/02	264	8.6,6.3,8.4	42	0	2.69	0.02	0.18	0.03
	2013 TE6	10/25-10/30	239	9.1,6.2	38	4	2.46	0.02	0.12	0.02
	2013 XY8	12/10-12/10	553	12.4,12.4	75	-6	0.06055	0.00001	0.13	0.01
	2013 XY8	12/11-12/11	188	31.2,31.2	94	-5	0.06054	0.00003	0.47	0.03
	2013 UH9	11/07-11/14	153	67.4,69.1	93	5	16.3	0.5	0.80	0.05
	2013 SU24	10/01-10/02	876	9.0,2.3	7	-2	0.23335	0.0001	0.63	0.10
	2013 SW24	10/01-10/02	234	19.9,19.3	3	11	7.09	0.02	0.18	0.02
	2013 SC25	10/31-11/02	182	30.0,31.6	42	23	12.96	0.02	0.72	0.03
	2013 RM43	10/26-11/03	1275	11.1,31.1	43	9	32.6	0.1	0.75	0.05
	2013 RH74	10/02-10/09	570	16.2,23.5	23	4	5.346	0.005	0.21	0.02
	2013 TB80	12/05-12/09	220	36.7,38.4	40	0	2.63	0.01	0.09	0.01

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

tables, including the references with bibcodes, is also available for download. When possible, researchers are strongly to obtain the original references listed in the LCDB for their work.

Tumbling Asteroids

Some of the objects reported here are confirmed (or suspected) to be in non-principal axis rotation (NPAR), or *tumbling*. The analysis of the periods (frequencies) involved is beyond the capabilities of the author. In such cases, the data are provided to Petr Pravec, Astronomical Institute, Czech Republic, who has developed specialized analysis tools for such objects. Details behind the analysis as well as a thorough discussion of tumbling asteroids in general are in Pravec *et al.* (2005). Also included is the PAR rating system, which gives an idea on the likelihood that the asteroid is in an NPAR state. This paper should be required reading for those doing asteroid lightcurve photometry.

Very briefly, the lightcurve of a tumbling asteroid is the sum of the integral multiples of two frequencies, i.e.,

$$1.0 / (nf1) + 1.0 / (mf2)$$

Except in those cases where $f1$ and $f2$ represent very short periods ($P < 1$ h) and there is an extensive data set covering many rotations of both the principal and precession axes, finding a unique solution

for $f1$ and $f2$ is very difficult, if not impossible. What is often determined is a dominant period ($1/f1$) with one or more *possible* solutions for the second period. Also, it is often not possible to determine which of the two periods is due to principal axis rotation and the other due to precession.

Individual Results

4450 Pan. Pravec *et al.* (2008) reported a period of 60 hours and that the asteroid probably tumbling (PAR = -1). No signs of tumbling were seen in the data obtained at CS3-PDS in 2013 September, although a more definitive dominant period of 56.48 h was found.

6063 Jason. This NEA appears to be in at least a slightly excited tumbling state. While some of the deviations in zero points in the raw plot of the data (first plot below) might be accounted for by calibration errors, the number and degree of adjustments was too many to exclude the possibility of tumbling. The second plot shows the lightcurve phased to a dominant period of about 52 hours, which was confirmed by Pravec. However a solution for a second period could not be determined before the asteroid faded and moved too far south for additional observations.

(10115) 1992 SK. Pravec *et al.* (1999) observed this asteroid for an extended time in 1999. Data from early March led a period of

7.328 h and amplitude of 0.72 mag ($\alpha = 41.6^\circ$). By the middle of March, the period had shortened to 7.31832 h and the amplitude increased to 1.03 mag ($\alpha = 69.0^\circ$). Polishook (2012) found a period of 7.31 h and amplitude 0.70 mag ($\alpha = 73.5^\circ$). The 2013 observations at $\alpha = 14^\circ$ showed, not unexpectedly, a lower amplitude of 0.50 mag as well as a period in good agreement with the earlier results.

(17511) 1992 QN. Pravec *et al.* (1998) reported $P = 5.9902$ h and $A = 1.10$ mag; Krugly *et al.* (2002) found $P = 5.99$ h and $A = 1.1$ mag. Analysis of the CS3-PDS data give a similar period with $A = 0.79$ mag.

(18109) 2000 NG11. Pravec *et al.* (2000a) reported $P = 4.2534$ h and $A = 1.13$ mag ($a = 6^\circ$). The CS3-PDS data led to $P = 4.255$ h and $A = 0.89$ mag ($\alpha = 21^\circ$). Usually, a larger amplitude is expected at higher phase angles. This could be explained by the fact that the Pravec *et al.* observations were made when the asteroid presented a more equatorial view than during the 2013 apparition.

(52760) 1998 ML14. Hicks *et al.* (1998) found $P = 14.98$ h and $A = 0.12$ mag. Ostro *et al.* (2001) reported an effective diameter of about 1 km based on radar observations while Mueller *et al.* (2011) found $D \sim 0.81$ km based on IR data. The CS3-PDS data led to $P = 14.28$ h and $A = 0.15$ mag.

(53435) 1999 VM40. Pravec *et al.* (2000) reported a period centered on 5.189 h using data from mid-January to early February 2000. The amplitude ranged from 0.26 to 0.38 mag over phase angles 1.7 - 21.5° . The 2013 PDS observations produced $P = 5.186$ h and $A = 0.32$ mag at $\alpha = 38.8^\circ$.

(65733) 1993 PC. The lightcurve for 1993 PC showed significant changes over only a two-week span as the phase angle increased from 12° to 34° . In the early part of 2013 October, the amplitude was 0.73 mag. The period was 4.28 h, although this is based on data from only one night and a minimum of coverage of a second cycle. By 19-25 October, the amplitude had increased to 0.93 mag, and the period decreased to 4.184 h.

(88710) 2001 SL9. This is a known binary (Pravec *et al.*, 2001; 2006). They reported a primary period of 2.4003 h and an orbital period of 16.40 h for the satellite. Analysis of the 2013 data from CS3-PDS showed a primary period in good agreement with the earlier finding (first plot). Only two well-defined events were observed from 25 September through 3 October, which led to 16.19 h for the orbital period. Furthermore, the secondary event, if one is to be seen at all, occurs about 0.1 cycle too soon (or late). The 2000 apparition seemed to show shadow transits as well as occultation and/or eclipses. It might be possible that the viewing geometry didn't allow seeing the actual satellite event but did catch a shadow event. This might explain the eccentric placement of the shallow event at 0.2 phase in the second plot below.

(142781) 2002 UM11. The period of 6.8 h reported here is just one of many possible solutions (see the period spectrum). No long term trend was seen in the data, at least within the expected ± 0.05 mag spread in night-to-night zero point calibrations.

(163696) 2003 EB50. If the data from three nights are excluded and some significant adjustments to zero points are made, a case can be made that this object is in (near) single axis rotation with $P = 27.2$ h and $A = 0.73$ mag, meaning that the remaining sessions have the right slope (up or down) for their locations within the modeled lightcurve and don't "cross swords" at some point.

However, including all sessions produces a lightcurve (see below) with two sessions that are essentially flat and "too high" while a third session has a slope that is decidedly different from what it should be for its location. Overall, this should be considered a likely tumbler, with $PAR = -1$, tending to -2 , with no second period guessed at let alone determined.

(249595) 1997 GH28. No previously reported period could be found. The lightcurve is somewhat unusual for the significantly different depths of the minimums.

(25146) 2007 SJ. The period of less than three hours makes this a good candidate for being binary. However, no signs of a satellite were seen during the three nights of observations.

(262623) 2006 WY2. The low amplitude and noise on the order of at least half the amplitude made finding a unique period very difficult. Three plots are presented. The first shows a monomodal lightcurve with $P = 16.3$ h; the second is a bimodal lightcurve with $P = 32.0$ h; the final plot shows the period spectrum between 13-36 hours and that neither solution stands out from one another or the general background.

1997 WQ23. No reports of a period were found in the literature. The amplitude of 0.54 mag at the relatively low phase angle of 31° makes a bimodal solution almost certain.

2003 WX25. There were no prior entries in the LCDB (Warner *et al.*, 2009) for this NEA. The period spectrum (not shown) showed a strong preference for the bimodal solution of a monomodal lightcurve with half the period.

2006 CT. This asteroid was observed to assist radar observations made about the same time. The lightcurve shows a very unusual shape, including an almost flat bottom at the deeper minimum. There are also some unexplained "events" (attenuations) that could not be removed with simple subtractive dual-period analysis. The radar analysis is in progress and may help provide insights into the true nature of the asteroid.

2006 HU30. This NEA presents a conundrum. The raw data (first plot) shows a definite overall trend indicating a very long period (about 800 h; third plot). If this trend is subtracted, the result is a low amplitude lightcurve with a period of either 24 or 48 hours (second plot). This is suspicious since it coincides with an integral multiple of the interval between observing sessions.

It's possible the shorter period is due to systematic effects where the data trend up or down over the course of a night's observations. To test this, the images were re-measured using a star near the middle of the average field. That star showed no trend over the several hours of a night's observations. Flat fields were used in all cases and random checks of sky background levels in images with the flat field applied showed a 1% variation or less. Thus, the asteroid traveling across the field would not appear to have caused a constant trend. If anything, it would have reached a minimum or maximum when nearing field center.

For now, the "primary" period is assumed to be on the order of 800 hours and the "secondary" period is unexplained. If there is a satellite, the numbers would indicate a very long orbital period and the odds of seeing mutual events to be exceedingly small.

2010 SL13. There were no entries in the LCDB for this asteroid. The asymmetry of the lightcurve favors a bimodal solution.

2010 CL19. This appears to be the first reported period for 2010 CL19.

2010 XZ67. The data set was too sparse (too short a total time span) for Pravec to determine if this was a tumbler or not. Removing some sessions does allow finding a period of 15.05 h (second plot), which also seems to reveal itself when using all data (first plot).

2011 CQ4. The frequent problem with observing NEAs with backyard telescopes is that the asteroid does not remain bright enough long enough for complete analysis. This is especially true if there are signs of tumbling or, in this case, a period on the order of a few hundred hours. The plot shows the data phased to $P = 128$ h when assuming a monomodal solution. Since the amplitude is 0.19 mag at $\alpha = 31^\circ$, it is probably safe to assume that $A > 0.2$ mag at $\alpha(0^\circ)$. This starts to favor a bimodal solution with a period of about 255 hours.

2013 VJ2. The period spectrum (third plot) covering 2-10 hours shows that no one period dominates over any other or even the background. The first two plots show the data phased to periods of 3.8 h (monomodal) and 7.6 h (bimodal). It seems likely that these are valid solutions, i.e., not picked out of the noise, but neither can be formally excluded.

2013 YL2. The first plot shows the raw data from one of two nights (2014 Jan 1). Given the large amplitude and phase angle, there is no physical shape that can produce this lightcurve assuming single axis rotation (see Harris *et al.*, 2014). Therefore, the object is almost certainly tumbling. Analysis by Pravec found the dominant period of about 2.97 h (second and third plots) but the second period could not be uniquely identified. One possible solution was 2.32 h, which is about 0.03 h longer than one of the minor minimums in the period spectrum.

2013 UR3. Neither a bimodal solution of $P = 22.22$ h nor a monomodal solution of $P = 11.08$ h can be formally excluded. A feature near the second minimum in the 22-hour solution does tend to favor it over the shorter period.

2013 XA4. The estimated diameter for this NEA is 150 meters. This makes it possible that it is a super-fast rotator, i.e., one with $P < 2$ h. The period spectrum (first plot) shows that $P \sim 1.8$ h is possible, being only slightly less likely than the bimodal solution at 3.57 h. There appears to be enough asymmetry in the bimodal plot to make the longer period more likely, although the shorter period cannot be formally excluded.

2013 UH5. There were no previous entries in the LCDB.

2013 TE6. Given the high noise and low amplitude, the solution of $P = 2.46$ h may just be the result of Fourier analysis locking onto noise. A search up to 6 hours actually favors a period of 4.96 h. Neither can be formally excluded but it's probably better to say that neither should be formally included.

2013 XY8. The two plots (first, 2013 Dec 10; second, Dec 11) show the dramatic difference that can occur in a lightcurve with changing phase angle. The plot from Dec 10 shows an amplitude of 0.13 mag. The plot from Dec 11, with the same vertical scale, has an amplitude of 0.47 mag. Short exposures (15 s) were used to minimize trailing and to avoid "smearing" the data such that the true rotation period could not be found (see the discussion in Pravec *et al.*, 2000b).

2013 UH9. A half-period analysis led to the final result of 16.3 h.

2013 SU24. This was an unusual case where there were sufficient data to find the two periods of a tumbling asteroid after only two nights of observations. The period spectrum shows two distinct pairs, one set being the half period of the other. Of interest is that the lesser member of each pair is also well-defined versus the background and that is not harmonically related to the other member. This is not often seen but, as it turned out, the "secondary" solution in the set was near the second period found by Pravec in his analysis.

The second plot shows all data phased to the dominant bimodal solution of about 0.2334 hours (14.004 min). The third and fourth plots show the data forced to the two periods found by Pravec, 0.23335 h and 0.19894 h (14.001 min and 11.964 min). While these show the two periods fairly well, the better plots are like those shown in Pravec *et al.* (2005).

2013 SW24. There were no previous entries in the LCDB for this asteroid.

2013 SC25. Fortunately, the amplitude was large enough and the nights long enough to overcome the period of the asteroid being close to commensurate with an Earth day.

2013 RM43. The two plots show the data phased to the periods found by Pravec. The longer period, 32.6 h, is the more dominant. The second period, 26.1 hours, is less certain and may be an integral multiple of the true frequency ($1/P$). Pravec rates this as $PAR = -2$, with a slight tendency to -3 .

2013 RH74. Hicks *et al.* (2013) reported $P = 5.38$ h and $A = 0.20$ based on observations around 2013 Oct 15. The CS3-PDS data obtained on Oct 2-9 lead to a solution of $P = 5.346$ h and $A = 0.21$. However, a double period of 10.692 h cannot be formally excluded.

2013 TB80. A scan of periods ranging from 1 to 10 hours found a sharp minimum at about 2.6 hours but a number of other longer periods as well, many harmonically related to 2.6 h. Assuming that the solution of 2.632 h is correct, the phase angle of 35° and low amplitude may help explain the asymmetry of the lightcurve, where the maximums are about 0.7 rotation phase apart.

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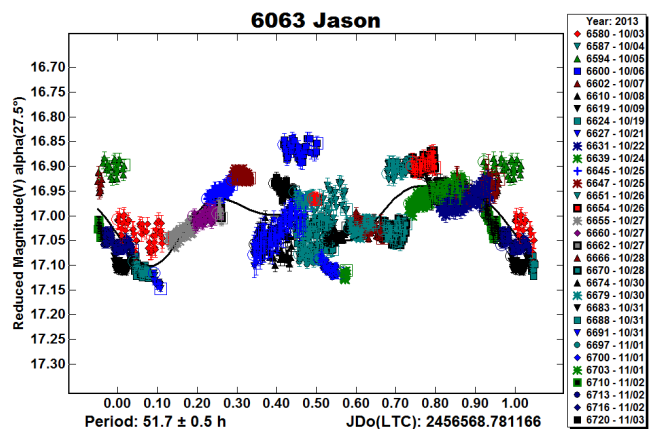
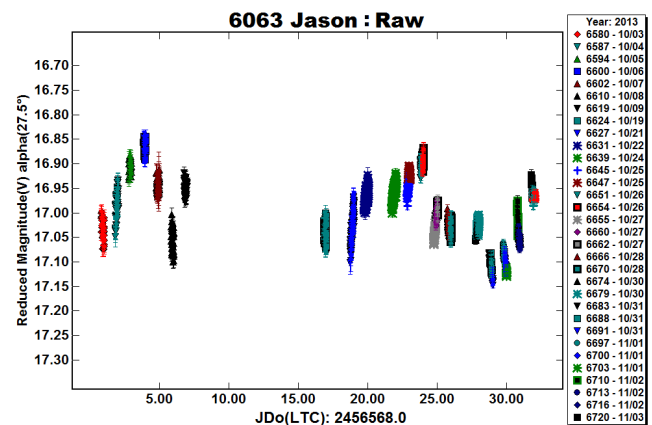
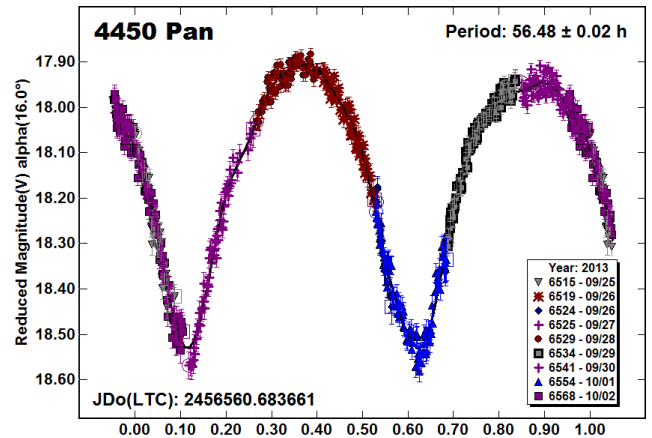
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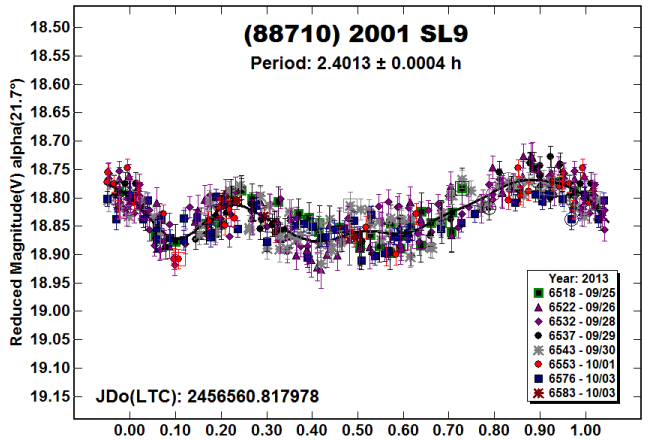
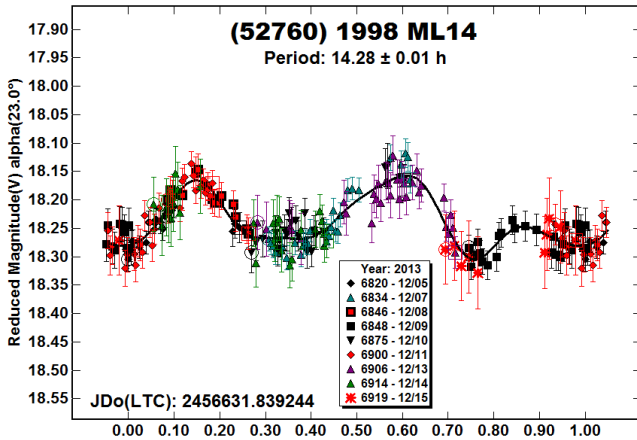
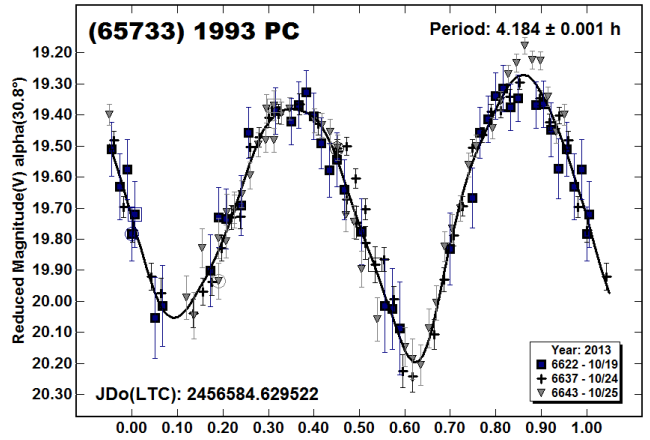
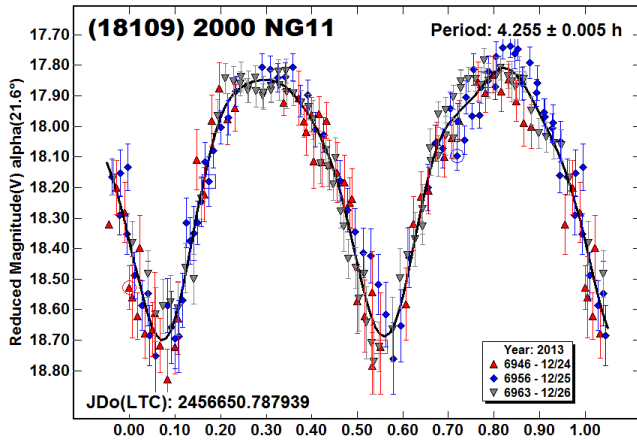
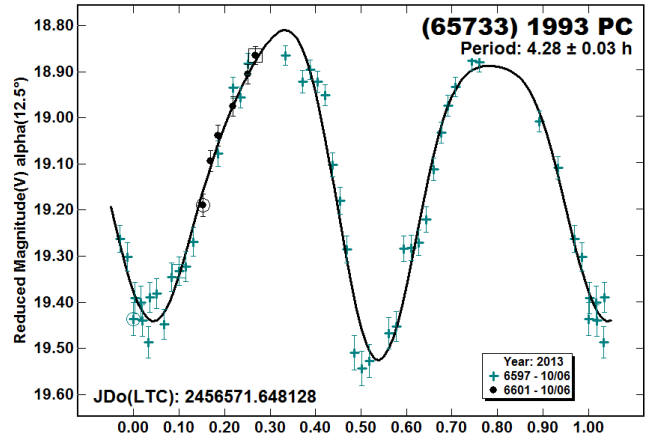
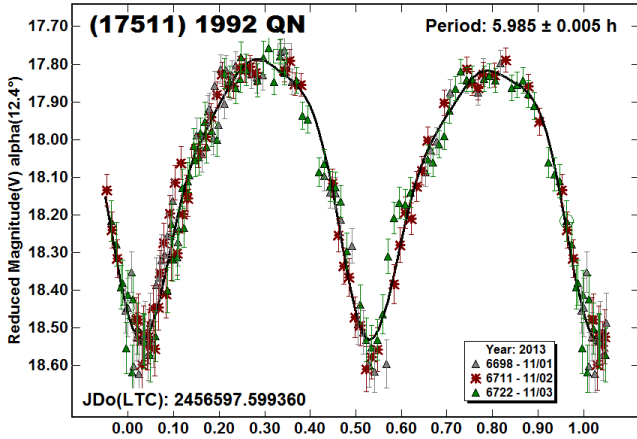
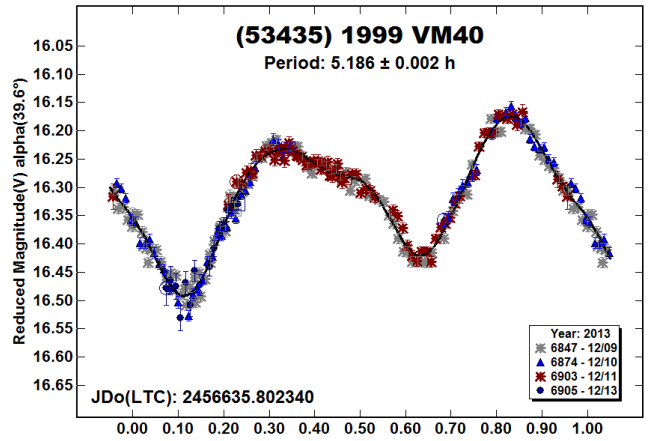
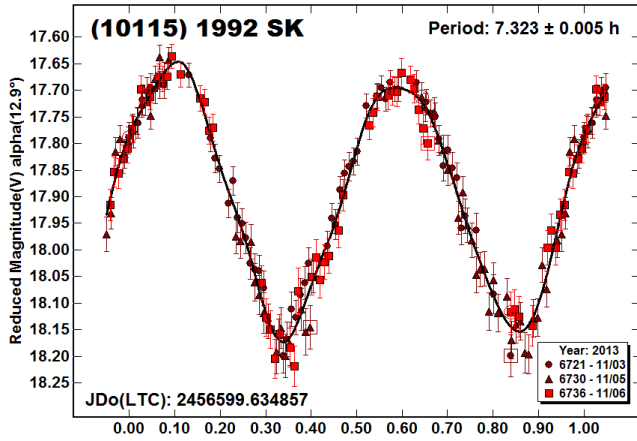
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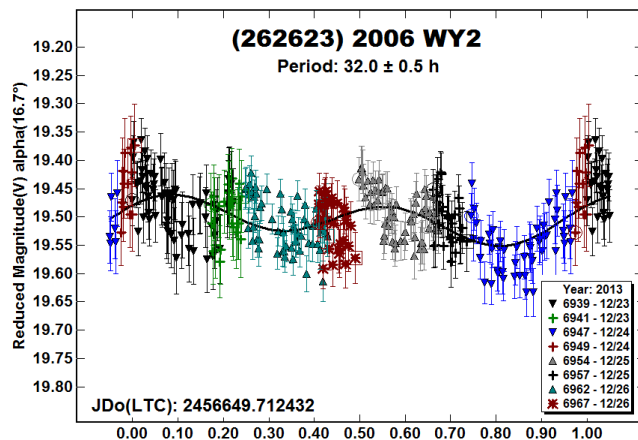
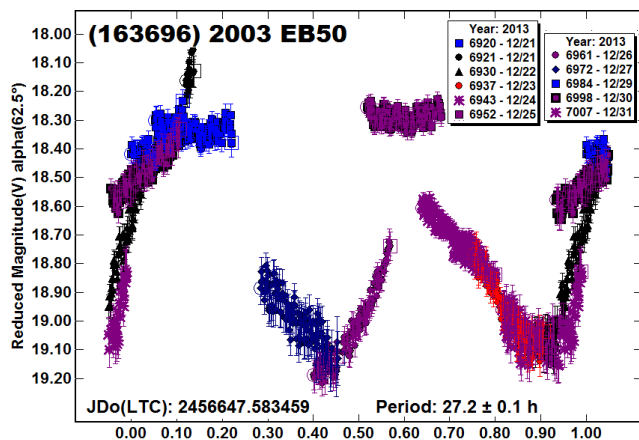
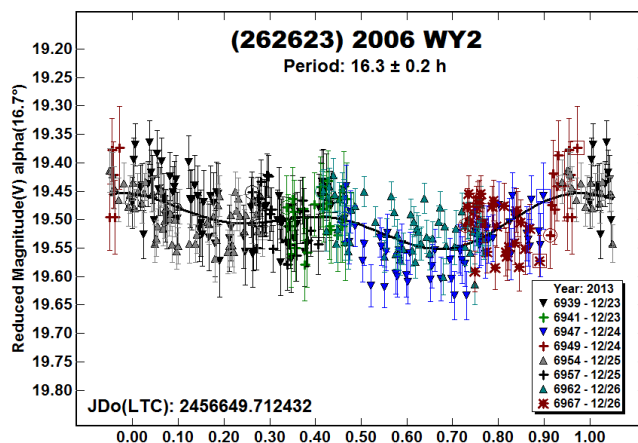
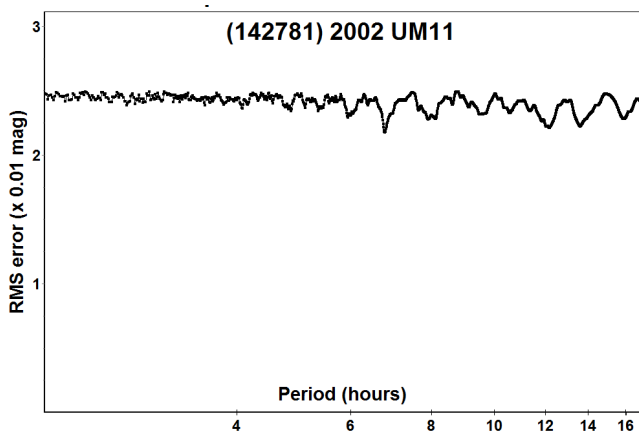
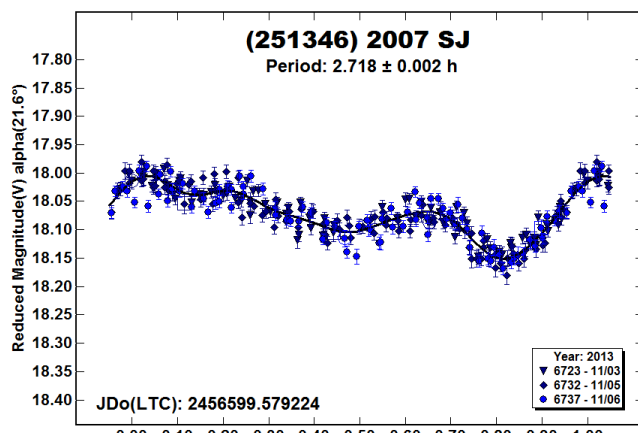
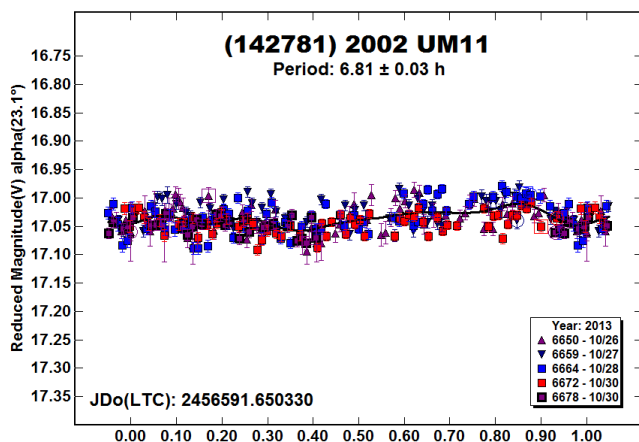
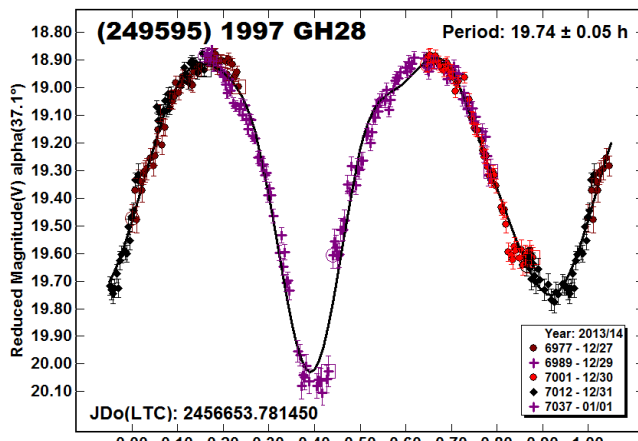
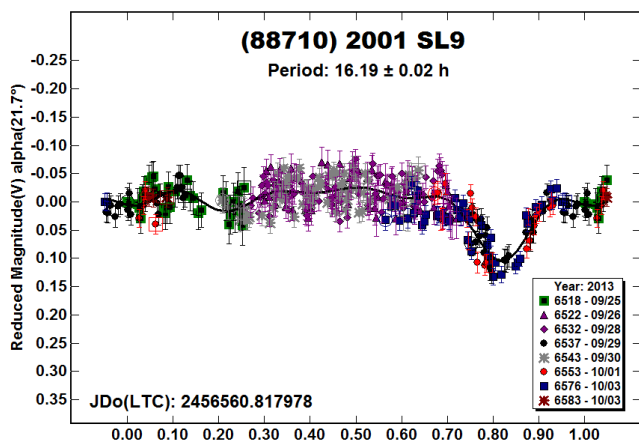
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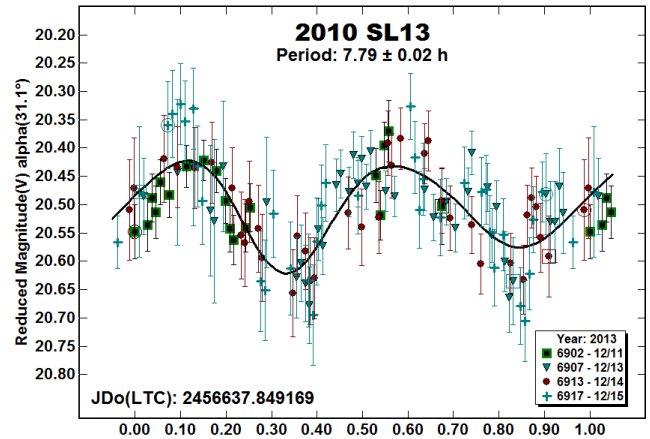
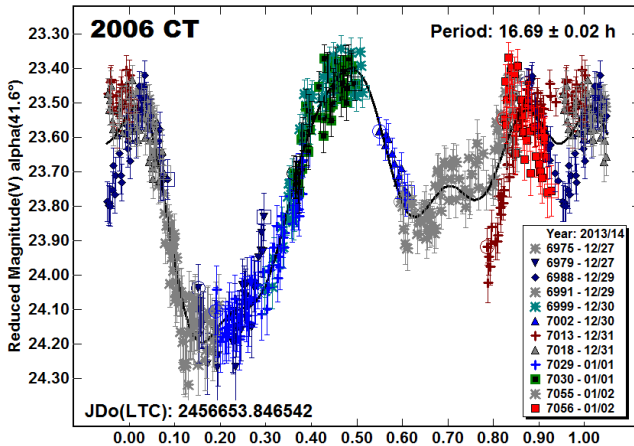
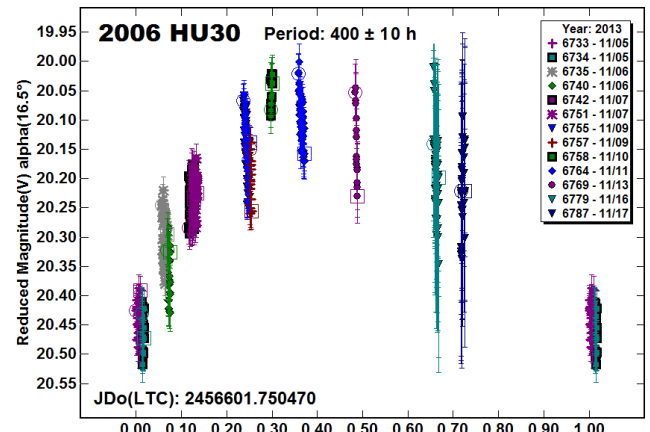
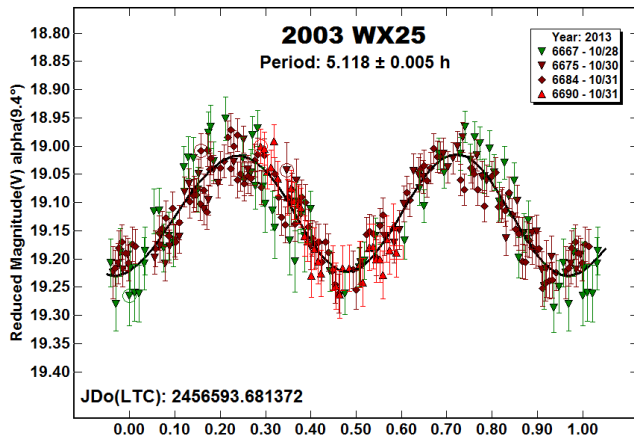
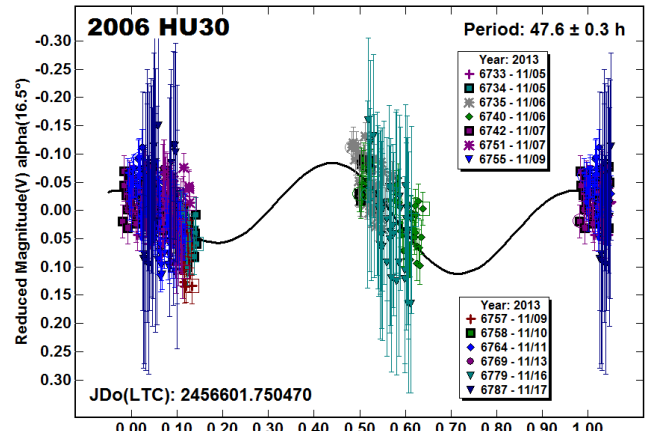
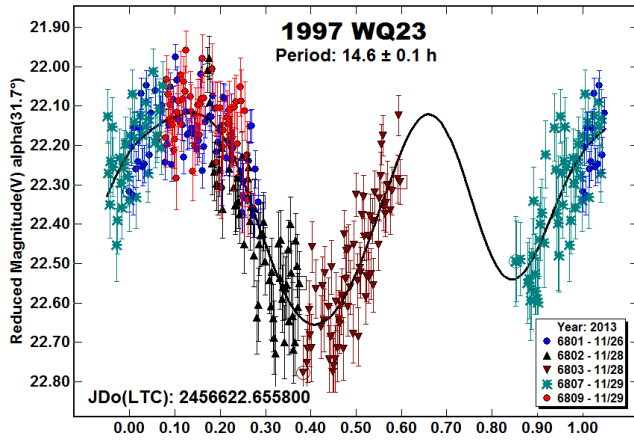
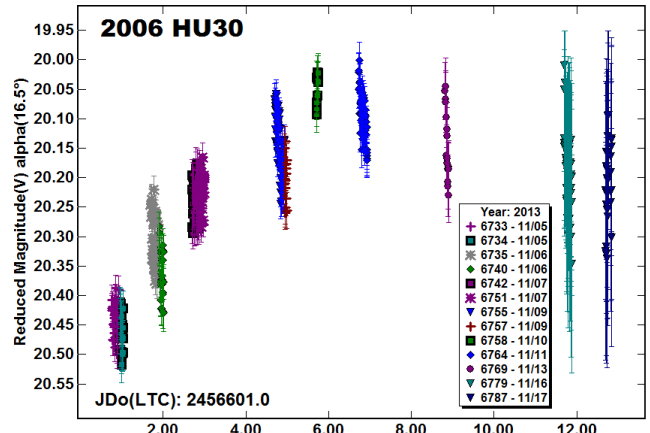
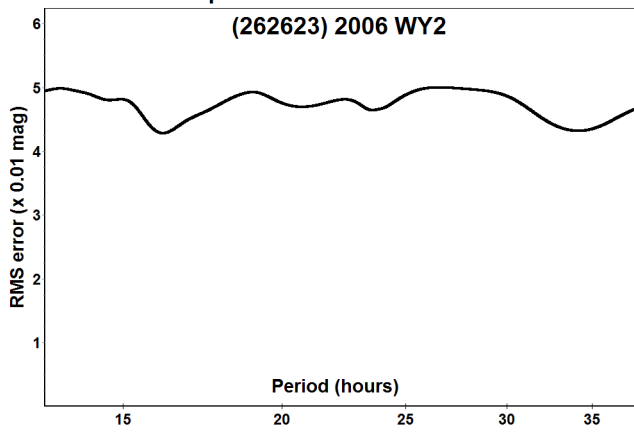
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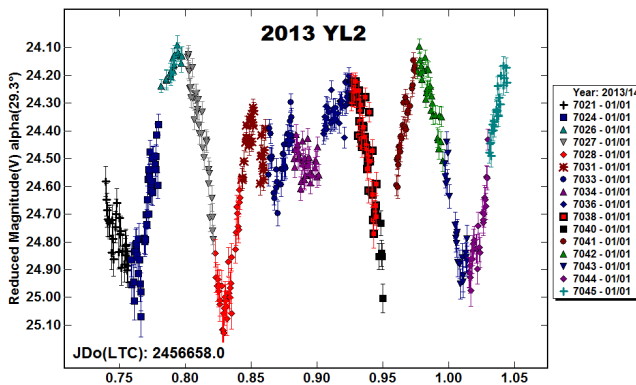
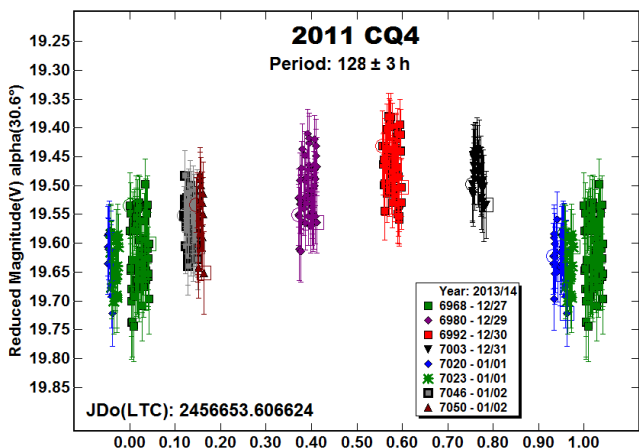
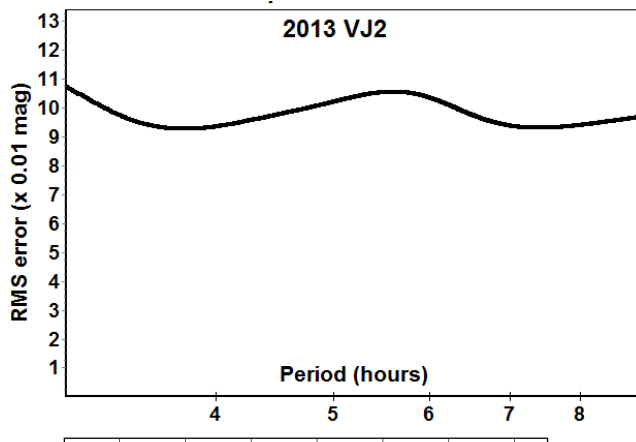
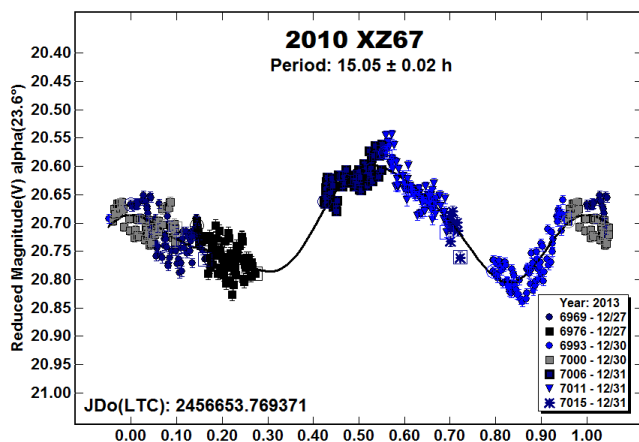
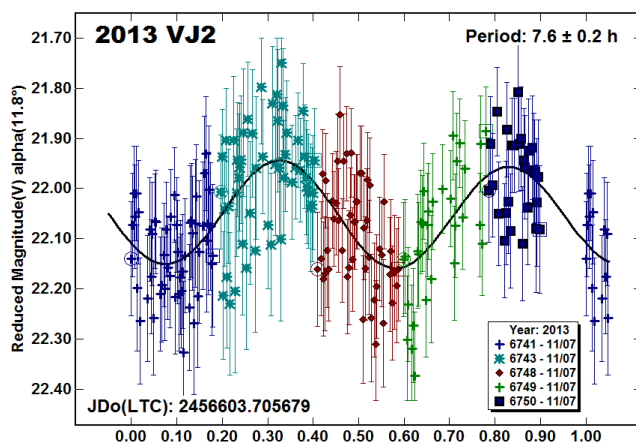
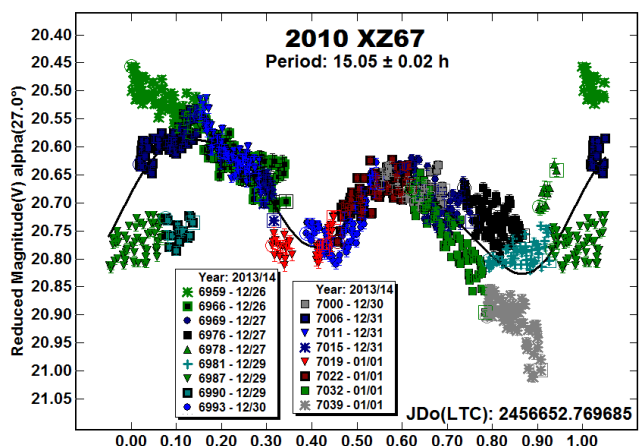
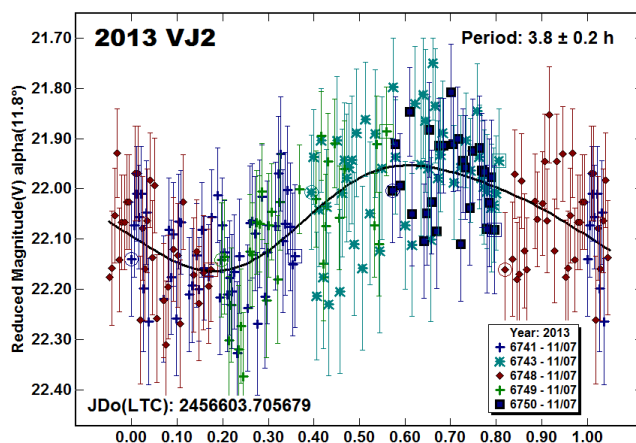
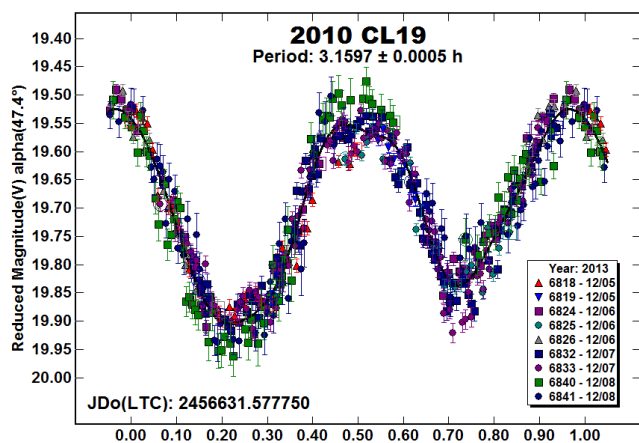
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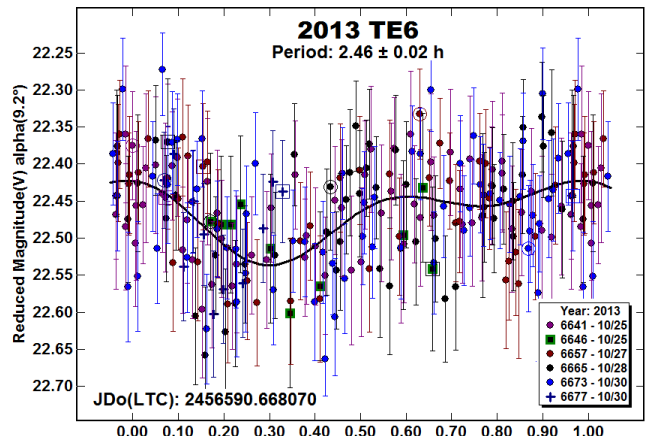
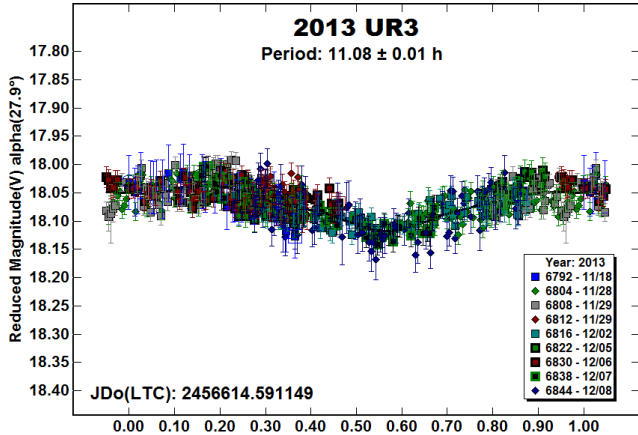
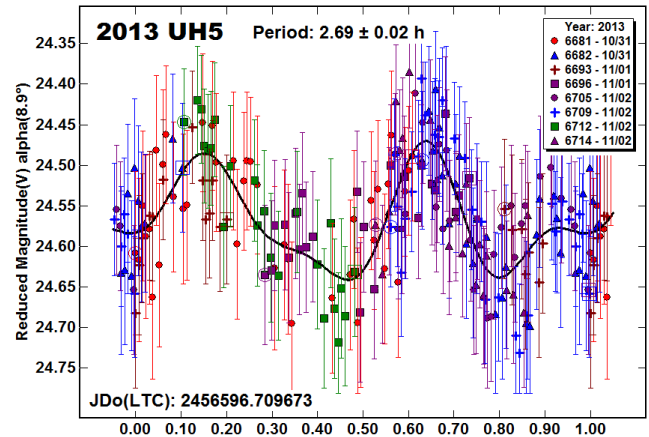
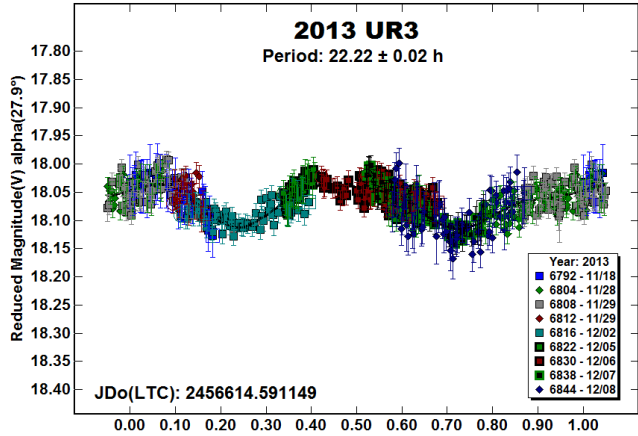
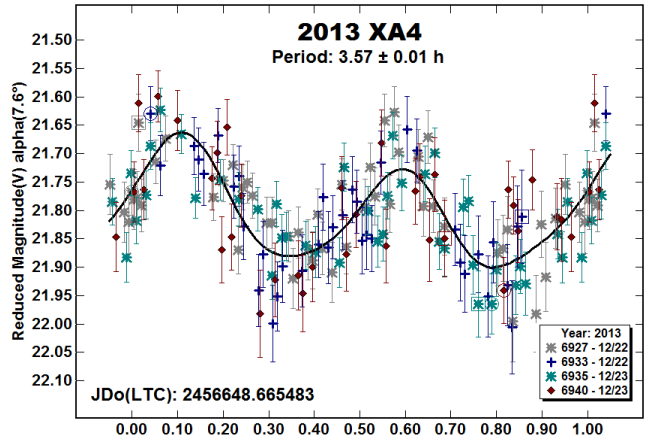
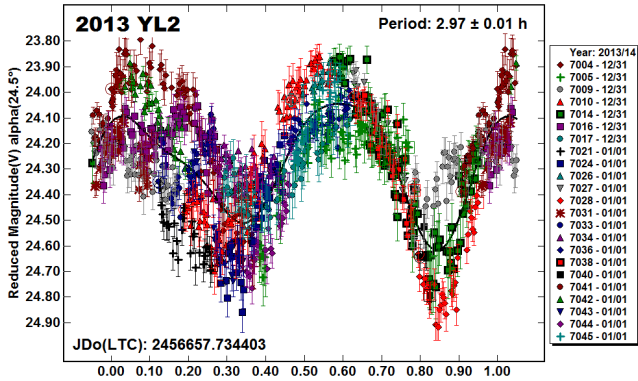
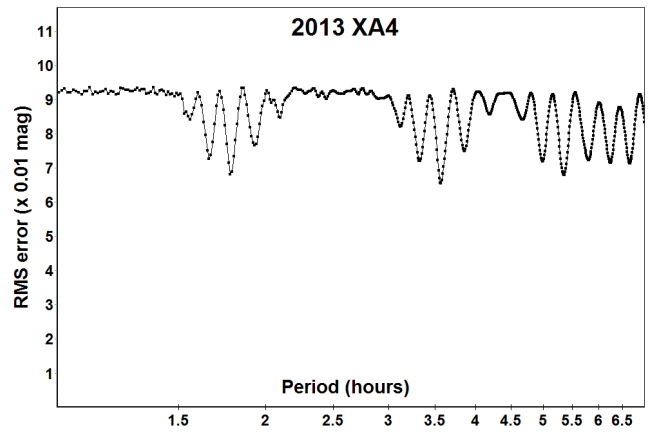
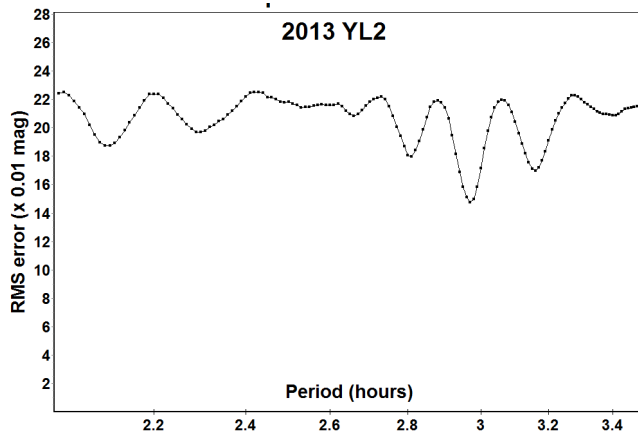


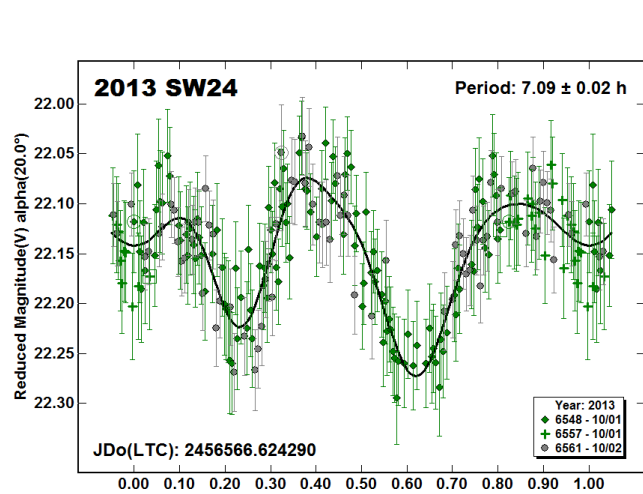
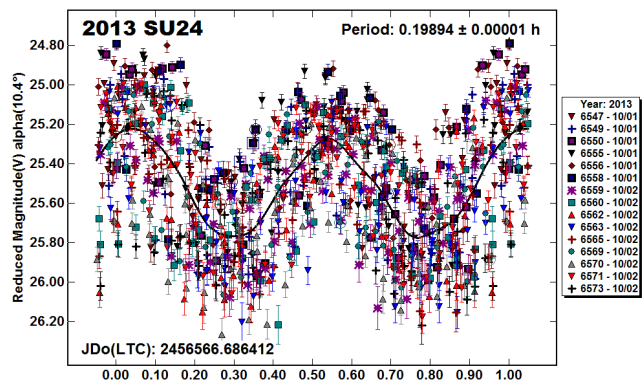
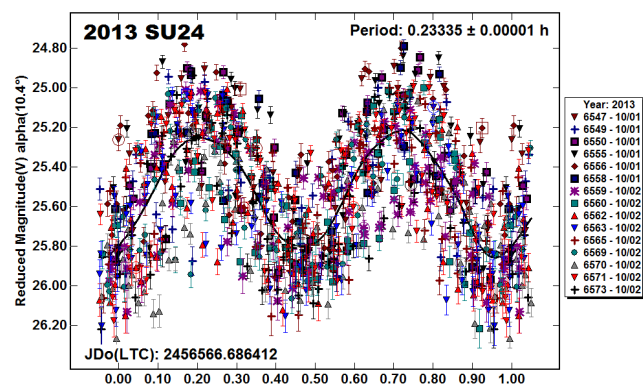
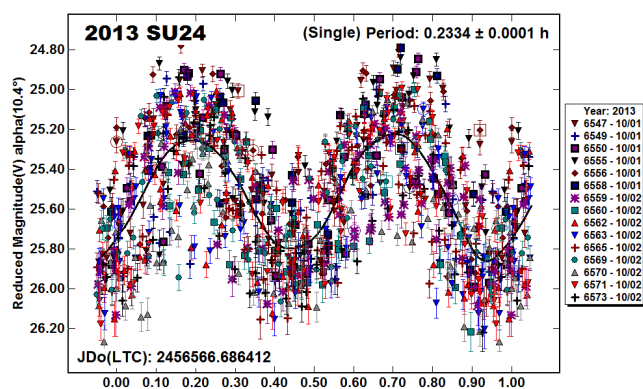
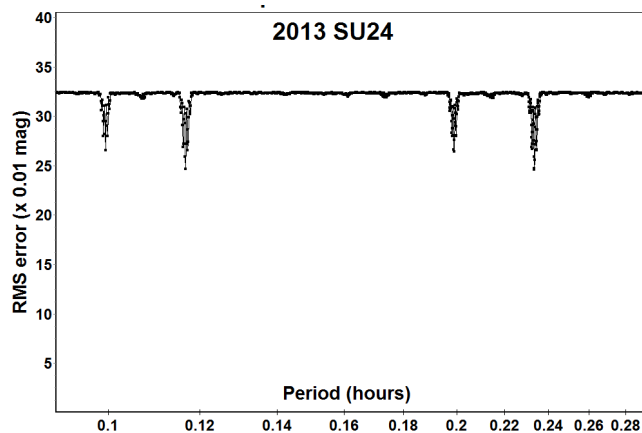
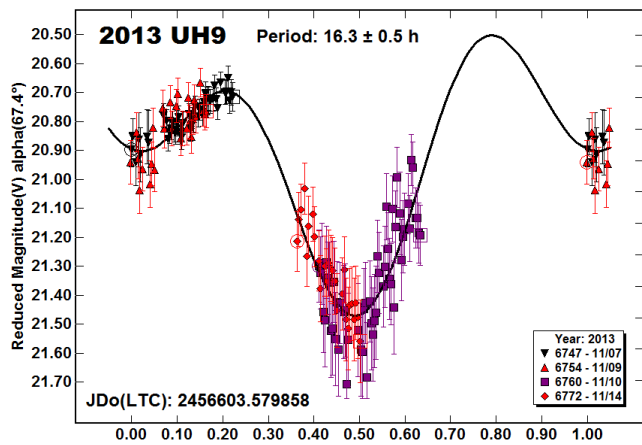
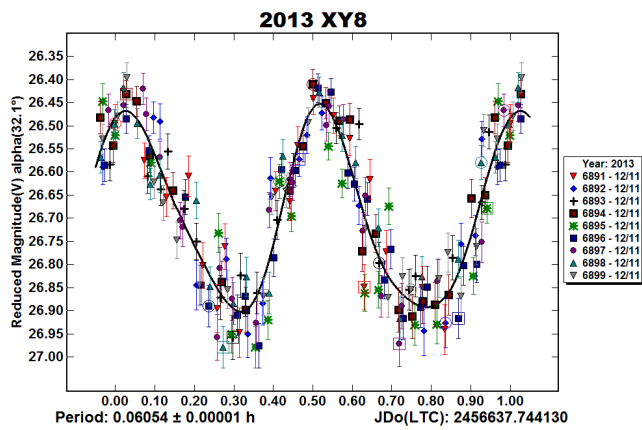
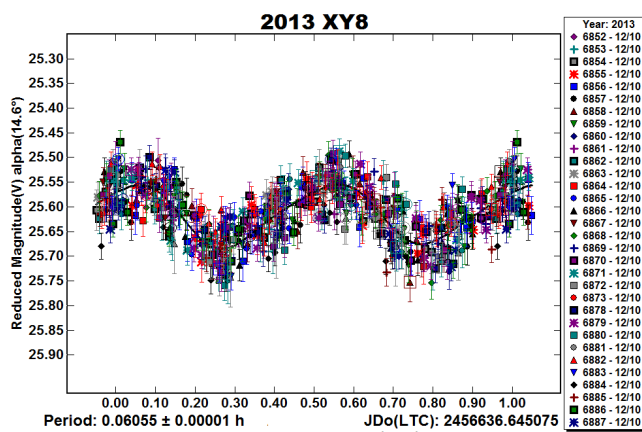


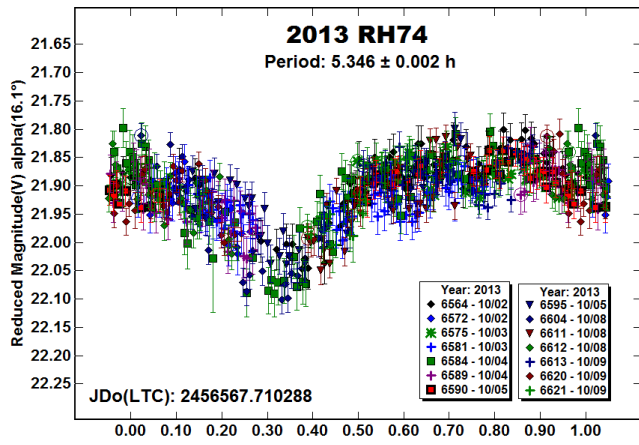
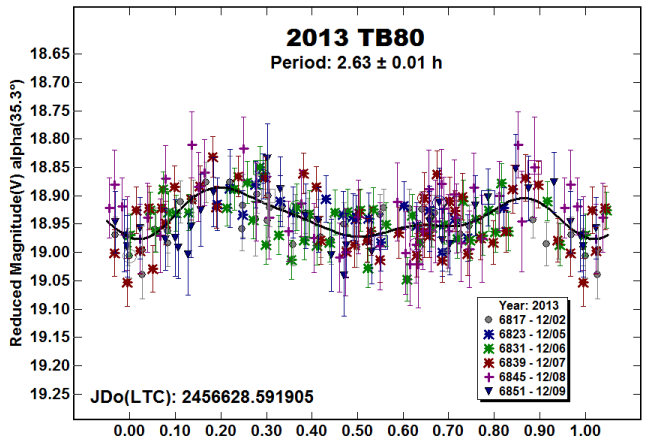
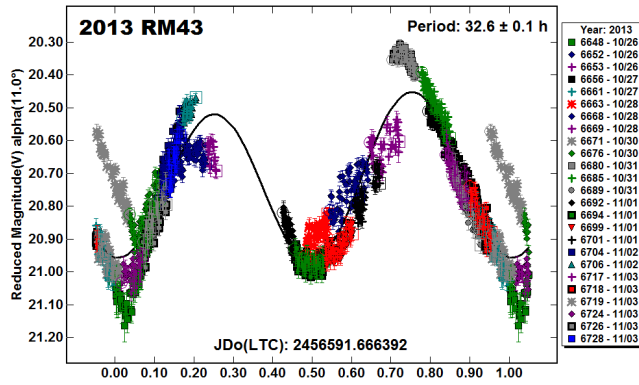
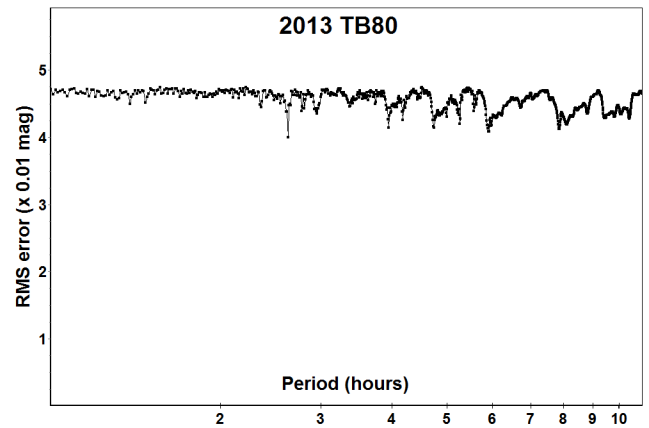
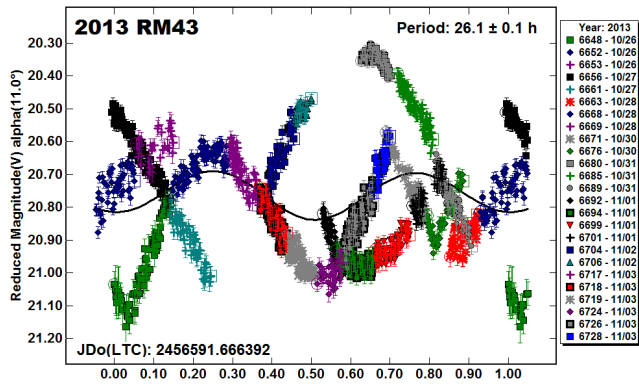
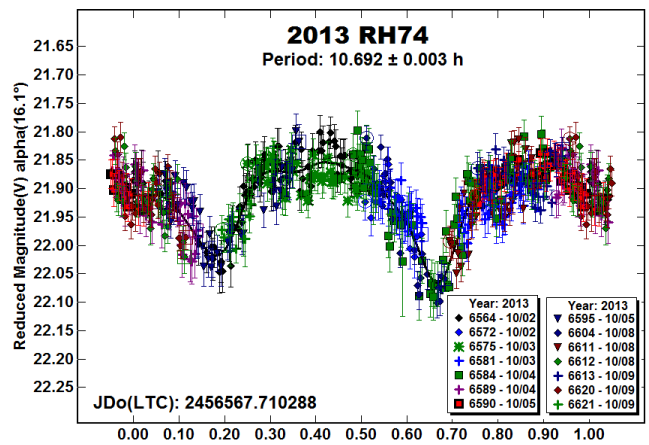
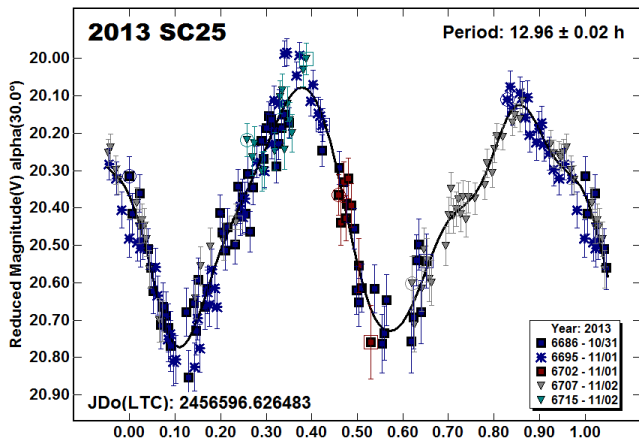












LIGHTCURVE ANALYSIS OF THE NEAR-EARTH ASTEROID (162566) 2000 RJ34

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(Received: 14 January)

Analysis of CCD photometry observations of the near-Earth asteroid (162566) 2000 RJ34 indicates a period of 50.5 ± 0.1 h. The amplitude was 0.78 ± 0.03 mag. The long period nearly commensurate with an Earth day made it critical that at least two stations, well-separated in longitude, be involved in the observing campaign.

CCD photometric observations of the near-Earth asteroid (162566) 2000 RJ34 were made by the authors from 2013 November 5-16. Table I lists the observers and equipment used while Table II lists the dates of observation and the observer.

OBS	Telescope	Camera
Warner	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Benishek	0.35-m f/10 Schmidt-Cass	ST-8XME

Table I. List of observers and equipment.

Obs	Dates (2013 November)	Sessions
Warner	05-07, 09-11	1 2 3 5 7 8
Benishek	08-09, 16	4 6 9

Table II. Dates of observation for each observer. The Sessions column gives the session numbers shown in the lightcurve legend.

The phase angle increased from 21.9° to 27.6° during the span of the observations. The phase angle bisector longitude/latitude (see the appendix in Harris *et al.*, 1984) ranged from $36.5^\circ/23.5^\circ$ (Nov 5) to $38.4^\circ/25.2^\circ$ (Nov 16) while the asteroid remained near $V = 16.3$.

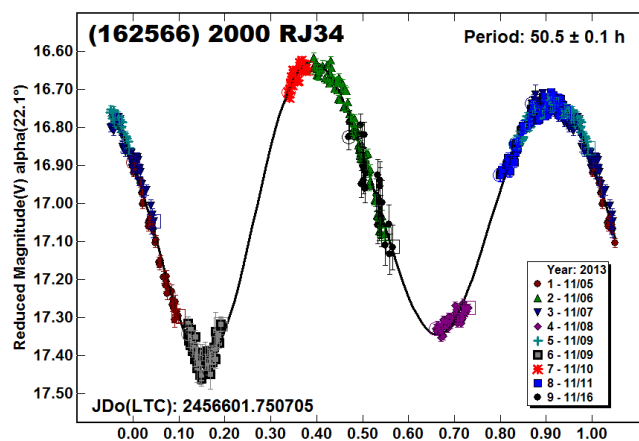
Initial measurements by both authors were made using *MPO Canopus* (Bdw Publishing) using the Comp Star Selector utility in that program to select up to five comparison stars of near solar color. The MPOSC3 catalog provided with *MPO Canopus* was used to provide the comparison star magnitudes. The magnitudes in the catalog are based on the 2MASS catalog converted to the BVRcIc system using formulae developed by Warner (2007). Benishek sent his data files to Warner, who then merged those data with his to create the combined data set for period analysis. This was also done in *MPO Canopus*, which implements the Fourier analysis FALC algorithm developed by Harris (Harris *et al.*, 1989).

In the lightcurve below, the “Reduced Magnitude” is Johnson V corrected to unity distance by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. In addition, the magnitudes were normalized to the phase angle given in parentheses, i.e., $\alpha(22.1^\circ)$, using $G = 0.15$. The horizontal axis is the rotation phase, ranging from -0.05 to 1.05 .

The initial observations by Warner indicated a period nearly commensurate with an Earth day (about 48 hours), meaning that

observations from one night to the next covered alternating halves of the lightcurve. In such cases, observations at different locations in longitude can often resolve the ambiguities of a nearly-commensurate period or fill in parts of the lightcurve so that a more accurate period and amplitude can be determined. It’s better if the difference in longitude between two observers doesn’t nearly match the period of the lightcurve or is also Earth-day commensurate. For example, if two observers are almost exactly 6 hours apart (90°) and the period is also about 6 hours, the western observer sees almost the exactly same part of the lightcurve but on the following rotation.

The combined data set included 510 observations used in the period analysis, which found an unambiguous solution of $P = 50.5 \pm 0.1$ h and amplitude $A = 0.78 \pm 0.03$ mag. A more accurate and precise period would have required covering the lightcurve more times and filling in some of the missing parts. This was not possible due to weather and the asteroid moving into evening twilight.



Acknowledgements

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**ROTATION PERIOD DETERMINATIONS FOR
1425 TUORLA, 1468 ZOMBA, 1486 MARILYN,
2112 ULYANOV, AND (105158) 2000 OL**

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Synodic rotation periods and lightcurve amplitudes were determined for five asteroids observed in 2013: 1425 Tuorla, 1468 Zomba, 1486 Marilyn, 2112 Ulyanov, and (105158) 2000 OL.

Photometric data for five minor planets were collected from 2013 April through September at two observing sites: Belgrade Astronomical Observatory (1425 and partly 105158) and the newly established Sopot Astronomical Observatory. The observations from the Belgrade Observatory were conducted using a 0.40-m *f*/10 Meade LX-200 GPS Schmidt-Cassegrain (SCT) and SBIG ST-10XME CCD while the observations at the Sopot Observatory used a 0.35-m Meade LX-200 GPS SCT and SBIG ST-8 XME.

All observations were unfiltered and unguided. Both CCD cameras were operated in 2x2 binning mode in order to increase signal-to-noise ratio. Prior to measurements, all images were dark and flat field corrected. Differential photometry with up to five comparison stars, data merging, and period analysis were performed in *MPO Canopus* (Warner, 2012). Only the instrumental magnitudes were used for all period determinations. To produce the best lightcurve fit, the zero point of each individual data set was adjusted until a minimum Fourier residual was reached. The CALL website maintained by Warner (2013) was used to determine target selection.

Observations and Results

1425 Tuorla. A search for previous period determinations for this main-belt asteroid found the rotation period reported by Behrend (2004; 6.967 h). More recently, Garceran (2013) reported a period of 6.76 h. Both results have been marked with an uncertainty of $U = 2$ in the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) which implies that “the period may be wrong by 30 percent or so” since the results are based on less than full phase coverage or there is an ambiguity in the solution. This target was observed on six nights between 2013 April 13–21, which resulted in 881 data points. The composite lightcurve shows a period of 7.75 ± 0.06 h and amplitude of 0.24 ± 0.02 mag. This result was adopted based on dense full-phase coverage and for having the lowest RMS error in the Fourier analysis. Other solutions seen in the *MPO Canopus* period spectrum (RMS vs. period) had larger RMS fits.

1468 Zomba. The only previous reference to a period determination for this Mars-crossing asteroid is by Wisniewski and McMillan (1987; 2.77 h). This result is characterized with an uncertainty code of $U = 2$ in the LCDB. The target was observed on four nights in 2013 September in order to check the results. Data analysis found a period of 2.772 ± 0.006 h and amplitude of 0.36 ± 0.01 mag. This bimodal solution is fully consistent with Wisniewski and McMillan.

1486 Marilyn. Behrend (2012) reported a period of 2.2837 h based on an incomplete lightcurve obtained by M. Audejean. Dense

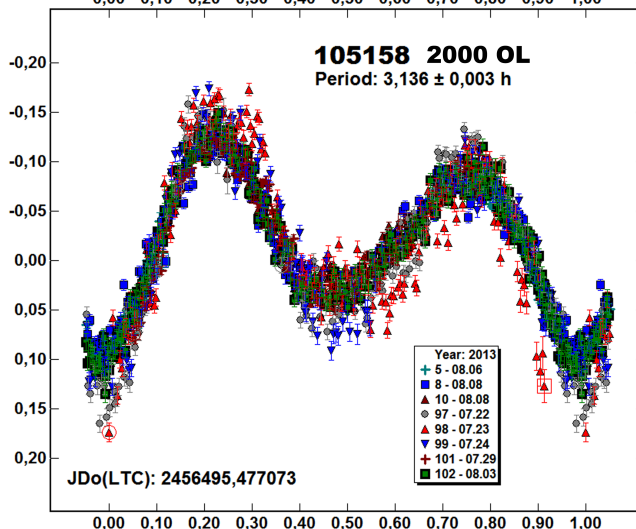
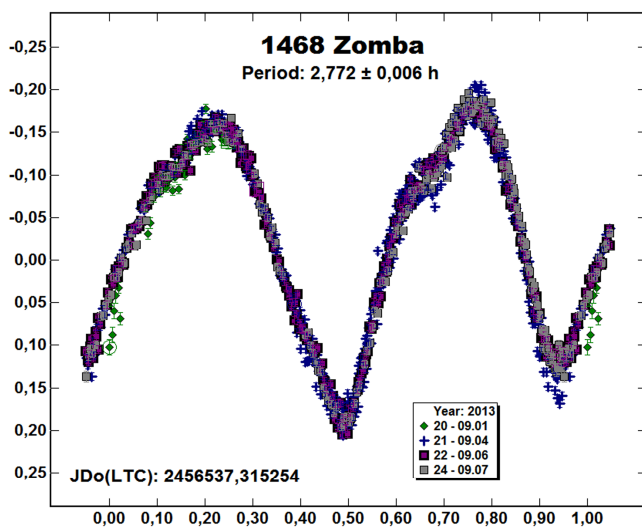
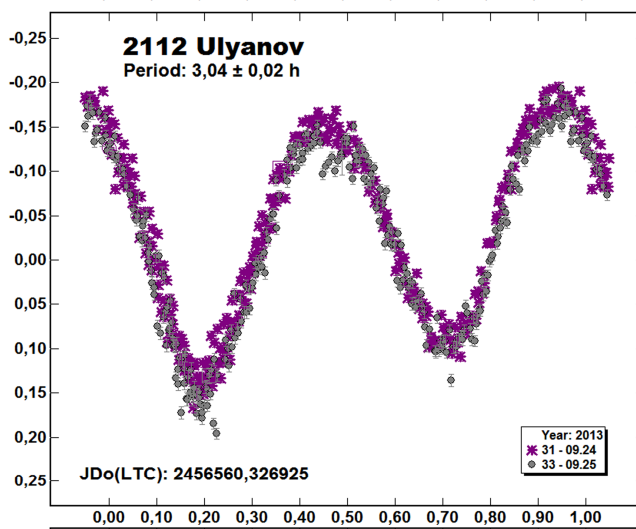
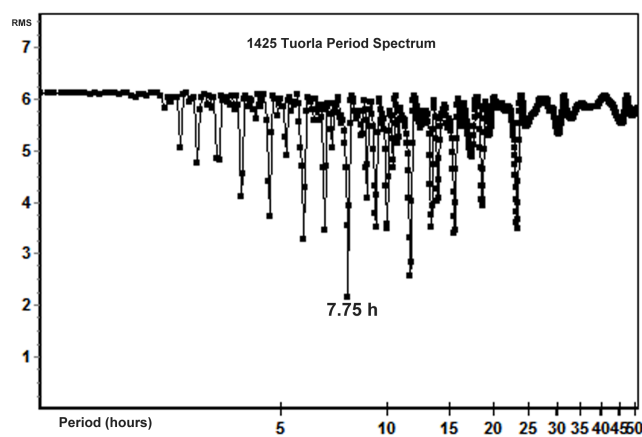
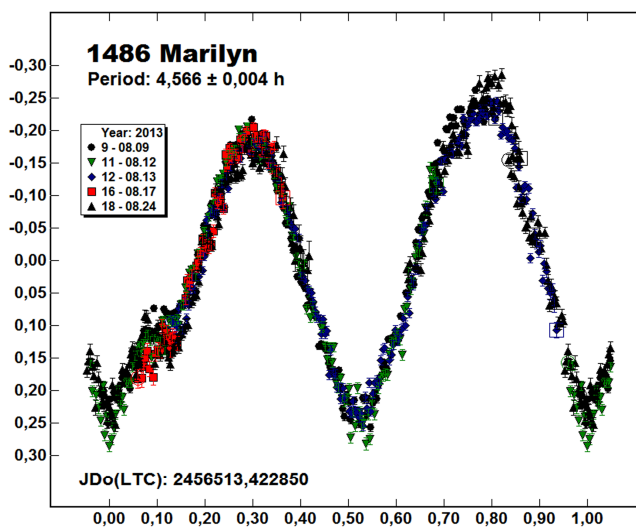
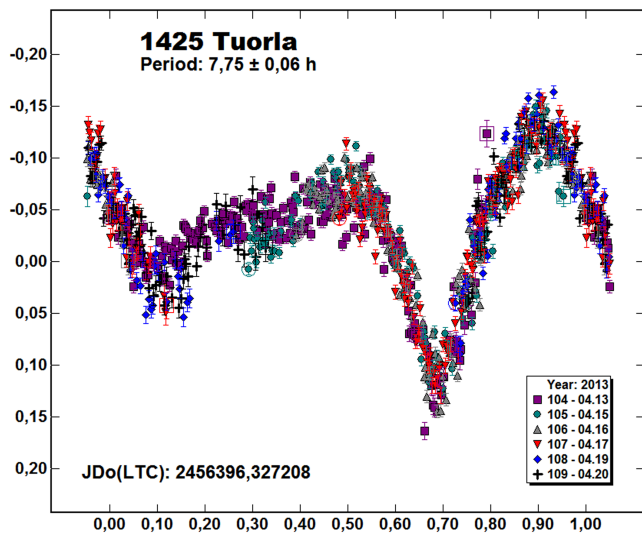
photometric data collected on five nights from 2013 August 8–25 revealed a synodic period of 4.566 ± 0.004 h for this main-belt asteroid. This is nearly twice the monomodal period reported by Behrend and one that could be formally excluded in the most recent analysis. The amplitude of the composite lightcurve ($A = 0.48 \pm 0.01$ mag) almost certainly favors the bimodal over monomodal period (Brian D. Warner, private communication). All complex lightcurves with several minima and maxima were discarded as physically unjustified. The quadrimodal lightcurve phased to a period of 9.132 h was ruled out for the same reason described in the case of (105158) 2000 OL.

2112 Ulyanov. The only previous period determination for this main-belt asteroid is by Maleszewski and Clark (2004; 3.000 h). In order to check this result, the asteroid was observed on two consecutive nights in late 2013 September. The bimodal lightcurve found by the author shows a period of 3.04 ± 0.02 h, which is slightly different from that found by Maleszewski and Clark. The amplitude was 0.32 ± 0.01 mag.

(105158) 2000 OL. Observations for this Mars-crossing asteroid were acquired on eight nights from 2013 July 21 through August 08. Fourier period analysis in *MPO Canopus* indicated two possible solutions: a bimodal lightcurve phased to 3.136 h and a quadramodal lightcurve phased to 6.272 h. Simple inspection of the 6.272 h lightcurve shows the two halves appear nearly the same, which leads to the conclusion that the correct period is the shorter one. The lightcurve for the shorter period shows an amplitude of 0.23 ± 0.01 mag. This result is consistent with the only previous period determination by Koff and Brincat (2001), whose also found $P = 3.136 \pm 0.003$ h.

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TARGET ASTEROIDS! OBSERVING TARGETS FOR 2014 APRIL THROUGH JUNE

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Asteroids to be observed by the *Target Asteroids!* program during the period of 2014 April through June are presented. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and easier to observe for small telescope users and 2) analogous to 101955 Benu, the target asteroid of the OSIRIS-REx sample return mission.

Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for robotic sample return. The program also focuses on the study of asteroids that are analogous to 101955 Benu, the target asteroid of the NASA OSIRIS-REx sample return mission. Most target asteroids are near-Earth asteroids (NEA) though observations of relevant Main Belt asteroids may also be requested.

Even though many of the observable objects in this program are faint, acquiring a large number of low S/N observations allows many important parameters to be determined. For example, an asteroid's phase function can be measured by obtaining photometry taken over a wide range of phase angles. The albedo can be constrained from the phase angle observations, as there is a direct correlation between phase function and albedo (Belskaya and Shevchenko, 2010). The absolute magnitude can be estimated by extrapolating the phase function to a phase angle of 0°. By combining the albedo and absolute magnitude, the size of the object can be estimated.

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

Quarterly Targets

Target Asteroids! objects brighter than $V = 20.0$ are presented in detail. A short summary of our knowledge of each asteroid and 10-day (shorter intervals for objects that warrant it) ephemerides are presented. The ephemerides include rough RA and Dec positions, distance from the Sun in AU (r), distance from Earth in AU (Δ), V magnitude, phase angle in degrees (PH) and elongation from the Sun in degrees (Elong).

We ask observers with access to large telescopes to attempt observations of asteroids that are between V magnitude ~ 20.0 and ~ 22.0 during the quarter (contained in the table below).

Asteroid Number	Name	Peak V Mag	Time of Peak Brightness
(99799)	2002 LJ3	20.2	early Apr
(137799)	1999 YB	20.3	late Jun
(138911)	2001 AE2	22.0	late Jun
(163249)	2002 GT	21.8	early Apr
(173664)	2001 JU2	20.2	early Apr
(187040)	2005 JS108	22.0	early Apr
(190491)	2000 FJ10	21.7	late Jun
(311925)	2007 BF72	21.1	early Apr
	2002 TD60	21.8	late Jun
	2003 CC	21.0	late Jun
	2007 TK8	21.8	mid May
	2008 SO	21.8	early Apr
	2008 WN2	21.4	early May

The $V < 20$ selected targets are split up into four sections: 1) Carbonaceous *Target Asteroids!* List objects, 2) *Target Asteroids!* List objects of unknown type, 3) non-carbonaceous *Target Asteroids!* List objects, and 4) other asteroids analogous to the OSIRIS-REx target Benu or provide an opportunity to fill some of the gaps in our knowledge of Benu (examples include very low and high phase angle observations, phase functions in different filters and color changes with phase angle).

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

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

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

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

Carbonaceous Target Asteroids! List objects

None this quarter.

Target Asteroids! List objects of unknown type

(292220) 2006 SU49 ($a=1.41$ AU, $e=0.31$, $i=2.5^\circ$, $H=19.5$)

There is little known about the physical properties of this low delta-V potential spacecraft target. Though it only brightens to $V=19.7$ at opposition on June 28 UT, a large span of phase angle coverage is possible this quarter (from 52° to 1.9°).

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	18 53.5	-26 48	0.77	1.25	21.4	52	89
04/11	19 11.7	-26 28	0.75	1.30	21.3	50	94
04/21	19 25.6	-26 08	0.72	1.34	21.2	46	101
05/01	19 34.5	-25 53	0.69	1.39	21.1	43	109
05/11	19 37.7	-25 48	0.65	1.44	20.9	38	118
05/21	19 34.5	-25 53	0.62	1.48	20.7	32	128
05/31	19 24.4	-26 07	0.60	1.52	20.5	25	140
06/10	19 08.1	-26 21	0.58	1.56	20.2	16	153
06/20	18 47.5	-26 25	0.59	1.60	20.0	8	167
06/30	18 26.1	-26 13	0.62	1.63	19.8	2	176

1994 CJ1 ($a=1.49$ AU, $e=0.32$, $i=2.3^\circ$, $H=21.4$)

1994 CJ1 is another low delta-V asteroid that has not been well characterized. In fact, no lightcurve, color or phase results have been published for it. It will peak at $V=18.4$ in early July. Between early June and early August, its phase angle will range from 89° to 29° . An absolute magnitude of 21.4 suggests the possibility of rapid (<2 h) rotation.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	08 39.2	+19 41	0.25	1.13	20.7	52	116
04/11	08 41.4	+21 12	0.24	1.09	20.8	61	106
04/21	08 50.6	+22 25	0.23	1.06	20.8	69	98
05/01	09 06.4	+23 23	0.21	1.03	20.8	76	91
05/11	09 28.7	+24 11	0.19	1.01	20.8	82	86
05/21	09 58.7	+24 50	0.16	1.00	20.6	86	83
05/31	10 39.7	+25 08	0.14	1.00	20.3	88	82
06/10	11 38.3	+24 27	0.11	1.01	19.8	87	86
06/20	13 02.7	+20 57	0.09	1.03	19.1	78	96
06/30	14 47.5	+12 24	0.09	1.05	18.5	61	114

Non-carbonaceous Target Asteroids! List objects

3361 Orpheus ($a=1.21$ AU, $e=0.32$, $i=2.7^\circ$, $H=19.0$)

Much is already known about Orpheus. It is a V-type asteroid on a low delta-V orbit with a rotation period of 3.6 h and lightcurve amplitude of ~ 0.3 magnitudes. With a high albedo of 0.36, this V-type asteroid is ~ 0.35 km in diameter. *Target Asteroids!* members have been observing Orpheus since late 2013. The current quarter provides an opportunity to extend our phase angle coverage of Orpheus to low phase angles.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	19 13.3	-19 32	0.52	1.07	20.2	67	83
04/11	19 27.9	-18 12	0.52	1.12	20.1	62	90
04/21	19 38.6	-16 55	0.51	1.18	20.0	57	97
05/01	19 44.4	-15 47	0.49	1.23	19.9	52	105
05/11	19 44.4	-14 51	0.47	1.28	19.7	45	114
05/21	19 37.6	-14 12	0.45	1.32	19.4	38	125
05/31	19 23.4	-13 54	0.43	1.36	19.2	29	138
06/10	19 02.4	-13 57	0.42	1.40	18.9	19	152
06/20	18 37.4	-14 18	0.43	1.44	18.7	9	166
06/30	18 12.5	-14 50	0.46	1.47	18.7	6	170

2001 QC34 ($a=1.13$ AU, $e=0.19$, $i=6.2^\circ$, $H=20.0$)

2001 QC34 is a Q- or O-type asteroid. Phase function and lightcurve photometry are needed to shed more light on this potential spacecraft target, which was once considered as a target for the JAXA Hayabusa 2 mission.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	06 04.7	-61 20	0.10	1.00	18.2	89	84
04/11	08 12.4	-63 37	0.11	1.03	17.8	70	103
04/21	10 11.0	-58 40	0.11	1.06	17.6	57	117
05/01	11 27.9	-49 30	0.13	1.09	17.6	45	129
05/11	12 16.4	-39 58	0.15	1.12	17.8	38	136
05/21	12 50.4	-31 59	0.18	1.15	18.2	35	138
05/31	13 17.3	-26 00	0.22	1.18	18.7	36	135
06/10	13 40.9	-21 53	0.26	1.21	19.2	38	131
06/20	14 02.8	-19 12	0.32	1.23	19.7	41	126
06/30	14 24.0	-17 35	0.38	1.25	20.2	43	121

Other Asteroids Analogous to the OSIRIS-REx Target Benu

163 Erigone ($a=2.37$ AU, $e=0.19$, $i=4.8^\circ$, $H=9.5$)

Erigone is the parent body of the 'Erigone' asteroid family: a carbonaceous family located in the inner Main Belt and possible source of carbonaceous spacecraft targets such as Benu. Vokrouhlicky *et al.* (2006) found an age of 280 million years for the formation of this family.

Erigone is a Ch-type asteroid meaning it shows evidence of hydrated minerals in its spectra. It is ~ 72 km in diameter with an albedo of 0.055, rotation period of 16.14 h and lightcurve amplitude of ~ 0.4 magnitudes. Minimum phase angle and peak brightness were reached in late February. This quarter allows observations at phase angles of 18 to 26°.

Our plan is to determine if Erigone's phase function is dependent on color and whether its color changes with phase angle and rotational phase. Due to its brightness, we also ask capable observers to obtain spectra at different phase angles and rotational phases.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	10 05.3	+12 47	1.28	2.13	12.9	18	137
04/11	10 06.0	+13 06	1.38	2.15	13.2	21	128
04/21	10 09.7	+13 04	1.50	2.17	13.5	23	119
05/01	10 15.9	+12 45	1.62	2.19	13.7	25	110
05/11	10 24.3	+12 09	1.75	2.21	13.9	26	103
05/21	10 34.3	+11 21	1.88	2.23	14.1	26	96
05/31	10 45.8	+10 21	2.02	2.26	14.3	26	89
06/10	10 58.3	+09 11	2.16	2.28	14.5	26	83
06/20	11 11.7	+07 53	2.30	2.30	14.6	25	77
06/30	11 25.7	+06 29	2.43	2.32	14.7	24	71

495 Eulalia ($a=2.49$ AU, $e=0.13$, $i=2.3^\circ$, $H=10.8$)

Eulalia is the parent of another carbonaceous, inner Main Belt family, which may be the source of 101955 Benu. Walsh *et al.* (2013) found that Eulalia is the true parent of the old 'Polana' family, now renamed the 'Eulalia' family. The 'Eulalia' family is estimated to be between 0.9 and 1.5 billion years old.

As with most large Main Belt asteroids, much is known about Eulalia such as its taxonomy (C-type), albedo (0.057), and diameter (~ 39 km). It has a long rotation period that is estimated to be around 29 h in length. Eulalia can be observed from an extreme minimum phase angle of 0.10° on April 1 UT to 21° in late June. A peak brightness of $V=14.3$ is also reached on April 1 UT. Our plan is to obtain the same sort of photometric and spectroscopic data summarized in the Erigone section.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	12 41.7	-04 10	1.78	2.77	14.3	0	179
04/11	12 33.1	-03 07	1.79	2.78	14.7	4	168
04/21	12 25.4	-02 11	1.84	2.78	14.9	8	156
05/01	12 19.5	-01 26	1.91	2.79	15.1	12	144
05/11	12 15.7	-00 56	2.00	2.79	15.4	15	133
05/21	12 14.3	-00 43	2.10	2.80	15.6	17	123
05/31	12 15.1	-00 44	2.22	2.80	15.7	19	114
06/10	12 18.1	-01 01	2.35	2.80	15.9	20	105
06/20	12 22.9	-01 30	2.48	2.80	16.0	21	97
06/30	12 29.5	-02 10	2.62	2.80	16.2	21	89

(154275) 2002 SR41 ($a=1.08$ AU, $e=0.49$, $i=11.6^\circ$, $H=20.2$)

No physical characteristics of 2002 SR41 have been published although radar observations were made in the past. During the month of June this NEA will be observed from large phase angles ($>100^\circ$) to a late June minimum of 39° . Peak brightness occurs on June 13 at $V=16.5$. Colors and lightcurve photometry are also requested. This object is a radar target.

DATE	RA	DEC	Δ	r	V	PH	Elong
06/06	06 35.6	+47 11	0.05	0.97	21.5	146	31
06/08	08 26.0	+60 36	0.04	0.98	18.8	126	51
06/10	12 06.9	+62 06	0.04	1.00	17.1	101	76
06/12	14 16.6	+48 43	0.05	1.02	16.5	79	97
06/14	15 06.3	+36 31	0.06	1.04	16.5	65	111
06/16	15 30.2	+28 09	0.07	1.05	16.8	56	120
06/18	15 44.1	+22 27	0.09	1.07	17.1	50	125
06/20	15 53.2	+18 24	0.11	1.08	17.4	46	128
06/22	15 59.6	+15 23	0.12	1.10	17.7	43	131
06/24	16 04.6	+13 03	0.14	1.12	17.9	42	132
06/26	16 08.6	+11 11	0.16	1.13	18.2	40	133
06/28	16 11.9	+09 38	0.18	1.15	18.4	39	133

(242708) 2005 UK1 ($a=2.50$ AU, $e=0.70$, $i=0.8^\circ$, $H=18.0$)

Little is known of this $H=18.0$ NEA. It is brighter than $V=20$ for the whole quarter. 2005 UK11 reaches a maximum phase angle of 123° in early May and a minimum phase of 26° in late June. Maximum brightness occurs in late May at $V=15.3$. Lightcurve and color observations are also requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	03 56.7	+19 57	0.59	0.76	19.6	93	50
04/11	04 26.0	+21 31	0.47	0.76	19.7	105	47
04/21	04 57.9	+23 01	0.35	0.79	19.8	116	45
05/01	05 40.5	+24 40	0.24	0.85	19.7	123	45
05/11	07 05.6	+26 01	0.14	0.93	18.3	118	54
05/21	10 42.7	+15 39	0.09	1.02	15.7	78	96
05/31	13 46.7	-05 17	0.14	1.12	15.6	37	137
06/10	14 52.8	-12 43	0.25	1.23	16.7	27	145
06/20	15 24.1	-15 46	0.37	1.33	17.7	26	144
06/30	15 44.3	-17 30	0.50	1.44	18.5	27	139

(243566) 1995 SA ($a=2.46$ AU, $e=0.64$, $i=19.9^\circ$, $H=17.4$)

The WISE infrared space observatory observed 1995 SA and found a low albedo of ~ 0.09 , suggesting a possible carbonaceous nature. The phase angle reaches a maximum of 111° in mid-April. The asteroid will be as bright as $V\sim 17$ -18 throughout the quarter as its phase angle decreases from its 111° maximum to 55° .

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	05 54.7	+43 24	0.18	0.98	16.9	90	78
04/11	04 09.9	+62 18	0.20	0.92	17.7	106	62
04/21	01 09.5	+67 08	0.23	0.89	18.3	111	56
05/01	23 23.5	+60 54	0.29	0.88	18.4	107	57
05/11	22 48.3	+53 55	0.35	0.89	18.4	98	61
05/21	22 38.9	+48 25	0.40	0.93	18.4	89	67
05/31	22 37.9	+44 13	0.45	0.98	18.5	80	73
06/10	22 38.6	+40 47	0.48	1.05	18.5	71	81
06/20	22 37.6	+37 36	0.51	1.13	18.5	63	89
06/30	22 33.1	+34 13	0.53	1.22	18.5	55	99

2003 GS ($a=0.89$ AU, $e=0.21$, $i=12.0^\circ$, $H=19.0$)

2003 GS reaches a peak magnitude of $V=14.7$ on April 10/11. Its phase angle spans a range from 13° to 109° during the course of the quarter. Since little is known of this NEA, any photometry, whether lightcurve, color, or phase angle is requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	14 32.9	-21 02	0.10	1.08	15.5	29	148
04/11	13 58.5	+02 10	0.08	1.08	14.7	13	165
04/21	13 17.9	+25 52	0.09	1.08	15.5	35	141
05/01	12 41.4	+40 31	0.12	1.07	16.6	55	118
05/11	12 15.2	+47 56	0.15	1.05	17.4	68	103
05/21	11 58.3	+51 55	0.18	1.03	18.1	77	92
05/31	11 46.5	+54 25	0.20	1.00	18.6	85	82
06/10	11 35.4	+56 24	0.22	0.97	19.0	93	74
06/20	11 18.9	+58 15	0.23	0.94	19.4	100	65
06/30	10 50.7	+59 47	0.24	0.90	19.9	109	57

2011 JR13 ($a=1.30$ AU, $e=0.73$, $i=24.7^\circ$, $H=19.6$)

2011 JR13 is yet another NEA with no published physical characterization. It passes within 0.05 AU of Earth on May 20/21. At that time it will also reach a peak brightness of $V=15.5$. During mid to late May the phase angle will increase from 30° to $\sim 130^\circ$. Its peak brightness will allow color and lightcurve observations even in moderate-sized telescopes. This object is a radar target.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	16 45.7	-35 42	0.84	1.56	21.7	35	115
04/11	16 57.9	-35 36	0.66	1.47	21.0	34	122
04/21	17 09.6	-34 49	0.49	1.37	20.2	34	130
05/01	17 21.5	-32 29	0.32	1.26	19.0	32	137
05/11	17 39.0	-24 33	0.16	1.15	17.3	30	144
05/14	17 48.9	-18 04	0.12	1.11	16.6	31	145
05/17	18 06.7	-04 38	0.08	1.07	15.8	37	140
05/20	18 49.1	+27 29	0.05	1.03	15.5	62	115
05/23	21 48.5	+69 21	0.05	0.99	17.3	105	71
05/26	02 52.4	+68 17	0.09	0.95	19.8	127	48
05/29	04 03.3	+60 09	0.13	0.91	21.4	135	38

2013 WF108 ($a=1.99$ AU, $e=0.57$, $i=23.5^\circ$, $H=20.0$)

The final target of the quarter is a recent discovery by the Pan-STARRS asteroid survey. A close approach to 0.03 AU of Earth takes place on May 24. On May 26 it reaches a peak brightness of $V=16.1$. The close flyby provides an opportunity to observe this NEA at phase angles from 39° to over 100° . This object is also a radar target.

DATE	RA	DEC	Δ	r	V	PH	Elong
04/01	04 31.8	-16 35	0.54	0.87	21.4	86	60
04/11	04 46.4	-17 47	0.45	0.85	21.3	95	57
04/21	04 59.4	-18 36	0.35	0.85	21.3	105	54
05/01	05 10.8	-18 18	0.24	0.87	21.2	115	51
05/11	05 23.3	-14 32	0.13	0.91	21.0	127	46
05/21	06 07.6	+16 43	0.04	0.97	20.7	145	32
05/26	14 10.1	+68 20	0.03	1.01	16.1	89	88
05/31	16 29.9	+45 15	0.08	1.04	16.9	62	112
06/05	16 47.4	+37 41	0.13	1.08	17.8	54	119
06/10	16 54.1	+33 54	0.18	1.12	18.4	49	123
06/15	16 57.8	+31 23	0.23	1.16	19.0	45	124
06/20	17 00.3	+29 24	0.29	1.21	19.4	43	125
06/25	17 02.4	+27 39	0.34	1.25	19.8	41	126
06/30	17 04.5	+26 01	0.40	1.29	20.1	39	126

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CCD LIGHTCURVE AND PERIOD ANALYSIS OF 712 BOLIVIANA

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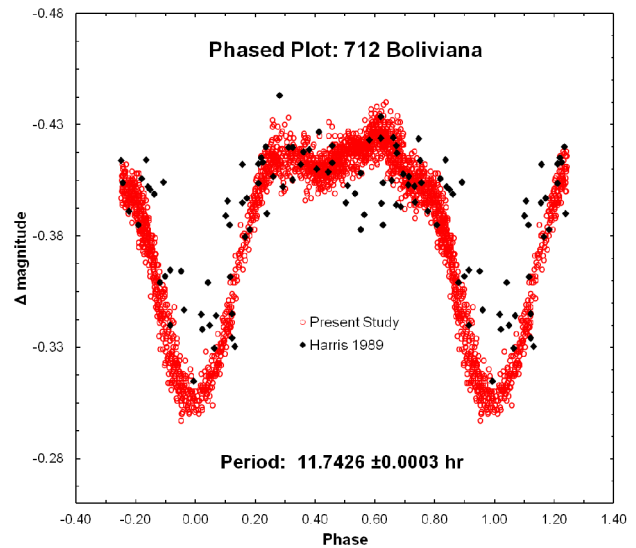
Analysis of combined CCD-derived lightcurves captured at UnderOak Observatory and photoelectric data from the literature has resulted in a revised synodic period solution for 712 Boliviana of $P = 11.7426$ h.

Discovered in 1911 by Max Wolf, 712 Boliviana is a moderately-sized ($D = 128$ km) C-type asteroid with an albedo of $p_V = 0.051$. Only two published papers regarding the rotation period of the asteroid were found: a report by Zappala *et al.* (1983) in which a partial lightcurve was obtained, and a later study by Harris and Young (1989) which combined new photoelectric data with those from Zappala *et al.* (1983) in order to improve the estimate for the rotation period.

The instrument used for the data obtained at UnderOak Observatory (UO) was a 0.2-m $f/10$ catadioptric OTA equipped with an SBIG ST-8XME thermoelectrically-cooled CCD. This combination produced a field-of-view (FOV) of about 21×14 arcmin. Unfiltered 60-sec exposures were continually captured during each session. Image calibration/registration procedures typically used at UO for CCD photometry have been published elsewhere (Alton, 2013). Data reduction with *MPO Canopus* (Warner, 2013) used at least two non-varying comparison stars in the same FOV to generate lightcurves by differential aperture photometry. Data were light-time corrected but not reduced to standard magnitudes. Fourier analysis (Harris *et al.*, 1989) yielded a period solution from the dataset acquired at UO; the combined data set was independently analyzed using a statistical method featured in *Peranso* (Vannmunster, 2006). Phased data are available upon written request.

For the new study, a total of 1927 images were taken over 11 nights in 2013 Oct-Nov. Fourier analysis within *MPO Canopus* was seeded with the rotation period (11.732 h) obtained from the JPL Solar System Dynamics website and produced the best folded fit at 11.743 ± 0.001 h. This value was independently confirmed using *Peranso* by applying periodic orthogonals (Schwarzenberg-Czerny, 1996) to fit observations and analysis of variance (ANOVA) to evaluate fit quality. The peak-to-peak amplitude ($A = 0.12$) was similar to that observed in the other two published lightcurves for this object. Alan Harris (private communications) graciously provided the photoelectric observations ($n = 79$) from Table Mountain Observatory (Harris and Young, 1989) which were originally used to estimate the first synodic period (11.732 ± 0.003 h) derived from a full lightcurve. The authors stated that they were confident in this value but could not rule out a period which was twice as long. Combined analysis (ANOVA) of these data ($n = 2006$; total time span: 12090.33 d) produced a slightly longer and presumably less equivocal value (11.7426 ± 0.0003 h) for the rotation period of 712 Boliviana.

Observatory	Year	Dates Observed
Table Mountain	1980	Oct 12-14, 26, 30, Nov 01, 02, 04, 05
UnderOak	2013	Oct 25, 26, 28, 29, Nov 02-04, 08, 09, 14, 19



Acknowledgement

Many thanks to Dr. Alan Harris for providing lightcurve data critical to improving the synodic period estimate for this poorly studied main belt asteroid.

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ROTATION PERIOD DETERMINATION FOR 560 DELILA

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Lightcurves of 560 Delila were obtained by a collaboration between Bassano Bresciano Observatory and Organ Mesa Observatory. For 560 Delila, the period is 29.913 ± 0.003 hours, amplitude 0.15 ± 0.02 magnitudes with an irregular lightcurve.

The Asteroid Lightcurve Data Base (Warner et al. 2013) indicates no previous rotation period determination for 560 Delila, only an amplitude > 0.1 magnitude. Observers Pilcher at Organ Mesa Observatory (G50) and Strabla at Bassano Bresciano Observatory (565) collaborated to obtain a dense lightcurve, the first ever of 560 Delila. Equipment at Organ Mesa Observatory consists of a 0.35 meter Meade LX200 GPS Schmidt-Cassegrain, SBIG STL-1001E CCD, with a clear filter, 60 second exposure time, unguided. At Bassano Bresciano Observatory a 0.32 meter Schmidt telescope operating at F/3.1 and Starlight CCD camera MX-916 applied at direct focus was used with 120 second exposure time, unfiltered, unguided. *MPO Canopus* (BDW Publishing, 2010) was used to measure the images photometrically. Comparison stars with near solar colors were selected with the Comparison Star Selector included in this software. More accurate magnitudes for these stars were obtained from the Sloan r' magnitudes CMC14 (Carlsbad Meridian Circle) catalog posted on the VizieR (2013) web site, which were converted to Johnson-Cousins R magnitudes by $R=r'-0.22$. A Fourier analysis algorithm developed by Harris et al. (1989) was utilized to obtain the period which satisfied the data with minimum residual. Even with the use of CMC14 magnitudes, it was necessary to adjust the instrumental magnitudes of the individual sessions by several $\times 0.01$ magnitude for the minimum residual fit displayed in the lightcurve.

Photometric data from a total of 17 sessions 2013 Oct. 27 - Dec. 4 provide a good fit to a synodic rotation period 29.913 ± 0.03 hours, amplitude 0.15 ± 0.02 magnitudes, with a somewhat irregular lightcurve.

References

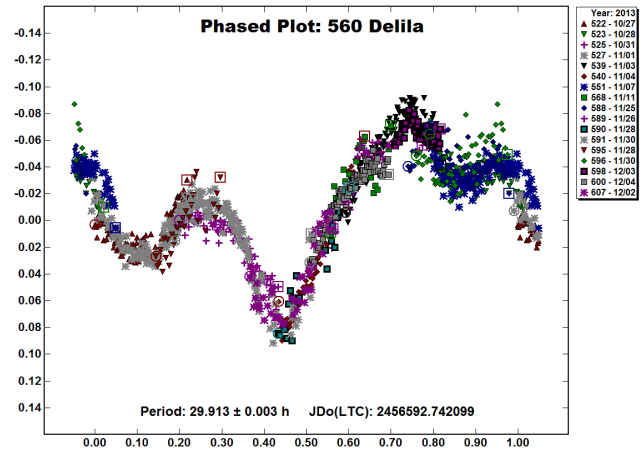
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<http://minorplanet.info/lightcurvedatabase.html>

Observatory	Date	Phase Angle	Time h.	Num Obs
Organ Mesa	2013-10-27	19.7	6.5	322
Organ Mesa	2013-10-28	19.4	6.9	345
Organ Mesa	2013-10-31	18.6	7.0	244
Organ Mesa	2013-11-01	18.3	7.1	260
Organ Mesa	2013-11-03	17.8	6.7	265
Organ Mesa	2013-11-04	17.5	6.1	230
Organ Mesa	2013-11-07	16.5	7.6	370
Bassano Br.	2013-11-11	15.0	4.3	83
Bassano Br.	2013-11-25	9.2	7.2	126
Bassano Br.	2013-11-26	8.8	6.5	136
Bassano Br.	2013-11-27	8.5	5.1	68
Bassano Br.	2013-11-28	7.9	4.5	93
Organ Mesa	2013-11-30	7.3	9.7	337
Bassano Br.	2013-11-30	7.0	4.5	164
Bassano Br.	2013-12-02	6.1	6.0	117
Organ Mesa	2013-12-03	5.9	3.3	163
Organ Mesa	2013-12-04	5.4	5.6	270



ROTATION PERIOD DETERMINATION FOR 989 SCHWASSMANNIA

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The lightcurve of 989 Schwassmannia obtained from the collaborative observations performed at three observatories located in the United States and Serbia revealed a synodic rotation period of 107.85 ± 0.01 hours for the main-belt asteroid.

The main-belt asteroid 989 Schwassmannia was discovered by Friedrich Karl Arnold Schwassmann at the Hamburg-Bergedorf Observatory on 1922 November 18. A search for previous rotation period determinations for the asteroid found a tentative period of 4.58 h reported by Behrend (2013) based upon a fragmentary lightcurve obtained from observations carried out by F. Manzini in 2004. This solution has been marked with an uncertainty flag of $U = 1$ on the CALL website (2013), indicating that it is likely to be completely wrong.

In order to check the previously-reported results, Benishek began photometric observations of 989 Schwassmannia on 2013 October 11 at the newly equipped Sopot Astronomical Observatory using a 0.35-m $f/10$ Meade LX-200 GPS Schmidt-Cassegrain (SCT) and an SBIG ST-8XME CCD camera. Analysis of the initial sessions undoubtedly indicated a long period significantly different from the result reported by Behrend. In early November, a collaboration with observers in the United States was established that included Frederick Pilcher at Organ Mesa Observatory who used a 0.35-m $f/10$ Meade LX-200 SCT equipped with an SBIG STL-1001E CCD, and Luis Martinez at Lenomiya Observatory, who used a 0.28-m $f/6.3$ (focal reducer) Celestron CPC-1100 and an SBIG ST-8XME CCD. The exposures were unfiltered and unguided for all observers. As of 2013 December 10, the collaborative observations resulted in 25 sessions – of which, 12 were obtained by Benishek, 11 by Pilcher, and 2 by Martinez – and 6032 data points. The data covered a phase angle range 9.8 to 24.7 degrees, a phase angle bisector longitude range from 24.9 to 32.9 degrees, and phase angle bisector latitude range from 14.2 to 6.1 degrees. The authors used *MPO Canopus* software by BDW Publishing to perform differential photometry data reduction, data sharing, and lightcurve construction.

Instrumental magnitudes were used in the period analysis. Determination of the optimal solution for period was carried out by adjusting the zero points for particular sessions along the magnitude (vertical) axis until the minimum RMS error value from the Fourier analysis was reached. The analysis covered a wide range of periods, among which were singled out two with nearly comparable RMS errors and reasonable physical justification: first, a bimodal solution with a period of ~ 107.9 h and, second, a

quadramodal with a period of ~ 215.6 hours. Some more complex lightcurve solutions with multiple minima and maxima were immediately ruled out as physically unreasonable. A closer inspection of the Fourier series coefficients indicated uniformity of the even and odd terms for the short period while in the case of the long period, there was a tendency for rather large even term coefficients with respect to the odd term coefficients. This fact favors the shorter period as a reliable solution.

Refined period values for the bimodal lightcurve were derived independently by Pilcher and Benishek, whose results were, respectively, 107.82 ± 0.02 h and 107.85 ± 0.01 h; we chose to adopt that longer period for this work. The smallest value for RMS error in this particular case was obtained by using the highest number of harmonic orders in the Fourier analysis possible in *MPO Canopus*, i.e. 15. The amplitude is 0.35 ± 0.02 mag, as calculated from the lightcurve.

Figure 1 shows the final lightcurve plot. To make the data points more readable, they have been binned in sets of 3 with maximum time between binned data points of 5 minutes.

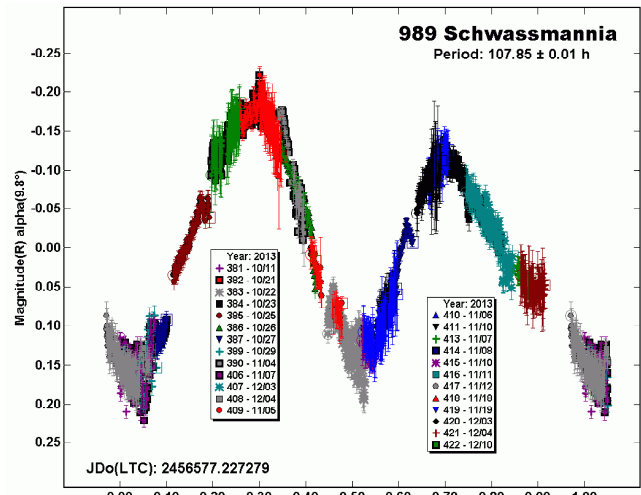


Figure 1. The bimodal lightcurve phased to 107.85 hours. The Y-axis is the differential magnitude from a fixed reference point.

References

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2014 APRIL-JUNE

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We present lists of asteroid photometry opportunities for objects reaching a favorable apparition and having either none 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.

Changes

In the last issue of the *MPB*, we noted that the format of this article hadn't changed for some time. Furthermore, the reasons for photometry observations have changed focus in some ways from raw numbers to specific goals or targets. Finally, the task of producing the lists was becoming too daunting given the rapid increase in data and results. We asked for feedback on what changes, if any, you would like to see. Given the production cycle of the *MPB*, readers had access to the electronic version only a short time before this article had to be prepared, and so little time for thoughtful ideas to filter back. So, we will "ride, boldly ride" and strike off on a new path in hopes that we continue to serve the photometry community well. Here's how we are moving forward:

Lightcurve Opportunities. For now, this list remains essentially unchanged, including objects with less than ideally-determined (or no) lightcurve parameters that reach brightest during the current quarter.

Low Phase Angle Opportunities. This list also remains unchanged. The need for these observations is still great, as are observations well away from opposition in order to establish well-determined absolute magnitude (H) and phase slope parameter (G).

Shape Modeling Candidates. This is the greatest departure from the past. There are now almost 700 models for nearly 400 objects in

the DAMIT database. There is no rating system to say which objects really don't need any new observations (probably not too many). Matters are further complicated by the ability to use *sparse datasets* such as those from the NEA surveys. In many cases, the combination of regular (*dense*) lightcurves and sparse data allows finding a reasonable solution with fewer dense lightcurves, and so a dedicated campaign on an object may not really add much useful information versus working another object. A strong exception to this line of thinking would be for near-Earth asteroids (NEAs). These objects are very likely candidates for rotation changes due to thermal effects (e.g., YORP) or planetary encounters. Well-determined lightcurves over a number of apparitions are needed to measure these effects.

It is a great help when modeling to know the period of the asteroid as precisely as possible; this dictated the objects included in the list for modeling as did whether or not the object was listed in DAMIT. The result is a list of objects with $U = 3-3$ and *not* in DAMIT. This contradicts the past where objects *were* in DAMIT and needed only one or two more curves. Again, this required extensive research into each object in DAMIT to determine that fact and couldn't account for new results in a timely way.

So, the idea now is to work on increasing the number of objects in DAMIT by breaking "new ground". This is important because recent research has shown that the trend in spin axis alignments for smaller asteroids favors the ecliptic poles, or at least not the ecliptic plane, mostly likely is the result of YORP. Now that calibrated sparse data are becoming more available as are dense lightcurve data from sources such as ALCDEF, modeling may start progressing even more rapidly.

However, this does not mean that "old ground" should be forgotten. Ďurech is looking at adding an on-line tool for the DAMIT site that would generate a list of "best" candidates for a given time based on the data already in DAMIT. We will keep you posted on those developments.

Finally, when visiting the DAMIT site, be sure to check out some of the other links, e.g., the Interactive Service for Asteroid Models (<http://isam.astro.amu.edu.pl/>). There's even an app for Android devices to display models using data from DAMIT or other sources that have the proper format.

Radar Opportunities. For now, we continue with a short list of objects with ephemerides, but without comment, tied to planned radar observations. However, we want to emphasize that these should *not* be your only guide. See below for more.

Photometry Opportunities

We present lists of "targets of opportunity" for the period 2014 April-June. In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

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

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

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

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

There are several to plan observations in support of radar.

Future radar targets:

<http://echo.jpl.nasa.gov/~lance/future.radar.nea.periods.html>

Past radar targets:

<http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html>

Arecibo targets:

<http://www.naic.edu/~pradar/sched.shtml>

<http://www.naic.edu/~pradar>

Goldstone targets:

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

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

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

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

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. We urge you to consider submitting your raw data to the ALCDEF page on the Minor Planet Center web site:

http://www.minorplanetcenter.net/light_curve

This is the largest publicly available database of raw lightcurve data that contains 1.5 million observations for more than 2300 objects.

Lightcurve Opportunities

An asterisk (*) follows the name if the asteroid is reaching a particularly favorable apparition.

#	Name	Brightest			LCDB Data			U
		Date	Mag	Dec	Period	Amp		
735	Marghanna	04 04.2	14.6	+6	15.95		0.11	2
895	Helio	04 04.6	13.4	-38	9.3959	0.10-0.23	2	2
662	Newtonia	04 04.8	13.6	+0	16.46		0.42	2
2378	Pannekoek	04 07.5	15.0	-1	11.8806	0.08-0.14	2	2
781	Kartvelia	04 08.9	14.2	+15	19.06	0.22-0.28	2	2
1353	Maartje	04 09.9	14.0	-10	22.98		0.40	2
478	Tergeste	04 12.5	12.2	-18	16.104		0.23	2+
953	Painleva	04 14.3	13.5	-6	10.	0.03-0.10	1	1
2091	Sampo	04 15.4	15.0	+6	71.3		0.38	2
1331	Solvejg	04 18.2	14.4	-6	10.		0.3	1
904	Rockefellia	04 21.8	14.6	-7	5.82	0.10-0.18	2	2
1136	Mercedes	04 25.1	15.0	-12	24.64	0.10-0.15	2	2
3523	Arina*	04 25.4	14.2	-6			0.10	
11549	1992 YY*	04 27.3	15.0	-28	2.671		0.08	2
5064	Tanchozuru	04 28.2	15.0	-3	8.13		0.7	2-
299	Thora	04 29.1	14.3	-15				

#	Name	Brightest			LCDB Data			U
		Date	Mag	Dec	Period	Amp		
3039	Yangel*	04 29.7	14.9	-2				
1706	Dieckvoss	04 29.8	14.3	-18				
2120	Tyumenia*	05 02.4	14.7	-16	2.769	0.33-0.39	2	2
1417	Walinskia	05 03.0	14.9	-5				
772	Tanete*	05 05.2	12.2	+1	11.8		0.10	2
1031	Arctica*	05 06.4	13.5	-14	51.	0.09-0.22	2	2
957	Camelia	05 07.7	13.9	-19	150.		0.30	1+
551	Ortrud	05 11.3	14.0	-18	13.05	0.09-0.18	2	2
981	Martina	05 11.6	14.9	-18	11.267		0.20	2
814	Taurus	05 11.8	14.6	+1	35.8	0.18-0.20	2	2
3996	Fugaku	05 12.0	14.8	-15				
398	Admete	05 12.1	14.9	-28				
613	Ginevra	05 13.3	14.0	-28	13.024	0.20-0.63	2	2
4122	Ferrari	05 14.3	15.0	-30				
2035	Stearns*	05 15.5	14.3	+18	51.89	0.20-	0.7	2
1197	Rhodesia	05 16.2	13.3	-27	16.062	0.22-0.32	2	2
1549	Mikko	05 16.7	15.0	-14	11.49		0.03	1+
1593	Fagnes	05 19.2	15.0	+1	25.1		0.47	2
1068	Nofretete*	05 21.6	14.7	-29	6.15		0.04	2
1026	Ingrid	05 22.6	14.7	-13	5.		0.5	2
9233	Itagijun*	05 24.4	14.9	-5	110.95		0.6	2
1329	Eliane	05 25.3	14.0	+3	106.	0.18-0.30	2-	2-
1763	Williams	05 25.6	14.8	-28	> 36.		0.3	2
2056	Nancy	05 26.6	14.9	-19	> 15.		0.08	1
4378	Voigt*	05 26.9	13.8	-9	10.796		0.50	2
1237	Genevieve	05 27.2	14.1	-23	16.37	0.17-0.23	2-	2-
2014	Vasilevskis*	05 27.5	14.0	+10	36.25		0.30	1
494	Virtus*	05 27.9	12.7	-27	5.57	0.03-0.12	2+	2+
716	Berkeley	05 28.6	14.4	-8	15.55		0.25	2+
749	Malzovia*	05 28.7	13.2	-14				
1243	Pamela*	05 29.3	13.6	-21	26.017	0.42-0.71	2	2
7834	1993 JL*	05 29.5	14.8	-16				
630	Euphemia	05 30.4	14.6	-8	350.	0.20-0.45	2	2
3089	Oujianquan*	05 31.6	14.1	-12	11.198		0.45	2
3116	Goodricke	06 01.0	14.8	-20	10.		0.09	2
2324	Janice*	06 01.6	14.3	-23	23.2		0.19	2-
6874	1994 JO1*	06 05.9	14.3	-21				
3166	Klondike	06 12.4	14.1	-25	> 12.		0.2	2
846	Lipperta	06 13.0	14.8	-23	1641.		0.30	2
1284	Latvia	06 15.5	14.5	-34	9.644	0.10-0.21	2	2
3237	Victorplatt*	06 16.0	14.3	-27	10.36	0.12-0.24	2	2
927	Ratisbona	06 16.8	14.3	-44	12.994		0.12	2
622	Esther	06 19.4	13.9	-12	47.5		0.57	2
3184	Raab	06 19.8	14.5	-21				
530	Turandot	06 20.1	13.0	-14	19.947	0.10-0.16	2+	2+
9103	Komatsubara*	06 20.1	14.9	-22				
777	Gutenberg	06 21.6	14.0	-28	12.88		0.25	2
1591	Baize*	06 23.1	12.8	-24	7.78	0.26-0.37	2+	2+
1242	Zambesia	06 23.3	14.7	-38	17.305	0.24-1.36	2	2
3165	Mikawa*	06 24.1	14.0	-24	5.08	0.08-0.25	2	2
1199	Geldonia	06 26.8	14.6	-15	28.3		0.11	2-
761	Brendelia	06 28.2	14.4	-27	57.96		0.25	2+
3570	Wuyeesun*	06 28.2	14.7	-27				
764	Gedania	06 28.3	14.3	-19	24.9751	0.09-0.35	2	2
1713	Bancilhon*	06 29.8	14.5	-28				
15779	Scottroberts*	06 30.8	14.9	-28				

Low Phase Angle Opportunities

#	Name	Date	α	V	Dec	Period	Amp	U
855	Newcombia	04 08.2	0.23	13.5	-07	3.003		0.35 3
1353	Maartje	04 09.8	0.95	14.0	-10	22.98		0.40 2
60	Echo	04 12.5	0.50	10.9	-08	25.208	0.07-0.22	3
175	Andromache	04 21.1	0.21	13.2	-12	8.324	0.21-0.30	3
446	Aeternitas	04 26.2	0.67	12.6	-12	15.7413	0.36-0.51	3
769	Tatjana	05 01.1	0.16	12.6	-15	35.08	0.30-0.33	3+
957	Camelia	05 07.8	0.79	13.9	-19	150.		0.30 1+
907	Rhoda	05 08.4	0.93	13.4	-20	22.44		0.16 3-
182	Elsa	05 09.2	0.94	12.9	-15	80.088	0.69-0.72	3
551	Ortrud	05 11.3	0.17	14.0	-18	13.05	0.09-0.18	2
311	Claudia	05 11.9	0.87	13.7	-16	7.532	0.16-0.89	3
976	Benjamina	05 13.4	0.83	13.1	-21	9.746	0.17-0.18	3-
701	Oriola	05 14.1	0.71	13.1	-21	9.090		0.20 3
9	Metis	05 15.6	0.86	9.6	-17	5.079	0.04-0.36	3
177	Irma	05 20.0	0.59	13.9	-22	13.856	0.30-0.37	3-
1243	Pamela	05 29.3	0.25	13.7	-21	26.017	0.42-0.71	2
742	Edisona	06 01.6	0.67	13.6	-24	18.52	0.24-0.30	3
1927	LA	06 02.3	1.00	13.6	-20			
818	Kapteynia	06 05.1	0.44	13.6	-24	16.35	0.09-0.12	3
1773	Rumpelstilz	06 10.1	0.37	13.8	-24			
259	Aletheia	06 11.0	0.80	11.3	-21	8.143		0.12 3
215	Oenone	06 11.9	0.82	12.9	-25>20.			0.1 2
146	Lucina	06 12.8	0.38	11.3	-22	18.557	0.08-0.17	3
690	Wratislavia	06 14.4	0.92	12.4	-20	8.64	0.08-0.31	3
198	Ampella	06 14.7	0.65	11.0	-25	10.379	0.03-0.22	3
471	Papagena	06 18.4	0.37	11.1	-25	7.113	0.10-0.14	3

#	Name	Date	α	V	Dec	Period	Amp	U
678	Fredegundis	06 22.5	0.63	12.8	-25	11.61624	0.25-0.27	3
1591	Baize	06 23.1	0.48	12.8	-24	10.	0.26	2
3165	Mikawa	06 24.1	0.27	14.0	-24	5.08	0.08-0.25	2
752	Sulamitis	06 24.3	0.50	13.5	-25	27.367	0.20-0.36	3
486	Cremona	06 28.4	0.45	12.9	-24	65.15	0.80-1.00	3-
1075	Helina	06 28.4	0.49	13.9	-22			
158	Koronis	06 29.2	0.11	13.2	-23	14.218	0.28-0.43	3

Shape/Spin Modeling Opportunities

This is a *partial* list of objects reaching brightest this quarter with well-determined periods and are *not* in the DAMIT database. However, since they have a high U rating, this means there is at least one dense lightcurve of high quality. A second one, along with sparse data, could easily lead to the asteroid being added to DAMIT.

#	Name	Brightest		Dec	Period	LCDB Data Amp	U
		Date	Mag				
495	Eulalia	04 01.1	14.3	-4	28.967	0.04-0.30	3
92	Undina	04 03.9	11.6	+8	15.941	0.16-0.20	3
921	Jovita	04 05.5	14.0	-10	15.64	0.07-0.12	3-
855	Newcambia	04 08.2	13.5	-7	3.003	0.35	3
491	Carina	04 11.8	14.0	+3	14.87	0.12	3
60	Echo	04 12.4	10.9	-8	25.208	0.07-0.22	3
113	Amalthea	04 13.6	11.1	+0	9.935	0.19-0.20	3
3873	Roddy	04 13.7	13.8	-43	2.4782	0.05-0.11	3
100	Hekate	04 16.6	12.1	-1	27.066	0.11-0.23	3
1146	Biarmia	04 18.8	13.1	-13	5.47	0.20-0.32	3
420	Bertholda	04 23.4	13.1	-17	11.04	0.24-0.29	3
502	Sigune	04 25.0	14.0	+26	10.922	0.25-0.53	3
446	Aeternitas	04 26.3	12.6	-12	15.7413	0.36-0.51	3
75	Eurydike	04 26.4	12.9	-17	5.357	0.10-0.15	3
108	Hecuba	05 07.4	12.3	-22	14.256	0.05-0.2	3-
1712	Angola	05 07.9	13.7	-23	11.527	0.38	3
488	Kreusa	05 08.8	11.9	-7	19.26	0.08-0.2	3
232	Russia	05 09.4	12.6	-7	21.91	0.14-0.31	3-
976	Benjamina	05 13.3	13.1	-21	9.746	0.17-0.18	3-
701	Oriola	05 14.1	13.1	-21	9.09	0.2	3
65	Cybele	05 14.9	10.9	-14	6.0814	0.01-0.12	3
31	Euphrosyne	05 15.5	12.1	-35	5.53	0.06-0.13	3
177	Irma	05 20.1	13.9	-22	13.856	0.24-0.37	3
790	Pretoria	05 23.1	12.2	-26	10.37	0.05-0.18	3
342	Endymion	06 01.7	14.0	-19	6.319	0.15-0.23	3
424	Gratia	06 04.1	13.7	-17	19.47	0.32	3
660	Crescentia	06 06.8	12.2	+4	7.92	0.18-0.33	3
490	Veritas	06 08.5	13.1	-10	7.93	0.33-0.58	3
380	Fiducia	06 09.2	12.6	-20	13.69	0.04-0.32	3
98	Ianthe	06 09.4	12.9	-47	16.479	0.27-0.34	3
259	Aletheia	06 11.0	11.3	-21	8.143	0.12	3
109	Felicitas	06 12.8	13.7	-34	13.191	0.06-0.12	3
61	Danae	06 14.2	12.0	-49	11.45	0.13-0.30	3
198	Ampella	06 14.9	11.0	-25	10.379	0.03-0.22	3
206	Hersilia	06 17.0	12.5	-18	11.128	0.08-0.20	3
466	Tisiphone	06 18.8	13.0	-35	8.824	0.03-0.16	3
1274	Delportia	06 19.3	13.9	-31	5.615	0.05-0.09	3
678	Fredegundis	06 22.6	12.7	-25	11.6162	0.25-0.27	3
752	Sulamitis	06 24.3	13.4	-25	27.367	0.20-0.36	3
362	Havnia	06 25.9	12.6	-35	16.92	0.09-0.11	3
1735	ITA	06 26.5	13.9	-48	12.599	0.27	3-
1075	Helina	06 28.5	13.9	-22	44.9	0.64	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.net/iau/MPEph/MPEph.html>
JPL: <http://ssd.jpl.nasa.gov/?horizons>

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

(363599) 2004 FG11 (Mar-Apr, H = 21.0, PHA)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	14 54.4	+05 18	0.16	1.14	18.6	30.1	145	156	+0.02	+53
04/02	14 59.8	+06 37	0.15	1.12	18.4	31.3	144	158	+0.06	+53
04/03	15 06.2	+08 11	0.13	1.11	18.3	32.8	143	155	+0.12	+53
04/04	15 14.0	+10 06	0.12	1.10	18.1	34.8	141	147	+0.20	+52
04/05	15 23.8	+12 26	0.11	1.08	17.9	37.4	139	139	+0.28	+51
04/06	15 36.2	+15 20	0.10	1.07	17.7	41.0	135	130	+0.37	+50
04/07	15 52.6	+18 59	0.08	1.06	17.5	45.7	131	122	+0.47	+48
04/08	16 15.0	+23 34	0.07	1.05	17.4	52.0	125	115	+0.56	+44

2003 HM (Apr, H = 22.2, PHA)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/20	08 48.5	+54 17	0.04	1.00	18.5	88.4	89	132	-0.75	+39
04/21	08 47.6	+43 44	0.04	1.01	18.4	86.1	91	145	-0.65	+39
04/22	08 47.1	+33 35	0.04	1.01	18.4	84.0	93	158	-0.54	+38
04/23	08 46.7	+24 23	0.05	1.01	18.5	82.3	95	168	-0.42	+35
04/24	08 46.4	+16 23	0.05	1.01	18.6	81.0	96	163	-0.31	+33
04/25	08 46.2	+09 36	0.06	1.01	18.8	80.0	97	151	-0.21	+30
04/26	08 46.0	+03 57	0.06	1.02	19.0	79.4	97	138	-0.13	+27
04/27	08 46.0	-00 46	0.07	1.02	19.1	78.9	97	125	-0.06	+25

2013 WF108 (May, H = 20.0, PHA)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/25	11 17.3	+72 12	0.03	1.01	16.3	102.7	76	98	-0.15	+43
05/26	14 09.1	+68 31	0.04	1.01	16.1	90.0	88	100	-0.08	+47
05/27	15 21.1	+61 35	0.05	1.02	16.2	80.9	97	103	-0.03	+48
05/28	15 53.6	+55 48	0.05	1.03	16.3	74.4	103	107	-0.01	+47
05/29	16 11.4	+51 23	0.06	1.03	16.5	69.6	107	110	+0.00	+46
05/30	16 22.4	+47 59	0.07	1.04	16.7	65.9	110	111	+0.02	+44
05/31	16 30.0	+45 20	0.08	1.05	16.9	63.0	113	111	+0.05	+43
06/01	16 35.4	+43 13	0.09	1.06	17.1	60.6	115	110	+0.10	+42

2011 JR13 (May, H = 19.6, PHA)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	22 35.9	-06 40	2.46	1.71	21.4	18.5	33	49	+0.02	-52
04/11	23 01.1	-05 31	2.40	1.70	21.4	20.5	37	166	+0.82	-56
04/21	23 26.2	-04 22	2.33	1.69	21.4	22.5	40	67	-0.65	-59
05/01	23 51.5	-03 14	2.27	1.69	21.3	24.4	44	65	+0.03	-62
05/11	00 16.7	-02 10	2.19	1.68	21.3	26.2	47	174	+0.84	-64
05/21	00 42.1	-01 13	2.12	1.67	21.3	27.9	51	47	-0.56	-64
05/31	01 07.5	-00 24	2.05	1.67	21.3	29.5	54	79	+0.05	-63
06/10	01 32.9	+00 15	1.97	1.67	21.2	31.0	58	162	+0.88	-61

(304330) 2006 SX217 (May, H = 18.8, PHA)

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/10	03 33.7	-60 50	0.12	0.99	17.6	94.5	79	103	+0.76	-47
05/15	03 39.0	-63 53	0.16	1.00	17.9	88.5	83	99	-1.00	-45
05/20	03 43.1	-65 47	0.19	1.02	18.1	83.7	86	84	-0.67	-43
05/25	03 46.5	-67 08	0.22	1.03	18.4	79.6	88	80	-0.15	-42
05/30	03 49.2	-68 14	0.25	1.04	18.5	75.9	90	89	+0.02	-41
06/04	03 51.4	-69 14	0.28	1.06	18.7	72.6	92	97	+0.33	-41
06/09	03 52.8	-70 13	0.31	1.08	18.8	69.5	94	96	+0.80	-40
06/14	03 53.2	-71 14	0.33	1.10	19.0	66.6	96	87	-0.99	-39

IN THIS ISSUE

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

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3896	Pordenone	46	112	30705	Idaios	29	95
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4727	Ravel	13	79	49667	1999 OM2	36	102
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4943	Lac d'Orient	16	82	51958	2001 QJ256	29	95
5040	Rabinowitz	34	100	52760	1998 ML14	47	113
5110	Belgirate	12	78	53435	1999 VM40	47	113
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6041	Juterkilian	16	82	85118	1971 UU	34	100
6063	Jason	47	113	86192	1999 SV1	36	102
6249	Jennifer	36	102	88710	2001 SL9	47	113
6602	Gilclark	36	102	105158	2000 OL	60	126
6634	1997 KB	26	92	119744	2001 YN42	36	102
7087	Lewotsky	36	102	120578	1995 QV12	36	102
7173	Sepkoski	36	102	125742	2001 XT117	34	100
7352	1994 CO	29	95	134549	1999 RN154	36	102
7505	Furusho	36	102	138095	2000 DK79	9	75
9068	1993 OD	36	102	142781	2002 UM11	47	113
9873	1992 GH	36	102	162566	2000 RJ34	59	125
9950	ESA	26	92	163696	2003 EB50	47	113
10115	1992 SK	47	113	249595	1997 GH28	47	113
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12369	Pirandello	36	102		2006 HU30	47	113
12920	1998 VM15	34	100		2010 CL19	47	113
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16141	1999 XT147	34	100		2011 CQ4	47	113
16197	Bluepeter	16	82		2013 RH74	47	113
17171	1999 NB38	29	95		2013 RM43	47	113
17365	1978 VF11	29	95		2013 SC25	47	113
17492	Hippasos	29	95		2013 SU24	47	113
17511	1992 QN	47	113		2013 SW24	47	113
18109	2000 NG11	47	113		2013 TB80	47	113
18137	2000 OU30	29	95		2013 TE6	47	113
20210	1997 GQ7	16	82		2013 UH5	47	113
21321	1997 AN2	36	102		2013 UH9	47	113
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24448	2000 QE42	29	95		2013 XY8	47	113
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The deadline for the next issue (41-3) is April 15, 2014. The deadline for issue 41-4 is July 15, 2014.