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41.

## LIGHTCURVE AND PHASE CURVE OF 1130 SKULD

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The lightcurve period of asteroid 1130 Skuld is confirmed to be  $P = 4.807 \pm 0.002$  h. Its phase curve is well-matched by a slope parameter  $G = 0.25 \pm 0.01$

The 2009 October-November apparition of asteroid 1130 Skuld presented an excellent opportunity to measure its phase curve to very small solar phase angles. I devoted 13 nights over a two-month period to gathering photometric data on the object, over which time the solar phase angle ranged from  $\alpha = 0.3$  deg to  $\alpha = 17.6$  deg. All observations used Altimira Observatory's 0.28-m Schmidt-Cassegrain telescope (SCT) working at  $f/6.3$ , SBIG ST-8XE NABG CCD camera, and photometric V- and R-band filters. Exposure durations were 3 or 4 minutes with the SNR  $> 100$  in all images, which were reduced with flat and dark frames. Differential photometry and lightcurve analysis were done with *MPO Canopus* using 3 to 5 comparison stars in each field of view. Comp stars were selected using *Canopus*' "comp star selector", which ensured that the comp stars were similar in color to the asteroid.

The comp stars were measured in two ways. First, a clear and stable night in 2009 December was devoted to "all sky" photometry to determine the standard V- and R-band magnitude of the stars by comparison to Landolt standard stars (principally SA-93), with appropriate correction for atmospheric extinction. Second, for some fields, there was sufficient overlap that the comp stars could be "bridged" using convenient field stars; this enabled me to confirm that the comp stars were stable over the period between "lightcurve nights" and the comp star calibration night. The formal errors in the V- and R-band magnitudes of the comp stars were generally better than  $\pm 0.03$  mag and their consistency between nights was also this good.

The lightcurve at small solar phase angle is shown in Figure 1. This is a typical bimodal lightcurve with a period of  $P = 4.807 \pm 0.002$  h and amplitude  $A = 0.25$  mag, peak-to-peak. This period confirms the results previously reported by Behrend (2009), which were based on data from 2004 provided by François Colas, and by

Robinson (2009) from his data taken in 2002. There is no evidence of any change of (V-R) color with asteroid rotation.

As a result of the relatively short period of this lightcurve, every night provided at least one minimum and maximum of the lightcurve. The phase curve was determined by polling both the maximum and minimum points of each night's lightcurve. Since

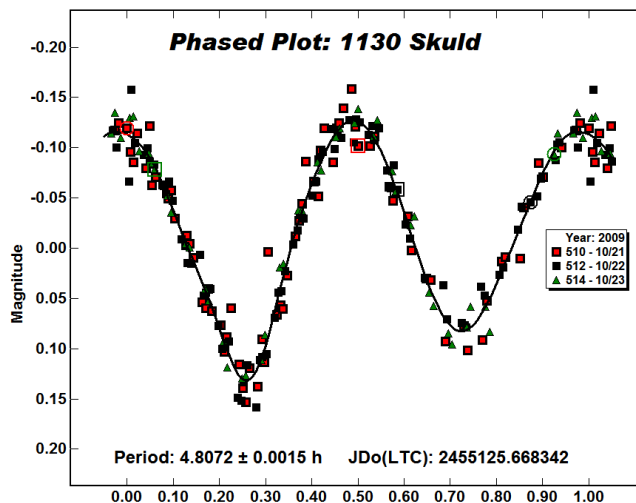


Figure 1: Phased lightcurve, at low solar phase angle

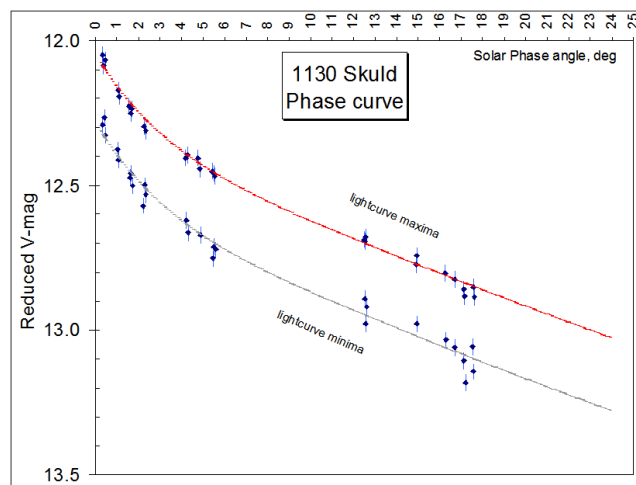


Figure 2: Phase curves of 1130 Skuld at maximum and minimum light.

both the primary and secondary maxima are of nearly equal brightness, all of the extrema were polled without distinction between primary or secondary. The primary and secondary minima differ by about 0.05 mag, but they were treated equally as well; this contributes to the somewhat higher scatter in the “lightcurve minima” phase curve, compared to the phase curve for the “lightcurve maxima.” Two methods were used to poll the asteroid’s brightness at the extrema. First, the Fourier fit to the lightcurve was adjusted up and down to minimize the mean-square error to the measured lightcurve data in the neighborhood of the extremum of interest, and then the magnitude of the Fourier fit was determined. Second, the actual photometric measured data point at the time of maximum/minimum light was recorded. The difference between these two estimates of maximum or minimum brightness rarely differed by more than a few hundredths of a magnitude. Both the “Fourier fit” and the “actual measured” data points are included in the final phase curve in order to give a visual feel for the quality of the data.

The JPL Horizons ephemeris system was used to determine the solar phase angle ( $\alpha$ ), Sun and Earth distances ( $R$  and  $D$ , respectively) for the time of each lightcurve extremum, and the reduced magnitude  $V_R = V - 5\log(RD)$  was calculated using this information. The phase curves ( $V_R$  vs.  $\alpha$ ) for the lightcurve maxima and minima are shown in Figure 2. The best fits to the data are:

Lightcurve brightness maxima

$$H_{max} = 12.053 \pm 0.006, G = 0.259 \pm 0.008$$

Lightcurve brightness minima

$$H_{min} = 12.289 \pm 0.009, G = 0.246 \pm 0.014$$

Combining these, the best estimate of the mean V-magnitude is

$$H_0 = 12.17 \pm 0.02, G = 0.25 \pm 0.01$$

This value of absolute magnitude is consistent with the previously-reported data recorded in the asteroid lightcurve database.

This appears to be the first report of a phase curve for this object. In the small bodies node (<http://pdssbn.astro.umd.edu/>), 1130 Skuld is identified as a “class S” asteroid, and the slope parameter determined here is consistent with that designation. It is a member of the Flora dynamical family; I note that the slope parameter for 4 Flora is reported as  $G = 0.28$ , so my reported slope parameter of 1130 Skuld is quite similar to that of the main body of this family.

#### References

Behrend (2009) reported at:

[http://obswww.unige.ch/~behrend/page\\_cou.html](http://obswww.unige.ch/~behrend/page_cou.html)

Robinson (2009) reported at: <http://btboar.tripod.com/lightcurves/>

#### Acknowledgements

This research made use of the JPL Horizons system (<http://ssd.jpl.nasa.gov/?horizons>), and the NASA Astrophysics Data System (<http://adswww.harvard.edu/index.html>).

## CCD PHOTOMETRY AND LIGHTCURVE ANALYSIS OF 985 ROSINA AND 990 YERKES FROM GRUP D’ASTRONOMIA DE TIANA (G.A.T.) OBSERVATORY

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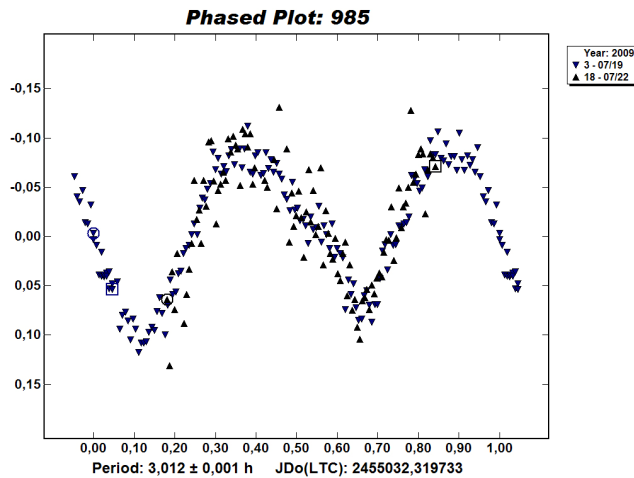
Two first lightcurve determination attempts were carried out from the Grup d’Astronomia de Tiana Observatory on several nights spanning from 2009 July 19 to November 10. The asteroids covered by this work are 985 Rosina, a body of known lightcurve parameters, and 990 Yerkes, a main-belt asteroid whose period had not been determined to date. We obtained a synodic period of  $3.012 \pm 0.001$  h for 985 Rosina that matches very accurately previous lightcurve measurements. For 990 Yerkes a  $24.56 \pm 0.01$  h period and 0.25 mag amplitude has been tentatively established by our observations.

The *Grup d’Astronomia de Tiana* (G.A.T.) Observatory is situated in Tiana, in the southernmost part of the *Serra de Marina*, a moderately-polluted suburban park 15 km north of Barcelona. In spite of the limitations imposed by the local light conditions, useful observations can still be carried out thanks to the forest surrounding the building. The G.A.T. Observatory was recently equipped with a Paramount GEM (German Equatorial Mount), a 43-cm modified Dall-Kirkham Planewave reflector, and a dual-chip SBIG STL-1001 CCD camera with filter wheel and AO-L adaptive optics unit, yielding a 28.9' x 28.9' field of view and an effective resolution of 1.70 arc sec/pix.

This work has been carried out by four members of the G.A.T.: Jaume Martínez, who has been carrying out a high-school research project, was in charge of target selection, telescope operation, and data processing; Joan Martín operated the telescope and acquired images on several nights; Ramón Bosque worked in data reduction and revised this paper, and Josep M. Aymami acquired, processed and reduced data, and wrote this paper.

985 Rosina is a Mars-crossing (MC) asteroid ( $e = 0.27669$ ,  $a = 2.2997$ ) with a well known rotational period of 3.0126 h (quality code 3; see documentation in Warner et al, 2009) and an amplitude of 0.22 mag (Behrend, 2009). We collected 260 60s images on the nights of 2009 July 19 and July 22 through a C filter with *Maxim DL* acquisition software. The imaging chip of the STL-1001 CCD camera operated at  $-20^\circ$  C and all images were calibrated with master bias, dark, and flat frames. Differential photometry of the asteroid was performed “live” at the observatory by using *Fotodif*, a free software program that allows us to follow the asteroid’s lightcurve easily on-site as the images are being downloaded. Measurements carried out with different software packages (*Astrometrica* and *Focas II*) showed that the asteroid’s brightness compared to a number of stars in the R band of the USNO A2 catalogue was approximately mag 13.8. With the weather cooperating, we managed to capture a full rotation period on the very first night and, after obtaining images on a second night, we could derive our own lightcurve with *Canopus*, which shows a period of  $3.012$  h  $\pm$  0.001 h and 0.22 mag amplitude,

which are in good agreement with the published data (see references in Warner et al, 2009).



**990 Yerkes.** This main-belt asteroid ( $e = 0.21556$ ,  $a = 2.66838$ ) was the next target of a short list that we set at the end of northern summer. The choice was based on its favourable location in the sky in the 2009 September–November timeframe with a maximum forecast brightness of about mag 14 as well as the fact that no known period had been reported to date according to the Lightcurve Database (Warner et al. 2009). Free software, *Orbitas*, helped us prepare an ephemeris showing that 990 Yerkes would remain rather weak until mid-August 2013, when it would briefly reach mag 14 again. We subsequently discovered that 990 Yerkes had been included in the Lightcurve Photometry Opportunities section of the third quarter *Minor Planet Bulletin*.

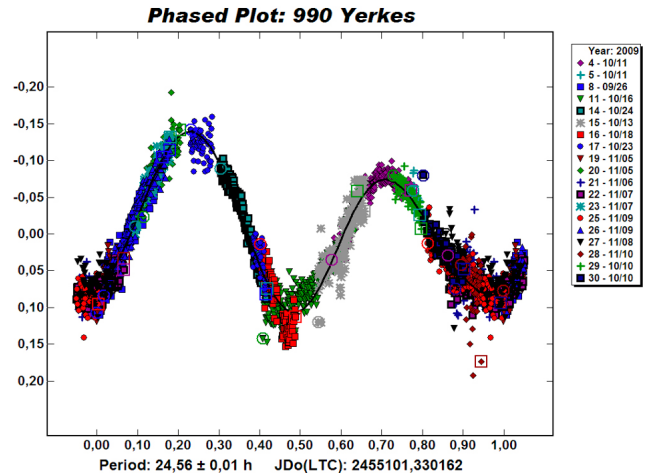
Our observations cover a range of phase angles ( $5.3^\circ$  to  $16.7^\circ$ ). Only on three nights did the asteroid rise above mag 14. The images were fully calibrated with master bias, dark, and flat frames, with the CCD chip working at  $-15^\circ\text{C}$ .

Date	Phase Angle	Forecast Mag.	Observations
2009 09 26	16.7	14.47	39
2009 09 27	16.2	14.45	96
2009 10 11	9.9	14.43	147
2009 10 13	9.0	14.09	156
2009 10 14	8.6	14.07	97
2009 10 16	7.7	14.03	236
2009 10 17	7.3	14.01	82
2009 10 18	6.9	13.99	114
2009 10 23	5.3	13.91	234
2009 10 24	5.1	13.91	12
2009 11 05	6.9	14.06	106
2009 11 06	7.3	14.09	258
2009 11 07	7.7	14.12	188
2009 11 08	8.1	14.14	169
2009 11 09	8.6	14.17	16

Table I. Observing circumstances for 990 Yerkes.

Initial data from the first observing sessions (2009 Sep 26 to Oct 11) spanning 3 h each night showed clear ascending and descending branches of notable amplitude (over 0.15 mag). It soon became clear that 990 Yerkes rotational period was going to be longer than we might have anticipated. On the night of Oct 11, an ascending branch and a turning point were clearly established and several additional fragments were observed between Oct 11 and Oct 24. A series of cloudy days prevented us from continuing to

monitor the asteroid, and we could only speculate on several solutions ranging from 25 to 32 h. We restarted the observations after the October full moon, and 60s–90s exposures were acquired the nights of Nov 5 to Nov 10 through C filter. These provided more comprehensive coverage and allowed us to refine the lightcurve that we present here. Our best estimate period for 990 Yerkes  $24.56 \pm 0.01$  h with 0.25 mag. amplitude.



#### Acknowledgements

Special thanks to Ramon Naves (MPC 213) who made suggestions during the project, and Julio Castellano (MPC 939) who keeps improving *FotoDif* with new capabilities. Brian Warner gently helped to solve some issues. Thanks also to all the members of the G.A.T. for the telescope time we were granted. The economic support from the *Ajuntament de Tiana* and the *Diputació de Barcelona* is gratefully acknowledged.

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## LIGHTCURVE AND H-G PARAMETERS FOR SLOW ROTATOR 244 SITA

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Lightcurves and absolute photometry near opposition revealed photometric results for 244 Sita:  $P = 129.056 \pm 0.021$  h,  $A = 0.80 \pm 0.05$  mag,  $H = 12.21 \pm 0.07$  mag,  $G = 0.59 \pm 0.11$ .

Selection of 244 Sita was made from the quarterly lightcurve photometry opportunities article published in *The Minor Planet Bulletin* (Warner et al, 2009a). Asteroid 244 was a reasonably bright target with V magnitudes ranging from 13.4 to 15.1 and nightly visibility of 4 to 6 hours over the period 2009 October 1 to December 1. Opposition was on October 12.

Observations were made with a 0.36-m C-14 f/6.7 Schmidt-Cassegrain telescope and SBIG ST-10XME camera. The camera was run at -15C and binned 2x2 resulting in 1.4 arcsecond/pixel scale. No guiding was necessary. On each night a Landolt reference field was imaged with V, R, and Clear filters at an air mass as close as possible to 2 followed by a Henden field as close as possible to air mass of 1 and in close proximity to the study asteroid, which was also imaged in the three filters. Exposures ranged from 30 to 120 seconds. The nightly three-color data were reduced using *MPO Canopus/PhotoRed* routines (Bdw Publishing, 2008), computing transforms, extinction, and V-R color indices for the reference stars and object, thus reducing the values to standard magnitudes. The target field in V filter was also reduced using the *Quick Binzel* routine within *PhotoRed*. This routine calculates the V offset for a number of field stars and applies the average offset to the target V mag. This method proved more consistent with the poor nightly sky conditions.

Initial photometric data of 244 Sita indicated that it was a slow rotator with a period greater than 70 hours. Extensive instrumental data consisting of 2199 images were collected from 2009 October 1 through December 1 to reach sufficient confidence in the period of  $129.056 \pm 0.021$  h with an amplitude of  $0.80 \pm 0.05$  mag. Alternate periods of 131.38 h and 127.90 h were also investigated but rejected due to their lower confidence levels. Previously published data by Brinsfield (2009) indicated a period of  $129.51 \pm 0.03$  h with amplitude of  $0.82 \pm 0.25$  mag. While results closely matched an attempt to fit the data to  $P = 129.51$  h yielded a low confidence solution.

The data from 244 Sita were corrected to a mean value such that all data points were effectively at the same part of the lightcurve. The data were then corrected for (R) Sun-asteroid distance and (r) the Earth-asteroid distance. The H/G calculator in *MPO Canopus* was used to make these calculations and plot the data. For a more complete discussion of the H-G magnitude system and reduction process refer to Vander Haagen (2009) or contact the author by email for an electronic version of that paper.

With a derived value of  $G = 0.59 \pm 0.11$ , the results were correlated with data published on the relationship among albedos, phase slope parameter ( $G$ ), and taxonomic class (Warner et al. 2009b, Table 4). 244 Sita's phase slope parameter ( $G$ ) places the

asteroid above the highest albedos of the V and E taxonomic class with  $G = 0.483 \pm 0.025$ . Checking the Bus and Binzel (2002) SMASS II spectral classification shows 244 Sita designated as a Sa taxonomic subclass with all S primary class assumed  $G = 0.242 \pm 0.112$ . This discrepancy cannot be explained.

Using the subclass Sa albedo for 244 Sita and previously noted Table 4,  $p_V = 0.176 \pm 0.042$ . Assuming a  $G = 0.592$  places the slope parameter ( $G$ ) outside the highest range for the V and E class with albedos of  $0.479 \pm 0.068$ . Using this range of albedos and absolute magnitude,  $H = 12.21$ , allows calculation of the diameter using the expression (Pravec and Harris, 2007):

$$\log D_{(\text{km})} = 3.1235 - 0.2H - 0.5\log(p_V)$$

This expression yields  $D = 6.95$  km,  $p_V = 0.479$  and  $D = 11.46$  km,  $p_V = 0.176$ .

In conclusion, the period and amplitude of 244 Sita correlate well with previously published data. The slope parameter from this study produces more questions than answers. With  $G = 0.592$  it is significantly higher than any previously direct-measured slope parameter value, Vander Haagen (2009), and does not correlate with ( $G$ ) values expected from the SMASS II spectral

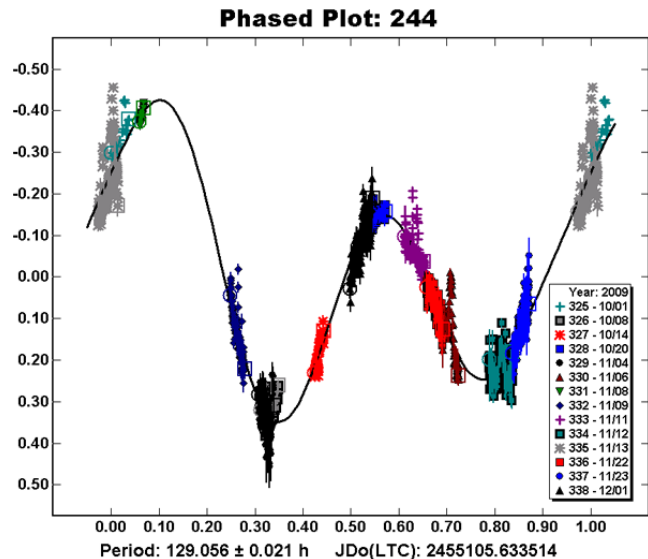


Figure 1. Lightcurve of 244 Sita Phased to 129.056 h

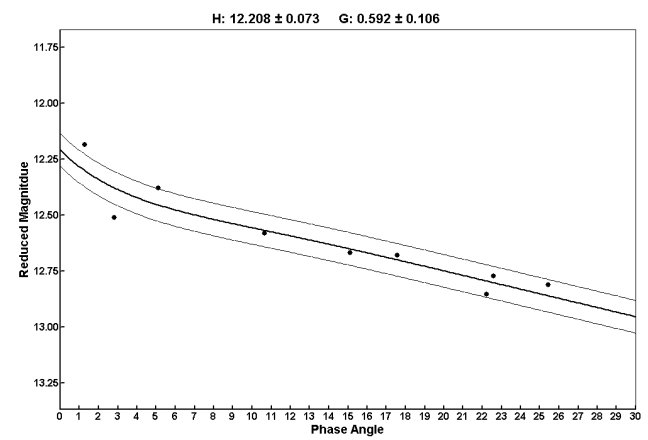


Figure 2. 244 Sita H-G Parameter Phase Angle Plot

classification for 244 Sita. Errors in absolute magnitude, phasing, and calculation of the normalization offset could contribute to a partial answer. Several trials to simulate that condition were made and did not significantly lower the slope parameter value. Further study of this asteroid will be necessary.

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### ROTATION PERIOD DETERMINATIONS FOR 81 TERPSICHORE, 419 AURELIA, 452 HAMILTONIA, 610 VALESKA, 649 JOSEFA, AND 652 JUBILATRIX

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Synodic rotation periods and amplitudes have been found for 81 Terpsichore  $10.943 \pm 0.002$  h,  $0.08 \pm 0.01$  mag with one maximum and minimum per cycle; 419 Aurelia  $16.781 \pm 0.001$  h,  $0.10 \pm 0.01$  mag; 452 Hamiltonia  $2.8813 \pm 0.0001$  h,  $0.17 \pm 0.03$  mag; 610 Valeska  $4.9047 \pm 0.0002$  h,  $0.17 \pm 0.03$  mag; 649 Josefa  $10.481 \pm 0.001$  h,  $0.33 \pm 0.04$  mag; and 652 Jubilatrix  $2.6627 \pm 0.0001$  h,  $0.27 \pm 0.03$  mag.

Observations to produce these reported period and amplitude determinations have all been made at the Organ Mesa Observatory. Equipment consists of a Meade 35 cm LX200 GPS S-C, SBIG STL-1001E CCD, differential photometry only, unguided exposures. An R filter was used for the brighter targets 81 Terpsichore and 419 Aurelia. A clear filter was used for the other targets, which were all very faint. Image measurement and lightcurve analysis were done by *MPO Canopus*. Due to the large number of data points acquired for each target in this study the lightcurves have been binned in sets of three data points with a maximum of five minutes between points.

81 Terpsichore. Zeigler (1990) obtained a smooth bimodal lightcurve with period 11.02 hours, amplitude 0.10 magnitude. Fauerbach et. al. (2007) found a more complex lightcurve at a different longitude, with compatible period 11.207 hours, amplitude 0.10 magnitude. New observations on 7 nights 2009 Oct. 24 – Dec. 5 show a period  $10.943 \pm 0.002$  hours, amplitude  $0.08 \pm 0.01$  magnitudes with an irregular monomodal lightcurve. A bimodal lightcurve with period 21.883 hours was examined. It was rejected because the two halves looked the same and the coefficients of the higher order odd harmonics were systematically much smaller than those of the even order harmonics.

419 Aurelia. The Asteroid Lightcurve Data Base (Harris et. al. 2009) shows a period 16.788 hours, reliability 3 (secure). New observations were made on 9 nights 2009 Sept. 24 – Nov. 22 to provide data for a spin/shape model. These show a period  $16.781 \pm 0.001$  hours. The amplitude increased from  $0.08 \pm 0.01$  magnitudes in September and October to  $0.10 \pm 0.01$  magnitudes in November as a consequence of increasing phase angle.

452 Hamiltonia. The Asteroid Lightcurve Data Base (Harris et. al. 2009) shows no previous observations. Observations on 5 nights 2009 Sept. 26 – Oct. 18 show a period  $2.8813 \pm 0.0001$  hours, amplitude  $0.17 \pm 0.03$  magnitudes.

610 Valeska. The Asteroid Lightcurve Data Base (Harris et. al. 2009) shows no previous observations. Observations on 6 nights 2009 Oct. 12 – Nov. 8 show a period  $4.9047 \pm 0.0002$  hours, amplitude  $0.17 \pm 0.03$  magnitudes.

649 Josefa. The Asteroid Lightcurve Data Base (Harris et. al. 2009) shows no previous observations. Observations on 6 nights 2009 Oct. 16 – Nov. 20 show a period  $10.481 \pm 0.001$  hours, amplitude  $0.33 \pm 0.04$  magnitudes.

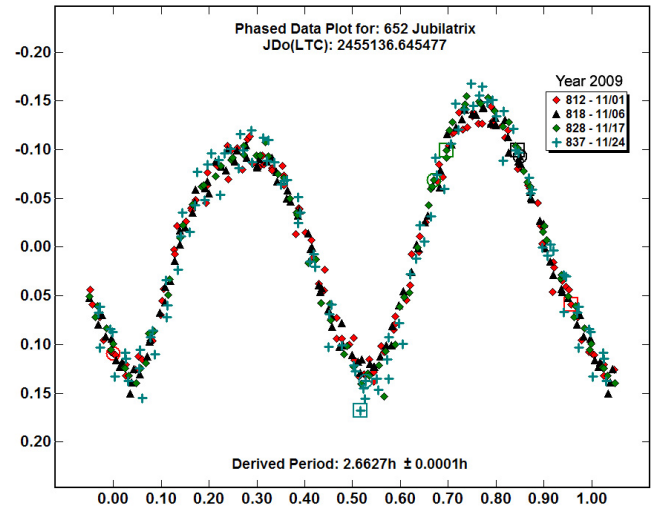
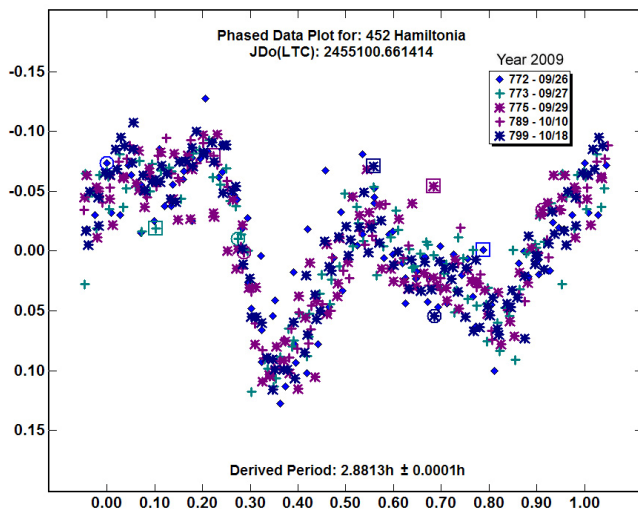
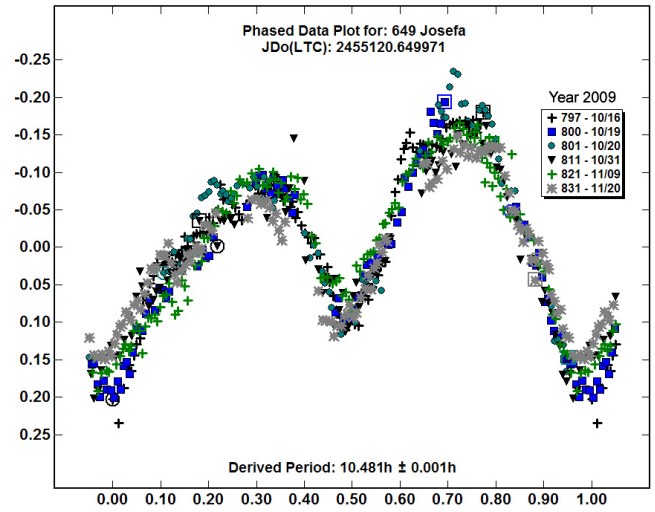
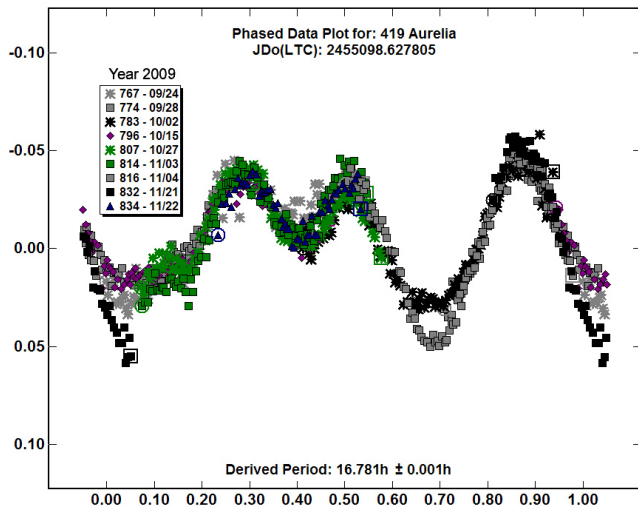
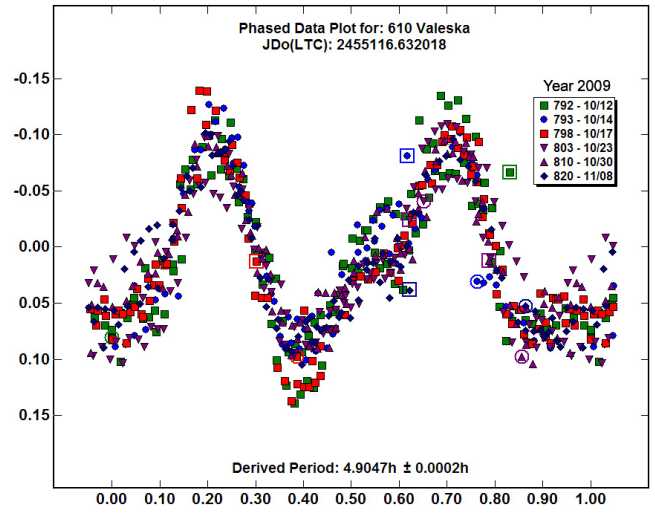
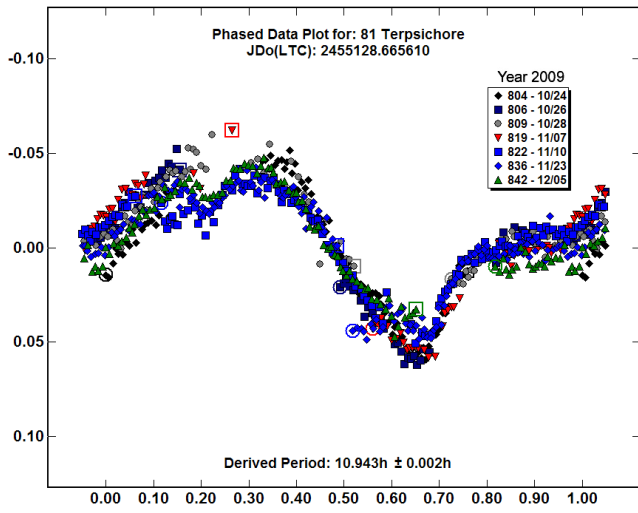
652 Jubilatrix. The Asteroid Lightcurve Data Base (Harris et. al. 2009) shows no previous observations. Observations on 4 nights 2009 Nov. 1 – 24 show a period  $2.6627 \pm 0.0001$  hours, amplitude  $0.27 \pm 0.03$  magnitudes. When, as in this study, successive sessions are separated in time by many cycles, the number of cycles between sessions cannot be counted accurately and alias periods arise. If these sessions are separated by different numbers of days, the aliases are removed. Attention was given to this procedure, and other minima in the period spectrum did not show plausible lightcurves.

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**TROJAN ASTEROIDS OBSERVED FROM GMARS  
AND SANTANA OBSERVATORIES:  
2009 OCTOBER - DECEMBER**

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Lightcurves for six Trojan asteroids were obtained from Santana and GMARS Observatories from 2009 October to December: 588 Achilles, 1583 Antilochus, 2456 Palamedes, 3548 Eurybates, 3564 Talyhybius, and 3793 Leonteus.

Observations at Santana Observatory (MPC Code 646) were made with a 0.30-m Schmidt-Cassegrain (SCT) with an SBIG STL-1001E. Observations at GMARS (Goat Mountain Astronomical Research Station, MPC G79) were made with two telescopes, both 0.35-m SCT using SBIG STL-1001E CCD Cameras. All images were unguided and unbinned with no filter. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989). The asteroids were selected from the Trojan family that had no published or an ambiguous rotational period.

The results are summarized in the table below, as are individual plots. The plots are “phased”, i.e., they range from 0.0 to 1.0 of the stated period. The plots are scaled such that 1.0 mag has the same linear size as the horizontal axis from 0.0 to 1.0. This is done to avoid the visual impression that the amplitude variation is greater than it actually is, which can create the impression of a physically implausible lightcurve. 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; Stephens, 2008).

588 Achilles. All images were taken at Santana Observatory. Zappala (1989) observed Achilles in 1988 September on a single night reporting a period of about 10 h. Angeli (1999) reported a period of 8.67 h. Shevchenko (2009) observed Achilles between 2007 July and October and in 2008 September, reporting a period of 7.306 h. The period of 7.312 h reported here is in good agreement with the Shevchenko results.

1583 Antilochus. Images on 2009 December 14 and 19 were obtained at GMARS. All others were at Santana Observatory. Behrend (2009) reported a period of 22.6 h based upon a single

night of observations in 2009 December. Zappala et al. (1989) reported a period exceeding 12 hours based upon a single night of observations in 1985 September. The stated amplitude was 0.10 magnitude. It was 0.05 mag when a few outlier data points were removed. Binzel and Sauter (1992) observed a single night in 1988 January showing an amplitude of 0.03 magnitude over 3 hours.

2456 Palamedes. All images were taken at GMARS. No previous periods were reported.

3548 Eurybates. All observations were obtained at GMARS. No previous periods were reported.

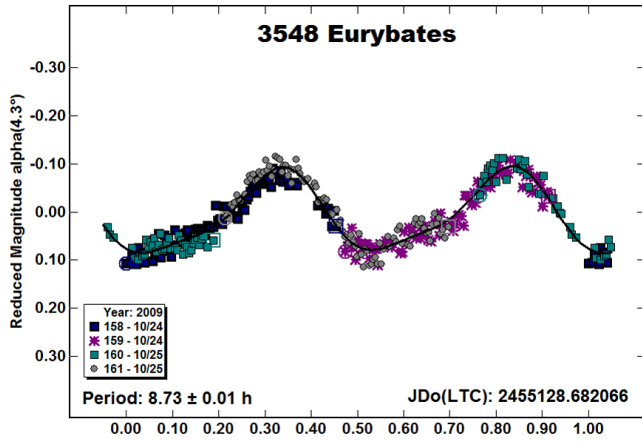
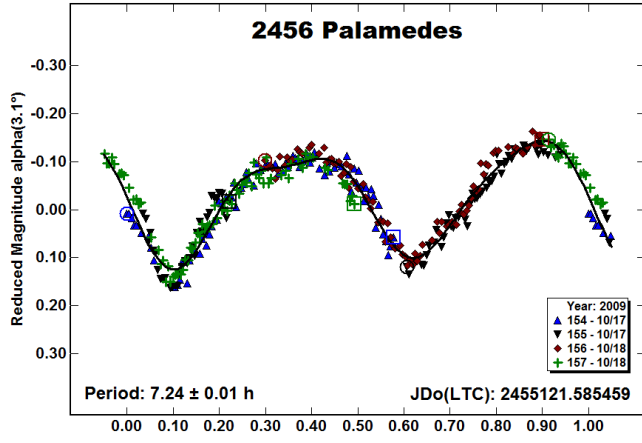
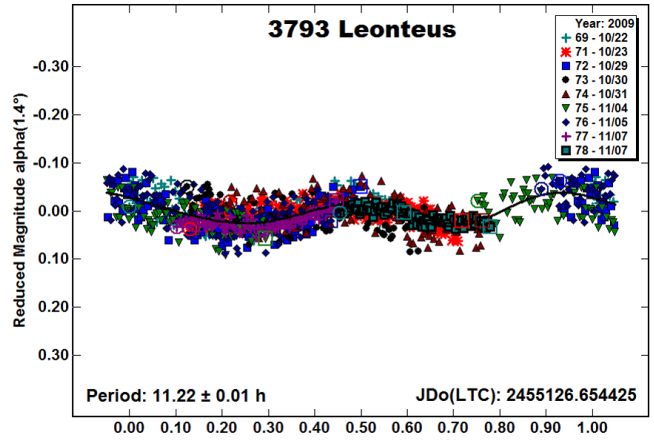
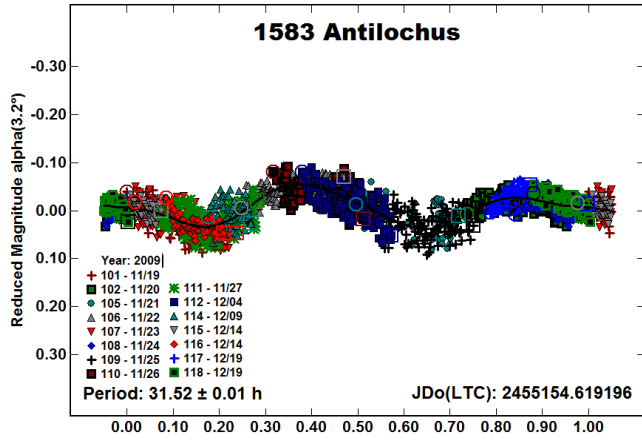
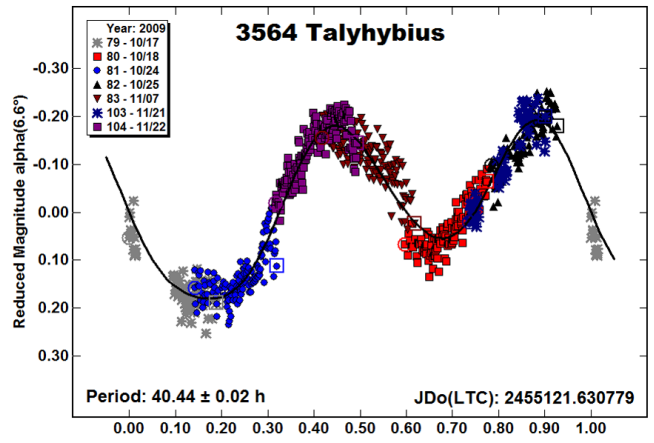
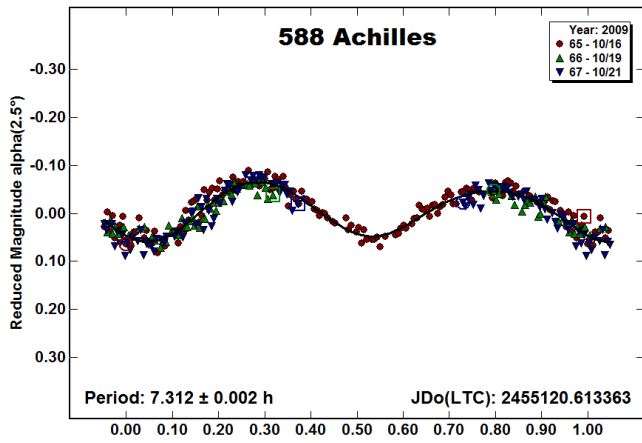
3564 Talyhybius. All observations were obtained at GMARS. No previous periods were reported.

3793 Leonteus. Images on 2009 November 16 were obtained at GMARS. All other observations were obtained at Santana Observatory. No previous periods were reported.

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#	Name	mm/dd 2009	Data Pts	$\alpha$	L <sub>PAB</sub>	B <sub>PAB</sub>	Per (h)	PE	Amp (mag)	AE
588	Achilles	10/16 - 10/21	588	2.5, 2.6	24	11	7.312	0.003	0.11	0.03
1583	Antilochus	11/19 - 12/19	1,733	2.8, 8.6	44	-3	31.52	0.01	0.09	0.02
2456	Palamedes	10/17 - 10/18	353	2.9, 3.0	20	13	7.24	0.01	0.27	0.03
3548	Eurybates	10/24 - 10/25	339	4.4, 4.2	50	1	8.73	0.01	0.19	0.03
3564	Talyhybius	10/17 - 11/22	810	0.2, 6.5	24	1	40.44	0.02	0.38	0.03
3793	Leonteus	10/22 - 11/07	1,006	1.5, 2.8	33	-5	11.22	0.01	0.05	0.02



**A COLLABORATIVE STUDY OF THE ROTATIONAL PERIOD OF (26380) 1999 JY65**

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Lightcurve data of (26380) 1999 JY65 were acquired at the Gothers Observatory in the UK and Via Capote Observatory in California. A synodic period of  $13.653 \pm 0.001$  h with amplitude of 0.42 mag was obtained in this collaborative effort.

Observations at Gothers Observatory were made using a Meade LX-200 0.25-m Schmidt-Cassegrain (SCT) equipped with a focal reducer to yield a focal ratio f/4.15. The CCD imager was a QHY6Pro featuring a 752 X 585 array of 8.6x8.3 micron pixels. The CCD was operating at a temperature of -10° C. All observations were taken unfiltered at 1x binning yielding an image scale of 1.63x1.69 arcseconds per pixel. All images were dark and flat field corrected. Observations at the Via Capote Observatory were made using a Meade LX-200 0.36-m SCT at the f/10 prime

focus. The CCD imager was an Alta U6 featuring a 1024x1024 array of 24-micron pixels. All observations were made unfiltered at 1x binning yielding an image scale of 1.44 arcseconds per pixel. All images were dark and flat field corrected.

The target was selected from the Collaborative Asteroid Lightcurve Link (CALL) web-site (Warner, 2009) and "Lightcurve Opportunities" articles from the *Minor Planet Bulletin*. A combination of different tools was used. Data acquired at the Gothers Observatory were calibrated and differential photometry performed using *Astrometrica* (Raab, 2009) with the Carlsberg Meridian Catalogue 14 (Evans et al., 2002) used for reference magnitudes. Data acquired at Via Capote were measured using *MPO Canopus* (Bdw Publishing). At Via Capote, observations were made using unfiltered differential photometry and all data were light-time corrected. Period analysis was also done with *Canopus*, incorporating the Fourier analysis algorithm developed by Harris (1989).

Observations began at Gothers Observatory on 2009 September 26, four days prior to opposition. After the first two sessions, the data seemed to suggest a period of close to 24 hours and a posting was made on the CALL web-site (Warner, 2009) requesting collaboration from a location well-displaced in longitude from Gothers. Via Capote joined the study with initial measurements beginning on October 17. Equipment and weather limitations at Gothers limited the data to four sessions with 256 observations. Via Capote was able to observe the target well into November and obtained 521 measurements on the target over seven sessions. Total coverage of the target spanned 50 days, which included opposition. Due mostly to differences in the processing software, combining the observations proved to be challenging. First, the data obtained at Via Capote were phased to obtain a best-fit lightcurve period of  $13.653 \pm 0.001$  h (Figure 1). These phased data were then exported to a spread sheet analysis tool where they were combined with the data from Gothers, the latter being adjusted to provide the best fit to the Via Capote data. Essentially, the Via Capote data were used to determine the lightcurve characteristics and then the Gothers data were applied to confirm the analysis. The combined data set is plotted below (Figure 2). The data legend indicates which location supplied the data on a given date.

There is significant dispersion of the data around the maxima and minima of the curve. This is true for data obtained at both locations. The most likely cause is the fact that the solar phase angle changed rather significantly from the first to the last observation session and the target crossed through opposition. In the Via Capote data for example, on October 17, the phase angle was  $10.4^\circ$  and the curve's amplitude was about 0.27 mag. By November 14, the solar phase angle was  $21.1^\circ$  and the amplitude was about 0.44 mag. As a result of this variability, the uncertainty in the amplitude value reported here is a rather large 0.1 mag.

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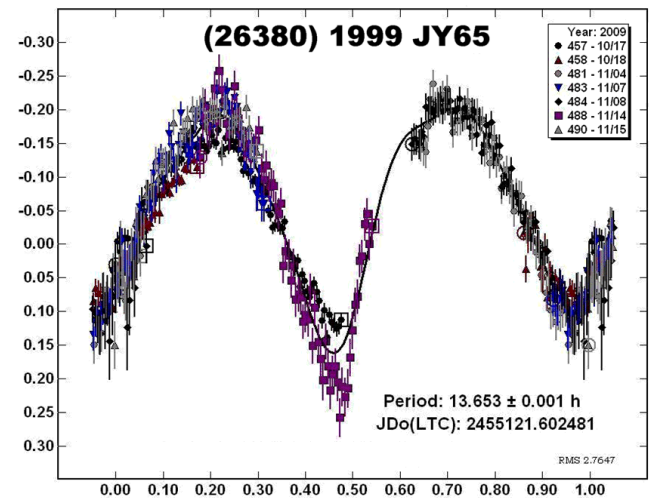


Figure 1. The Via Capote data phased to 13.653 h.

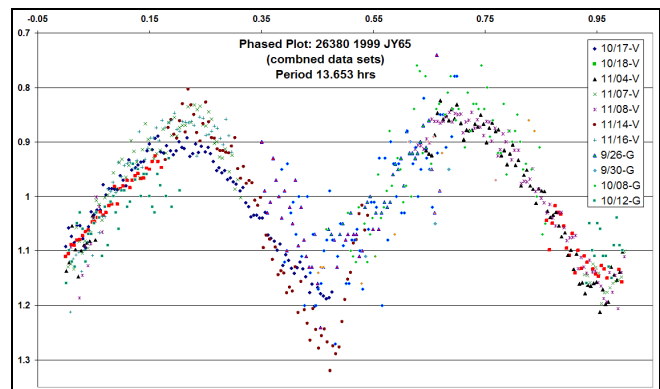


Figure 2. The combined data set for (26380) 1999 JY65.

Date Range (mm/dd/2009)	Data Points	Phase	L <sub>PAB</sub>	B <sub>PAB</sub>	Per(h)	PE	Amp(m)	AE
09/26 - 11/16	777	5.0 4.4 21.4	9.0	3.9	13.653	± 0.001	0.42	0.1

Table I. The combined observation results for (26380) 1999 JY65. The middle phase angle value is the minimum phase angle observed and the two end values are those at the beginning and end of the observing campaign.

## ROTATION PERIOD DETERMINATION FOR 285 REGINA

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The synodic rotation period and amplitude for 285 Regina are found to be  $9.542 \pm 0.001$  hours,  $0.16 \pm 0.03$  magnitudes

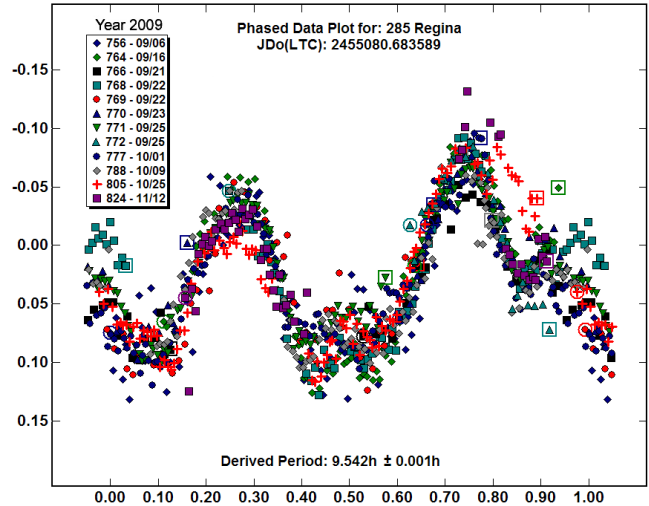
Observations by Pilcher were obtained at the Organ Mesa Observatory. Equipment consisted of a 35 cm Meade S-C, SBIG STL-1001E CCD, clear filter and unguided. Observations by Benishek were obtained at the Belgrade Astronomical Observatory with a 40 cm Meade S-C, SBIG ST-10 XME CCD, unfiltered and unguided.

Molnar et. al. (2008) published the only previous period determination with a period 31.64 hours. New observations on 12 nights 2009 Sept. 6 – Nov. 12 show a period of  $9.542 \pm 0.001$

hours, amplitude  $0.16 \pm 0.03$  magnitudes, and rule out the much longer period.

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## ASTEROID LIGHTCURVE ANALYSIS AT THE VIA CAPOTE OBSERVATORY: 4TH QUARTER 2009

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(Received: 30 December 2009)

Nine asteroids were observed and their lightcurve periods and amplitudes were measured at the Via Capote Observatory from 2009 September through December 2009: 449 Hamburga ( $18.263 + 0.004$  h; 0.09 mag), 527 Euryanthe ( $26.06 + 0.01$  h; 0.12 mag), 1023 Thomana ( $17.65 + 0.01$  h; 0.38 mag), 1345 Potomac ( $11.41 + 0.01$  h; 0.24 mag), 1398 Donnera ( $7.23 + 0.01$  h; 0.15 mag), 1564 Srbija ( $9.135 + 0.001$  h; 0.17 mag), 1994 Shane ( $8.220 + 0.001$  h; 0.26 mag), 2888 Hodgson ( $6.905 + 0.001$  h; 0.14 mag), and 15967 Clairearmstrong ( $5.90 + 0.01$  h; 0.33 mag).

CCD observations of nine asteroids were made at the Via Capote Observatory from 2009 September to December. The telescope was a Meade LX-200 0.36-m Schmidt-Cassegrain (SCT) working at the f/10 prime focus. The CCD imager was an Alta U6 with a 1024x1024 array of 24-micron pixels. All observations were made unfiltered at 1x binning yielding an image scale of 1.44 arcseconds per pixel. All images were dark and flat field corrected. The images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. The data were light-time corrected. Period analysis was also done with *Canopus*, which incorporates the Fourier analysis algorithm

developed by Harris (1989). Most target selections were made using the Collaborative Asteroid Lightcurve Link (CALL) website (Warner, 2009) and "Lightcurve Opportunities" articles from the *Minor Planet Bulletin*. Priority was given to asteroids that did not have a published rotational period.

The results are summarized in the table below along with individual lightcurves and additional comments, as required. Four of the six targets studied during the reporting period did not have previously published lightcurves.

1023 Thomana. Behrend (2009) reports a period of 17.561 h, which agrees well with the period derived during this campaign (17.56 hr). The amplitude was observed to be somewhat higher here than what Behrend reported (0.25 mag vs. 0.38 mag).

1345 Potomac. Both Hartman et al. (1988) and Dahlgren et al. (1998) report a period of 11.40 h and curve amplitude of 0.22 mag. The results here agree those previous studies.

1398 Donnera. Behrend (2009) reports a period of 7.3 h and amplitude of 0.23 mag based on incomplete coverage. Complete coverage obtained during this campaign allows for the period to be further refined to 7.23 h with an amplitude of 0.15 mag.

1564 Srbija. Angliongto and Mijic (2007) report a period of 29.64 h and amplitude of 0.37 mag with incomplete coverage. Complete coverage, spanning opposition, was obtained during this campaign. The period was determined to be 9.135 h and the amplitude 0.17 mag. This is a very substantial departure from the Angliongto result. The period spectrum shown below reveals a candidate period matching the Angliongto report; it is less preferred than the 9.135 h period.

1564 Srbija has a rather unusual-shaped lightcurve exhibiting a very prominent minimum. An attempt was made to sample data

more densely in this transitional area of the lightcurve. The result shows how the amplitude of this feature seemed to flatten out and shift phase somewhat as the measurements approached opposition. This may be the result of some pronounced shadowing occurring over a very prominent physical feature on the asteroid itself, the general result of the dependency of amplitude on phase angle (see Zappalà et al., 1990), and/or a change in the synodic period over the span of the observations.

1994 Shane. Florczak et al. (1997) report a period of 25 h and amplitude of > 0.1 mag with fragmentary data. Complete coverage obtained during this campaign suggests a period of 8.220 h and amplitude of 0.26 mag. The period spectrum does reveal a candidate period matching the Florczak et al. report; however, this appears to be a third harmonic of the preferred period.

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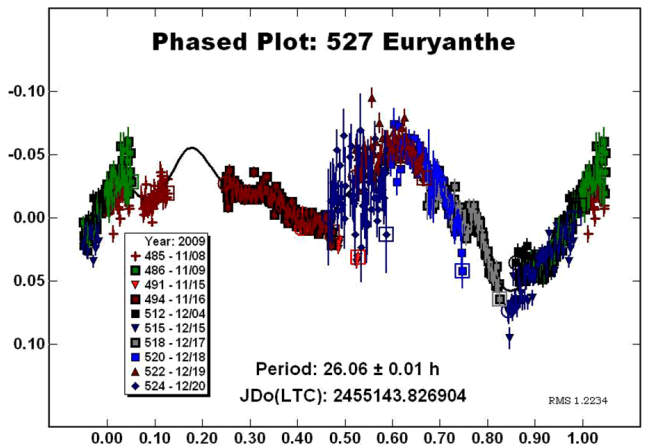
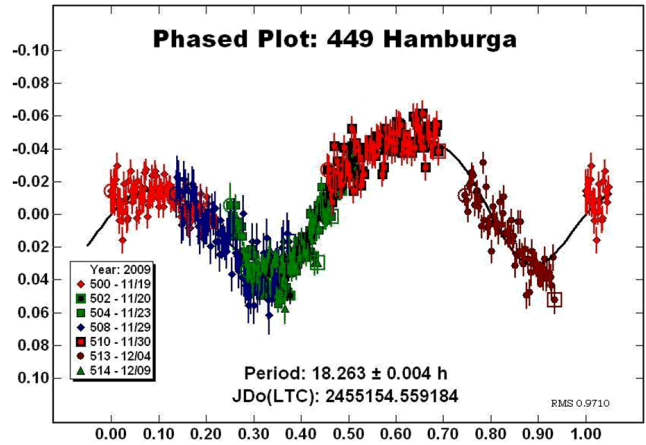
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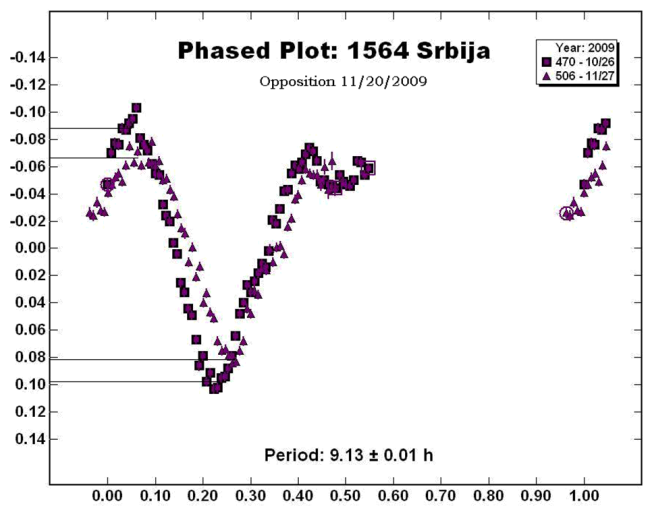
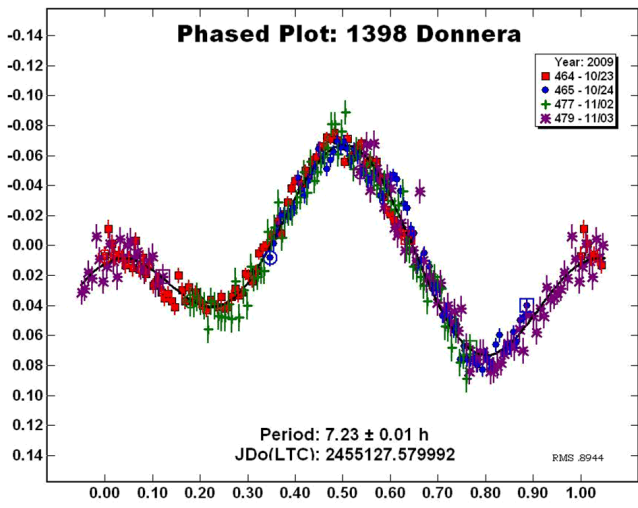
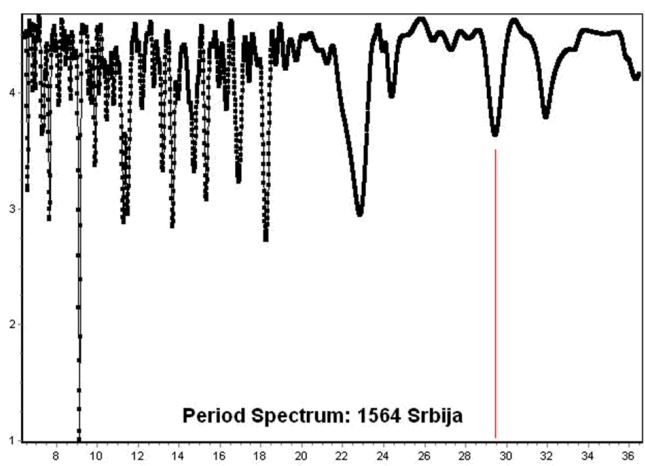
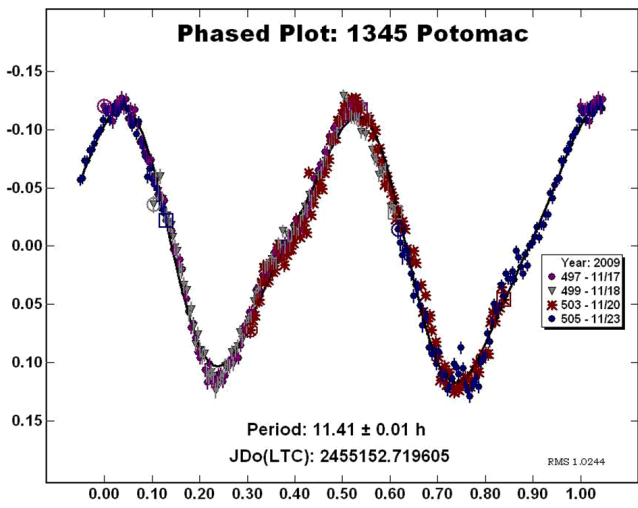
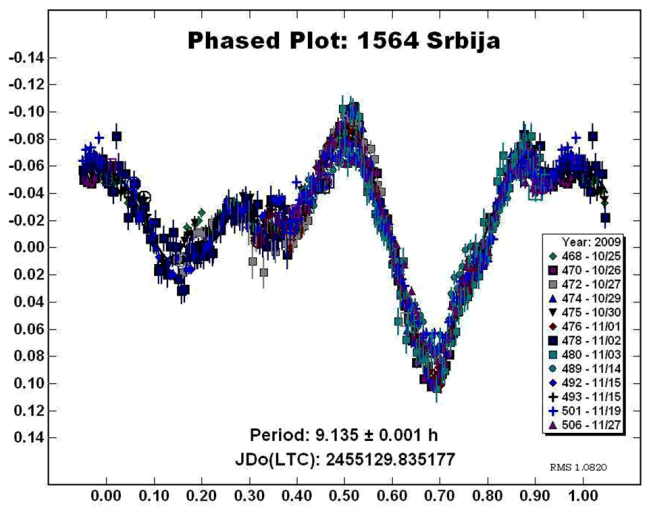
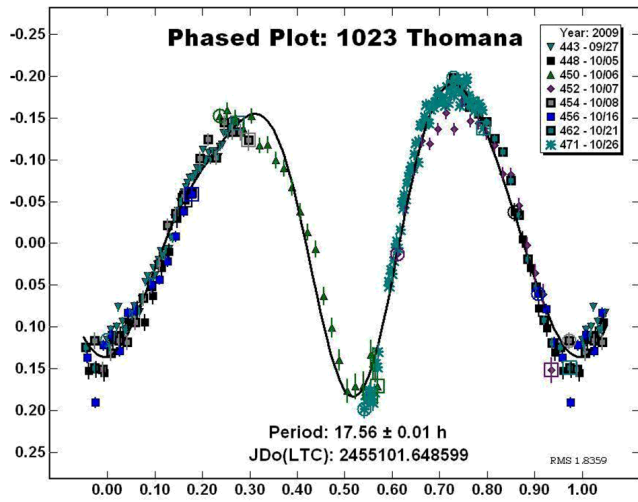
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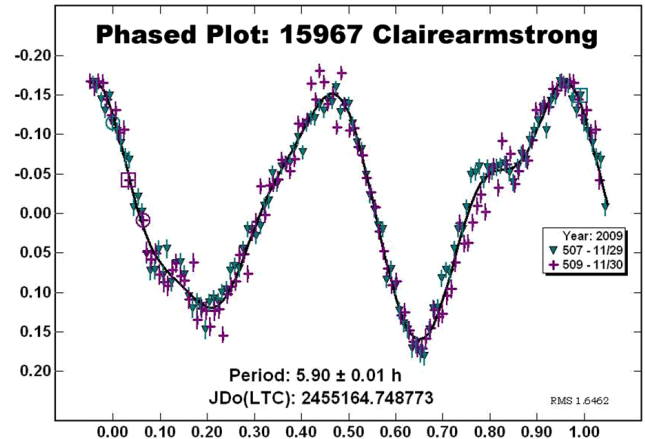
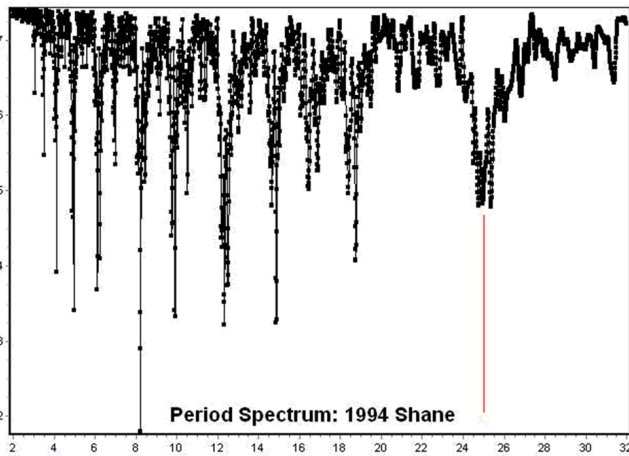
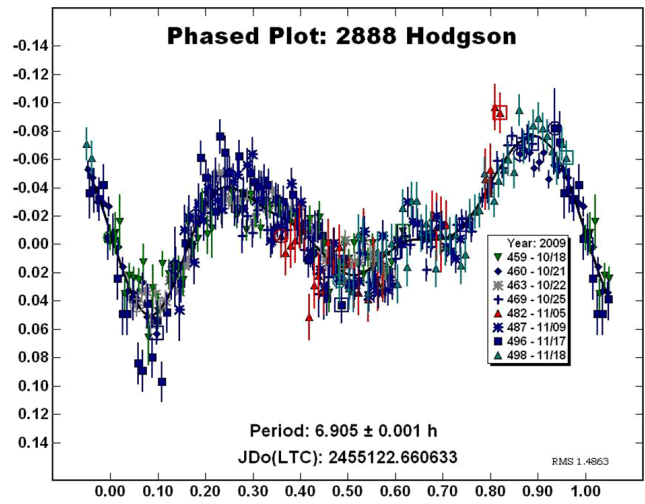
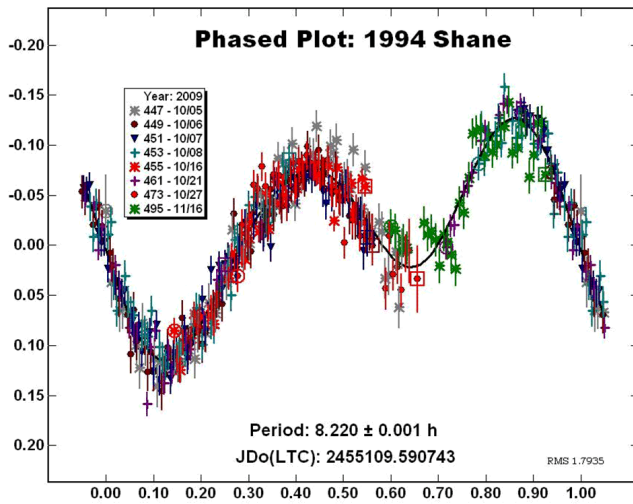
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Asteroid	Date Range (mm/dd/2009)	Data Points	Phase	L <sub>PAB</sub>	B <sub>PAB</sub>	Per(h)	PE	Amp (m)	AE
449 Hamburga	11/19-12/09	508	19.9	7	-3	18.263	0.004	0.09	0.02
527 Euryanthe	11/08-12/20	774	5.7, 5.4, 15.2	50	-11	26.06	0.01	0.12	0.02
1023 Thomana	09/27-10/26	259	14.7	336	6	17.56	0.01	0.38	0.02
1345 Potomac	11/17-11/23	446	4.7	63	-13	11.41	0.01	0.24	0.02
1398 Donnera	10/23-11/03	320	14	1	14	7.23	0.01	0.15	0.02
1564 Srbija	10/25-11/27	866	11.6, 5.8, 7.2	55	-12	9.135	0.001	0.17	0.04
1994 Shane	10/05-11/16	448	22.4	346	12	8.220	0.001	0.26	0.05
2888 Hodgson	10/18-11/18	392	17.2	10	5	6.905	0.001	0.14	0.03
15967 Clairearmstrong	11/29-11/30	221	10.3	73	-15	5.90	0.01	0.33	0.02

Table I. Observing circumstances. Where 3 numbers are indicated for phase angle, measurements of the target occurred over opposition. The middle value is the minimum phase angle observed and the two end values are the phase angles at the beginning and end of the observing campaign.





## 2705 WU: A TUMBLING ASTEROID

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2705 Wu was observed in 2009 July through September. The initial results showed a lightcurve with synodic period of  $150.5\text{h} \pm 0.5\text{h}$ . The observations were also checked for variations seen in the mean lightcurve. After eliminating other causes of the variations, it was concluded that 2705 Wu exhibited Non-Principal Axis (NPA) rotation, or tumbling behavior. Attempts to derive the secondary period were unsuccessful.

Observations of 2705 Wu were made at Kingsgrove Observatory in 2009 July through September. The asteroid was selected because there were no previous reports of its lightcurve and because it was listed as a target of opportunity on the CALL web site (Warner, 2008). A 0.25-m Schmidt-Cassegrain telescope (SCT) operating at  $f/10$  was used in combination with an SBIG ST-9XE CCD camera operating at 1x binning. This resulted in a

resolution of 1.67 arcseconds per pixel (Oey 2008). Exposures of 300s through a clear filter maximized the signal-to-noise ratio (SNR). *MPO Canopus* v.9.4.0.10, which incorporates the Fourier analysis algorithm developed by Harris (1989), was used for period analysis. Data were linked internally using the Comp Star Selector (CSS) feature of *Canopus*. Since the system is sensitive towards the red, R magnitudes were used in the CSS. A careful reduction of the data using this method resulted in an error of 0.03–0.05 m in the nightly zero points (see Stephens, 2008).

After having established the initial period of 150 h in the first few observing runs, a tendency to shift from the mean lightcurve started to show. There are a number of reasons for these apparently random deviations. One is the well-known phase-amplitude relationship where the amplitude decreases as the object approaches opposition. Another, to a smaller extent, is the opposition effect where the asteroid brightens more than expected by simple geometry near opposition. The third is a change in the synodic period brought on by changing viewing aspects over a relatively long observing run. This slight speeding up or slowing down in the synodic period is quantified by the equation (Pravec, 2005):

$$\Delta|\text{Psyn-Psid}| \sim d(\text{PAB})/d(T) * P^2$$

Where  $|\text{Psyn-Psid}|$  is the difference between the synodic and sidereal periods,  $d(\text{PAB})/d(T)$  is the rate of change in the Phase Angle Bisector (Harris, 1984), and P is the period in the same

units used in the rate of change. The maximum calculated value of  $\text{Psyn-Psid}$  for 2705 Wu was 0.79h.

In the enlarged portion of the lightcurve shown in Fig. 2, the observed shift of the period amounted to 6 h, assuming the internal linking of the data sets was correct. Taking into account the observational and the calibration errors described, the accumulated errors were limited to 0.05m. A closer inspection of the phase plot in Fig. 1 shows that the deviation from the mean is seen throughout the whole lightcurve. Fig. 3 at phase 0 shows a deviation of  $\sim 0.25$ m. Since these far exceed the expected linking errors, the presumption is that the misalignments are due to unexpected changes in the apparent synodic period and/or amplitude.

Based on its large lightcurve amplitude of 1.2 mag, 2705 is likely a highly elongated body with an axial ratio (a/b) of  $\sim 3.0$ . For such an object, the lightcurve should be similar for both principal axis (PA) and non-principal axis (NPA) rotation over a short period of time. However, the lightcurve deviations due to NPA rotation should become apparent after a few rotational cycles (Harris 1994). Although it was clear from just visual inspection of the lightcurve that there were apparent deviations, no clear pattern emerged (Fig. 1). Canopus does not include the necessary tools to analyze the complex nature of tumbling asteroids and so the data were sent for analysis to Petr Pravec, who has developed the necessary tools (Pravec, 2005). After eliminating the cause of variations due to the changing geometry, changing viewing aspects and inherent catalog errors over the duration of the observation, the presence of NPA rotation was confirmed. Although the complex nature of the lightcurve was detected, the secondary period could not be derived due to lack of sufficient data. It may require an even longer observing period than 2.5 months for a sound result. This asteroid is rated at PAR -1 tending to -2 (Pravec, private communications).

#### Acknowledgement

I would like to thank Petr Pravec and Peter Kušník of the Ondřejov observatory for their help with this paper and to Brian Warner, who has created a user friendly data reduction software (MPO Canopus) making it so much easier to work on this long period target.

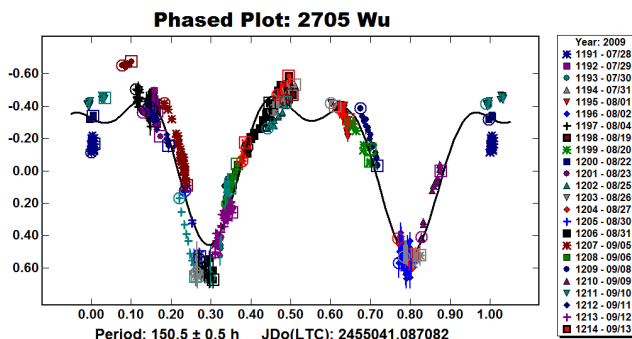


Figure 1. The combined data set for 2705 Wu phased to 150.5 h.

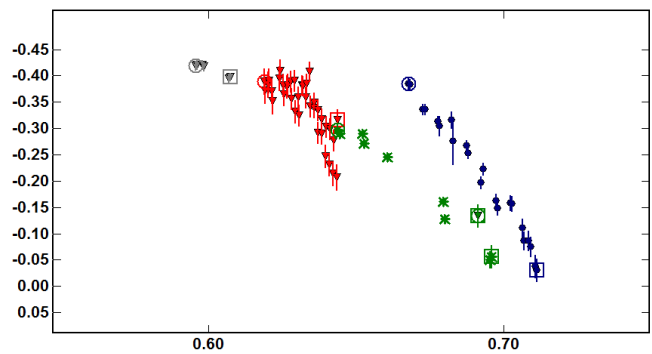


Figure 2. A close-up of the lightcurve at phase 0.65

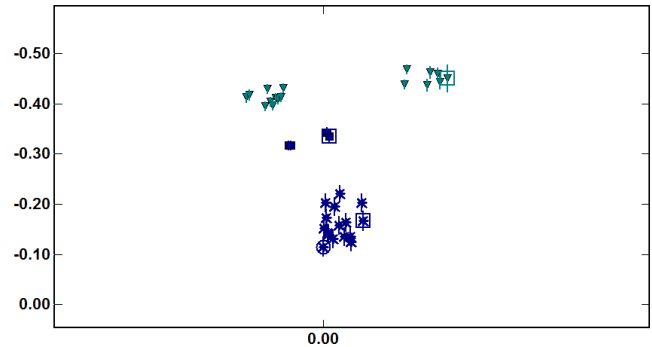


Figure 3. A close-up of the lightcurve at phase 0.

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## ANALYSIS OF THE LIGHTCURVE OF (20421) 1998 TG3

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We report CCD photometric observations of (20421) 1998 TG3, a Phocaea group member. Our analysis found two periods,  $11.8905 \pm 0.0008$  h and  $8.046 \pm 0.0001$  h. There were no definitive indications of mutual events, as would be expected in a binary system. We offer two possible explanations for the dual periods.

Observations of the Phocaea member, (20421) 1998 TG3, were started by Pray in 2009 August as part of the Photometric Survey for Asynchronous Binary Asteroids (Pravec et al., 2008, and references therein). Additional observations were added by Warner and Vilagi over the following three weeks. Warner used SDSS  $r'$  magnitudes to calibrate the night-to-night zero points of his observations to approximately  $\pm 0.03$  mag. During the initial stages of the observing campaign, the period solution varied considerably, ranging from a few hours to nearly 24 hours. It eventually stabilized to approximately 11.8 h but several sessions showed small deviations that could not be explained by observational or systematic problems.

Analysis of the final data set of approximately 650 data points revealed two periods:  $11.8905 \pm 0.0008$  h and  $8.046 \pm 0.0001$  h. No definitive evidence of mutual events of a binary system, i.e., eclipses and/or occultations, were recorded. This leaves the cause of the dual period subject to speculation. The two more likely, but unproven, possibilities are 1) a binary system with the two periods being the rotation rate of the primary and a satellite and to which object each period belongs is not known, or 2) the asteroid is in a state of non-principal axis rotation (NPAR). The tumbling damping time for the asteroid, with  $D \sim 5.5$  km, is about 100 My for a period of 24.7 h. Since both periods are well less than this, the chances of the asteroid being in a tumbling state are not very favorable (see Pravec et al., 2005, for a discussion of NPAR and damping times). In summary, we say that while the period of 11.89 h seems reasonably secure, the signal for the 8.05 h second period is weak and, furthermore, even with the additive 2-component model, there still remain some small unexplained deviations.

A final solution, if one is to be had at all, will require several observers over a range of longitudes with all data placed on a well-calibrated system. Unfortunately, the next opportunity within

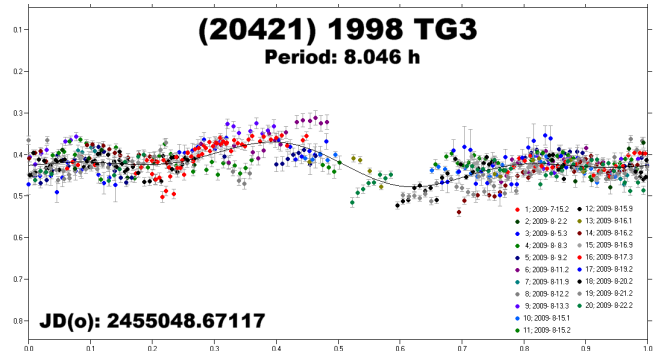
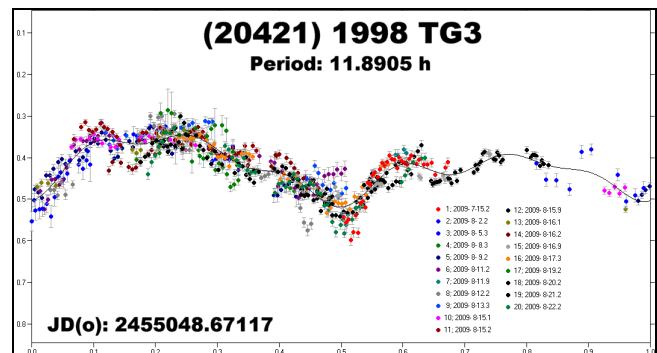
reach of modest instruments doesn't come until 2013 September when the asteroid will be a  $V \sim 15.8$  and  $+13^\circ$  Declination.

### Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX 09AB48G, by National Science Foundation grant AST-0907650, and by a 2007 Gene Shoemaker NEO Grant from the Planetary Society. The work at Ondřejov was supported by the Grant Agency of the Czech Republic, Grant 205/09/1107. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by NASA and NSF.

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## ABSOLUTE MAGNITUDES OF ASTEROIDS 1176 LUCIDOR AND 2093 GENICHESK

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Observations of 1176 Lucidor and 2093 Genichesk resulted in absolute magnitudes ( $H$ ) of  $11.35 \pm 0.04$  and  $13.28 \pm 0.04$  and slope parameters ( $G$ ) of  $0.34 \pm 0.07$  and  $0.25 \pm 0.07$ , respectively.

The asteroids 1176 Lucidor and 2093 Genichesk were chosen from a list of asteroids with suspect absolute magnitude values published by the Minor Planets Section of the Association of Lunar and Planetary Observers (ALPO) as part of their Magnitude Alert Project (MAP). For this project I used the Sierra Stars Observatory Network (SSON) 0.61-m f/10 Cassegrain robotic telescope located in California, USA. Imaging was conducted between 2009 September 9 and 2009 September 27. Three images, each of 60 s duration and spaced approximately 1 hour apart, were taken each clear night (15 in total) through a V filter. Magnitudes were measured using *Astrometrica* choosing the CMC-14 catalogue (Evans, 2001) while positions were similarly measured but using the USNO-B.1 catalogue (Monet et al, 2003). The methodology for measuring V magnitudes, which has been incorporated into *Astrometrica*, is described in the paper "A method for determining the V magnitude of asteroids from CCD images" by Richard Miles and Roger Dymock (2009).

Using the *MPO Canopus* H and G Calculator, phase curves were generated (Figs. 1 and 2), the absolute magnitudes,  $H$ , determined to be  $11.35 \pm 0.04$  and  $13.28 \pm 0.04$  and slope parameters,  $G$ , to be  $0.34 \pm 0.07$  and  $0.25 \pm 0.07$  for asteroids 1176 Lucidor and 2093 Genichesk respectively.

The values obtained from the Minor Planet Center at the time of writing were  $H = 10.9$  and  $G = 0.15$  for 1176 Lucidor and  $H = 12.6$  and  $G = 0.15$  for 2093 Genichesk (it is standard practice to quote a value of 0.15 for  $G$  where no specific value has been determined). The new values for  $H$  and  $G$  (and the observational data) have been forwarded to the Magnitude Alert Project for inclusion in a future *Minor Planet Bulletin* paper.

It should be noted that the derived values of  $H$  and  $G$  may vary slightly from opposition to opposition due to, for example, the orientation of an asteroid's axis of rotation with respect to the Earth. The quoted values are usually an average over several oppositions and thus relate to the actual size of the asteroid.

### Acknowledgements

The work was partially funded by a BAA Robotic Telescope Project grant for which I am most grateful.

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[http://astrosurf.com/aude/map/index\\_us.htm](http://astrosurf.com/aude/map/index_us.htm)

Astrometrica software: <http://www.astrometrica.at/>

BAA Robotic Telescope Project:  
<http://www.britastro.org/iandi/robotic02.htm>

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MPO Canopus:  
<http://www.minorplanetobserver.com/MPOsoftware/MPOcanopus.htm>

Sierra Stars Observatory Network web site:  
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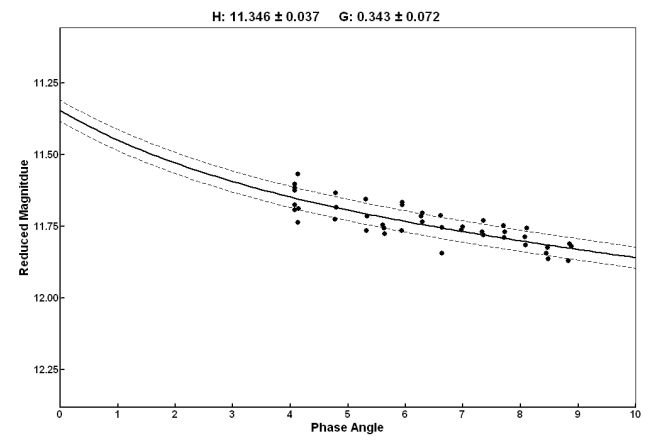


Fig. 1. Phase curve of asteroid 1176 Lucidor

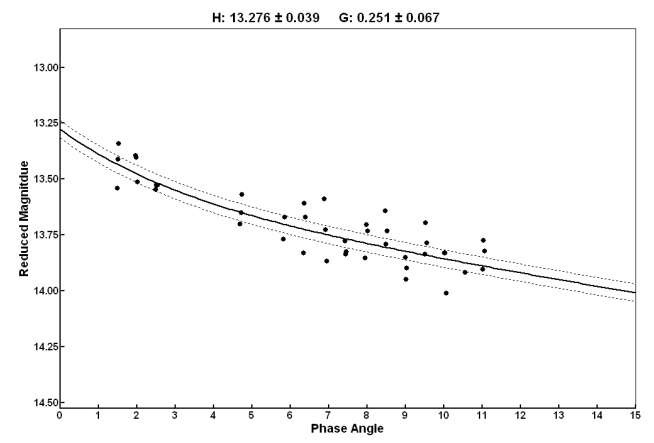


Fig. 2. Phase curve of asteroid 2093 Genichesk

**ASTEROID LIGHTCURVE ANALYSIS AT  
THE PALMER DIVIDE OBSERVATORY:  
2009 SEPTEMBER–DECEMBER**

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Lightcurves for 26 asteroids were obtained at the Palmer Divide Observatory (PDO) from 2009 September through December: 298 Baptistina, 546 Herodias, 1355 Magoeba, 1626 Sadeya, 1750 Eckert, 2001 Einstein, 2083 Smither, 3086 Kalbaugh, 4125 Lew Allen, 4531 Asara, 4736 Johnwood, 5230 Asahina, 5841 Stone, 6141 Durda, (6444) 1989 WW, 9739 Powell, 16669 Rionuevo, 24654 Fossett, (29242) 1992 HB4, (29308) 1993 UF1, (31850) 2000 EB22, (37634) 1993 UZ, (38047) 1998 TC3, (40203) 1998 SP27, (218144) 2002 RL66, and NEA 2009 XR2. In addition, data for 1355 Magoeba from 2006 were re-analyzed. The periods derived from the 2006 and 2009 apparitions cannot be reconciled. The solution based on the 2009 data has been adopted as the one more likely correct. For four of the asteroids, 2001 Einstein, 3086 Kalbaugh, 4736 Johnwood, and 5841 Stone, the 2009 data were combined with those from earlier apparitions to derive spin axis and shape models.

CCD photometric observations of 26 asteroids were made at the Palmer Divide Observatory (PDO) from 2009 September through December. See the introduction in Warner (2009c) for a discussion of equipment, analysis software and methods, and overview of the plot scaling.

298 Baptistina. The period for the prototype of the family of the same name had been previously reported at 7 h (Wisniewski 1997) and 9.301 h (Ditteen 2007). Observations in 2008 by Majaess et al. (2009) found a period of 16.23 h, which was confirmed by the observations made in late 2009 at PDO.

546 Herodias. Szekely et al. (2005) found a period of 10.4 h, though it was “fairly uncertain”, mostly due to a low amplitude. The data from PDO led to a period close to theirs:  $10.77 \pm 0.01$  h.

1355 Magoeba. The author previously reported a period of 32.9 h (Warner 2007a). The data from the 2009 apparition gave a very different result of 5.946 h. This prompted re-measuring the original images from 2006 using the 2MASS to BVRI conversions to link the several nights (see Warner 2007c). The results were different,  $31.65 \pm 0.05$  h, but not significantly so. Given the longer runs during the 2009 apparition and the fact that they were on successive nights, it’s believed that the shorter period (5.946 h) should be adopted as being more likely correct.

1626 Sadeya. Previous works by Florczak (1997), Oey (2008), and Behrend (2009) all reported a period of about 3.4 h, the same as found with the PDO data.

1750 Eckert. This asteroid shows definite signs of being in non-principal axis rotation (NPAR, tumbling). The object was followed long enough to go through a second cycle, when the lightcurve did not repeat itself. The approximate tumbling

damping time for a period of 375 h and the estimated diameter  $D = 5.7$  km is well in excess of the age of the Solar System. See Pravec et al. (2005) for a discussion of damping times and tumbling.

2001 Einstein. This Hungaria member was observed by the author in 2004 and 2008 (see Warner 2005 and 2008b). The data from the three apparitions were combined with sparse data from the Catalina Sky Survey (CSS, MPC 703) to find a shape and spin axis model. See the discussion below.

2083 Smither. A period of 2.676 h was previously reported by the author (Warner 2007a). In 2009, the period was found to be  $2.6717 \pm 0.0005$  h. There were a few minor deviations on three nights that could be “removed” by subtracting out a period of 30.09 h. However, these were too insignificant to give them credence and so their cause remains unexplained. The plot for this curve shows the data after the subtraction if for no other reason than to present a slightly “cleaner” curve.

3086 Kalbaugh. This Hungaria member was observed for the third time by the author with the intent of finding a shape and spin axis model (see Warner 2005 and 2008a). The results of the modeling are discussed below.

4125 Lew Allen. This is the second time this Hungaria member was observed by the author. The first time (Warner 2007b) the period was found to be 4.628 h with an amplitude of 0.20 mag. The period from 2009 is 4.625 h but with an amplitude of 0.46 mag, giving hope that a shape and spin axis model might be possible with data from another apparition.

4736 Johnwood. This is the third Hungaria observed for spin axis and shape modeling. It was previously observed by the author in early 2005 (Warner 2005). The modeling results, discussed below, were not as definitive as for 2001 Einstein and 3086 Kalbaugh but better than those for 5841 Stone.

5230 Asahina. The tumbling damping time for this asteroid and the period of 89.3 h is on the order of 3 Gy. In which case, it would seem likely to find some traces of the asteroid being in non-principal axis rotation (NPAR). However, no such indications were seen when portions of the lightcurve were covered a second time. Either the object is not tumbling at all or it is doing so only very slightly and so the variations in the lightcurve are hidden within the errors of the night-to-night calibrations.

5841 Stone. This Hungaria was observed in 2006 by the author (Warner 2007a). In both cases, a period of 2.89 h was found. Despite having data from only two apparitions, an attempt was made to model the asteroid by adding sparse data from the Catalina Sky Survey. The results are outlined below.

6141 Durda. The tumbling damping time for the period of 460 h found for this asteroid exceeds the age of the Universe by many times. There were no obvious signs of NPAR, however it was not possible to cover the lightcurve completely even once, let alone a second time to see if there were any variations due to tumbling.

9739 Powell. This Hungaria was observed by the author in 2006 (Warner 2007a). At that time, a period of 18.2 h was reported, with an alternate of 36.5 h being possible. The 2009 data lead to a period of 16.7 h, assuming a monomodal curve. Given the amplitude of only 0.11 mag, this is not an unreasonable assumption, although a period of 33.5 h with bimodal curve cannot be formally excluded. The data from the 2006 apparition

could not be made to fit the shorter period. With the improvement in night-to-night data linking in recent versions of *MPO Canopus*, the new period of 16.7 h (or 33.5 h) is preferred.

(218144) 2002 RL66. The period of 616 h and estimated diameter  $D = 3.4$  km for this Mars-crosser make it a likely candidate for being a “tumbler.” However, no signs of such were seen. Here, too, it was not possible to cover the entire lightcurve to confirm that it did or did not repeat itself from one cycle to the next.

### Shape and Spin Axis Modeling

While finding a shape model provides a more graphic result, finding the orientation of the spin axis is more important in many cases. For one, determining the sense of rotation, prograde or retrograde, lends support to theories about Yarkovsky drift. This effect is the result of thermal re-radiation of sunlight by an asteroid such that the semi-major axis increases over time if the asteroid is in prograde rotation and decreases if in retrograde motion.

A sample of Yarkovsky drift is shown in Fig. 1, which shows a subset of members of the Hungaria family plotted with absolute magnitude ( $H$ ) versus semi-major axis ( $a$ ). If the drift were due only to the impetus received at the collision that formed the family, the spread in  $a$  would be very small, as shown by the vertical green line. Instead, one sees a “V” shape that grows wider with larger  $H$  (smaller diameter). This is as expected since the thermal push is stronger for smaller asteroids. Asteroids to the left of the vertical line are expected to be in retrograde rotation while those to the right should be in prograde rotation. See Warner et al. (2009b) and references therein for a more detailed discussion of this effect and the Hungaria population

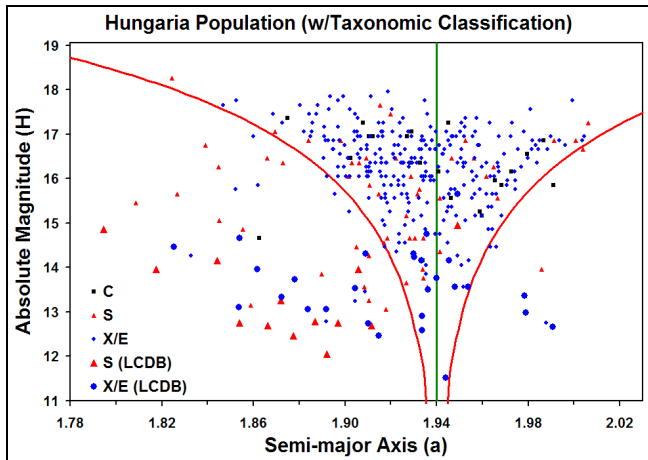


Figure 1. A plot of Hungaria population members with taxonomic classification. The “V” defines the dynamical Hungaria family with Yarkovsky spreading. The vertical green line defines the family if only collisional spreading were involved. From Warner et al. (2009b).

In the pole search plots that follow, blue represents lower values of ChiSq, i.e., the “more probable” solutions. Red represents the “worst” solutions. These plots were produced by *MPO LCInvert* (written by the author). For a discussion of shape modeling and pole searches, see Higley et al. (2008) and references therein.

2001 Einstein. The pole search plot (Fig. 2) shows a definite bias towards negative values of beta (latitude), indicating the asteroid is in retrograde rotation. A check of its  $H$ - $a$  parameters ( $H =$

12.85,  $a = 1.9332$ ) shows that, as expected, the asteroid lies to the left of the vertical line in Fig. 1.

The “brick-like” appearance (Fig. 3) is the result of inversion method that results in large flat areas representing significant concavities. It’s possible that the true shape in this case is a bi-lobed object, i.e., something similar to a dumbbell. The large amplitude of the lightcurve at different viewing aspects supports the asteroid being highly elongated.

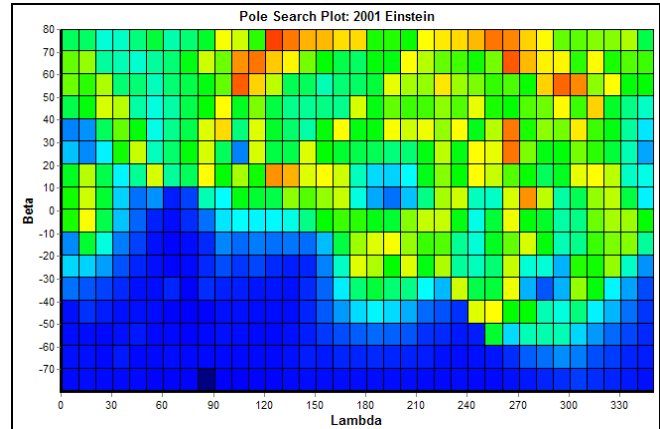


Figure 2. The pole search results for 2001 Einstein. See the text for an explanation of the color-coding.

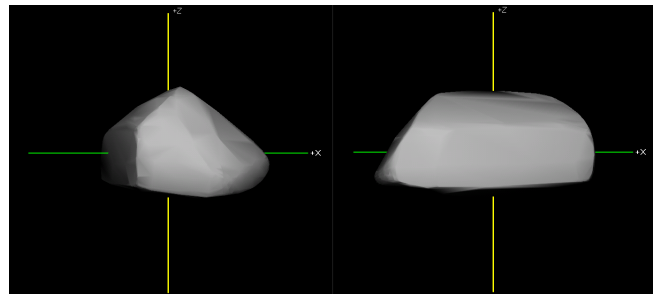


Figure 3. The asteroid equatorial view of 2001 Einstein at  $Z = 0^\circ$  and  $Z = 90^\circ$ .

3086 Kalbaugh. This Hungaria’s pole search plot (Fig. 4) also shows that it is very likely in retrograde motion. The  $H$ - $a$  parameters ( $H = 13.6$ ,  $a = 1.9356$ ) place it to the left of the center line of the “V” in Figure 1.

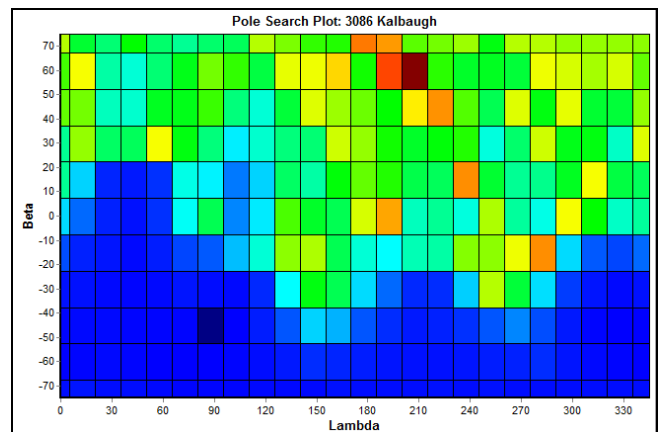


Figure 4. The pole search plot for 3086 Kalbaugh.

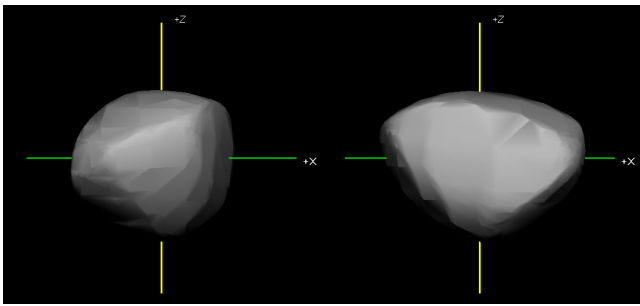


Figure 5. The asteroid equatorial view of 3086 Kalbaugh at  $Z = 0^\circ$  and  $Z = 90^\circ$ .

4736 Johnwood. The pole search plot (Fig. 6) favors prograde motion, which is also indicated by the  $H$ - $a$  parameters ( $H = 13.5$ ,  $a = 1.9576$ ). This is the most that can be determined with the available data. All the shape models showed rotation about the longest axis of the asteroid instead of the shortest, which is physically improbable.

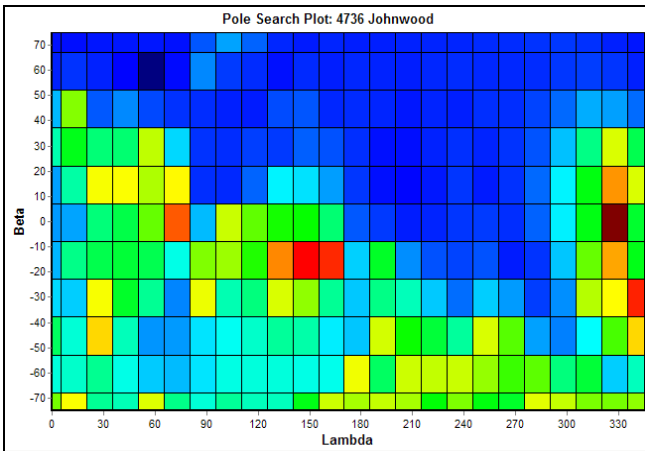


Figure 6 The pole search plot for 4736 Johnwood.

5841 Stone. This is a case of too little, too soon. The pole search plot (Fig. 7) shows only a very small region of “better” solutions, those being near  $(180^\circ, 0^\circ)$ . This does make some sense in light of the low amplitude of the lightcurve at viewing angles that differ by  $90^\circ$  and if one presumes a nearly spheroidal shape, as seen in Figure 8. A check of the  $H$ - $a$  parameters ( $H = 13.9$ ,  $a = 1.9258$ ) shows that the asteroid should be in retrograde motion. The current model is inconclusive on that account. Data from future apparitions may (or may not) resolve the issue.

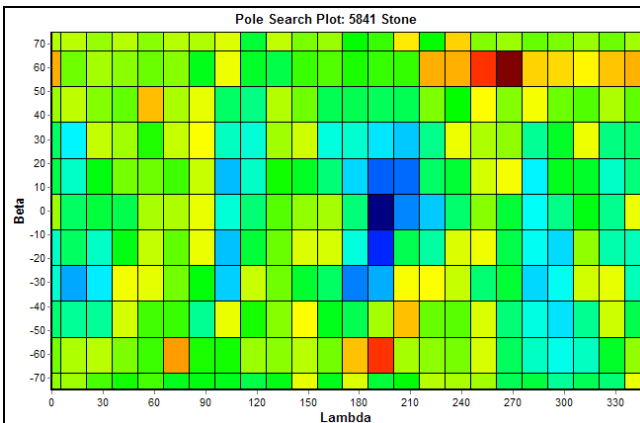


Figure 7. The pole search plot for 5841 Stone.

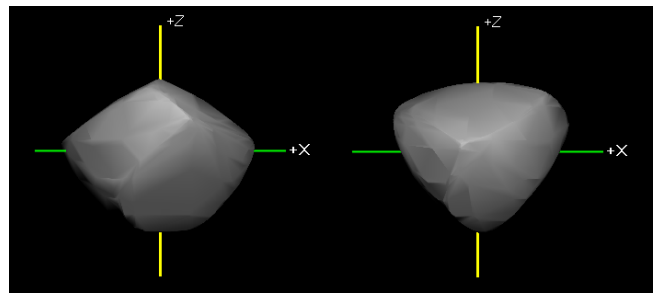


Figure 8. The asteroid equatorial view of 5841 Stone at  $Z = 0^\circ$  and  $Z = 90^\circ$ .

Asteroid	Pole (Long,Lat)	Sidereal Per (h)
2001	(90, -70)	$5.48503 \pm 0.00002$
3086	(90, -45)	$5.17910 \pm 0.00002$
4736	(60, +60)	$6.21576 \pm 0.00003$
5841	(195, +0)	$2.889026 \pm 0.000006$

Table I. The pole is the ecliptic longitude and latitude of the “best” solution. The error is generally a circle with a  $15^\circ$  radius centered on the given position. The period error corresponds to a  $10^\circ$  rotation error over the duration of the data set.

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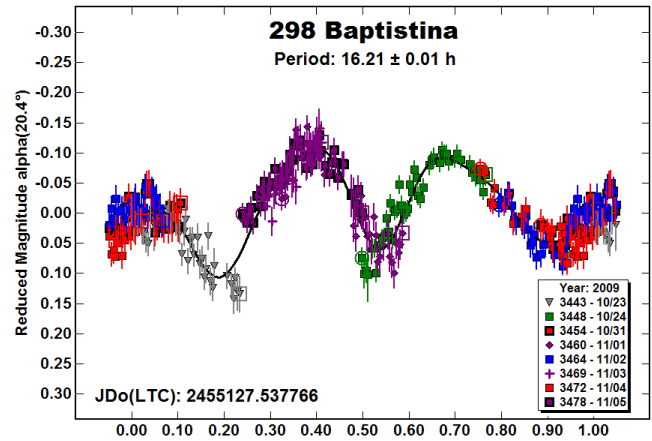
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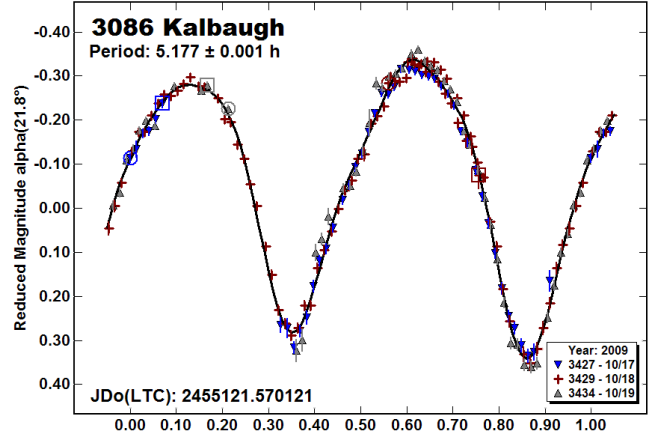
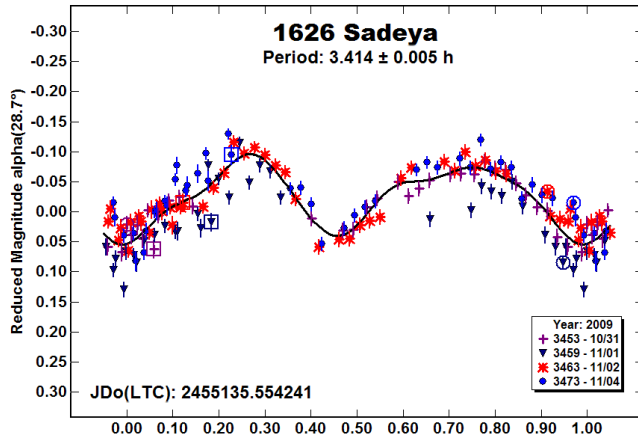
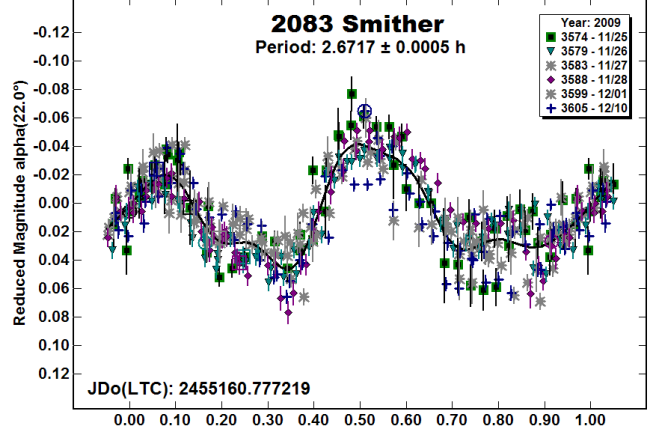
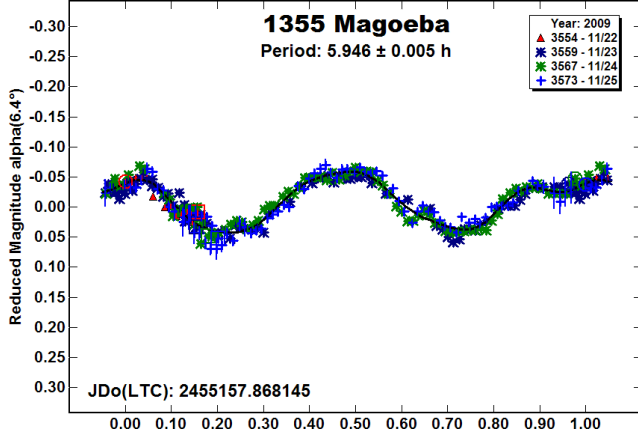
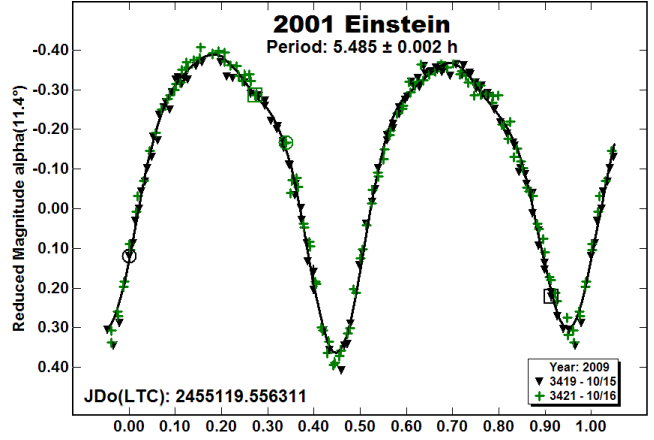
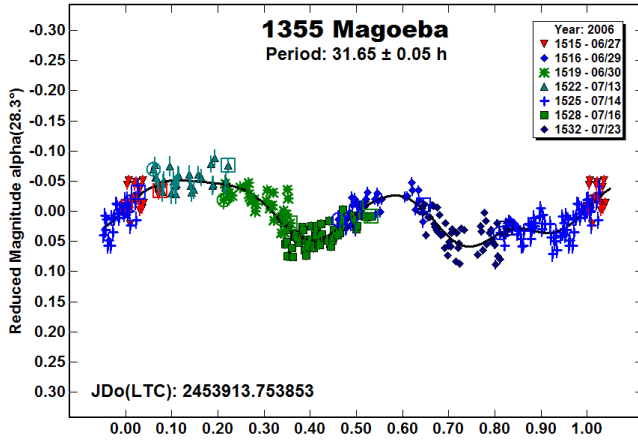
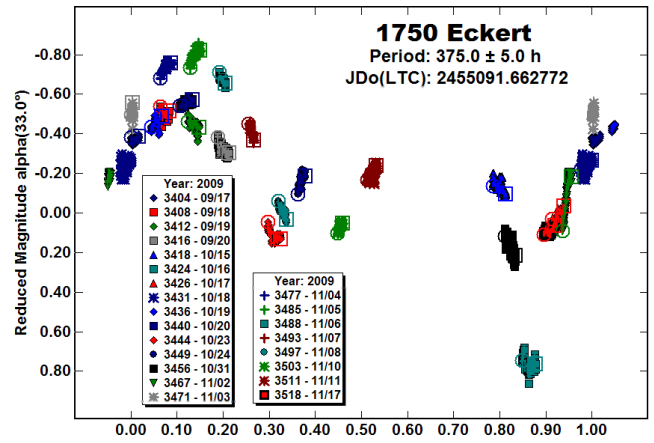
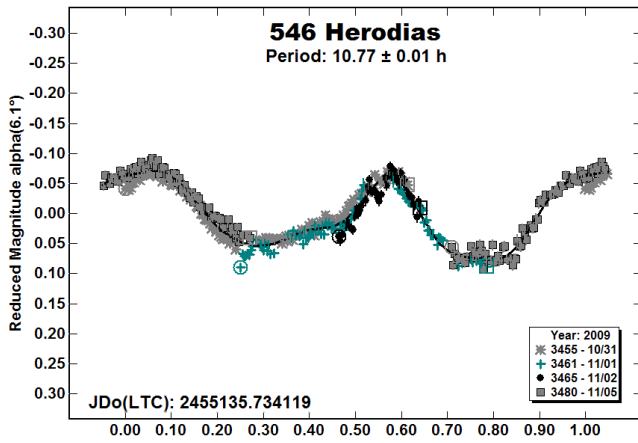
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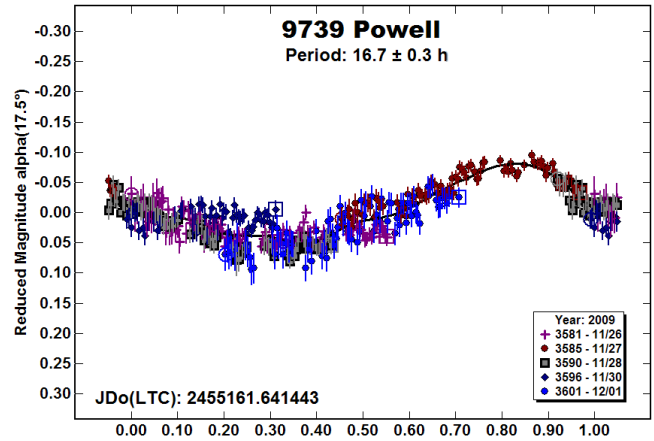
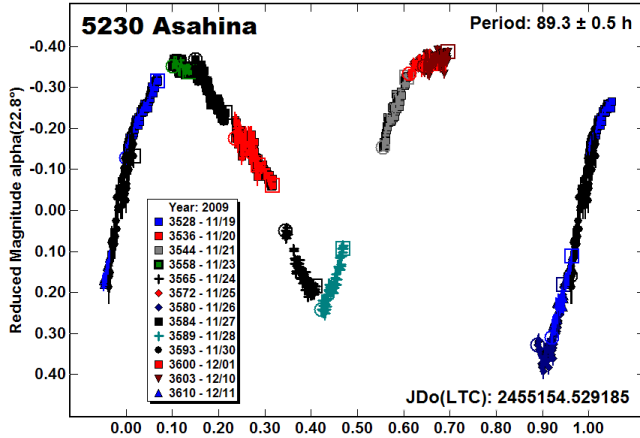
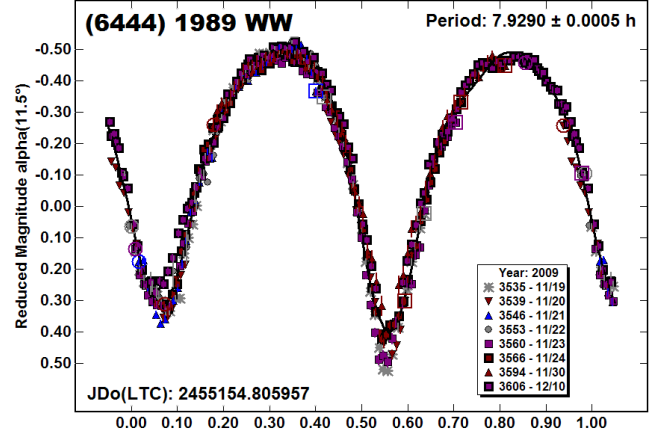
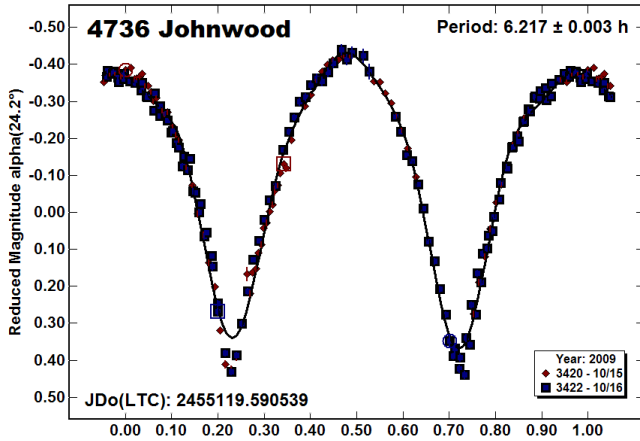
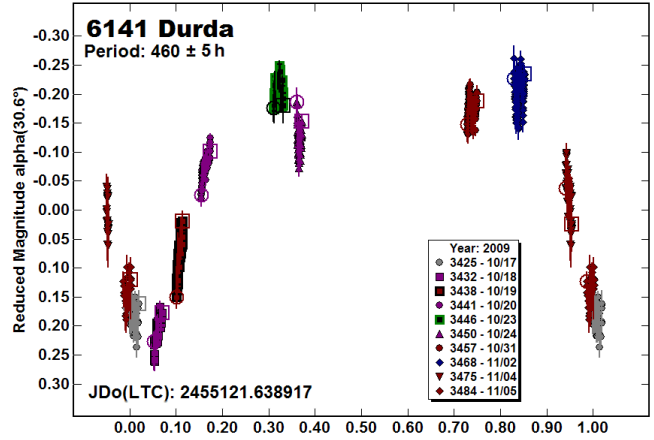
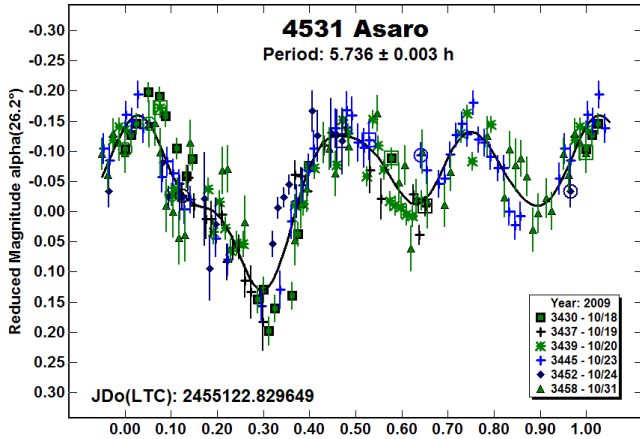
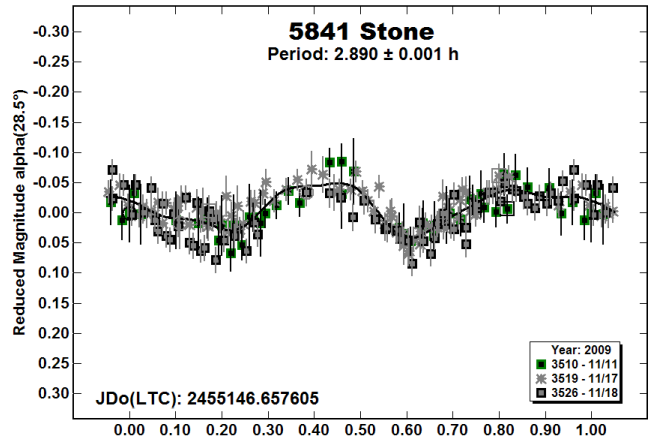
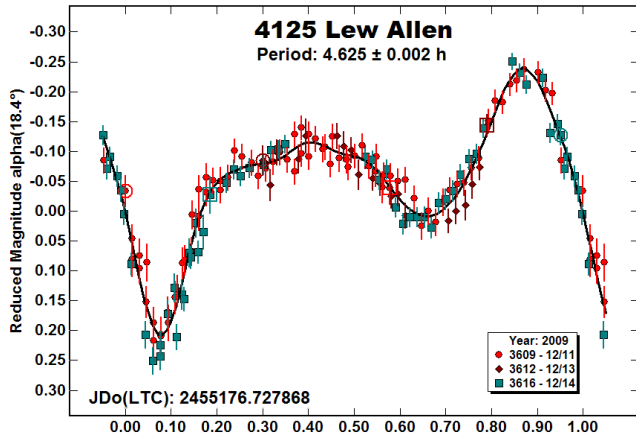


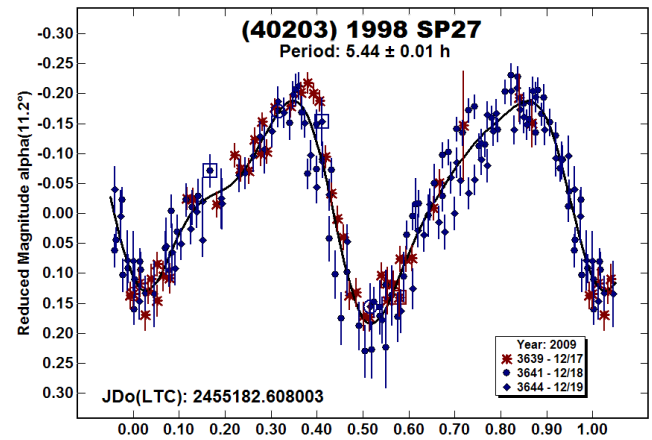
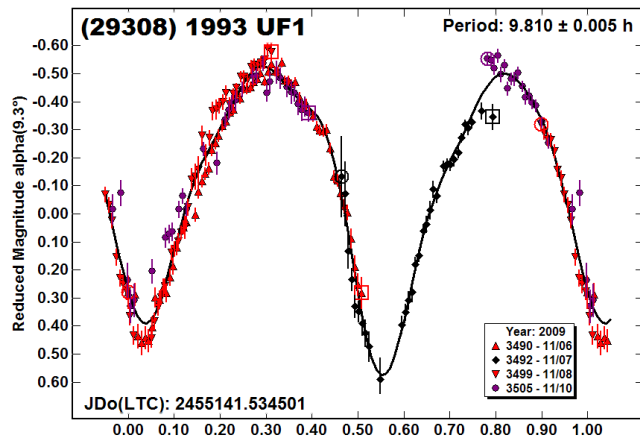
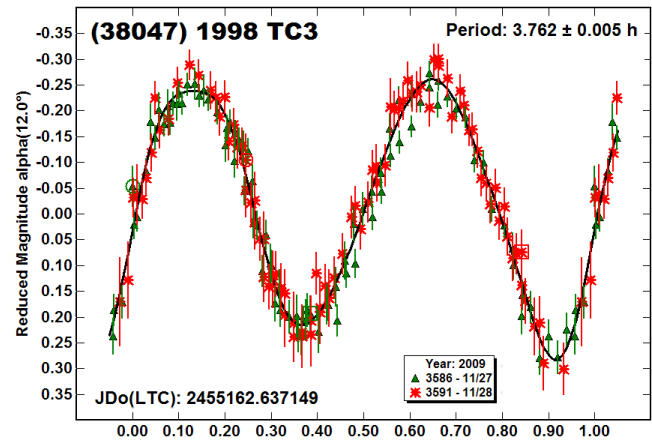
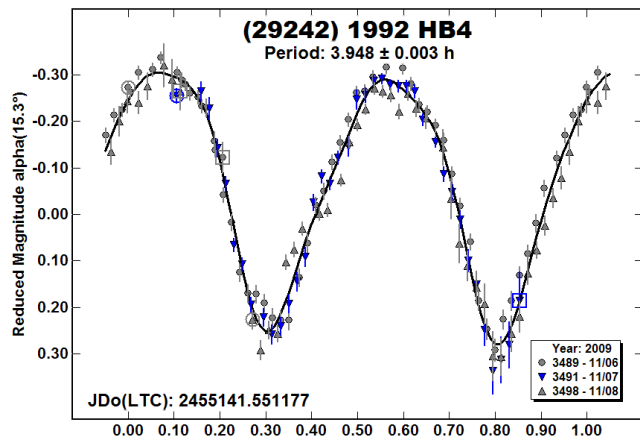
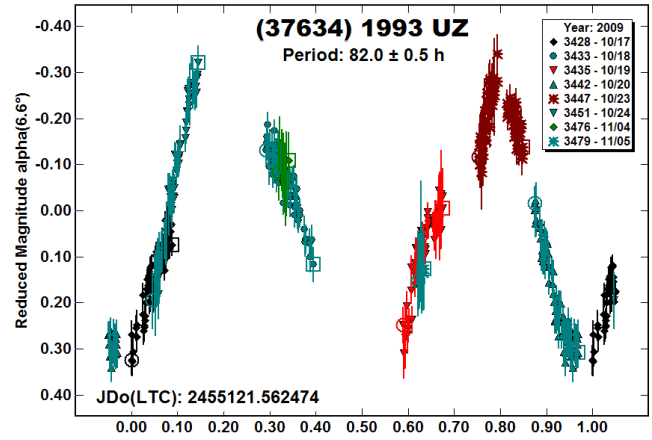
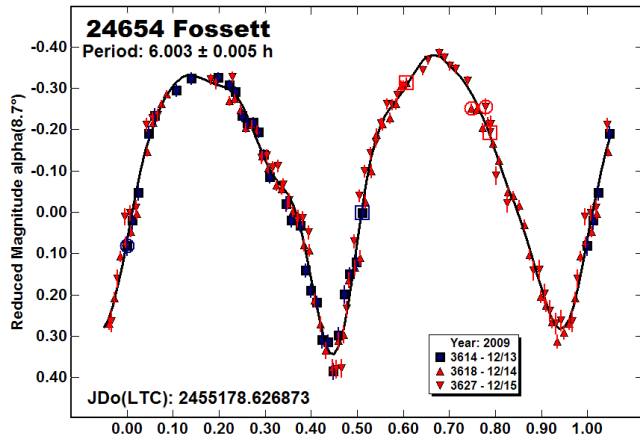
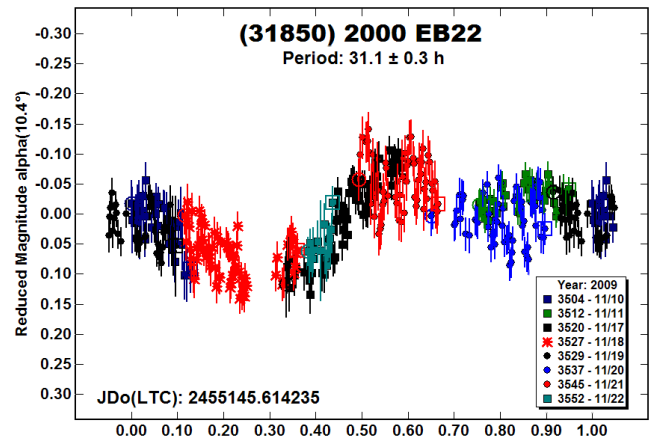
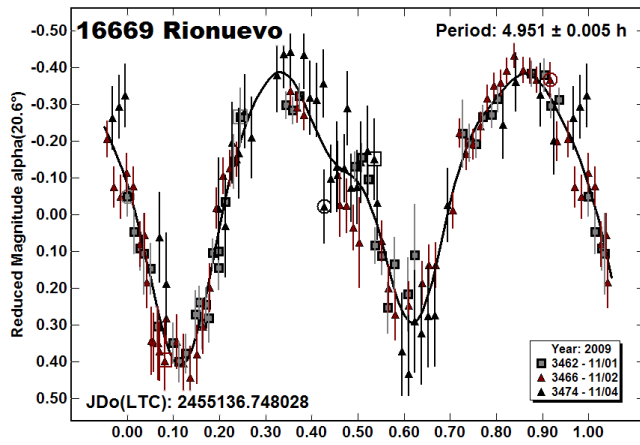
#	Name	mm/dd 2009	Data Pts	$\alpha$	$L_{PAB}$	$B_{PAB}$	Per (h)	PE	Amp (mag)	AE
298	Baptistina	10/23-11/05	306	20.1,22.4	343	-2	16.21	0.01	0.25	0.02
546	Herodias	10/31-11/05	387	6.5,5.0	48	8	10.77	0.01	0.18	0.02
1355	Magoeba (H)	11/22-11/25	259	5.7,7.2	56	-8	5.946	0.005	0.12	0.01
1355	Magoeba (H)	06/27-07/23*	300	28.4,24.1	315	32	31.65	0.05	0.10	0.01
1626	Sadeya	10/31-11/04	172	28.7	338	29	3.414	0.005	0.19	0.02
1750	Eckert (H)	09/17-11/17	1764	33.2,21.9	35	26	375	5	0.87	0.05
2001	Einstein	10/15-10/16	237	11.5	31	17	5.485	0.002	0.74	0.02
2083	Smither (H)	11/25-12/10	396	22.6,15.0	97	-4	2.6717/30.09	0.0005	0.09	0.01
3086	Kalbaugh (H)	10/17-10/19	176	21.6	356	24	5.177	0.001	0.66	0.02
4125	Lew Allen (H)	12/11-12/13	102	18.5	114	-4	4.625	0.002	0.44	0.02
4531	Asaro (H)	10/18-10/31	177	26.4,22.8	65	22	5.736	0.003	0.29	0.03
4736	Johnwood (H)	10/15-10/16	187	24.1	20	33	6.217	0.003	0.84	0.02
5230	Asahina	11/19-12/11	782	22.0,31.8	31	-15	89.3	0.5	0.67	0.05
5841	Stone (H)	11/11-11/18	192	28.8,27.1	86	29	2.890	0.001	0.10	0.01
6141	Durda (H)	10/17-11/05	684	30.9,24.2	59	23	460	5	0.50	0.03
6444	1989 WW	11/19-12/10	507	12.3,3.0,4.1	73	-4	7.9290	0.0005	0.98	0.03
9739	Powell (H)	11/26-12/01	420	18.1,15.6	89	13	16.7/33.5	0.3	0.11	0.01
16669	Rionuevo (H)	11/01-11/04	137	21.3,19.6	68	-7	4.951	0.005	0.73	0.03
24654	Fossett (H)	12/13-12/15	139	9.0,8.5	89	10	6.003	0.005	0.74	0.02
29242	1992 HB4 (H)	11/06-11/08	139	14.4,15.7	24	0	3.948	0.003	0.58	0.02
29308	1993 UF1 (H)	11/06-11/10	198	8.3,11.1	32	1	9.810	0.005	0.94	0.02
31850	2000 EB22 (H)	11/10-11/22	392	9.5,16.8	37	9	31.1	0.3	0.20	0.05
37634	1993 UZ (H)	10/17-11/05	426	6.6,15.4	20	6	82.0	0.5	0.70	0.05
38047	1998 TC3 (H)	11/27-11/28	182	12.6,12.1	82	9	3.762	0.005	0.54	0.02
40203	1998 SP27 (H)	12/17-12/19	188	10.9,11.3	85	14	5.44	0.01	0.37	0.02
218144	2002 RL66	11/18-12/11	1162	27.3,28.4	79	30	616	10	0.34	0.03
	2009 XR2	12/15-12/17	184	25.0,18.9	90	12	5.828	0.005	0.88	0.05

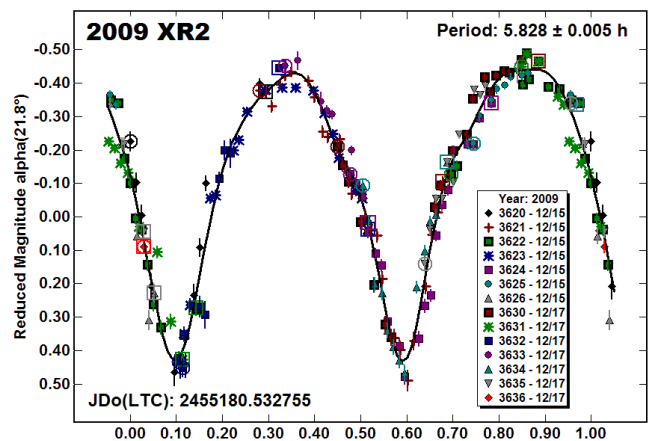
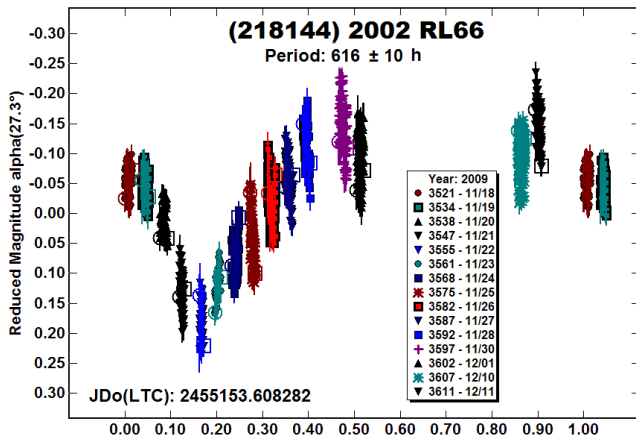
\* 2006 observations

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









### PERIOD DETERMINATIONS FOR 1131 PORZIA AND 1819 LAPUTA

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Lightcurve analyses for 1131 Porzia and 1819 Laputa are reported. The synodic rotation period and lightcurve amplitude values are, respectively:  $4.6584 \pm 0.0005$  h,  $0.15 \pm 0.02$  mag;  $9.8004 \pm 0.0002$  h,  $0.51 \pm 0.03$  mag.

Unfiltered CCD photometric observations of two minor planets, 1131 Porzia and 1819 Laputa, were made at the Belgrade Astronomical Observatory during 2009 in order to determine their synodic rotation periods. A 0.4-m Meade LX-200 GPS Schmidt-Cassegrain telescope operating at  $f/10$  was coupled with an unguided SBIG ST-10 XME CCD in the case of 1131 Porzia. An Apogee AP47p CCD was used on 1819 Laputa. *MPO Canopus* software (BDW Publishing) was used for the photometric reductions and period analysis. Both asteroids were selected from the lists of the potential lightcurve targets on the Collaborative Asteroid Lightcurve Link (CALL) web-site (Warner and Harris, 2009a; 2009b).

**1131 Porzia.** Prior to this work only one reference on rotation period determination for this Mars-crossing asteroid had been published. Wisniewski et al. (1995) reported a value for the period of 4.0 hours. Since it was marked with an uncertainty of  $U = 2$  on the CALL web-site (see Warner et al. 2009c, for an explanation of the U code system), the reported period was likely still uncertain. This degree of uncertainty and the fact that the period was given to only one significant figure were the reasons for observing the asteroid. Observations were started on 2009 November 18, six days before the opposition, and the last images were taken on 2009 November 27, resulting in 6 data sets. Unfortunately, unfavorable weather conditions prevented further observations and so expanding the data set over a longer interval. Based on the available data, two equally-possible lightcurve solutions were found: a bimodal lightcurve with  $P = 4.6584$  h (Figure 1) and a

physically justified quadrimodal lightcurve with  $P = 9.3171$  h (Figure 2). The RMS errors of both solutions were comparable and so could not be used to distinguish the “true” period.

On the other hand, a simple visual inspection of the 9.3171 h period lightcurve shows that the two halves of the curve appear nearly the same. In addition, analysis of the higher orders of the Fourier series coefficients (Frederick Pilcher, private communications) shows that even and odd terms are comparable for the short period while the odd terms have much smaller coefficients than the even terms for the long period. These facts strongly favor the  $4.6584 \pm 0.0005$  h period. The amplitude of the curve is  $0.15 \pm 0.02$  mag.

**1819 Laputa.** No results for the rotation period of this main-belt asteroid have been published previously. Given that the object reached  $V \sim 13.9$  in opposition on 2009 June 7, it was favorably-suited for photometric observations. Data were collected over 10 nights from 2009 May 23 through June 18. Even the first data sets indicated a simple bimodal lightcurve with an amplitude of about 0.5 mag. Analysis of the expanded data set confirmed the initial result: a bimodal lightcurve with a period of  $P = 9.8004 \pm 0.0002$  h and amplitude  $A = 0.51 \pm 0.03$  mag (Figure 3).

#### Acknowledgments

The authors wish to express gratitude to Frederick Pilcher for his support and exceptionally valuable suggestions on period determination for the asteroid 1131 Porzia.

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## LIGHTCURVES AND SPIN PERIODS FROM THE WISE OBSERVATORY – 2009

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Some random asteroids travel through the field of view of Wise Observatory's telescopes while observing other targets. We report here the lightcurves and period analysis of those asteroids with results that we determine to be the most secure.

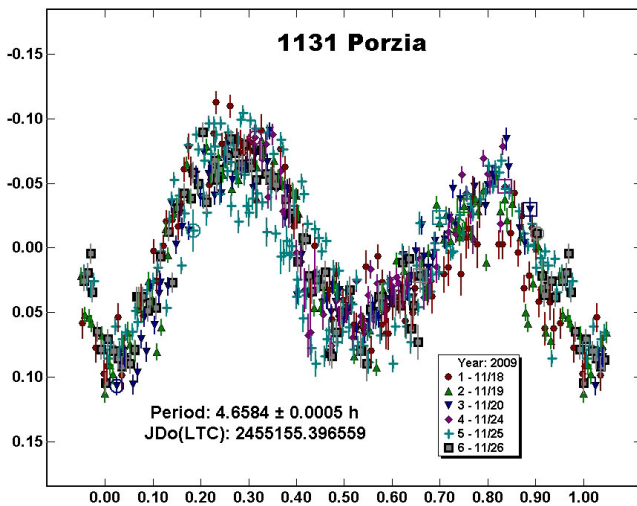


Figure 1. Composite bimodal lightcurve for 1131 Porzia

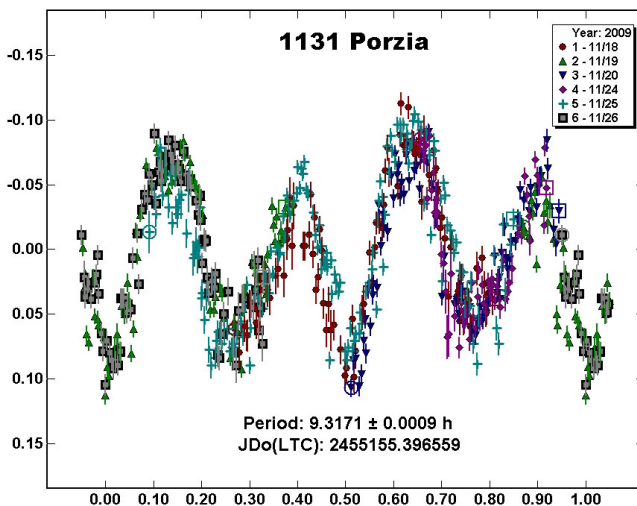


Figure 2. Composite quadramodal lightcurve for 1131 Porzia

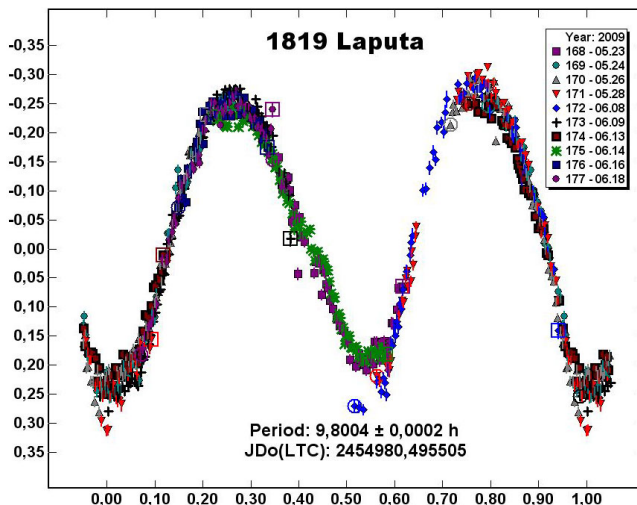


Figure 3. Composite lightcurve for 1819 Laputa

Photometry of asteroids has been done at the Wise Observatory since 2004. We have observed near-Earth asteroids (Polishook and Brosch, 2008), binary asteroids (Polishook et al., 2010), and small main-belt asteroids (Polishook and Brosch, 2009). While focusing on a specific target, some random asteroids cross our field of view. These objects are measured along with the prime targets, a lightcurve is drawn, and the spin period determined if possible. This paper presents photometric results of 18 asteroids with mostly secure periods. These and other measurements of other asteroids with short coverage of the spin or with low S/N can be obtained from the author by request.

Observations were performed using the two telescopes of the Wise Observatory (MPC 097): a 1-m Ritchey-Chrétien telescope and a 0.46-m Centurion telescope (referred to as *C18*; see Brosch et al., 2008, for a description of the telescope and its performance). The 1-m telescope is equipped with a cryogenically-cooled Princeton Instruments (PI) CCD. At the  $f/7$  focus of the telescope this CCD covers a field of view of  $13' \times 13'$  with  $1340 \times 1300$  pixels ( $0.58''$  per pixel, unbinned). The *C18* telescope was used with an SBIG STL-6303E CCD at the  $f/2.8$  prime focus. This CCD covers a wide field of view of  $75' \times 50'$  with  $3072 \times 2048$  pixels, with each pixel subtending  $1.47$  arcsec, unbinned. Observations were performed in “white light” with no filters (Clear). Exposure times were 120–300s, all with auto-guider. The asteroids were observed while crossing a single field per night, thus the same comparison stars were used while calibrating the images.

The observational circumstances are summarized in Table I, which lists the asteroid's designation, the telescope and CCD, the filter, the observation date, the time span of the observation during that night, the number of images obtained, the object's heliocentric distance ( $r$ ), geocentric distance ( $\Delta$ ), phase angle ( $\alpha$ ), and the Phase Angle Bisector (PAB) ecliptic coordinates ( $L_{PAB}$ ,  $B_{PAB}$  - see Harris et al. (1984) for the definition and ways of calculating these parameters).

The images were reduced in a standard way. We used the IRAF *phot* function for the photometric measurements. After measuring, the photometric values were calibrated to a differential magnitude level using  $\sim 700$  local comparison stars per field of the *C18* ( $\sim 400$  stars at the field of the 1-m). The brightness of these stars remained constant to  $\pm 0.02$  mag. Astrometric solutions were obtained using *PinPoint* ([www.dc3.com](http://www.dc3.com)) and the asteroids were identified in the MPC web database. Analysis for the lightcurve period and amplitude was done by Fourier series analysis (Harris and Lupishko 1989). See Polishook and Brosch (2009) for

complete description about reduction, measurements, calibration and analysis.

Lightcurves and spin periods of 18 asteroids, most with reliability code of 3, are reported here. See Warner et al (2009) for a discussion of the “U code” definitions in the Asteroid Lightcurve Database (LCDB). All objects are main belt asteroids with absolute magnitude in the range of 11.4–16.4 mag. None of the asteroids has published photometric measurements, except for 1906 Naef (Durkee and Pravec 2007) and 4554 Fanyinka (Clark 2008). In those cases, the periods given here are in agreement with the previous results. Since these asteroids were not the prime targets of our observing campaign, they were observed only for one or few nights. Therefore, the spin results, which are averaged on 4.9 hours, are biased against slow-rotators, tumblers, and potential binaries.

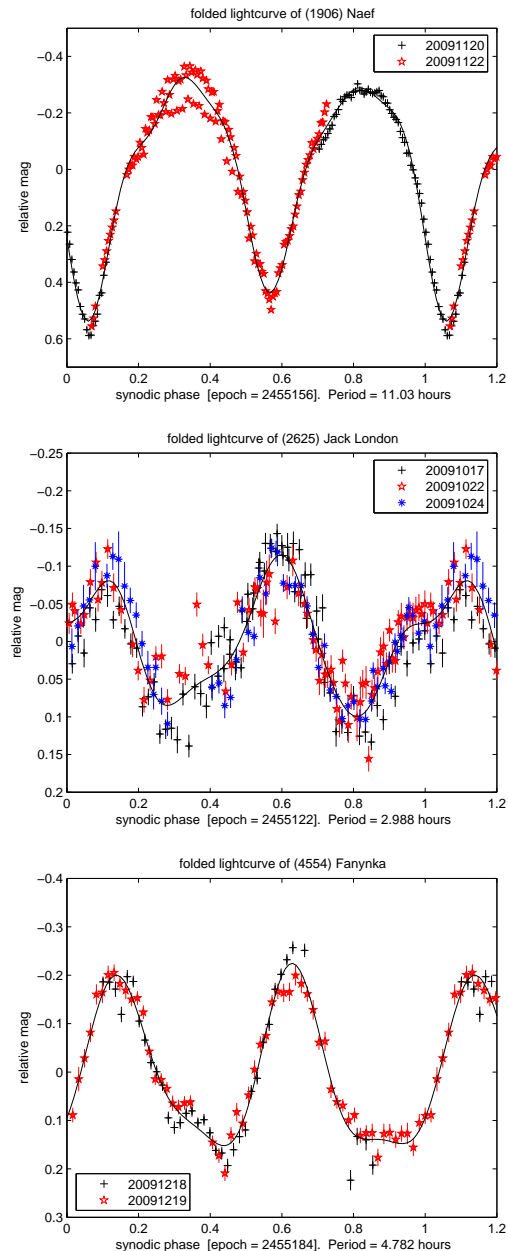
The results are listed in Table II, which includes the asteroid name, rotation period, reliability code (*U*), photometric amplitude, and the absolute magnitude *H* as appears in the MPC website ([www.cfa.harvard.edu/iau/mpc.html](http://www.cfa.harvard.edu/iau/mpc.html)). The folded lightcurves are presented afterwards on a relative magnitude scale. The composite lightcurve and  $3.63 \pm 0.05$  h period result for (40701) 1999 RG235 assumes two maxima and minima per rotation, even though the measured maxima are slightly offset in their peak values. A triple maximum for a nearly  $\sim 1$  magnitude amplitude would be very unlikely, but if triple, the alternate period would be  $5.40 \pm 0.07$  h. Some magnitude drops in the lightcurves of (94763) 2001 XM99 and (127311) 2002 JV90 resemble the signatures of binary asteroids, but these are faint objects with low signal-to-noise measurements. Nevertheless, they may be candidates for some future follow-up studies.

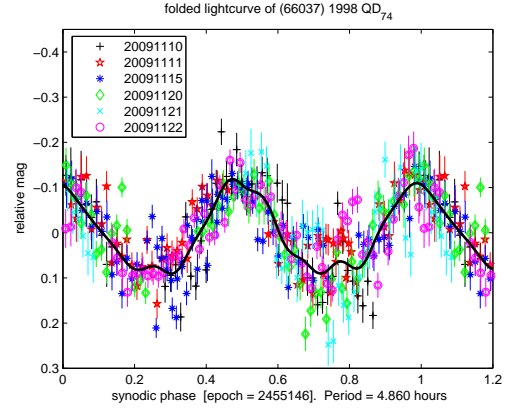
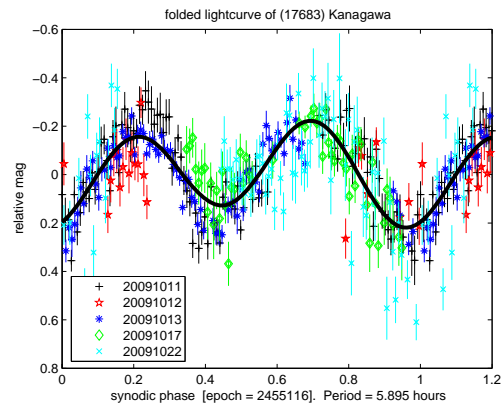
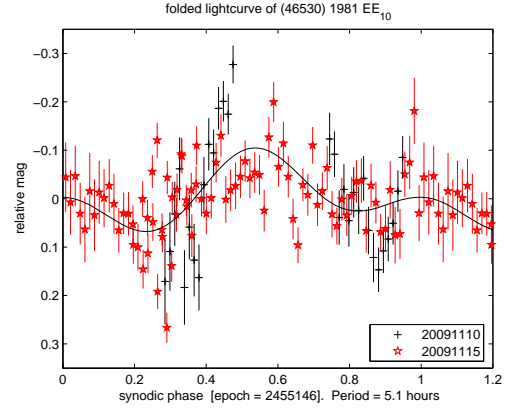
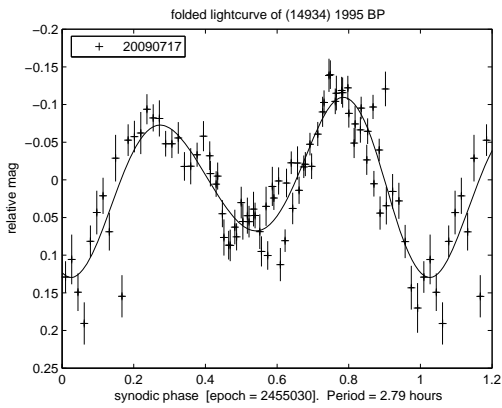
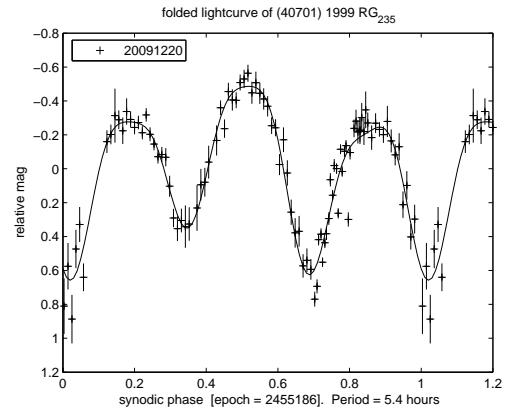
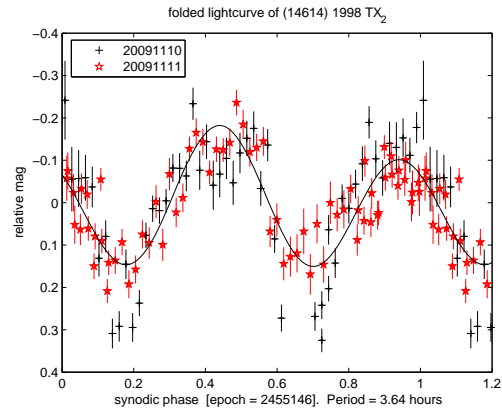
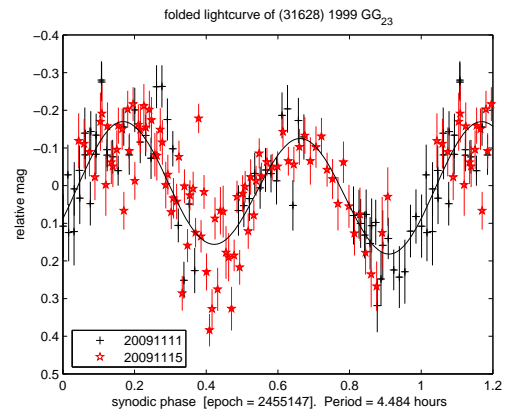
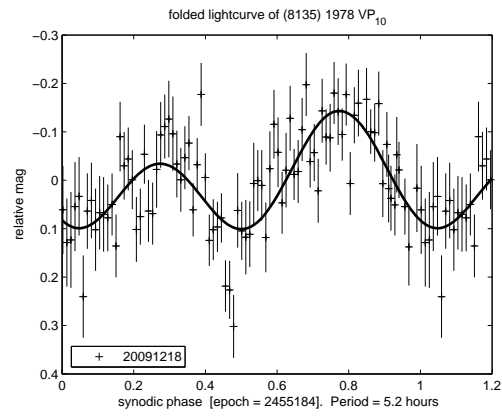
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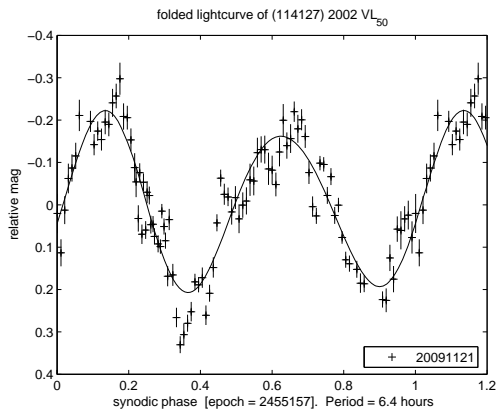
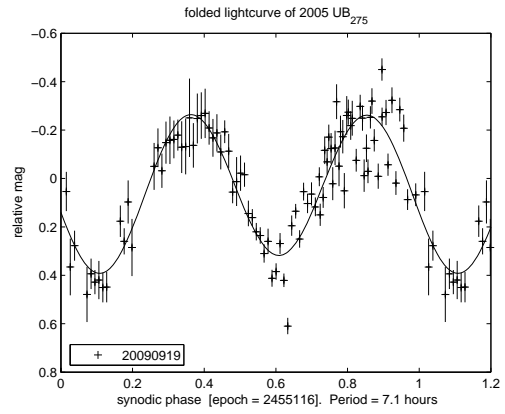
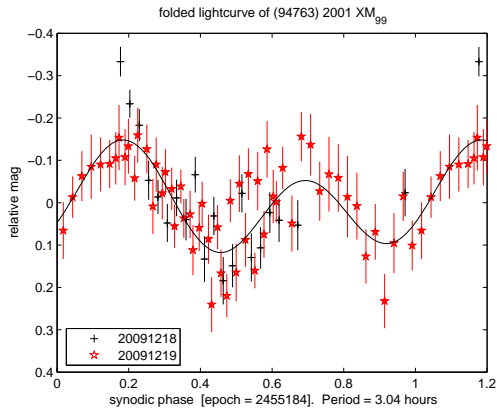
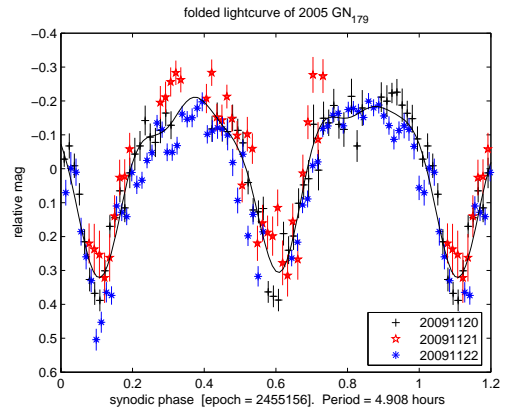
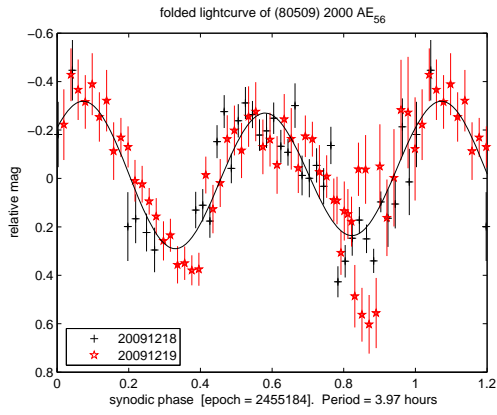
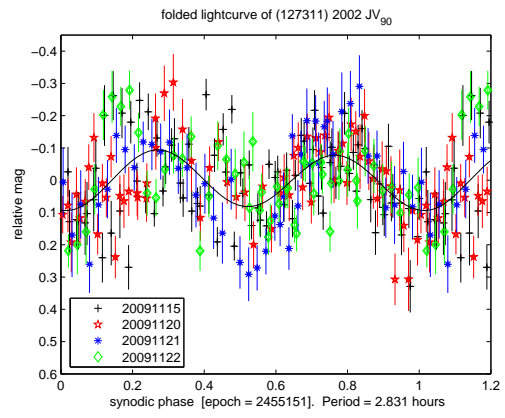
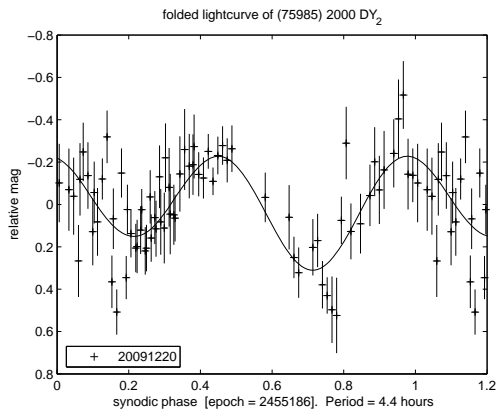
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Asteroid	Scope	CCD	Filter	Date	Time span [hours]	N	r [AU]	$\Delta$ [AU]	$\alpha$ [Deg]	$L_{PAB}$ [Deg]	$B_{PAB}$ [Deg]
1906 Naef	1m	PI	Clear	Nov 20, 2009	4.46	69	2.19	1.25	10.63	74	8
	1m	PI	Clear	Nov 22, 2009	7.22	120	2.19	1.24	9.69	74.2	8.1
2625 Jack London	C18	STL	Clear	Oct 17, 2009	3.92	81	1.99	1.23	23.52	346.2	-4.1
	C18	STL	Clear	Oct 22, 2009	4.78	79	2	1.28	24.76	347.3	-4.1
	C18	STL	Clear	Oct 24, 2009	4.14	60	2	1.3	25.21	347.7	-4.2
4554 Fanyinka	C18	STL	Clear	Dec 18, 2009	3.6	38	3.53	2.7	9.81	54.8	3
	C18	STL	Clear	Dec 19, 2009	4.49	58	3.53	2.71	10.08	54.9	3
(8135) 1978 VP <sub>10</sub>	C18	STL	Clear	Dec 18, 2009	5.34	88	2.59	1.9	18.21	131.8	3.1
(14614) 1998 TX <sub>2</sub>	C18	STL	Clear	Nov 10, 2009	3.71	51	3.07	2.09	3.19	55.6	3.7
	C18	STL	Clear	Nov 11, 2009	4.74	70	3.07	2.09	2.82	55.6	3.7
(14934) 1995 BP	C18	STL	Clear	Jul 17, 2009	4.15	85	2.14	1.31	19.86	328.8	1.6
17683 Kanagawa	C18	STL	Clear	Oct 11, 2009	5.05	100	3.37	2.6	12.42	339.2	-5.3
	C18	STL	Clear	Oct 12, 2009	2.63	23	3.37	2.61	12.62	339.3	-5.2
	C18	STL	Clear	Oct 13, 2009	4.44	83	3.37	2.63	12.83	339.3	-5.2
	C18	STL	Clear	Oct 17, 2009	3.54	54	3.37	2.68	13.6	339.5	-4.9
	C18	STL	Clear	Oct 22, 2009	4.19	71	3.38	2.74	14.43	339.7	-4.6
(31628) 1999 GG <sub>23</sub>	C18	STL	Clear	Nov 11, 2009	5.8	63	2.78	1.79	3.15	55.3	3.8
	C18	STL	Clear	Nov 15, 2009	6.45	87	2.77	1.79	1.97	55.4	3.9
(40701) 1999 RG <sub>235</sub>	C18	STL	Clear	Dec 20, 2009	6.13	97	2.53	1.8	18.02	131	3.8
(46530) 1981 EE <sub>10</sub>	C18	STL	Clear	Nov 10, 2009	3.37	31	2.31	1.33	4.2	54.8	3.4
	C18	STL	Clear	Nov 15, 2009	6.31	87	2.32	1.33	2.16	55.2	3.3
(66037) 1998 QD <sub>74</sub>	C18	STL	Clear	Nov 10, 2009	4.28	52	2.82	1.84	3.42	55.1	3.9
	C18	STL	Clear	Nov 11, 2009	5.8	66	2.82	1.84	3.02	55.2	3.9
	C18	STL	Clear	Nov 15, 2009	6.1	84	2.82	1.84	1.83	55.3	3.7
	C18	STL	Clear	Nov 20, 2009	4.15	60	2.82	1.84	2.1	55.5	3.6
	C18	STL	Clear	Nov 21, 2009	3.2	47	2.82	1.84	2.4	55.6	3.5
	C18	STL	Clear	Nov 22, 2009	4.44	65	2.82	1.84	2.71	55.6	3.5
(75985) 2000 DY <sub>2</sub>	C18	STL	Clear	Dec 20, 2009	5.83	73	3.01	2.31	15.1	133.3	3.7
(80509) 2000 AE <sub>56</sub>	C18	STL	Clear	Dec 18, 2009	3.51	37	2.47	1.62	14.2	57.5	2.7
	C18	STL	Clear	Dec 19, 2009	4.4	56	2.47	1.63	14.59	57.6	2.7
(94763) 2001 XM <sub>99</sub>	C18	STL	Clear	Dec 18, 2009	2.41	20	2.37	1.52	14.72	58.2	2.7
	C18	STL	Clear	Dec 19, 2009	4.4	56	2.37	1.53	15.13	58.3	2.7
(114127) 2002 VL <sub>50</sub>	1m	PI	Clear	Nov 21, 2009	6.93	99	2.22	1.3	12.19	80.2	-0.7
(127311) 2002 JV <sub>90</sub>	C18	STL	Clear	Nov 15, 2009	6.25	91	2.94	1.95	1.68	55.2	3.6
	C18	STL	Clear	Nov 20, 2009	4.65	67	2.94	1.96	2.14	55.3	3.9
	C18	STL	Clear	Nov 21, 2009	3.2	47	2.95	1.96	2.44	55.4	3.9
	C18	STL	Clear	Nov 22, 2009	4.52	66	2.95	1.97	2.76	55.4	3.9
(189265) 2005 GN <sub>179</sub>	C18	STL	Clear	Nov 20, 2009	4.65	60	1.92	0.93	3.23	56.1	3.2
	C18	STL	Clear	Nov 21, 2009	3.2	38	1.91	0.93	3.64	56.2	3
	C18	STL	Clear	Nov 22, 2009	4.52	66	1.91	0.93	4.1	56.3	2.9
2005 UB <sub>275</sub>	C18	STL	Clear	Sep 19, 2009	8.44	94	2.26	1.27	5.74	5.9	2.9

Table I. Observing circumstances. See the text for an explanation of the columns.

Asteroid name	Period [hours]	U	Amplitude [mag]	H by MPC [mag]
1906 Naef	11.03 ± 0.02	2	0.95 ± 0.03	12.7
2625 Jack London	2.988 ± 0.001	3	0.22 ± 0.05	13.1
4554 Fanyinka	4.782 ± 0.006	2	0.40 ± 0.04	11.4
(8135) 1978 VP <sub>10</sub>	5.2 ± 0.4	2	0.3 ± 0.1	13.9
(14614) 1998 TX <sub>2</sub>	3.64 ± 0.01	2	0.25 ± 0.07	14.1
(14934) 1995 BP	2.79 ± 0.06	2	0.25 ± 0.05	13.5
17683 Kanagawa	5.895 ± 0.004	3	0.4 ± 0.1	12.7
(31628) 1999 GG <sub>23</sub>	4.484 ± 0.004	2	0.4 ± 0.1	14.8
(40701) 1999 RG <sub>235</sub>	3.63 ± 0.05	3	1.2 ± 0.1	14.7
(46530) 1981 EE <sub>10</sub>	5.1 ± 0.6	1	0.3 ± 0.1	16.1
(66037) 1998 QD <sub>74</sub>	4.860 ± 0.001	2	0.30 ± 0.07	14.4
(75985) 2000 DY <sub>2</sub>	4.4 ± 0.3	2	0.6 ± 0.1	14.1
(80509) 2000 AE <sub>56</sub>	3.97 ± 0.01	2	0.6 ± 0.1	15.4
(94763) 2001 XM <sub>99</sub>	3.04 ± 0.01	2	0.35 ± 0.08	14.9
(114127) 2002 VL <sub>50</sub>	6.4 ± 0.2	3	0.45 ± 0.05	15.8
(127311) 2002 JV <sub>90</sub>	2.831 ± 0.002	2	0.3 ± 0.1	14.5
(189265) 2005 GN <sub>179</sub>	4.908 ± 0.004	3	0.60 ± 0.10	16.4
2005 UB <sub>275</sub>	7.1 ± 0.2	2	0.7 ± 0.2	15.4

Table II. Derived periods and amplitudes. The *U* code (reliability) is the suggested value. The value in the Asteroid Lightcurve Database (LCDB, Warner et al., 2009) may differ.

## A TRIO OF HUNGARIA BINARY ASTEROIDS

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We report on our CCD photometric observations and analysis of three Hungaria asteroids. 1509 Esclangona, was a known binary before observations were started. Periods of  $3.25283 \pm 0.00002$  h and  $6.6422 \pm 0.0003$  h are found, with amplitudes of 0.13 mag and 0.04 mag. They are likely the individual rotations of the primary and secondary, respectively. 2131 Mayall and (26471) 2000 AS152, are new binary discoveries stemming from the on-going study of the Hungaria asteroids at the Palmer Divide Observatory. Both had previously reported lightcurve solutions with no evidence of binary nature. For 2131 Mayall,  $P_{\text{primary}} = 2.5678 \pm 0.0001$  h, and  $P_{\text{orb}} = 23.48 \pm 0.01$  h with amplitudes of  $A_{\text{primary}} = 0.09$  mag and  $A_{\text{secondary}} = 0.05$  mag. For (26471) 2000 AS152 we report:  $P_{\text{primary}} = 2.68679 \pm 0.00003$  h,  $P_{\text{orb}} = 39.28 \pm 0.01$  h, and  $A_{\text{primary}} = 0.22$  mag. The latter two cases demonstrate why NEA and inner main-belt objects that fit the general characteristics of potential binaries ( $P = 2\text{-}5$  h;  $D < 10$  km,  $A < 0.30$  mag) should be observed at various viewing geometries to determine their true nature.

This inner main belt Hungaria group has been the subject of directed work by Warner and Harris in collaboration with Pravec since 2005 (see Warner et al., 2009b) that has produced lightcurves on approximately 150 members of the group and lead in large part to the discovery of 10 known and 5 suspected binary asteroids. As part of this effort, the authors participated in three different campaigns in 2009 that obtained data for three Hungaria asteroids. The primary purpose was to obtain data for spin axis and shape modeling although one of them, 1509 Esclangona, was a known binary. Two others, 2131 Mayall and (26471) 2000 AS152, were new binary discoveries, even though they had been well-observed in the past.

This points out the value, beyond the obvious one for modeling, in observing a given asteroid at several apparitions, even if the period is well-established after the first set of observations. It is particularly true when the object's physical and rotational characteristics are within the realm of potential binary asteroids, i.e.,  $P = 2\text{-}5$  h;  $D < 10$  km,  $A < 0.30$  mag. As shown with 2131 Mayall, it took a third set of data obtained at a viewing aspect different from the previous two to discover its binary nature. Also shown with 2131 Mayall is the advantage of longer observing runs. The previous apparitions allowed nightly runs about one-half those in 2009. Given the orbital period's closeness to the 24-hour observing cadence, the longer runs were able to reveal the satellite's rotation in a smaller number of runs.

1509 Esclangona. This Hungaria asteroid was previously discovered to be binary by Merline et al. (2003) using adaptive optics observations. They did not report a rotation period for the primary or orbital period of the satellite but did report a projected separation of 140 km and estimated size of the satellite of  $D \sim 4$  km. Behrend (2009) reported a period of 1.27 h based on observations in 2001. Warner (2005) reported a synodic period of 3.247 h based on observations in late 2004. At that time, there were no indications of the satellite's presence. Initial observations

by Warner in 2009 September indicated the possibility of a two periods within the lightcurve data. An observing campaign was formed that provided data from 2009 Sept 9 to Oct 27. Analysis by Pravec found two distinct periods:  $3.25283 \pm 0.00002$  h and  $6.6422 \pm 0.0003$  h with amplitudes of 0.13 mag and 0.04 mag, respectively. It appears likely that the two lightcurve components are due to the rotation of the primary and its satellite. Given the relatively large separation of the two objects, observing mutual events (occultations and/or eclipses) is highly unlikely. It is probable that the shorter period and larger amplitude belong to the primary object in the system.

Figure 1 shows the data phased to a period of 3.25283 h after removing the effects of the longer period. This is presumably the primary's lightcurve. Figure 2, presumably that of the satellite, shows the data phased to the longer period after removing the primary's lightcurve.

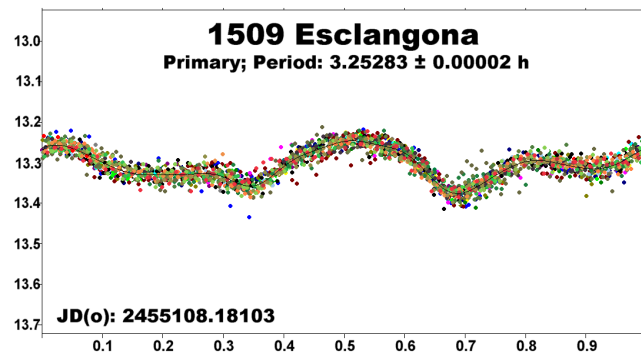


Figure 1. Lightcurve of the presumed primary of 1509 Esclangona.

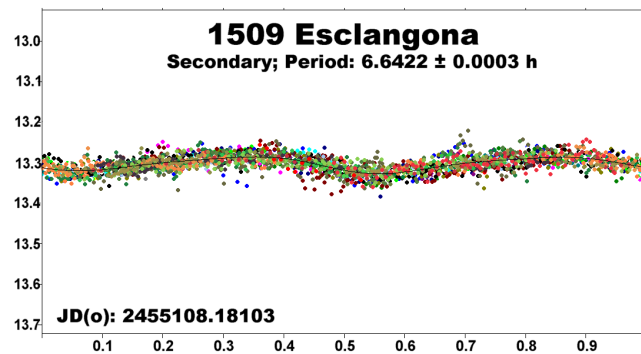


Figure 2. Lightcurve of the presumed secondary of 1509 Esclangona.

**2131 Mayall.** This Hungaria was observed previously by Warner (2005) and Warner et al. (2007). In both cases, the synodic period was found to be  $P \sim 2.57$  h with an amplitude of  $A \sim 0.08$  mag. In neither case was there any indication that the asteroid was binary. Warner started observing it in 2009 November with the intent of obtaining data for spin axis and shape modeling. The first night showed the expected 2.57 h period but with an “upward bowing” of the average magnitude over the duration of the run. This effect was noticed on subsequent runs. Initial analysis by Pravec indicated the possibility of a second period and so an observing campaign was formed. Data obtained from 2009 November 30 through December 13 by the authors confirmed the binary nature of the asteroid with the observation of mutual events in addition to the “bowing”, which is the result of rotation of the elongated satellite that is tidally locked to its orbital period.

Analysis by Pravec found periods of  $P_{\text{primary}} = 2.5678 \pm 0.0001$  h; and  $P_{\text{orb}} = 23.48 \pm 0.01$  h. The amplitudes are  $A_{\text{primary}} = 0.09$  mag and  $A_{\text{secondary}} = 0.05$  mag. The diameter ratio is  $D_2/D_1 \geq 0.26$ . Figure 3 shows the primary's lightcurve while Figure 4 shows the satellite's lightcurve with rotation with mutual events. It should be noted that due the fact that the orbital period was very nearly commensurate with the typical observing cadence, 24 hours, it would have been very difficult – if not impossible – for a single station to have obtained sufficient data to resolve the system's characteristics.

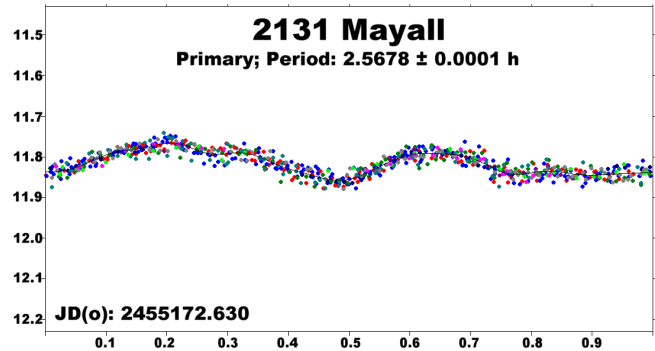


Figure 3. Primary lightcurve of 2131 Mayall.

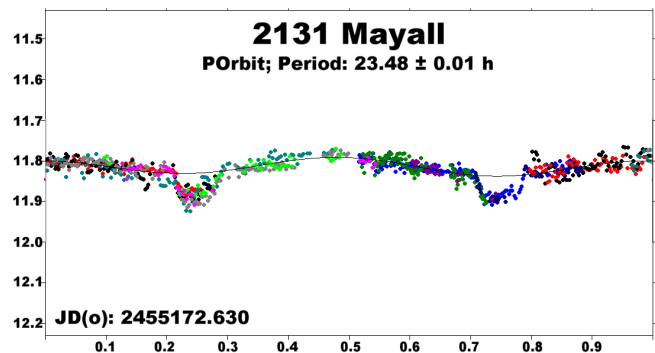


Figure 4. The lightcurve of the satellite of 2131 Mayall showing rotation and mutual events.

(26471) 2000 AS152. Behrend et al. (2009) reported a period of 2.684 h for this Hungaria member based on data in 2001. The amplitude was 0.24 mag. In 2008, Warner (2008) observed the asteroid, finding  $P = 2.687$  h and  $A = 0.20$  mag. There were no indications of the asteroid being binary in the 2008 observations. Warner started observing the asteroid in late 2009 as part of the PDO Hungaria program and almost immediately noted what appeared to be mutual events. An observing campaign involving the Binary Asteroid group under Petr Pravec was started.

Observations were obtained from 2009 July 13–Aug 2 that confirmed the binary nature of the asteroid with  $P_{\text{primary}} = 2.68679 \pm 0.00003$  h,  $P_{\text{orb}} = 39.28 \pm 0.01$  h, and  $A_{\text{primary}} = 0.22$  mag. The estimated size ratio is  $D_2/D_1 = 0.36 \pm 0.02$ . Only one type of event (occultation or eclipse) was observed, those being nearly central. There are three figures each for the primary and secondary lightcurves. The first shows the initial data set that was used to derive the system parameters. The second two, taken in mid-August and mid-September are not as dense but do show the evolution of both lightcurves as the viewing geometry changed.

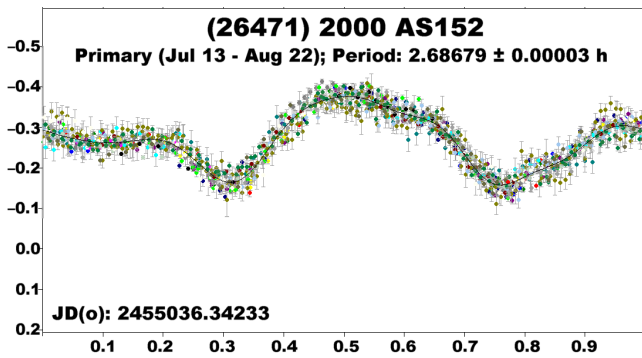


Figure 5. Primary lightcurve of (26471) 2000 AS152 in 2009 July and August.

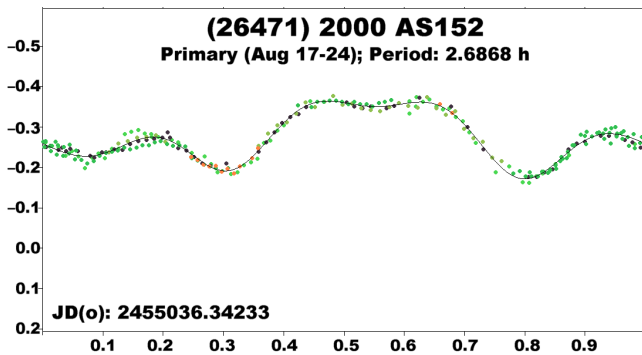


Figure 6. Primary lightcurve of (26471) 2000 AS152 in 2009 mid-August. Note the change in the shape of the curve.

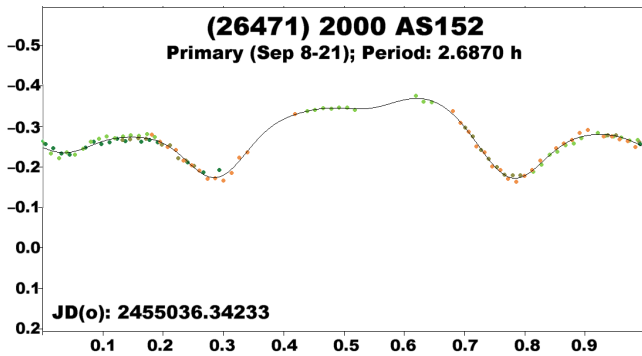


Figure 7. Primary lightcurve of (26471) 2000 AS152 in 2009 mid-September showing the lightcurve's continued evolution.

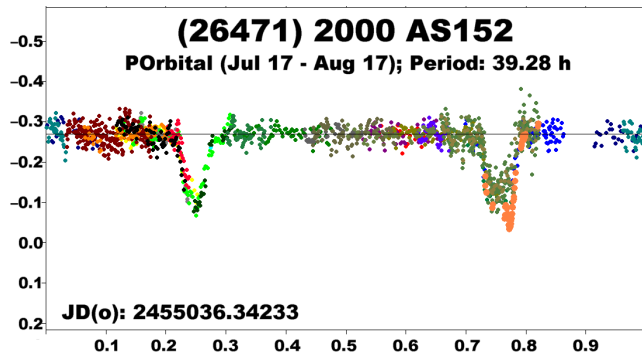


Figure 8. The lightcurve of the secondary of 2000 AS152 in 2009 July-August showing the mutual events that allowed finding the size ratio.

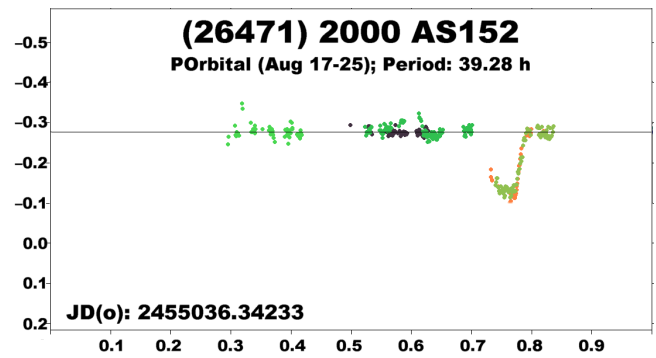


Figure 9. The lightcurve of the secondary of 2000 AS152 in 2009 mid-August. Note the change in the event at ~0.75 phase.

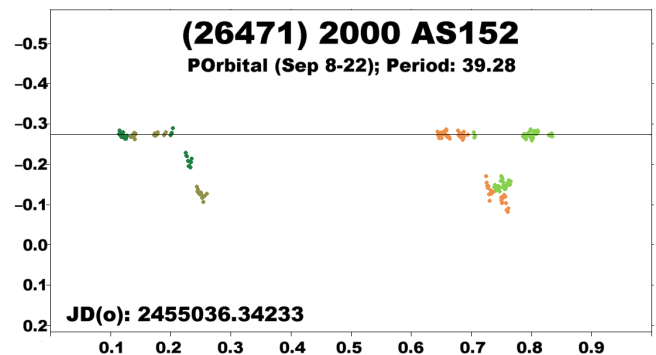


Figure 10. The lightcurve of the secondary of 2000 AS152 in 2009 mid-September shows a further evolution of the mutual event shape and depth.

### Conclusion

The discovery of 2131 Mayall and (26471) 2000 AS152 brings to 15 the total number of known or suspected Hungaria binaries. The 10 known binaries account for about 6% the total number of Hungarias with lightcurve parameters in the Asteroid Lightcurve Database (Warner et al., 2009). This is in good agreement with the ratio found by Pravec et al. (2006) for the NEA population and indicates a similar mechanism for binary formation, that being YORP spin-up and eventual fission of a small asteroid.

### Summary of Analysis and Observing Circumstances

#	P <sub>1</sub> h	P <sub>2</sub> h	Dates (2009)	Phase	PAB
1509	3.252	6.64	09/09-	26,2	22,32
	83	22	10/27	1	
2131	2.567	23.4	11/30-	25,2	91,34
	8	8	12/13	2	
26471	2.686	39.2	07/13-	29,2	327,2
	79	8	08/22	5	7
26471	2.686	39.2	08/17-	24.5	330,2
	8	8	08/24		9
26471	2.687	39.2	09/08-	26,2	334,3
	0	8	09/21	9	1

Table 1. P<sub>1</sub> is the period of the primary and P<sub>2</sub> is the period of the satellite which is also the orbital period, except for 1509 Esclangona (see the text). The PAB is the average Phase Angle Bisector longitude, latitude for the given date range.

### Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX 09AB48G, by National Science Foundation grant AST-0907650, and by a 2007 Gene Shoemaker NEO Grant from the Planetary Society. The work at Ondřejov was supported by the Grant Agency of the Czech Republic, Grant 205/09/1107. Research at Skalnaté Pleso Observatory was supported by the Slovak Grant Agency for Science VEGA, No. 2/7009/27. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by NASA and NSF.

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## ANALYSIS OF THE LIGHTCURVE OF 1101 CLEMATIS

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(Received: 13 October)

We report on our collaboration to obtain photometric data on the outer main-belt asteroid, 1101 Clematis. Data obtained in 2009 September yield a synodic rotation period of  $34.3 \pm 0.1$  h and lightcurve amplitude of  $0.16 \pm 0.02$  mag. The period spectrum shows a possible period at  $\sim 18.4$  h but the phased lightcurve plot shows this solution is unlikely. The period of 34.3 h differs significantly from previously reported results.

Equipment and basic image acquisition methods used by the authors have been previously described (see Stephens 2006; Warner 2009). We linked our observations from night-to-night using the 2MASS (Skrutskie et al., 2006) to BVRI conversions developed by Warner (2007) and applied as described by Stephens (2008).

Several periods had been previously reported for asteroid 1101 Clematis. Behrend (2009) found a period of 8.61 h based on data from 2002. Data from 2003 analyzed by Behrend gave only a period of  $> 6$  h and amplitude of  $> 0.02$  mag. Stephens (2004), using data obtained in 2003, found a period of 12.68 h with an amplitude of 0.4 mag. Given the wide range of results, we observed the asteroid in 2009 September with the hope of finding an accurate period. Unfortunately, Clematis proved to be a difficult target yet again. Our data, shown in the plot below, give a period of  $P = 34.3 \pm 0.1$  h and amplitude  $A = 0.16 \pm 0.02$  mag. Attempts to force the data to the other periods (as well as new

ones) were unsuccessful. The closest we came was a period of  $\sim 12.7$  h, but that was a monomodal solution and required removing one of the data sessions. Even after removing that session, a search for a period of  $\sim 25.4$  h, corresponding to a bimodal solution, produced totally unacceptable results. While not a perfect solution, we believe the result of 34.3 h is closer the true period of the asteroid than previous results.

### Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX 09AB48G, by National Science Foundation grant AST-0607505 and AST-0907650, and by a 2007 Gene Shoemaker NEO Grant from the Planetary Society. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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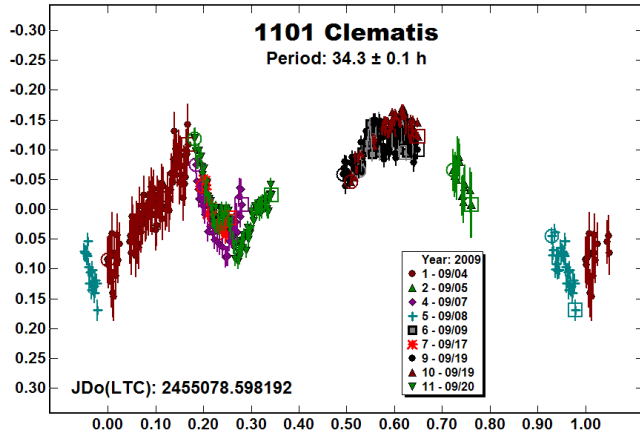
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Asteroid	2009	$\alpha$	$I_{PAB}$	$B_{PAB}$
1101 Clematis	09/04-20	10, 13	325	21

Table I. Observing circumstances. The phase angle column gives the values on the first and last date.

## LIGHTCURVE ANALYSIS OF ASTEROID 990 YERKES

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Photometric data were taken in late 2009 for main-belt asteroid 990 Yerkes. Data analysis revealed a likely synodic period of  $24.45 \pm 0.05$  h and estimated amplitude of  $0.35 \pm 0.05$  mag.

Main-belt asteroid 990 Yerkes was observed from 2009 November 8 through 2009 December 15. All observations were made with a 0.3m Schmidt-Cassegrain (SCT) operating at f/6.1 on a German Equatorial mount (GEM). The imager was an SBIG ST9 working at 1x1 binning which resulted in an image scale of 2.2 arc seconds/pixel. An SBIG AO-8 adaptive optics unit was employed. All images were taken through a Johnson V-band filter. The camera temperature was set in a range of  $-20^{\circ}\text{C}$  to  $-40^{\circ}\text{C}$  depending on ambient air temperature. Image acquisition and reduction were done with *CCDSofit*. Images were reduced with master dark and sky-flat frames. An imaging session began when the target reached approximately 35 degrees elevation. The GEM required that imaging be halted around target transit time in order to move the telescope to the other side of the pier. In order to avoid the "meridian flip" problem (Miles and Warner, 2009) a new photometry session was started after each meridian flip. Other than this interruption, the camera took continuous exposures, pausing only to download each image. Exposures were 300 seconds.

Observations were reduced using differential photometry. Period analysis was done with *Canopus*, incorporating the Fourier analysis algorithm developed by Harris (1989). A minimum of two comparison stars from the UCAC2 catalog (Zacharias et al., 2004) were used on each image. 521 data points were used. 990 Yerkes was selected as a target due to its favorable sky position and lack of any previously published lightcurve. While analyzing my data, I became aware that a team in Spain had recently observed 990 Yerkes and were preparing to publish their results (Martinez et al., 2010). Although the data is noisy at points, it appears that a period  $24.45 \pm 0.05$  h is likely. Another solution ( $16.45 \pm 0.05$  h) was found but the data fit was not nearly as good. Estimated amplitude of the lightcurve is  $0.35 \pm 0.05$  mag.

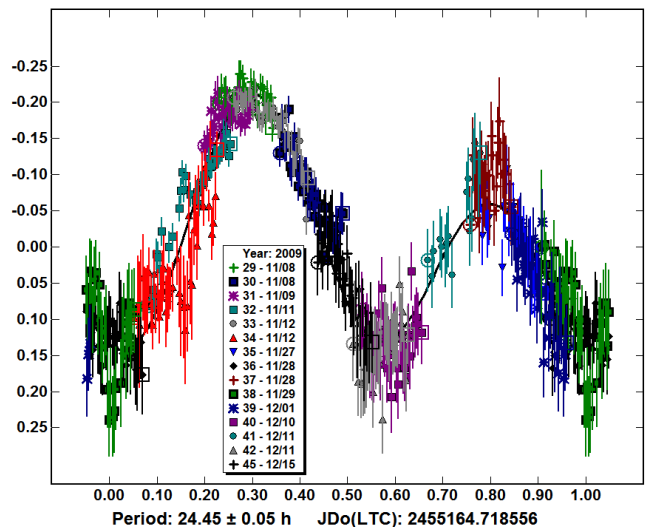
## Acknowledgements

Thanks to Brian Warner for guidance in constraining the period. This paper makes use of data products from The Second U.S. Naval Observatory CCD Astrograph Catalog (UCAC2).

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## Phased Plot: 990 Yerkes



**REVISION: PHOTOMETRIC OBSERVATIONS AND  
LIGHTCURVE ANALYSIS OF NEAR-EARTH ASTEROIDS  
(136849) 1998 CS1, 2006 SZ217, AND 2008 UE7**

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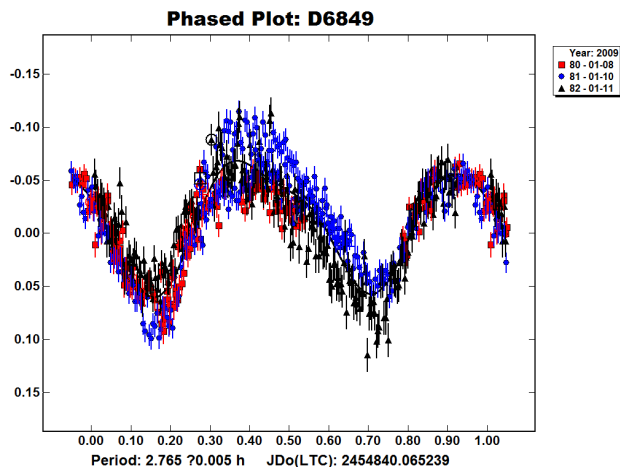
Regarding our published lightcurve analysis result for (136849) 1998 CS1. See Ye et al. (2009; *Minor Planet Bulletin* **36**, 180-181). The result is revised after the availability of further reference information (Benner et al., 2009). The revised rotation period is  $2.765 \pm 0.005$  hr, which is consistent with the result described by Benner et al. (2009). The wrong estimation in the original Ye et al. manuscript was due to the lack of long observing session (no more than 3hr), thus the short period got filtered out from the period search. For the observers with short observing intervals each night, we recommend to have at least one "long" session in the campaign to ensure to cover the possibility of a short rotation period.

**Acknowledgements**

This revision is submitted on behalf of all original authors of Ye et al. (2009). We would like to thank Lance A. M. Benner, Michael W. Busch, Alan W. Harris, Brian D. Warner and Petr Pravec for their valuable discussions.

**Reference**

Benner, L. A. M., Brozovic, M., Giorgini, J. D., Nolan, M. C., Magri, C., Ostro, S. J., Jao, J. S., Lawrence, K. J., Margot, J. L., Busch, M. W., Shepard, M. K., Howell, E. S., Taylor, P. A., and Carter, L. M. (2009). Arecibo and Goldstone Radar Images of Near-Earth Asteroid (136849) 1998 CS1, 41th DPS meeting #43.09.



**ROTATION PERIOD DETERMINATION  
FOR 53 KALYPSO**

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(Received: 9 January)

New data taken at a different viewing angle have led to a revision in the period for 53 Kalypto. A synodic rotation period and amplitude have been found to be  $9.036 \pm 0.001$  h,  $0.14 \pm 0.02$  mag. Considering all available data, this value is now considered more secure compared with a period exactly twice as long.

Observations by Pilcher at the Organ Mesa Observatory used a Meade 35 cm LX200 GPS S-C, SBIG STL-1001E CCD, differential photometry only, unguided exposures, R filter. Observations by Pray at the Carbuncle Hill Observatory are with a 0.51m f/4 reflector with SBIG ST-10XME CCD at the prime focus. Image measurement and lightcurve analysis were done by *MPO Canopus*.

Debehogne et al. (1982) obtained a very sparse lightcurve for which they claimed a period near 27 hours. Surdej et al. (1983) obtained additional observations later in the same opposition and linking the results obtained a possible period of 26.55 hours, but a reexamination suggests alias periods are likely. Harris and Young (1989) obtained additional lightcurves and suggested their own results and those by Debehogne et al. (1982) and Surdej et al. (1983) more likely indicate a period 16-20 hours. Pray et al. (2006) found a period  $18.075 \pm 0.005$  hours, amplitude 0.14 magnitudes.

Observations by first author Pilcher on 6 nights 2009 Nov. 2 – 18 at phase angles 18 – 12 degrees show a somewhat asymmetric bimodal lightcurve with period  $9.034 \pm 0.001$  hours, amplitude  $0.14 \pm 0.02$  magnitudes. Pray et al. (2006) also show a bimodal lightcurve with twice the period. This discordance should be resolved. When the data of these six nights are phased to 18.068 hours, the two halves of the resulting quadrimodal lightcurve look nearly identical to each other and to the 9.034 hour lightcurve. The coefficients of the odd harmonics of the Fourier series for the 18.068 hour period are systematically considerably lower than for the even harmonics. Both of these considerations suggest that 9.034 hours, not twice as long, is the correct period. A seventh session was added 2009 Dec. 6 at phase angle 4.4 degrees with amplitude decreased to  $0.10 \pm 0.01$  magnitudes. Such a decrease with phase angle is usually found due to lesser shadowing by topographic irregularities. The best period for all seven sessions increased to  $9.036 \pm 0.001$  hours. This is likely due to the prograde motion of the phase angle bisector slowing upon approaching opposition. Such an increase in synodic period is suggestive of retrograde rotation, but the observed amount is too small to be definitive. Also for the lightcurve set including Dec. 6 the coefficients of the odd higher order harmonics of the Fourier series for the double period, now 18.069 hours, were not

systematically smaller than for the even harmonics. A nine hour session on one night necessarily includes only half of an 18 hour lightcurve. Combined with the aforementioned increase in synodic period, this does not constitute strong evidence against the shorter period.

When informed of the new 2009 observations, second author Pray re-examined his 2006 results and included an additional session 2006 Feb. 9. These could be fitted to both a 9.029 hour monomodal slightly irregular lightcurve or an 18.058 hour bimodal lightcurve in which the two halves closely resembled each other and the 9.029 hour lightcurve. Again a period near 9.03 hours is favored, with the considerably different forms of the 2006 and 2009 lightcurves a consequence of viewing at very different longitudes.

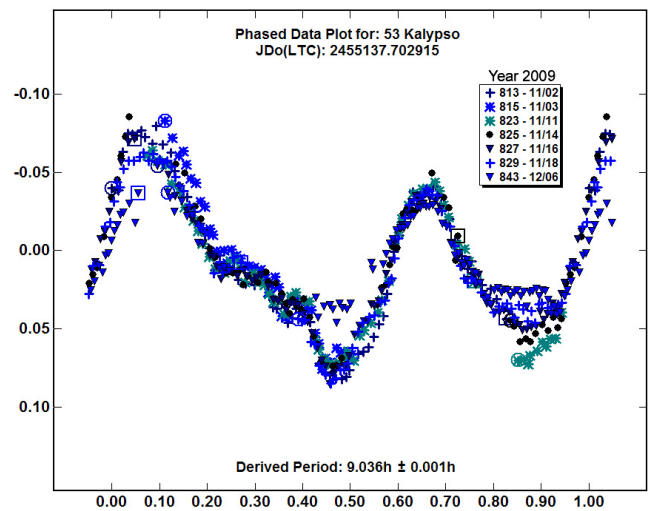
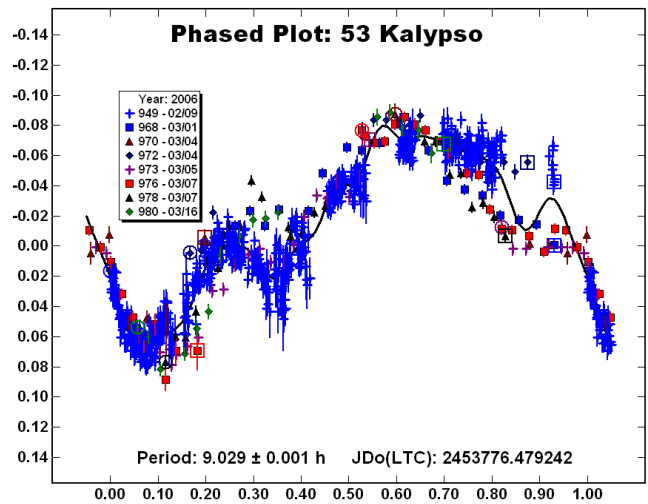
The lightcurves from 2006 rephased to 9.029 hours and from 2009 are separately presented.

#### Acknowledgments

Operations at Carbuncle Hill Observatory were partially funded by a Gene Shoemaker NEO Grant from the Planetary Society.

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#### LIBRARY ARCHIVE DONATION ACKNOWLEDGED

As previously announced (see *MPB* Volume 36, Number 4, page 194), *MPB* print subscriptions, except for library archives, will be discontinued after Volume 37 Issue Number 4. All future *Minor Planet Bulletin* issues will continue, as at present, to be available "free" in electronic format. A very generous donation, by a requested to remain anonymous contributor, will substantially perpetuate the ongoing library archives of future issues of the *Minor Planet Bulletin*. We offer our thanks for this support.

#### CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar year 2009 are encouraged to report them to the author on or before 2010 April 1. This will be the deadline for receipt of reports that can be included in the "General Report of Position Observations for 2009," expected to be published in *MPB* Vol. 37, No. 3.

## LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2010 APRIL - JUNE

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This time we feature several NEAs for radar support that may present some challenges given their fast sky motion, faintness, and/or proximity to the Sun. For more background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188.

### In Focus

We'll repeat from the last issue the need to observe asteroids even if they have well-established lightcurve parameters but do not yet have good spin axis or shape models. Every lightcurve of sufficient quality provides valuable information in support of such efforts, which are needed to resolve a number of questions about the evolution of individual asteroids and the general population.

Another area wanting more help is support for occultations. The recent article by Timerson et al (2009; *MPB* **36**, 98-100) discussing the results of three occultation campaigns shows the importance of adding lightcurve data to the mix by being able to determine the rotation phase of the asteroid at the time of the event. The CALL web site features a page devoted to occultation support:

<http://www.minorplanetobserver.com/astlc/Occultations.htm>

On that page are links to 2010 occultation highlights, maps showing asteroid shadow paths for various events, and the International Occultation Timing Association web site (IOTA). Many techniques and excellent software have been developed in recent years to make electronic occultation observations (video and CCD) easier and of greater scientific use. If you're looking for something a little different that has some good scientific benefit, we urge you to consider signing up in support of occultation work.

### The Opportunities Lists

We present four lists of "targets of opportunity" for the period 2010 April-June. In the first three sets of tables, Dec is the declination, U is the quality code of the lightcurve, and  $\alpha$  is the

solar phase angle. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

[www.minorplanetobserver.com/astlc/LightcurveParameters.htm](http://www.minorplanetobserver.com/astlc/LightcurveParameters.htm)

Note that the lightcurve amplitude in the tables could be more, or less, than what's given. Use the listing only as a guide.

Objects with no U rating or  $U = 1$  should be given higher priority when possible. **We urge that you do not overlook asteroids with  $U = 2$  on the assumption that the period is sufficiently established.** Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times.

The first list is those asteroids reaching mag < 15 at brightest during the period and have either no or poorly constrained lightcurve parameters. The goal for these asteroids is to find a well-determined rotation rate.

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

The third list is of those asteroids needing only a small number of lightcurves to allow shape and spin axis modeling. Those doing work for modeling should contact Josef Durech at the email address above and visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site for existing data and models: <http://astro.troja.mff.cuni.cz/projects/asteroids3D>.

The fourth list gives a brief ephemeris for planned radar targets. Supporting optical observations made to determine the lightcurve period, amplitude, and shape are needed to supplement the radar data. High-precision work, 0.01-0.03 mag, is preferred. Those obtaining lightcurves in support of radar observations should contact Dr. Benner directly at the email given above.

Future radar targets:

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

Past radar targets:

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

Arecibo targets:

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

Goldstone targets:

[http://echo.jpl.nasa.gov/asteroids/goldstone\\_asteroid\\_schedule.html](http://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html)

Once you have analyzed your data, it's important that you 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.

Funding for Warner and Harris in support of this article is provided by NASA grant NNX 09AB48G and by National Science Foundation grant AST-0907650.

### Lightcurve Opportunities

This list includes a few un-numbered objects reaching a favorable apparition that may not fit all the usual criteria but may not be seen for many years and so are higher-priority targets.

#	Name	Brightest				LCDB Data		Amp
		Date	Mag	Dec	U	Period	U	
2114	Wallenquist	04 07.5	14.5	- 7	2	5.49	0.30	
310	Margarita	04 07.6	13.1	- 9				
2297	Daghestan	04 09.9	14.6	- 6	2	7.7	0.37	
6961	Ashitaka	04 11.4	14.7	-12				
4569	Baerbel	04 12.1	14.6	-10				
3305	Ceadams	04 15.5	14.9	- 7				
5274	Degewij	04 16.2	15.0	-19				
567	Eleutheria	04 17.7	13.0	- 4	2	7.72	0.26-0.50	
1669	Dagmar	04 18.0	14.4	-11	1	> 12.	>0.15	
2375	Radek	04 22.8	14.1	+11	1		<0.1	
7476	Ogilsbie	04 26.6	14.1	+ 4	2			
1142	Aetolia	04 27.7	14.1	-11				
1162	Larissa	04 27.9	14.2	-14	1	13.0	0.1	
2954	Delsemme	05 01.3	14.8	- 8	2	4.69	0.21	
2500	Alascattalo	05 02.9	14.4	-14				
6139	Naomi	05 04.7	14.9	-31				
5630	Billschaefer	05 04.3	14.9	-12				
1773	Rumpelstilz	05 04.5	14.1	-11				
85818	1998 XM4	05 09.6	14.8	+ 7				
910	Anneliese	05 11.1	13.2	-18				
1109	Tata	05 11.1	13.9	-22	2	8.27	0.06	
1652	Herge	05 13.5	14.7	-21				
16405	1985 DA2	05 13.7	15.0	-32				
858	El Djezair	05 13.3	13.1	-14	2	22.31	0.1	
1680	Per Brahe	05 15.6	13.5	-15	2	3.44	0.11	
5483	Cherkashin	05 15.2	14.4	-17				
12453	1996 YY	05 16.1	14.9	-35				
1340	Yvette	05 18.1	14.6	-20	2	3.52	0.16	
1039	Sonneberga	05 18.2	14.2	-18	2	34.2	0.41	
7091	1992 JA	05 19.9	14.4	-16				
1200	Imperatrix	05 21.3	14.0	-16	2	13.34	0.23	
3419	Guth	05 23.7	14.7	-22				
23080	1999 XH100	05 24.7	15.0	-13				
19852	2000 TT58	05 26.3	15.0	-26				
1154	Astronomia	05 27.8	14.7	-19				
2854	Rawson	05 29.3	14.9	-30				
4191	Assesse	05 29.8	14.9	-16	1	5.4	>0.45	
1512	Oulu	05 30.0	14.3	-30	2+	132.3	0.33	
	1999 HE1	05 31.0	14.1	-33				
15520	1999 XK98	06 02.6	15.0	-26				
997	Priska	06 04.4	14.4	-20	2	16.22	0.61	
3870	Mayre	06 04.8	14.9	- 5				
7205	Sadanori	06 07.1	14.9	-24				
869	Mellena	06 08.9	14.7	- 8				
3985	Raybatson	06 08.1	14.3	-19	2	4.29	0.10	
2149	Schwambraniya	06 10.6	14.3	-27				
6441	Milenajesenska	06 14.5	15.0	-18				
1968	Mehlretter	06 14.9	14.9	-25				
9233	1997 CC1	06 15.5	14.5	- 9				
680	Genoveva	06 16.6	12.3	-46	2+	11.09	0.27	
3459	Bodil	06 20.5	14.1	-21				
5390	Huichiming	06 20.3	14.5	-26	2+	111.	0.25-0.60	
24391	2000 AU178	06 21.6	14.9	-18	2	5.43	0.35	
20231	1997 YK	06 23.8	14.7	-20	1		>0.4	
2171	Kiev	06 26.8	14.8	-21				
7834	1993 JL	06 26.5	14.6	-31				
3528	Counselman	06 27.0	14.9	-24				
1661	Granule	06 28.4	15.0	-22	2	> 24.	0.15	
6201	Ichiroshimizu	06 30.7	15.0	-23				
3614	Tumilty	06 30.8	14.1	-27	2-	26.8	0.10	

### Low Phase Angle Opportunities

#	Name	Date	$\alpha$	V	Dec	Period	Amp	U
91	Aegina	04 12.2	0.26	12.2	-09	6.025	0.15	3
102	Miriam	04 15.0	0.25	13.6	-10	23.613	0.04-0.14	3
1296	Andree	04 17.6	0.97	13.8	-13	5.18366	0.25	3
656	Beagle	05 01.9	0.16	13.8	-15	7.035	0.9	-1.2 3
735	Marghanna	05 02.2	0.22	13.7	-15	15.95	0.11	2
508	Princetonia	05 05.9	0.08	12.4	-17	52.8	0.40	3
90	Antiope	05 06.8	0.45	12.3	-15	16.509	0.08-0.90	3
80	Sappho	05 09.1	0.96	11.1	-15	14.030	0.1	-0.40 3
208	Lacrimosa	05 09.4	0.65	12.8	-19	14.085	0.15-0.33	3
910	Anneliese	05 11.1	0.08	13.2	-18			
12	Victoria	05 11.9	0.64	9.1	-19	8.6599	0.08-0.35	3
3259	Brownlee	05 23.4	0.17	13.6	-21	9.24	0.16	2
76	Freia	05 24.7	0.48	13.2	-19	9.969	0.10-0.33	3
230	Athamantis	05 26.2	0.56	10.3	-20	24.0055	0.1	-0.26 3
1693	Hertsprung	05 27.2	0.75	13.4	-20	8.825	0.45	3
564	Dudu	05 31.7	0.33	12.3	-21	8.882	0.43-0.55	3
1427	Ruvuma	06 03.1	0.73	13.5	-21	4.797	0.30	3
752	Sulamitis	06 09.6	0.46	13.3	-22	27.367	0.20	3
27	Euterpe	06 13.3	0.24	10.4	-23	10.410	0.15-0.21	3
1	Ceres	06 18.9	0.73	7.0	-25	9.074170	0.02-0.06	3
700	Auravictrix	06 24.6	0.47	13.2	-23	6.075	0.42	3
211	Isolda	06 29.0	0.37	12.7	-22	18.365	0.09-0.14	3

Note that 90 Antiope in the above list is a well-determined binary system, including pole orientation. It should be possible to estimate the amplitude of the curve for the upcoming apparition, including whether or not mutual events with the satellite will occur.

### Shape/Spin Modeling Opportunities

#	Name	Brightest			Per (h)	Amp	U
		Date	Mag	Dec			
487	Venetia	04 11.0	12.2	+06	13.28	0.05-0.30	2
270	Anahita	04 15.3	11.5	-13	15.06	0.25-0.34	3
114	Kassandra	04 18.4	11.2	-06	10.758	0.12-0.25	3
145	Adeona	04 26.6	11.7	-01	15.086	0.04-0.08	3
558	Carmen	05 03.6	13.3	-04	11.387	0.2	-0.31 3
376	Geometria	05 04.1	11.2	-26	7.74	0.14-0.19	3
704	Interamnia	05 06.5	11.1	-35	8.727	0.03-0.11	3
80	Sappho	05 09.3	11.0	-15	14.030	0.1	-0.40 3
12	Victoria	05 12.1	9.1	-19	8.6599	0.08-0.35	3
281	Lucretia	05 18.5	14.9	-23	4.348	0.38	3
76	Freia	05 24.6	13.1	-19	9.969	0.10-0.33	3
40	Harmonia	05 28.6	9.5	-18	8.910	0.13-0.36	3
338	Budrosa	06 05.0	12.5	-28	4.6084	0.47	3
30	Urania	06 05.3	10.7	-25	13.686	0.11-0.45	3

### Radar-Optical Opportunities

Use the ephemerides to judge your best chances for observing. Note that the intervals in the ephemerides are not always the same and that *geocentric* positions are given. Use the web sites below to generate updated and *topocentric* positions. In the ephemerides, E.D. and S.D. are, respectively, the Earth and Sun distances (AU), V is the V magnitude, and  $\alpha$  is the phase angle.

Minor Planet Center: <http://cfa-www.harvard.edu/iau/mpc.html>  
JPL Horizons: <http://ssd.jpl.nasa.gov/?horizons>

### 105 Artemis (2010 Apr-Jun)

Higley et al (2008; *MPB* 35, 63-66) reported a model with a sidereal period of 37.15506 h. Given that period, a collaboration among observers with well-distributed longitudes will lead the best possible results in the shortest time. The observations are needed to help determine rotation phase at the time of radar observations. They can also be used to refine the existing shape and spin axis models.

DATE	RA(2000)	DC(2000)	E.D.	S.D.	Mag	$\alpha$
04/01	17 41.30	-01 44.9	1.449	1.960	12.21	29.5
04/11	17 51.81	+01 03.5	1.362	1.958	12.04	28.6
04/21	17 59.48	+04 03.5	1.284	1.957	11.87	27.2
05/01	18 04.00	+07 07.7	1.217	1.957	11.70	25.6
05/11	18 05.19	+10 06.9	1.163	1.959	11.55	23.7
05/21	18 03.05	+12 48.8	1.122	1.962	11.41	21.9
05/31	17 57.98	+15 00.4	1.097	1.967	11.32	20.4
06/10	17 50.77	+16 30.1	1.088	1.972	11.28	19.6
06/20	17 42.60	+17 09.6	1.095	1.979	11.30	19.5
06/30	17 34.88	+16 57.5	1.117	1.988	11.38	20.3

### 2005 YU55 (2010 Apr)

This is repeated from *MPB* 37-1. There are no lightcurve parameters in the LCDB for this 120-meter ( $H = 22.0$ ) NEA. Given its small size, there is a chance that it may be a fast rotator, meaning it may be spinning faster than the  $\sim 2.2$  h spin barrier. Here again, a larger telescope will help keep the SNR high for a fast-moving object.

DATE	RA (2000)	DC (2000)	E. D.	S. D.	Mag	$\alpha$
04/11	13 09.95	-04 38.1	0.068	1.070	16.55	3.7
04/12	13 03.10	-03 44.7	0.060	1.062	16.41	6.1
04/13	12 54.41	-02 36.6	0.053	1.055	16.26	9.3
04/14	12 43.04	-01 07.2	0.046	1.048	16.09	13.2
04/15	12 27.66	+00 53.9	0.039	1.040	15.90	18.4
04/16	12 05.96	+03 43.9	0.033	1.033	15.70	25.4
04/17	11 33.77	+07 49.5	0.027	1.025	15.53	35.2
04/18	10 43.87	+13 41.0	0.022	1.018	15.47	49.7
04/19	9 27.04	+20 56.5	0.019	1.010	15.73	70.3
04/20	7 46.27	+26 30.7	0.018	1.003	16.59	94.9

#### (5604) 1992 FE (2010 May)

The period for this former radar target is 5.33 h (Higgins and Warner, 2009; *MPB* 36, 159-160). However, the pole solution is not known and so additional lightcurve data may help in that regard, especially if the synodic period can be determined accurately and independently before, near, and after opposition. If the period reaches a minimum near opposition, then the rotation is retrograde and, conversely, if it reaches a maximum, the rotation is prograde. Determining the sense of rotation can help with future modeling by eliminating some of the ambiguous solutions inherent in lightcurve inversion.

DATE	RA (2000)	DC (2000)	E. D.	S. D.	Mag	$\alpha$
05/01	16 10.53	-41 08.2	0.317	1.283	15.62	25.9
05/06	15 50.77	-41 48.8	0.292	1.273	15.32	22.2
05/11	15 26.36	-42 00.2	0.272	1.262	15.06	19.4
05/16	14 58.23	-41 29.5	0.255	1.249	14.88	18.8
05/21	14 28.30	-40 08.0	0.244	1.235	14.84	21.5
05/26	13 58.95	-37 56.3	0.236	1.218	14.91	26.9
05/31	13 32.22	-35 04.4	0.234	1.200	15.04	33.6
06/05	13 09.30	-31 48.6	0.234	1.180	15.22	41.0
06/10	12 50.54	-28 25.4	0.238	1.158	15.41	48.3
06/15	12 35.64	-25 07.4	0.243	1.134	15.62	55.4

#### 1999 MN (2010 June)

Hergenrother et al (2005; *BAAS* 37, 636-637) reported a period of 5.49 h for this 160 m ( $H = 21.4$ ) asteroid. Polishook and Brosch (2008, *Icarus* 194, 111-124) found an ambiguous solution favoring 2.8 h. The rapid motion of the asteroid will require larger apertures or stacking techniques to obtain sufficient SNR. *Note the ephemeris is for 0.5-day intervals.*

DATE	RA (2000)	DC (2000)	E. D.	S. D.	Mag	$\alpha$
06/03.0	20 38.81	-11 07.3	0.036	1.034	16.25	55.6
06/03.5	20 13.07	-12 41.8	0.034	1.037	15.99	48.9
06/04.0	19 45.48	-14 11.6	0.034	1.039	15.75	41.7
06/04.5	19 16.70	-15 31.6	0.033	1.042	15.54	34.4
06/05.0	18 47.60	-16 37.5	0.034	1.044	15.35	27.2
06/05.5	18 19.09	-17 26.7	0.034	1.047	15.19	20.1
06/06.0	17 52.00	-17 59.2	0.036	1.049	15.06	13.6
06/06.5	17 26.91	-18 16.7	0.037	1.052	14.94	7.9
06/07.0	17 04.15	-18 22.0	0.039	1.054	14.88	4.3
06/07.5	16 43.81	-18 18.2	0.042	1.057	15.09	5.8
06/08.0	16 25.79	-18 08.1	0.045	1.059	15.39	9.5
06/08.5	16 09.92	-17 54.0	0.047	1.061	15.68	13.3

#### 2007 XB10 (2010 June)

There are no lightcurve parameters in the LCDB for this 0.9 km ( $H = 17.5$ ) NEA, which stays well south during the apparition. The ephemeris is a compromise between magnitude and elongation. During the interval covered, the elongation is about 95°. In early June, the asteroid brightens some but then the elongation drops to well under 90°.

DATE	RA (2000)	DC (2000)	E. D.	S. D.	Mag	$\alpha$
05/15	06 58.63	-78 03.7	0.425	1.171	18.07	57.8
05/18	06 58.22	-76 49.8	0.384	1.147	17.87	60.1
05/21	06 59.37	-75 23.9	0.343	1.123	17.66	62.6
05/24	07 01.82	-73 40.4	0.302	1.100	17.42	65.5
05/27	07 05.39	-71 29.4	0.261	1.077	17.16	68.9
05/30	07 09.93	-68 33.7	0.220	1.056	16.88	73.0
06/02	07 15.32	-64 20.5	0.179	1.035	16.57	78.4
06/05	07 21.45	-57 40.9	0.139	1.015	16.26	86.1
06/08	07 28.17	-45 55.5	0.102	0.996	16.07	98.1

#### 2002 BF25 (2010 July)

The estimated size for this NEA is 100 meters ( $H = 22.3$ ). There are no lightcurve parameters in the LCDB. The apparition again favors Southern Hemisphere observers with larger instruments.

DATE	RA (2000)	DC (2000)	E. D.	S. D.	Mag	$\alpha$
07/10	23 46.43	-54 43.0	0.046	1.041	17.78	56.9
07/11	00 09.81	-54 01.4	0.043	1.037	17.68	59.9
07/12	00 35.93	-52 51.8	0.039	1.034	17.61	63.4
07/13	01 04.55	-51 04.2	0.036	1.030	17.55	67.6
07/14	01 35.11	-48 27.1	0.034	1.026	17.52	72.6
07/15	02 06.70	-44 49.4	0.031	1.022	17.55	78.4
07/16	02 38.20	-40 03.1	0.029	1.019	17.64	85.1
07/17	03 08.53	-34 08.3	0.028	1.015	17.83	92.6

### IN THIS ISSUE

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

Number	Name	Page	EP
53	Kalypso	75	35
81	Terpsichore	45	5
244	Sita	44	4
285	Regina	50	10
298	Baptistina	57	17
419	Aurelia	45	5
449	Hamburga	50	10
452	Hamiltonia	45	5
527	Euryanthe	50	10
546	Herodias	57	17
588	Achilles	47	7
610	Valeska	45	5

649	Josefa	45	5	2705	Wu	53	13
652	Jubilatrix	45	5	2888	Hodgson	50	10
985	Rosina	42	2	3086	Kalbaugh	57	17
990	Yerkes	42	2	3548	Eurybates	47	7
990	Yerkes	74	34	3564	Talyhybius	47	7
1023	Thomana	50	10	3793	Leonteus	47	7
1101	Clematis	73	33	4125	Lew Allen	57	17
1130	Skuld	41	1	4531	Asaro	57	17
1131	Porzia	64	24	4554	Fanynka	65	25
1176	Lucidor	56	16	4736	Johnwood	57	17
1345	Potomac	50	10	5230	Asahina	57	17
1355	Magoeba	57	17	5841	Stone	57	17
1398	Donners	50	10	6141	Durda	57	17
1509	Esclangona	70	30	6444	1989 WW	57	17
1564	Srbija	50	10	8135	1978 VP10	65	25
1583	Antilochus	47	7	9739	Powell	57	17
1626	Sadeya	57	17	14614	1998 TX2	65	25
1750	Eckert	57	17	14934	1995 BP	65	25
1819	Laputa	64	24	15967	Clairearmstrong	50	10
1906	Naef	65	25	16669	Rionuevo	57	17
1994	Shane	50	10	17683	Kanagawa	65	25
2001	Einstein	57	17	20421	1998 TG3	55	15
2083	Smither	57	17	24654	Fossett	57	17
2093	Genischesk	56	16	26380	1999 JY65	48	8
2131	Mayall	70	30	26471	2000 AS152	70	30
2456	Palamedes	47	7	29242	1992 HB4	57	17
2625	Jack London	65	25	29308	1993 UF1	57	17

31628	1999	GG23	65	25
31850	2000	EB22	57	17
37634	1993	UZ	57	17
38047	1998	TC3	57	17
40203	1998	SP27	57	17
40701	1999	RG235	65	25
46530	1981	EE10	65	25
66037	1998	QD74	65	25
75985	2000	DY2	65	25
80509	2000	AE56	65	25
94763	2001	XM99	65	25
114127	2002	VL50	65	25
127311	2002	JV90	65	25
136849	1998	CS1	75	35
189265	2005	GN179	65	25
218144	2002	RL66	57	17
	2005	UB275	65	25
	2006	SZ217	75	35
	2008	UE7	75	35
	2009	XR2	57	17

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\* \* \* \* \*

The deadline for the next issue (37-3) is April 15, 2010. The deadline for issue 37-4 is July 15, 2010.