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LIGHTCURVE ANALYSIS OF 1786 RAAHE AND 4729 MIKHAILMIL'

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CCD observations made of main-belt asteroids 1786 Raahe and 4729 Mikhailmil' revealed synodic periods of 18.72 ± 0.01 h and 17.74 ± 0.01 h respectively.

Main-belt asteroid 1786 Raahe was observed during seven consecutive nights during 2011 October 3-9 UT. 4729 Mikhailmil' was observed over three nights from 2010 December through 2011 January. No previously-reported lightcurve results were found for either object. 1786 Raahe was imaged in the V-band, and 4729 Mikhailmil' images were unfiltered. Both were imaged with a 0.3-meter Schmidt-Cassegrain (SCT) operating at f/6.1 on a German Equatorial mount (GEM). Details of the data reduction methods are in Ruthroff (2010).

1786 Raahe, Seven consecutive nights yielded 394 data points. Analysis found a period of 18.72 ± 0.01 h and amplitude of 0.48 ± 0.06 mag.

4729 Mikhailmil'. Four nights were obtained on this target, resulting in 378 data points. The first and second sessions were separated by nearly two weeks. While the period presented in the lightcurve, P = 17.74 ± 0.01 h, is one of many possible solutions, the minimum period (assuming a bimodal solution) is at least 4 hours.

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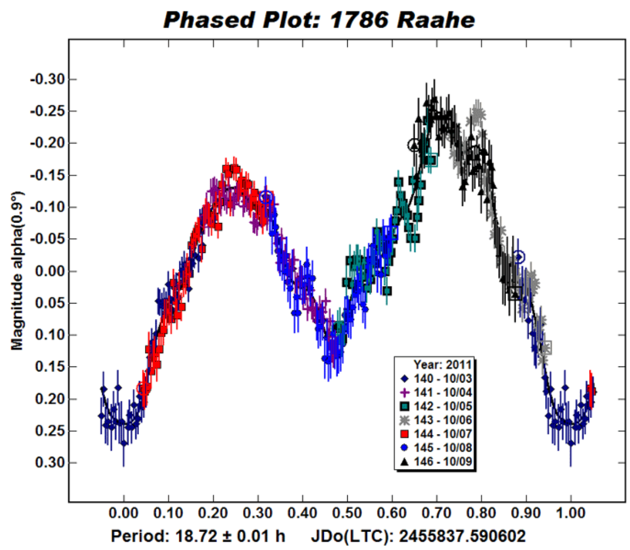

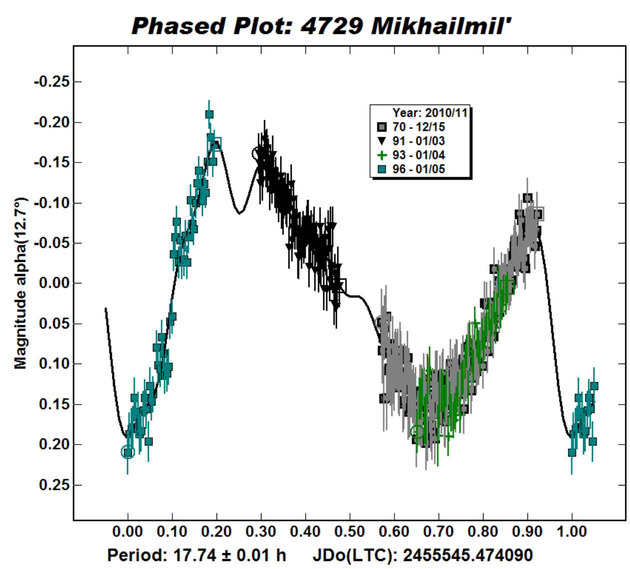

LIGHTCURVE RESULTS FOR ELEVEN ASTEROIDS

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Differential photometry techniques were used to develop lightcurves, rotation periods and amplitudes for eleven main-belt asteroids: 833 Monica, 962 Aslog, 1020 Arcadia, 1082 Pirola, 1097 Vicia, 1122 Lugduna, 1145 Robelmonte, 1253 Frisia, 1256 Normannia, 1525 Savolinna, and 2324 Janice. Ground-based observations from Badlands Observatory (BLO) in Quinn, SD, as well as the University of North Dakota Observatory (UND) in Grand Forks, ND, provided the data for the project. A search of the asteroid lightcurve database (LCDB) did not reveal any previously reported results for seven of the eleven targets in this study.

A summary of physical characteristics of the target asteroids appears in Table I. These are all main-belt asteroids with a mixed range of taxonomic classes, sizes, and albedos. Of the eleven targets, only four: 1082 Pirola, 1133 Lugduna, 1145 Robelmonte, and 1256 Normannia have previously published lightcurve work. The rotation periods for the four targets are listed in Table I. The lightcurves of two of the targets (1145 Robelmonte and 1256 Normannia) are rated U = 1 in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009; updates available at *http://www.minorplanet.info/lightcurvedatabase.html*), indicative of results too uncertain to use in rotation statistical studies. The U = 2 rating for 1133 Lugduna indicates some uncertainty in the results but they are still sufficient for statistical studies. The U = 3 rating for 1082 Pirola indicates a reliable period.

The basic specifications of the observatory telescopes and attached CCD arrays used during the project are given in Table II. Observations were made using a clear filter and standard exposure times of 180 seconds for Badlands Observatory and 60 seconds for UND Observatory. *Astronomer's Control Panel* (ACP) was used for observatory control and imaging, *Maxim D/L* for image calibration, and *MPO Canopus* for data reduction and period analysis.

The lightcurve analysis functions of *MPO Canopus* were the primary tools used to determine asteroid rotation periods and amplitudes. Effective use of these tools and the subsequent determination of plausible results from the data required extensive study of Warner's *The MPO User's Guide* (2010) and *Lightcurve Photometry and Analysis* (2006), the chapter entitled, "Photometry of Asteroids" in the *Solar System Photometry Handbook (Binzel, 1983), Astronomical Photometry*: A *Text and Handbook for the Advanced Amateur and Professional Astronomer (Henden, 1990)* and *Handbook of CCD Astronomy (Howell, 2006)*. These reference works provided a foundation of understanding about how the mechanics of photometry leading to period analysis work in actual practice. Tutorial sessions with *MPO Canopus* practice data were also used to increase familiarity with software functions. Finally, research of current successful lightcurve projects in journals such as *Minor Planet Bulletin* and *Icarus*, consultation with more experienced colleagues, as well as trial and error, were all employed as skill building tools.

Asteroid	Dia (km)	Tholen	p_V	LCDB Period/U
833 Monica	21.2		0.12	
962 Aslog	39.5	S	0.05	
1020 Arcadia	25.9	S	0.05	
1082 Pirola	43.	C	0.07	15.58 h/3
1097 Vicia	21.1		0.08	
1133 Lugduna	8.5	S	0.32	5 h/2
1145 Robelmonte	23.2	TDS*	0.12	21.1 h/1
1253 Frisia	30.1		0.07	
1256 Normannia	69.2	D	0.05	6.8 h/1 18.8 h/1
1525 Savonlinna	12.2		0.13	
2324 Janice	28.9		0.06	

Table I. Target Asteroids. Data from LCDB (Warner *et al.*, 2009) and Tedesco *et al.* (2005).

Obs	Loc	Telescope	F.L. (mm)	Dia. (mm)	CCD
1	UND	Meade SCT	4064	406	SBIG STL- 6503e
2	UND	Meade SCT	2540	254	SBIG STL-1301e
3	UND	Meade OTA	4064	406	Apogee U9000
4	BLO	Newtonian	3160	660	Apogee AP8p

Table II. Observatory equipment (BLO = Badlands Obs.; UND = University of North Dakota).

The results of a literature search and analysis for each asteroid are presented below.

833 Monica. The only published work on this asteroid is from the Two-Micron All Sky Survey (2MASS) for asteroids (Sykes *et al.*, 2000). Key orbital parameters for the asteroids were precisely determined during that study.

Observations of 833 Monica were made between 2010 August 6 and November 13. During that period, the target's distance from Earth ranged from 1.983 AU to 1.96 AU while the heliocentric distance ranged from 2.706 AU to 2.649 AU and solar phase angle ranged from +17.6° to –17.9° (Yeomans, 2011). A total of 1931 images were taken over 47 nights, producing 1338 "good" and 83 "acceptable" data points, which were used in deriving the period solution. Mean SNR values for the asteroid in individual sessions ranged from a high of 534.44 (±0.01 flux, ±0.05 mag) to a low of 75.04 (±0.01 flux, ± 0.13 mag). An eighth-order harmonic search with the Fourier analysis function in *MPO Canopus* (FALC; Harris et al., 1989) found a synodic rotation period of $P = 12.09 \pm 0.01$ h for a bimodal lightcurve (Figure 1). The lightcurve amplitude was A = value 0.13 ± 0.01 mag. The lightcurve shows distinct maximum peak magnitude values at approximately 0.15 and 0.70 rotation phase (X axis) while minimums are observed at 0.40 and 0.90.

962 Aslog. Zellner *et al.* (1985) observed 962 Aslog as part of their Eight-Color Asteroid Survey (ECAS) using the 1.54-m Catalina reflector as well as the 2.29-m Steward reflector at the University of Arizona. The asteroid was observed using eight filter pass bands ranging from 0.34 to 1.04µm wavelength (Zellner *et al.*, 1985). A table of color indices for Aslog was produced (Table III), with a

zero color index representing a neutral reflector, and a positive number representing a reddish slope with respect to the visual.

S-V	U-V	B-V	V	V-W	V-X	V-P	V-Z
0.406	0.343	0.150	15.094	0.151	0.174	0.171	0.171

Table III. Color Indices for 962 Aslog (Zellner *et al.*, 1985).

The data in Table III suggest that the asteroid has a reddish slope. Barucci *et al.* (1987) combined ECAS data with albedo and Infrared Astronomical Satellite (IRAS) data to classify 962 Aslog as an S-type asteroid, indicative of reddish color, moderate albedos, and a strong 1µm absorption feature.

Observations of 962 Aslog ran from 2010 September 11 through 2011 January 5. During the observation period, the Earth distance ranged from 1.713 AU to 1.7 AU; the heliocentric distance ranged from 2.619 AU to 2.606 AU, and the solar phase angle ranged from +12.3° to –10.5° (Yeomans, 2011). A set of 1060 images taken over 21 nightly sessions produced 628 "good" and 264 "acceptable" data points for lightcurve analysis. The mean SNR values for individual sessions ranged from a high of 476.76 (±0.01 flux, ±0.05 mag) to a low of 16.05 (±0.06 flux, ± 0.27 mag). Using a fourth-order harmonic search in *MPO Canopus*, analysis found a synodic period of *P* = 5.465 ± 0.01 h and *A* = 0.21 ± 0.01 mag (Figure 2). The bimodal lightcurve exhibits maximum peaks at 0.3 and 0.8 rotation phase and minimums at 0.0 and 0.5.

1020 Arcadia. Bus and Binzel (2002) observed 1020 Arcadia during Phase II of the Small Main Belt Asteroid Spectrographic Survey (SMASS II) with the 2.4-m Hiltner telescope at the MDM Observatory on Kitt Peak in Arizona. The asteroid was classified as an S type with a spectrum indicative of the presence of olivine (Bus, 2002). Orbital parameters of the asteroid were determined during the late 1990's as part of 2MASS (Sykes *et al.*, 2000). DeMeo *et al*. (2009) classified the asteroid as type Sr (indicative of a narrower 1µm feature than an S-type) with data obtained using SpeX, the low-to-medium resolution near infrared spectrograph and imager, on the 3-m NASA Infrared Telescope Facility (IRTF) located on Mauna Kea, Hawaii.

Observations of 1020 ran from 2010 September 20 through 2011 January 5, during which time the asteroids Earth distance ranged from 2.002 AU to 2.642 AU, its heliocentric distance ranged from 2.889 AU to 2.908 AU, and its solar phase angle ranged from +10.3° to –19.7° (Yeomans, 2011). A total of 542 images were taken over 10 nights, yielding 430 "good" data points. The mean SNR for individual sessions ranges from 193.26 (±0.01 flux, ± 0.08 mag) to 33.53 (±0.03 flux, ±0.19 mag). Using a fourth-order harmonic search in *MPO Canopus* found a synodic period *P* = 17.02 ± 0.02 hours and amplitude of 0.05 ± 0.01 mag (Figure 3). The slightly bimodal lightcurve shows distinct minima at approximately 0.17 and 0.65 rotation pahse. Maxima appear at approximately 0.02 and 0.52.

1020 Arcadia was an extremely difficult target to image. Scatter was seen in most session data and to a very high degree in the observing sessions of 2010 December 8 and 2011 January 5. Only four of ten observing sessions achieved a mean SNR >100. In addition, data coverage between 0.0 and 0.2 as well as 0.9 and 0.0 is rather limited. This leads to the conclusion the estimated solution for 1020 Arcadia derived here is tentative and the listed error correction value of ± 0.02 is conservative.

1082 Pirola. Baker *et al.2* (2001) obtained a rotation period of 15.8525 ± 0.0005 h and amplitude of 0.53 ± 0.01 mag for 1082 Pirola. The Planetary Data System classifies the asteroid as member of the "C" taxonomic group (Neese, 2010). Precise orbital parameters were documented during the 2MASS study (Sykes *et al*., 2000).

Observations of 1082 Pirola were made during the period of 2010 October 3 through 2011 February 3. During that time, its Earth distance ranged from 1.885 to 2.881 AU, the heliocentric distance ranged from 2.723 to 2.995 AU, and the solar phase angle ranged from +10.73° to –19.3° (Yeomans, 2011). The data set of 422 images taken over eight nights produced 386 "good" data points. The mean SNR values for individual sessions ranged from 521.47 (±0.01 flux, ±0.05 mag) to 95.67 (±0.01 flux, ±0.11 mag). Using a fourth-order harmonic search, the synodic rotation period was determined to be 15.85 ± 0.01 h with an amplitude of 0.60 ± 0.01 mag (Figure 4). The lightcurve for 1082 Pirola is classically bimodal with well-defined maxima at approximately 0.21 and 0.71 rotation phase. Minima appear at 0.1 and 0.51.

The period solution and amplitude compare favorably to the results of *P* = 15.8525 ± 0.0005 h, *A* = 0.53 ± 0.01 mag reported by Baker et al. (2011) using images obtained from three different observatories during the same apparition as this project. It should be noted that Baker's observations were taken on different nights than those used in this project. The slight anomaly observed at the minimum from 0.95 to 1.00 is also observed in the results obtained by Baker *et al.* (2011). This would suggest the anomaly is characteristic of the asteroid and could justify further investigation.

1097 Vicia. The only published work on this asteroid is from the Two Micron All Sky Survey (2MASS) for asteroids (Sykes *et al.*, 2000). Key orbital parameters for the asteroids were precisely determined during that study.

Observations of 1097 Vicia were made between 2010 October 5 and 2011 January 11. During the observation period, the target's distance from Earth ranged from 1.531 to 2.176 AU, the heliocentric distance ranged from 2.723 to 2.995 AU, and the solar phase angle ranged from +16.4° to –20.1° (Yeomans, 2011). A total of 568 images were taken over 11 nights, yielding 422 "good" and 52 "acceptable" data points for analysis. The mean SNR ranged from 366.72 (±0.01 flux, ±0.06 mag) to low of 43.28 (±0.02 flux, ±0.17 mag). Using a fourth-order harmonic search with *MPO Canopus*, the analysis found a rotation period of *P* = 26.5 ± 0.1 h, A = 0.08 ± 0.01 mag. (Figure 5). The lightcurve is softly bimodal and very similar to the plot developed for 1020 Arcadia, another low amplitude target. Maxima are seen at 0.18 and 0.57 rotation phase. Minima appear at 0.36 and 0.82. Unfortunately, there is no data coverage at the second minima. A second data gap exists between approximately 0.27 and 0.33 and there is also some scatter throughout the curve. These gaps create some uncertainty regarding the period and amplitude estimates.

It was initially thought this asteroid was an extremely slow rotator due to the flat featureless raw plots obtained early in the project. As the project progressed, distinct variations in magnitude were observed in the nightly data. The data from 1097 Vicia also benefitted from being re-run though *MPO Canopus* several times with improved and more precise comparison stars. Data quality increased markedly after this process was completed.

1133 Lugduna. This asteroid was also a target of ECAS (Zellner *et al.*, 1985). The results in Table IV below suggest the type S asteroid has a reddish slope. A five hour rotation period, measured by Franco in 2010 and classified as "less than full coverage", is found in the Asteroid Lightcurve Database (LCBD; Warner *et al.*, 2009).

S-V	U-V	B-V	V	V-W	V-X	V-P	V-Z
0.628	0.500	0.213	14.695	0.196	0.175	0.118	0.134

Table IV. Color Indices for 1133 Lugduna (Zellner *et al.*, 1985).

Observations of 1133 Lugduna began on 2010 October 5 and finished on 2011 February 15. Over this time, the Earth distance ranged from 0.911 to 1.812 AU, the heliocentric distance ranged from 1.804 to 2.03 AU, and the solar phase angle ranged from +19.9˚ to –29.1˚ (Yeomans, 2011). The data set was derived from 717 images taken over 12 nights that produced 592 "good" data points. The mean SNR values for individual sessions ranged from a high of 902.72 (±0.01 flux, ±0.04 mag) to a low of 34.0 (±0.1 flux, ±0.2 mag). A fourth-order harmonic search with *MPO Canopus* found P = 5.477 ± 0.001 h and A = 0.43 ±0.02 mag. (Figure 6). The period compares favorably with the provisional 5-hour period estimate of Franco in 2011 listed in the Asteroid Lightcurve Database (Warner et al., 2009). The lightcurve of 1133 Lugduna is clearly bimodal having observed maxima at 0.06 and 0.54 rotation phase. The largest minimum is visible at 0.24 and a smaller one is observed at 0.74. It was clear that this target had a short rotation period since data from several sessions overlapped the entire plot.

1145 Robelmonte. Hardersen (2003), using Keil (2000), determined the heating temperature of 1145 Robelmonte was ≈300˚K and was likely subjected to some level of aqueous alteration during formation. Moskovitz *et al.* (2008) and Hardersen (2003) agree on the taxonomic classification of this asteroid as "TDS" (i.e., T, D, or S class). Xu *et al.* (1995) produced a spectrum of the asteroid indicative of an iron dominated assemblage for SMASS I. Bus and Binzel (2002) produced a featureless red to near infrared spectrum for the SMASS II survey. Behrend (2010) produced a "provisional" lightcurve with a 21-hour period using data from a single night of observation.

Observations of 1145 Robelmonte ran from 2010 October 7 through 2011 March 16. The Earth distance ranged from 1.714 to 3.161 AU; the heliocentric distance ranged from 2.621 to 2.709 AU and the solar phase angle ranged from +11.2˚ to –17.4˚ (Yeomans, 2011). A total of 922 images were taken over 22 nights, yielding 596 "good" data points. The mean SNR values for individual sessions ranged from 436.40 (±0.01 flux, ±0.05 mag) to 19.71 (±0.05 flux, ±0.24 mag).

Period determination for 1145 Robelmonte was extremely difficult. Eleven observing sessions occurred between 2011 February and March during very poor winter weather. The data quality during those sessions was adversely affected. Initial iterations of period analysis using twelfth-order harmonics and data from all sessions yielded a P = 20.61 ± 0.01 h solution. This solution compared favorably to the 21-hour "provisional" period derived by Behrend (2010). Closer evaluation led to the suspicion 20.61 hours was not a good solution for several reasons. First, the observations used by Behrend covered a single night in 2008 and also contained large gaps in coverage. Given the "provisional" status of the solution, it was suspected that it might not be plausible. Second, after consultation with several colleagues, it was determined the use of a twelfth-order FALC search undermined the credibility of the results. A better solution could be found using FALC searches with the fourth-harmonic order, the default setting in *MPO Canopus*. Finally, the low SNR and overall quality of the 2011 February-March data adversely skewed results when the entire data set was run through FALC.

It was determined that more extensive data scrubbing was needed. The initial set of 596 "good" data points was subsequently reduced to 534 by eliminating one "acceptable" session and upgrading the comparison stars for all remaining sessions. This new data set was still unable to produce a plausibly credible period close to 21 h. A solution near 18 h showed some promise, but was rejected due to data gaps and fit. The next step was to reduce the data set further by splitting it into two groups: 2010 October and 2011 February-March. This placed the best data (2010 October) into one group and the worst data into the other group. Attempts were made to produce a credible 18 or 21 hour period solution using the split data, but the results obtained were not useful. Fourth-order harmonic FALC searches for the "half-period" and "double period" of 21 and 18 hours were run with the split data set.

One of the attempts, using 369 data points from 2010 October produced a very credible result of P = 9.01 ± 0.01 h and A = 0.18 ± 0.01 mag. This solution produces a bimodal lightcurve maxima occurring at approximately 0.18 and 0.66 rotation phase. Minima appear at approximately 0.51 and 0.82. An almost imperceptible upward wiggle is observed at 0.09. The observing session of 2010 October 17, conducted at University of North Dakota Observatory #2, provided coverage of eighty percent of the rotation lending additional credibility to the solution.

A FALC search, using only the 2011 February-March data, was forced to near the 9-hour period. This produced a plausible solution of 8.95 ± 0.01 h, comparing favorably with the solution produced with the 2010 October 2010 data alone. The 2011 February and-March solution lightcurve is somewhat similar to the 2010 October lightcurve in the separation of the minima and general shape. However the difference in quality between the two data sets is significant enough to conclude the 9.01-hour solution derived from the 2010 October data is the better one.

1253 Frisia. The only published work on this asteroid is from the Two Micron All Sky Survey (2MASS) for asteroids (Sykes *et al.*, 2000). Key orbital parameters for the asteroids were precisely determined during that study.

Observations of 1253 Frisia began on 2010 August 24 and ended on 2011 February 4. During the observation period, the target's distance from Earth ranged from 1.752 to 2.436 AU, the heliocentric distance ranged from 2.491 to 2.534 AU, and the solar phase angle ranged from +21.9˚ to –22.8˚ (Yeomans, 2011). A total of 422 images were were taken over 10 nights, yielding 312 "good" and 26 "acceptable" data points. The mean SNR values for individual sessions ranged from 320.18 (±0.01 flux, ±0.06 mag) to 12.50 (±0.08 flux, ± 0.3 mag).

A fourth-order harmonic search with FALC found a period of P = 14.557 ± 0.002 h and A = 0.16 ± 0.01 mag (Figure 8). The lightcurve for 1253 Frisia does not have a classic bimodal shape. There is a single large maxima at approximately 0.65 rotation phase and a primary minima at approximately 0.25. Small gaps in data coverage exist at 0.15 and 0.85. "Half-period" and "double-period" searches were conducted unable to produce a credible solution better than 14.557 hours. It is possible a better solution is obtainable with complete data coverage.

1256 Normannia. Franklin (1979) determined that the orbit of 1256 Normannia (a = 3.89 AU) is heavily influenced by the 3:2 mean motion resonance with Jupiter and is thus part of the Hilda group of asteroids. Sessin and Bressane (1988) created a complex model to study the restricted elliptic planar three-body problem near a first-order resonance and corroborated Franklin's conclusion regarding the effect of the mean motion resonance on the asteroid. Dahlgren (1998) concluded that the asteroid has the lowest collision velocity (3.39 km s^{-1}) and the lowest collision probability of Hilda asteroids greater than fifty kilometers in diameter. Ferraz-Mello (1998) determined that the asteroid resides in the middle-eccentricity region of the 3:2 orbital resonance. 1256 Normannia was also a subject of ECAS (Zellner *et al.*, 1985). ECAS results in Table V indicate the asteroid has a reddish slope.

S-V	U-V	B-V	V	V-W	V-X	V-P	V-Z
0.105	0.089	0.058	N/A	0.149	0.260	0.341	0.382

Table V. Weighted Mean Color Indices for 1256 Normannia (Zellner *et al.*, 1985).

Barucci *et al.* (1987) combined the ECAS data with albedo and IRAS data to classify 1256 Normannia as a type D (very low albedo) asteroid. Binzel and Sauter (1992), based on three nights of observations conducted at the University of Texas in 1991, derived a “tentative” lightcurve for this asteroid with a period of 6.8 h and amplitude of 0.06 mag. A provisional 18.8-h period with amplitude 0.05 magnitude was measured by Dahlgren *et al.* (1998) from six nights of observation at Calor Alto, Spain in 1994. Finally, Hartman *et al.* (1987) suggest the asteroid is potentially an extinct comet based on its low albedo and reddish color.

Observations of 1256 Normannia ran from 2010 September 20 through November 2. During this period, the asteroid’s Earth distance ranged from 2.801 to 2.714 AU, the heliocentric distance ranged from 3.664 to 3.685 AU, and the solar phase angle ranged from +8.8° to +3.8° (Yeomans, 2011). A set of 424 “good” data points was derived from 512 images taken over 10 nights. The mean SNR values for individual sessions ranged from 410.10 (±0.01 flux, ±0.05 mag) to 37.56 (±0.03 flux, ±0.19 mag). A fourth- order harmonic search with FALC found a synodic period *P* = 18.13 ± 0.02 h and A = 0.07 ± 0.01 mag (Figure 9).

The period solution derived here is not consistent with the 6.8 h period produced by Binzel and Sauter (1992). It should be noted that their observations were relatively incomplete to the extent the authors termed their derived 6.8 hour solution a “guess.” The solution of 18.1 h comes closer to Dahlgren’s (1998) provisional solution of 18.8 hours. FALC was run in an attempt to duplicate Dahlgren's result, but the 18.1 h period solution was determined to be a better fit of the data. The amplitude value of 0.07 mag is close to Binzel and Sauter’s estimate of 0.06 mag and Dahlgren’s 0.05 mag. The low amplitude value is also consistent with earlier work suggesting that 1256 Normannia, a type D object, is dark, reddish, and possibly an extinct comet (Hartmann et al., 1987).

The final lightcurve for 1256 Normannia exhibits a non-distinct bimodality typical of a low amplitude lightcurve. There are maxima at approximately 0.15 and 0.90 rotation phase. Minima are apparent 0.05 and 0.50. A slight data gap between 0.92 and 1.0 tempers the overall credibility of the solution.

<u>1525 Savonlinna.</u> The only published work on this asteroid is from the Two Micron All Sky Survey (2MASS) for asteroids (Sykes *et al.*, 2000). Key orbital parameters for the asteroids were precisely determined during that study.

Observations of 1525 Savonlinna began on 2010 November 3 and were completed on 2011 January 26. During the observation period, the Earth distance ranged from 1.277 to 2.052 AU, the heliocentric distance ranged from 2.245 to 2.481 AU, and the solar phase angle ranged from +7.1° to –22.7° (Yeomans). A total of 481 images were taken over 10 nights, yielding 384 “good” data points for analysis. Mean SNR values for individual sessions ranged from 183.78 (±0.01 flux, ±0.08 mag) to 26.59 (±0.04 flux, ±0.2 mag). An eighth-order harmonic search with *MPO Canopus* found *P* = 14.634 ± 0.002 h and *A* = 0.52 ± 0.02 mag (Figure 10). Distinct minima exist at approximately 0.10 and 0.87 rotation phase. There is scatter present in the data at the second minima. Maxima appear at 0.00 and 0.60. The irregular shape of the lightcurve curve could be the result of the shift in phase angle during the observing period. A relatively small target (D ~ 12 km), 1525 Savonlinna would exhibit large amplitude variations if irregular surface features exist and are imaged at highly divergent solar phase angles.

<u>2324 Janice</u>. Observations of 2324 Janice commenced on 2010 August 24 and finished on 2010 December 10. During the observation period, the target’s distance from Earth ranged from 2.419 to 2.713 AU, the heliocentric distance ranged from 3.334 to 3.434 AU, and the solar phase angle ranged from +16.5° to –13.2° (Yeomans, 2011). A total of 396 images were taken over 9 nights, yielding 289 “good” data points. The mean SNR values for individual sessions ranged from 155.86 (±0.01 flux, ±0.07 mag) to 7.83 (±0.13 flux, ± 0.39 mag).

2324 Janice was the most difficult target to image in this project. It was one of the most distant targets from Earth during the observation period. Low SNR was the norm for this target. Only five of the ten sessions achieved a mean SNR >100. Only six of ten sessions yielded data good enough to be included in period determination. Since good SNR was achieved from targets as bright (absolute magnitude 11.3) and as distant as 2324 Janice, a potential cause of the low SNR from 2324 Janice could be the orientation of the target with respect to Earth. A considerable amount of data scrubbing and session re-runs were required to produce a data set useful for the production of a plausible solution.

A sixth-order harmonic search with *MPO Canopus* found *P* = 23.2 ± 0.1 h, A = 0.19 ± 0.01 mag (Figure 11). Scatter and gaps are prevalent in the lightcurve, making the determination of true maxima and minima difficult. Given the low level of data quality, it would be reasonable to conclude that the 23.2 hour solution is extremely tentative and likely has a larger error than the 0.1 h calculated by the Fourier routine.

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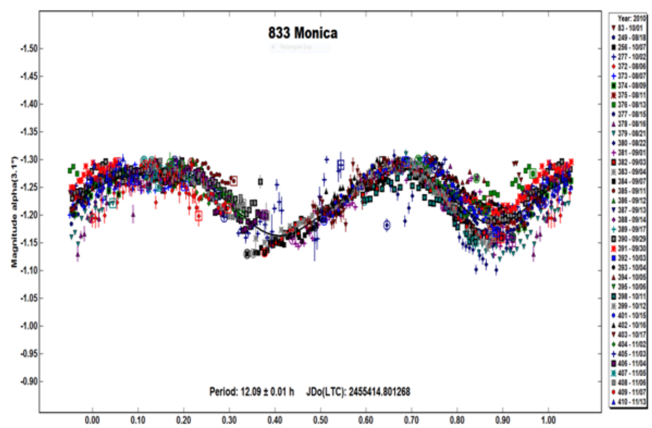

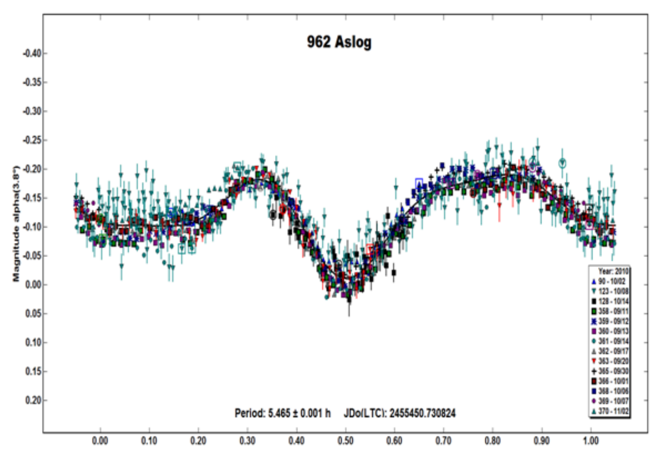

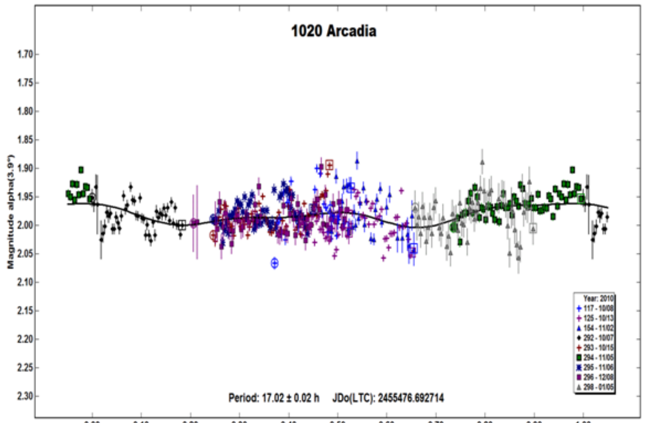
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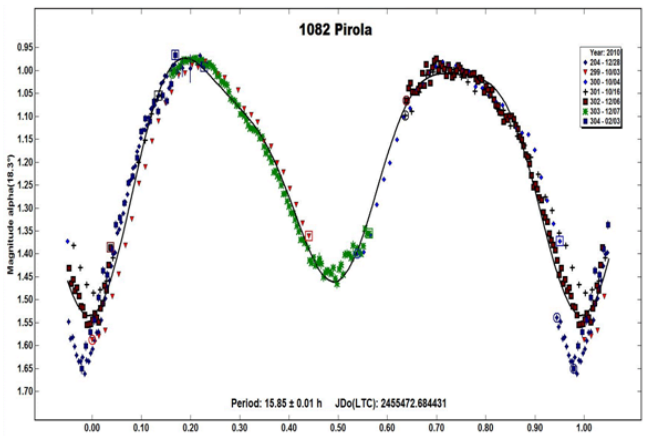
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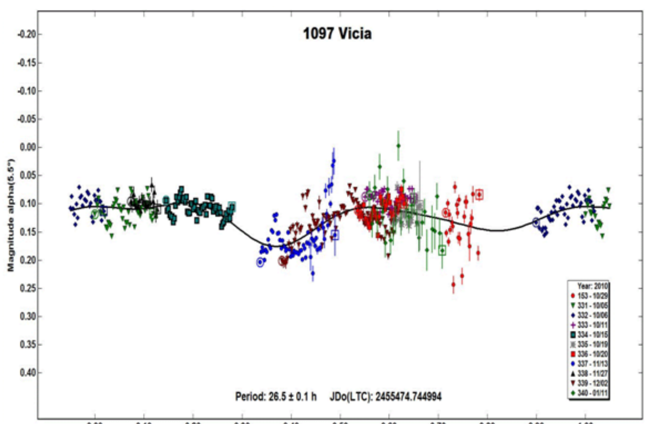
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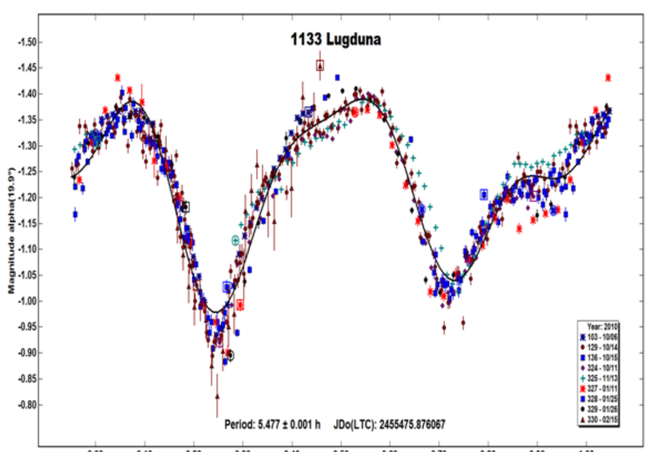
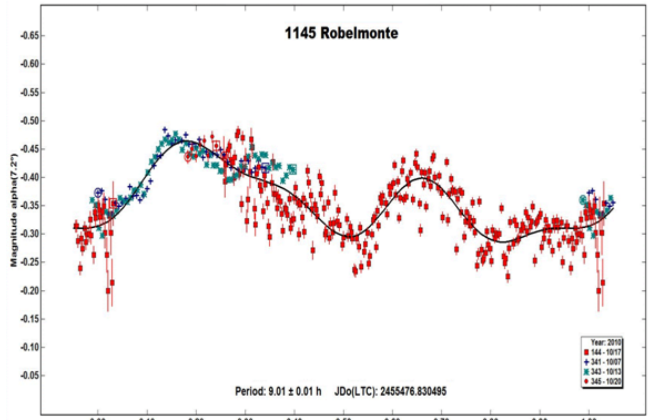

1133 Lugduna
Magnitude alpha(19.9°)
Period: 5.477 ± 0.001 h JDo(LTC): 2455475.876067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Magnitude alpha(7.2°)
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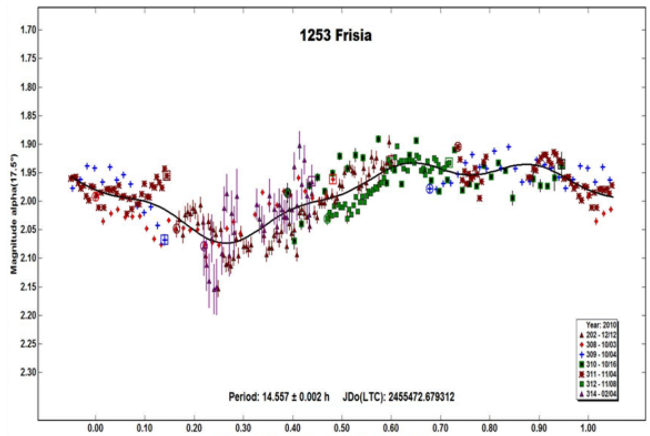
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Magnitude alpha(17.5°)
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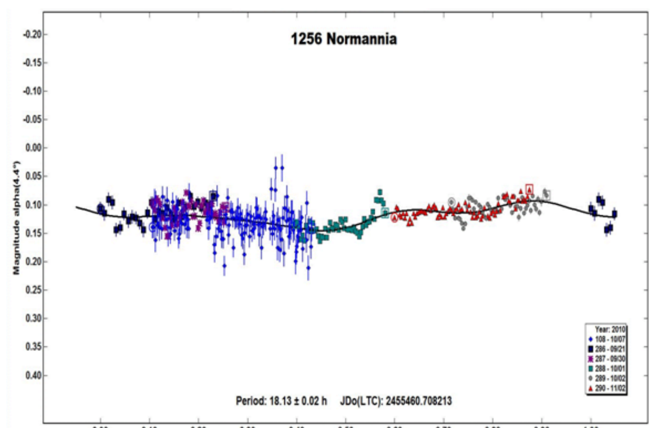
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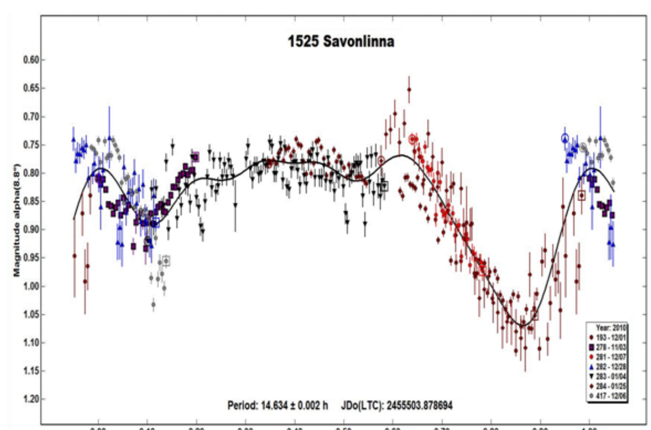
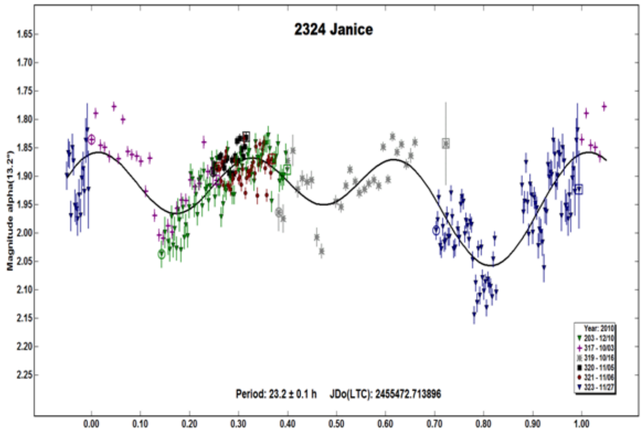
Magnitude alpha(4.4°)
Period: 18.13 ± 0.02 h JDo(LTC): 2455460.708213


1525 Savonlinna
Magnitude alpha(8.8°)
Period: 14.634 ± 0.002 h JDo(LTC): 2455503.878694



ROTATION PERIOD DETERMINATION FOR 180 GARUMNA: A TRIUMPH OF GLOBAL COLLABORATION

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Previous studies have suggested that 180 Garumna has a very nearly Earth-synchronous rotation period of 23.86 hours, with only a small part of the lightcurve sampled at a single location. A global collaboration among observers from four continents, East Asia, Australia, Europe, and North America produced the first ever lightcurve with full phase coverage that shows a definitive synodic rotation period 23.866 ± 0.001 h, amplitude 0.42 ± 0.02 mag.

Previously reported rotation periods and lightcurve coverage of the asteroid, 180 Garumna, are by Behrend (2011), 23.859 h, 50%; Clark (2010), 23.32 h, 50%; Stephens (2008), 23.89 h, 35%. To obtain full lightcurve coverage for an object believed to have rotation period very close to Earth-synchronous, it is necessary to have observations from several locations more or less evenly distributed in longitude around the Earth. Vladimir Benishek from central Europe, Shelby Delos, Timothy Barker, and Gary Ahrendts observing remotely from the Grove Creek Observatory, New South Wales, Australia, Hiromi and Hiroko Hamanowa from Japan, David Higgins from Australia, and Frederick Pilcher from western North America all contributed lightcurves to obtain full phase coverage. *MPO Canopus* software was used for lightcurve analysis and expedited the sharing of data among the collaborators.

Observations made on 19 nights from 2011 Sept. 20 to Nov. 27 show full lightcurve coverage with a period 23.866 ± 0.001 h, amplitude 0.42 ± 0.02 mag. A feature on the rising portion of the lightcurve near rotation phase 0.50 changed shape significantly through the interval of observation. Due to the large number of data points acquired, the lightcurve has been binned in sets of three data points with a maximum of five minutes between points.

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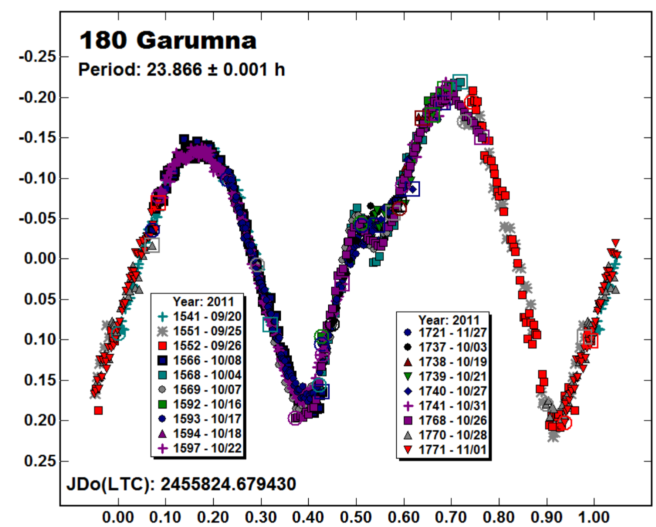

Obs	Telescope	CCD	Sess
Bennishek	40-cm SCT	SBIG ST-10XME	4
Delos, Barker, Ahrendts	25-cm SCT	SBIG ST-1001E	5
Hamanowa Hamanowa	40-cm Newt	SBIG ST-8	3
Higgins	35-cm SCT	SBIG ST-8e	3
Pilcher	35-cm SCT	SBIG STL-1001E	4

Table I. Observers and equipment. SCT = Schmidt-Cassegrain. Newt = Newtonian.

LIGHTCURVE PHOTOMETRY AND H-G PARAMETERS FOR 1151 ITHAKA

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Observers at three observatories worked in collaboration to obtain photometric observations of main-belt asteroid 1151 Ithaka over thirteen nights from 2011 August-October. The resulting analysis found a synodic period P = 4.93115 ± 0.00011 h with an amplitude AV = 0.12 ± 0.01 mag. The measured absolute visual magnitude, H = 12.94 ± 0.03 mag, slope parameter G = 0.05 ± 0.03, and color index V-R = 0.38 ± 0.03 mag are consistent with a low albedo C-type object. The diameter is estimated to be D = 14 ± 3 km.

The main-belt asteroid 1151 Ithaka was reported as a lightcurve photometry opportunity in the *Minor Planet Bulletin* (Warner *et al.*, 2011). As a result, the authors formed a collaboration to observe the asteroid. The observations were carried out from Balzaretto Observatory (A81) in Rome, Italy, Bigmuskie Observatory (B88) in Mombercelli, Asti, Italy, and from Shed of Science Observatory (H39) in Minneapolis, MN, USA, over a period spanning from 2011 August 23 to October 3, or a total of 41 days (Table I). The equipment used for observations is described in Table II.

#	Date 2011	Observer	Phase Angle	Data Points	Filter
1	Aug 23	L. Franco	8.5°	72	C
2	Aug 26	L. Franco	8.6°	89	C
3	Aug 28	L. Franco	8.8°	34	V,R
4	Sep 2	A. Ferrero	10.2°	69	R
5	Sep 5	A. Ferrero	11.4°	77	R
6	Sep 6	L. Franco	11.8°	86	C
7	Sep 6	A. Ferrero	11.8°	81	R
8	Sep 8	R. Durkee	12.3°	33	C
9	Sep 9	R. Durkee	12.7°	38	C
10	Sep 13	A. Ferrero	14.9°	90	R
11	Sep 15	L. Franco	15.8°	38	C
12	Sep 24	R. Durkee	19.6°	69	C
13	Oct 3	L. Franco	23.5°	25	C

Table I. Observations list.

Observer	Country	Telescope	CCD	Filters
Lorenzo Franco	Italy	SCT 0.20-m f/5.5	SBIG ST7-XME	Custom Scientific (Johnson V, Cousins R)
Andrea Ferrero	Italy	RC 0.30-m f/8	SBIG ST9	Astrodon Cousins R
Russell Durkee	USA	SCT 0.35-m f/8.5	SBIG ST10XE bin x2	

Table II. Observers and equipment list.

Each observer's computer clock was synchronized with atomic clock time via Internet NTP servers, giving a timing accuracy of less than one second. All images were calibrated with dark and flat-field frames. Differential photometry was done using *MPO Canopus* (Warner, 2010). The V and R magnitudes were calibrated using the method described by Dymock and Miles (2009) and CMC-14 selected reference stars with color index near solar values using the Vizier Service (VizieR, 2010). The same method was also applied to the clear filter observations after conversion to V magnitude using previously determined transformation coefficients. Observations in V and R band were acquired in alternating sequence (VRVR...).

Period analysis was done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.*, 1989). Before starting analysis, the sessions were aligned by changing the DeltaComp value for each session in *MPO Canopus* to reach zero-point value. The analysis found a synodic period of *P* = 4.93115 ± 0.00011 h (Fig.1). The period spectrum (Fig. 2) shows the principal period *P* and harmonics of 1/2P, 2/3P, and 2P. The bimodal solution of 2.4657 h has a higher RMS error compared to the quadramodal solution at 4.93115 h. In addition, visual inspection of the lightcurve shape shows a left/right axial asymmetry at the 0.5 phase. These suggest that the quadramodal solution is more likely correct.

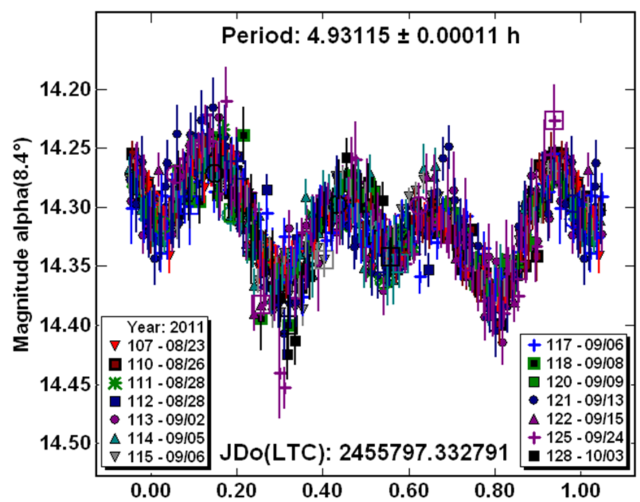

Figure 1.The lightcurve of 1151 Ithaka shows a period of 4.93115 ± 0.00011 h with an amplitude of 0.12 ± 0.01 mag.

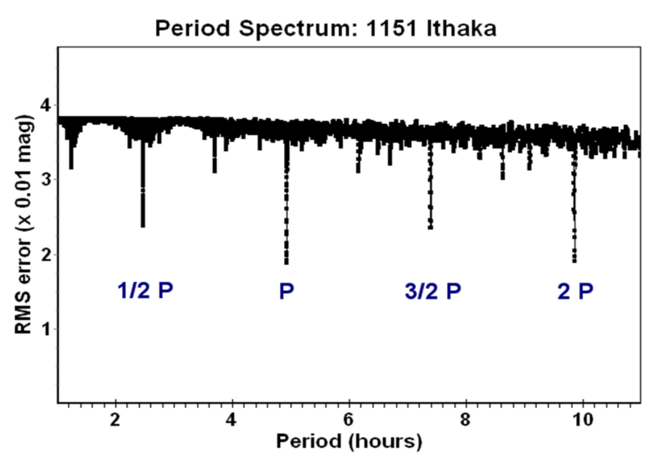

Figure 2. Period Spectrum show the principal period P and harmonics of 1/2P, 3/2P, and 2P.

The amplitude of A_V = 0.12 ± 0.01 was found by taking the mean values obtained from measuring the amplitude of individual sessions with polynomial fit in *Peranso* (Vanmunster, 2007). The asteroid was observed both in V and R band at Balzaretto Observatory on August 28. This allowed us to find the color index of V-R = 0.38 ± 0.03 (mean of 16 values). This value is typical of low albedo C-type asteroid (Shevchenko and Lupishko, 1998).

For each observing session we measured the V mag, corresponding to the light curve maxima using a polynomial fit in *Peranso*. These values were then used in the H-G Calculator function of *MPO Canopus*. From these data, we found H = 12.94 ± 0.03 mag and G = 0.05 ± 0.03. The latter value is also consistent with a C-type asteroid (Shevchenko and Lupishko, 1998). Unfortunately for this apparition, the smallest phase angle reached was 8.43°, far from the zero phase necessary for a optimal phase curve fit.

For the C-type asteroid, the geometric albedo p_V = 0.06 ± 0.02 (Shevchenko and Lupishko, 1998). Using this value, we find a diameter of D = 14 ± 3 km when using the expression (Pravec and Harris, 2007):

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

Year/Month/Day	UT	V mag	α (°)
2011 08 23	20:46	14.263	+8.45
2011 08 24	01:36	14.248	+8.45
2011 08 26	22:38	14.254	+8.54
2011 08 29	00:04	14.240	+8.84
2011 09 02	22:18	14.313	+10.20
2011 09 06	00:13	14.354	+11.37
2011 09 06	19:59	14.380	+11.71
2011 09 07	00:54	14.392	+11.80
2011 09 08	06:26	14.414	+12.33
2011 09 09	02:12	14.408	+12.69
2011 09 13	19:36	14.589	+14.85
2011 09 15	20:53	14.603	+15.80
2011 09 24	02:08	14.798	+19.55
2011 10 03	18:00	15.156	+23.49

Table III. The V magnitude at maximum lightcurve values used to compute H and G.

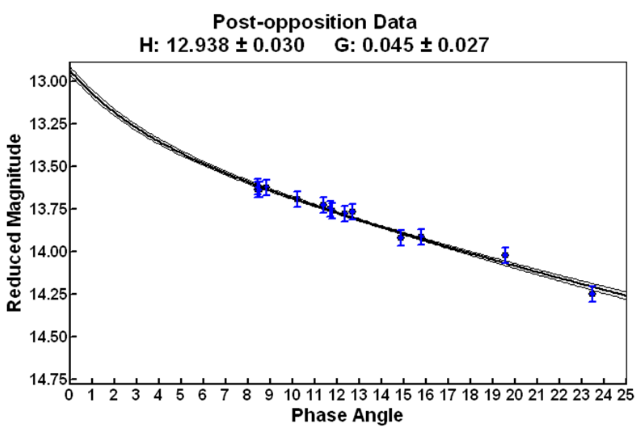

Figure 3. Visual reduced magnitude vs. phase angle values give H = 12.94 ± 0.03 mag and G = 0.05 ± 0.03.

Acknowledgements

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LIGHTCURVES OF 724 HAPAG, 2423 IBARRURI, 4274 KARAMANOV, 4339 ALMAMATER, AND 5425 VOJTECH

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Lightcurves observations and analysis revealed the following periods and amplitudes for the five asteroids: 724 Hapag, 3.13 ± 0.01 h, 0.10 ± 0.02 mag; 2423 Ibarruri, 73.08 ± 0.1 h, 0.27 ± 0.03 mag; 4274 Karamanov, 4.196 ± 0.002 h, 0.36 ± 0.03 mag; 4339 Almamater, 30.84 ± 0.03 h, 0.17 ± 0.04 mag; and 5425 Vojtech, 2.648 ± 0.001 h, 0.27 ± 0.05 mag.

Photometric data were collected on five asteroids at Stonegate Observatory using a 0.43-meter f/6.8 PlaneWave corrected Dall-Kirkham astrograph, SBIG ST-10XME camera, and V-filter. The camera was binned 2x2 with a resulting image scale of 0.95 arc-seconds per pixel. Image exposures were 120 seconds at –15° C, except for a few early runs at 60 seconds. Candidates for analysis were selected using the *MPO2011 Asteroid Viewing Guide* and all photometric data were obtained and analyzed using *MPO Canopus* (Bdw Publishing 2011). Published asteroid lightcurve data were reviewed in the Asteroid Lightcurve Database *(*LCDB; Warner *et al.* 2009).

The magnitudes in the plots (Y-axis) are not sky (catalog) values but differentials from the average sky magnitude of the set of comparison stars. The value on the Y-axis label, "alpha", is the solar phase angle at the time of the first set of observations. All data were corrected to this phase angle using *G* = 0.15.

<u>724 Hapag.</u> This asteroid was V = 15.1-15.3 over the period with poor S/N due to geometry and poor sky conditions. Data were collected from 2011 October 17-23 resulting in 3 data sets and 67 data points. A period of 3.13 ± 0.01 h with amplitude of 0.10 ± 0.02 mag was determined. There are no previous data reported in the LCDB.

<u>2423 Ibarruri.</u> This asteroid was V = 13.9-14.3 over the period. Data were collected from 2011 October 7 through November 2 resulting in 7 data sets and 170 data points. A period of 73.08 ± 0.07 h with amplitude of 0.27 ± 0.03 mag was determined. The long period and limited time span available per set made the solution less than fully confident. There are no previously reported data in the LCDB.

<u>4274 Karamanov.</u> This asteroid was V = 14.6-14.8 over the period. Data were collected from 2011 October 6-17 resulting in 4 data sets and 119 data points. A period of 4.196 ± 0.002 h with amplitude of 0.36 ± 0.03 mag was the most probable solution with a second lower probability, trimodal solution of 6.293 ± 0.1 h. There are no previously reported data in the LCDB.

<u>4339 Almamater.</u> This asteroid was V = 15.1-15.4 over the period with poor S/N due to geometry and poor sky conditions. Data were collected from 2011 October 6-25 resulting in 6 data sets 147 data points. A period of 30.84 ± 0.03 h with amplitude of 0.17 ± 0.04 mag was the most probable solution. There are no previously reported data in the LCDB.

<u>5425 Vojtech.</u> This asteroid was V = 15.2-15.5 over the period with poor S/N due to geometry and poor sky conditions. Data were collected from 2011 October 17- 25 resulting in 4 data sets and 95 data points. A period of 2.648 ± 0.001 h with amplitude of 0.27 ± 0.05 mag was the most probable solution with a second nearly-equal probability trimodal solution of 3.972 ± 0.001 h with amplitude of 0.28 ± 0.05 mag. There are no previously reported data in the LCDB.

Acknowledgments

The author appreciates the help from Brian Warner in phasing the long period asteroid 2423 Ibarruri.

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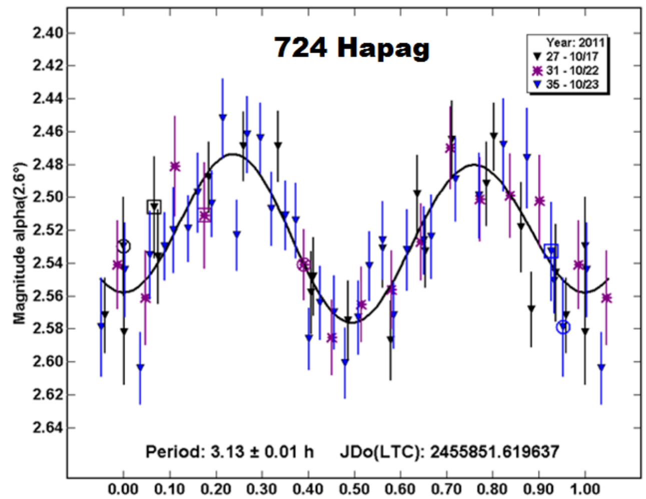

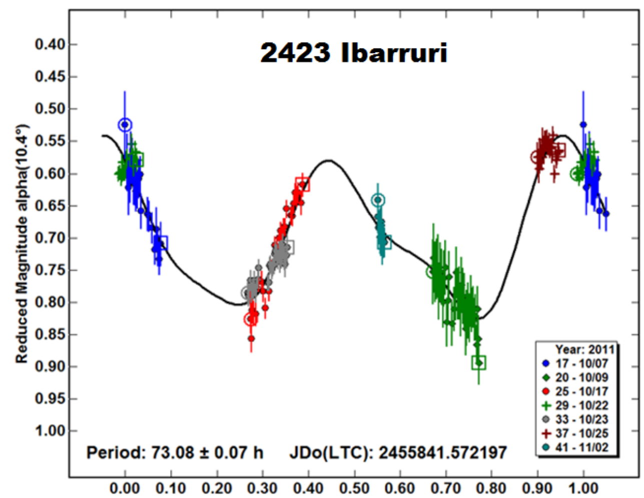

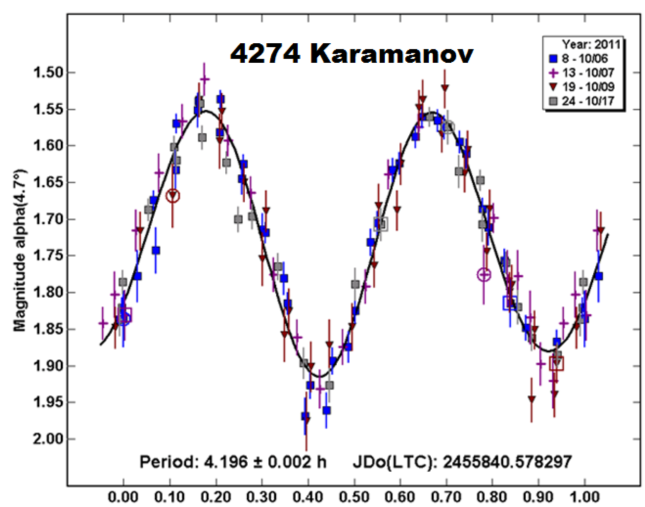

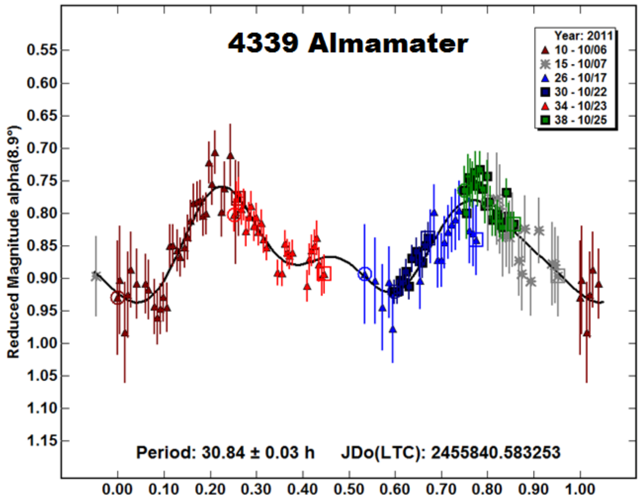

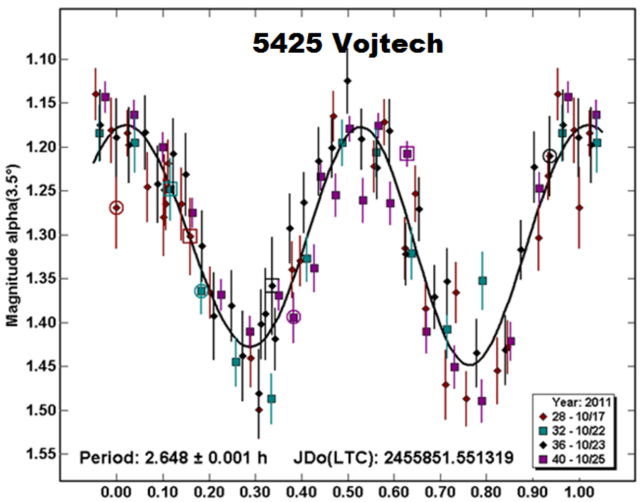

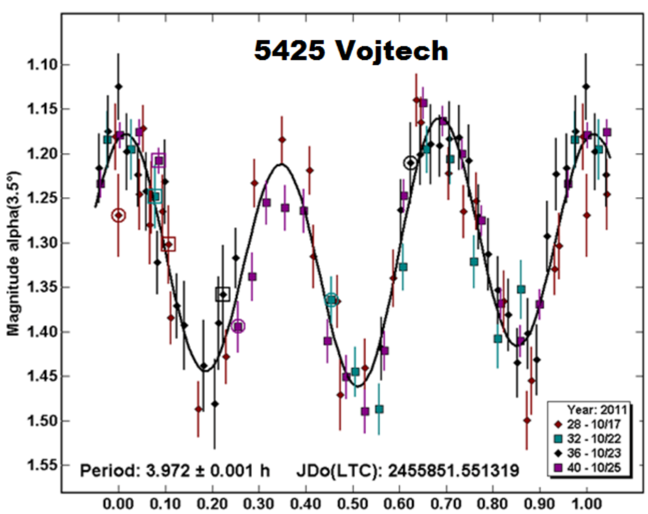

LIGHTCURVE PHOTOMETRY OF 1688 WILKENS

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(Received: 12 January)

Photometric observations of main-belt asteroid 1688 Wilkens were made over five nights during 2011 June and July. Analysis of the resulting data found a synodic period P = 7.248 ± 0.001 h with an amplitude A = 0.23 ± 0.02 mag.

The main-belt asteroid 1688 Wilkens was reported as a lightcurve photometry opportunity in the *Minor Planet Bulletin* (Warner *et al.*, 2011). Observations on five nights were carried out from Balzaretto Observatory (A81) in Rome, Italy, using a 0.20-m Schmidt-Cassegrain (SCT) reduced to f/5.5 and an SBIG ST7-XME CCD camera. All unfiltered images were calibrated with dark and flat-field frames. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2010).

The derived synodic period was P = 7.248 ± 0.001 h (Fig.1) with an amplitude of A = 0.23 ± 0.02 mag.

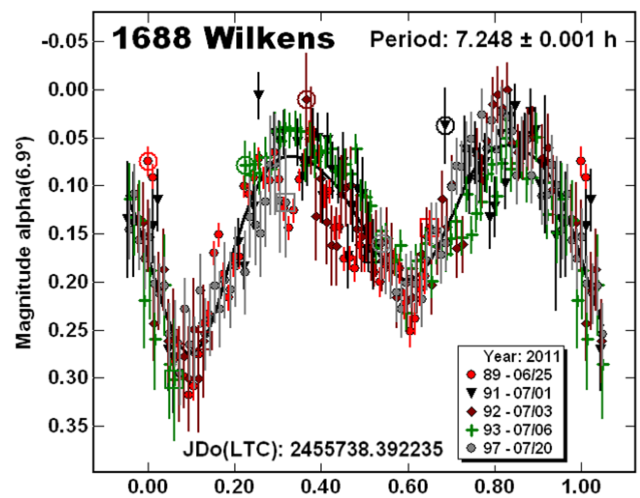

Figure 1. The lightcurve of 1688 Wilkens with a period of 7.248 ± 0.001 h and an amplitude of 0.23 ± 0.02 mag.

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ASTEROID LIGHTCURVE ANALYSIS AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2011 JULY- SEPTEMBER

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(Received: 2 December)

Photometric data for 32 asteroids were collected over 31 nights of observing from 2011 July thru September at the Oakley Southern Sky Observatory. The asteroids were: 918 Itha, 964 Subamara, 1946 Walraven, 2015 Kachuevskaya, 2130 Evdokiya, 2177 Oliver, 2632 Guizhou, 2840 Kallavesi, 3229 Solnhofen, 3343 Nedzel, 3419 Guth, 3438 Inarradas, 3523 Arina, 3910 Liszt, 4433 Goldstone, 4456 Mawson, 4482 Frerebasile, 4600 Meadows, 5042 Colpa, 5483 Cherkashin, (5486) 1991 UT2, 5560 Amytis, 6042 Cheshirecat, 6699 Igaueno, 9143 Burkhead, (10133) 1993 GC1, (10707) 1981 UV23, 12045 Klein, (14982) 1997 TH19, (15585) 2000 GR74, (16886) 1998 BC26, (26287) 1998 SD67.

Thirty two asteroids were observed from the Oakley Southern Sky Observatory in New South Wales, Australia, on the nights of 2011 July 20, 23-29, August 1-4, 20-31, and September 1-7. From the data, we were able to find lightcurves for 20 asteroids. Of the 20 lightcurves found, 17 were for asteroids with no previously published periods, while the remaining three were consistent with previously published results. Although we were unable to find good lightcurves for the remaining 12 asteroids, we were able to determine magnitude amplitudes.

The selection of asteroids was based primarily on their sky position about one hour after sunset. Next, asteroids without previously published lightcurves were given higher priority than those with known periods. In addition, asteroids with uncertain periods were also selected with the hope that improvements of previous results could be made. The telescope used was an f/8.1 0.5-meter Ritchey-Chretien optical tube assembly mounted on a Paramount ME. The camera was a Santa Barbara Instrument Group STL-1001E CCD camera with a clear filter. The image scale was 1.2 arcseconds per pixel. Exposure times varied between 45 and 210 seconds. Calibration of the images was done using master twilight flats, darks, and bias frames. All calibration frames were created using *CCDSoft*. *MPO Canopus* was used to measure the processed images.

As far as we are aware, these are the first reported observations for the period of the following asteroids: 964 Subamara, 2015 Kachuevskaya, 2130 Evdokiya, 2177 Oliver, 3229 Solnhofen, 3343 Nedzel, 3419 Guth, 3438 Inarradas, 3910 Liszt, 4433 Goldstone, 4600 Meadows, 5483 Cherkashin, (5486) 1991 UT2, (10133) 1993 GC1, 12045 Klein, (16886) 1998 BC26, and (26287) 1998 SD67.

1946 Walraven. Our results agree within experimental uncertainty with the period of 10.223 h found by van Gent (1933). There were no experimental uncertainties presented in van Gent's paper.

5560 Amytis. Our results agree within experimental uncertainty

Number	Name	Dates (mm/dd 2011)	Data Points	Period (h)	Period Error (h)	Amp (mag)	Amp Error (mag)
918	Itha	8/22 - 8/29	137			0.20	0.05
964	Subamara	8/22, 8/23, 8/25 - 8/29	137	6.864	0.004	0.11	0.02
1946	Walraven	8/20 - 8/21	39	10.22	0.02	0.88	0.02
2015	Kachuevskaya	7/20, 7/23, 7/25 - 7/29	163	42.01	0.03	0.76	0.04
2130	Evdokiya	7/25 - 7/29	90	4.356	0.003	0.40	0.06
2177	Oliver	8/22 - 8/29	135	6.1065	0.0011	0.45	0.04
2632	Guizhou	8/30 - 9/7	107			0.10	0.02
2840	Kallavesi	7/20, 7/23 - 7/29	171			0.27	0.02
3229	Solnhofen	8/1 - 8/4	81	11.52	0.01	0.38	0.02
3343	Nedzel	7/20, 7/23 - 7/29	214	5.4620	0.0005	0.56	0.06
3419	Guth	8/30 - 9/6	158	14.43	0.01	0.29	0.04
3438	Inarradas	8/1 - 8/4	97	24.82	0.02	0.38	0.03
3523	Arina	8/22 - 8/29	145			0.10	0.04
3910	Liszt	8/1 - 8/4	100	4.73	0.01	0.60	0.02
4433	Goldstone	8/1 - 8/4	77	10.115	0.013	0.20	0.04
4456	Mawson	8/22 - 8/29	118			0.20	0.04
4482	Frerebasile	8/22 - 8/29	194			0.10	0.02
4600	Meadows	8/22 - 8/25, 8/28, 8/29	98	11.682	0.011	0.16	0.02
5042	Colpa	8/20 - 8/21	41			0.10	0.01
5483	Cherkashin	8/30 - 9/7	165	6.148	0.002	0.22	0.03
5486	1991 UT2	7/20, 7/23, 7/25 - 7/29	125	17.90	0.02	0.25	0.05
5560	Amytis	8/30 - 9/7	152	7.732	0.003	0.44	0.03
6042	Cheshirecat	8/30 - 9/7	149	10.049	0.004	0.20	0.03
6699	Igaueno	8/22 - 8/29	132			0.15	0.05
9143	Burkhead	8/22 - 8/29	129			0.20	0.02
10133	1993 GC1	8/20 - 8/21	39	5.547	0.013	0.17	0.02
10707	1981 UV23	8/30 - 9/7	154			0.18	0.01
12045	Klein	8/1 - 8/4	93	8.9686	0.0007	0.55	0.02
14982	1997 TH19	7/20, 7/23, 7/25 - 7/29	161			0.10	0.04
15585	2000 GR74	8/20 - 8/21	44			0.21	0.01
16886	1998 BC26	8/30 - 9/7	163	5.9908	0.0014	0.18	0.04
26287	1998 SD67	8/1 - 8/4	94	10.648	0.014	0.38	0.04

with the period of 7.728 ± 0.001 h found by Hawkins (2008).

6042 Cheshirecat. Our results agree within experimental uncertainty with the period of 10.050 ± 0.002 h found by Stephens (2011).

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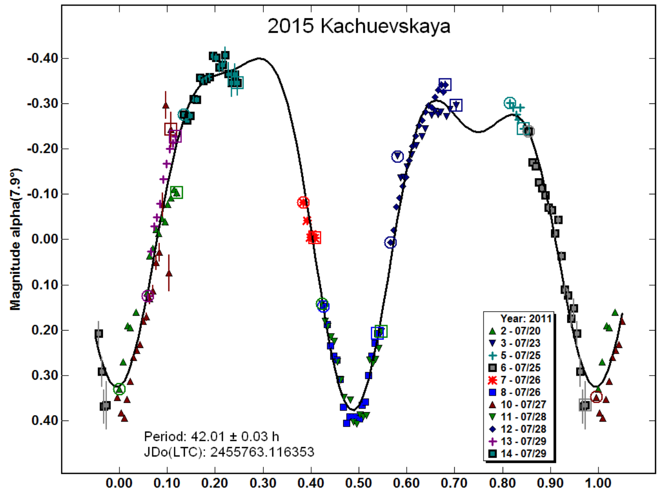

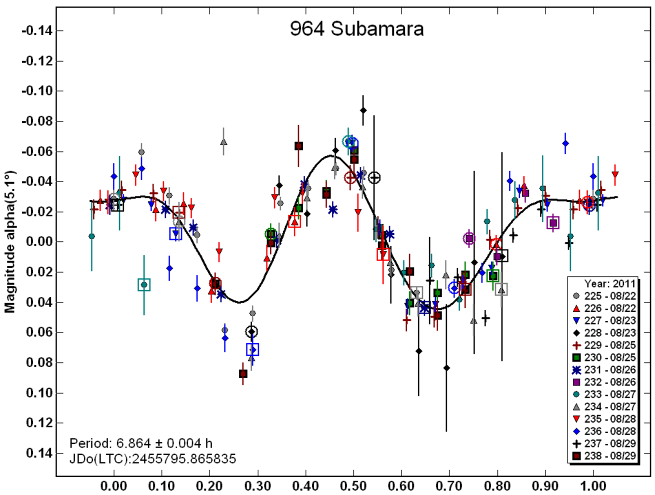

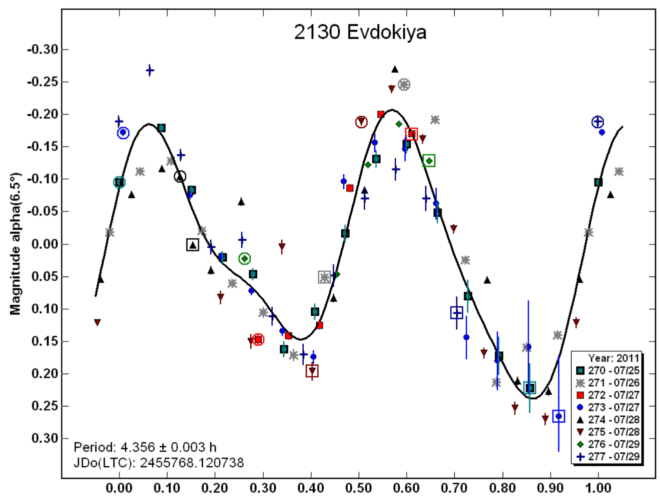

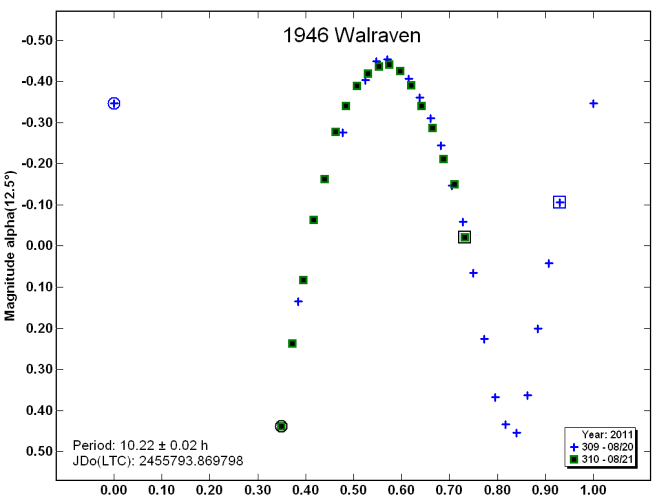

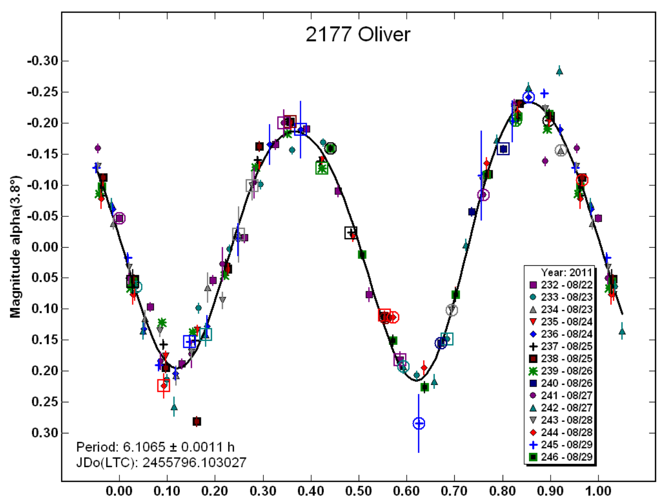

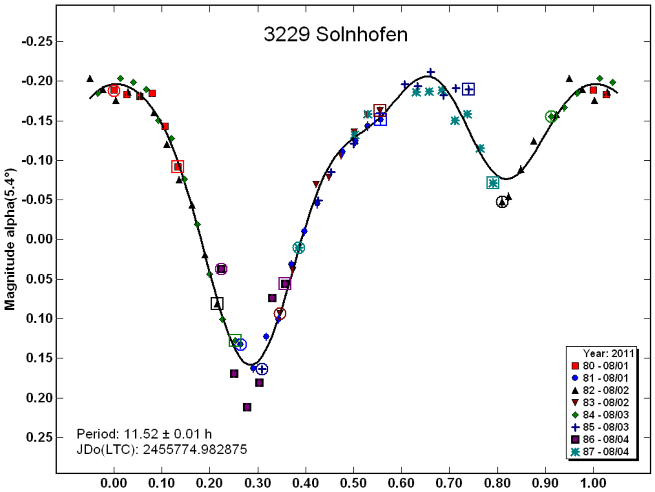
3229 Solnhofen
Magnitude alpha(5.4°)
Period: 11.52 ± 0.01 h
JDo(LTC): 2455774.982875
Year: 2011
80 - 08/01
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83 - 08/02
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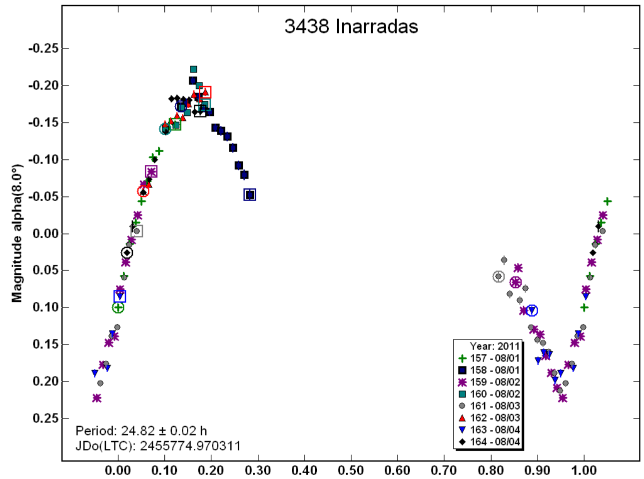
85 - 08/03
86 - 08/04
87 - 08/04


3438 Inarradas
Magnitude alpha(8.0°)
Period: 24.82 ± 0.02 h
JDo(LTC): 2455774.970311
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157 - 08/01
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159 - 08/02
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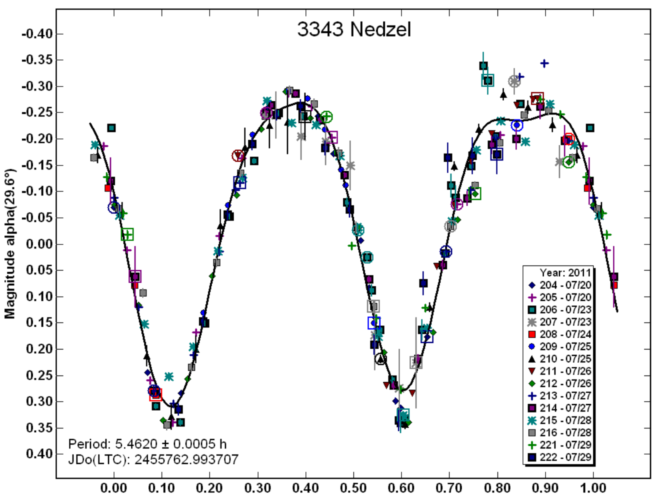
162 - 08/03
163 - 08/04
164 - 08/04


3343 Nedzel
Magnitude alpha(29.6°)
Period: 5.4620 ± 0.0005 h
JDo(LTC): 2455762.993707
Year: 2011
204 - 07/20
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206 - 07/23
207 - 07/23
208 - 07/24
209 - 07/25
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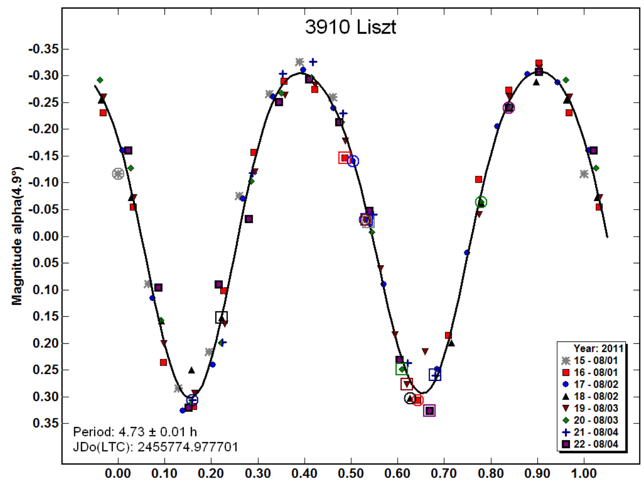
3910 Liszt
Magnitude alpha(4.9°)
Period: 4.73 ± 0.01 h
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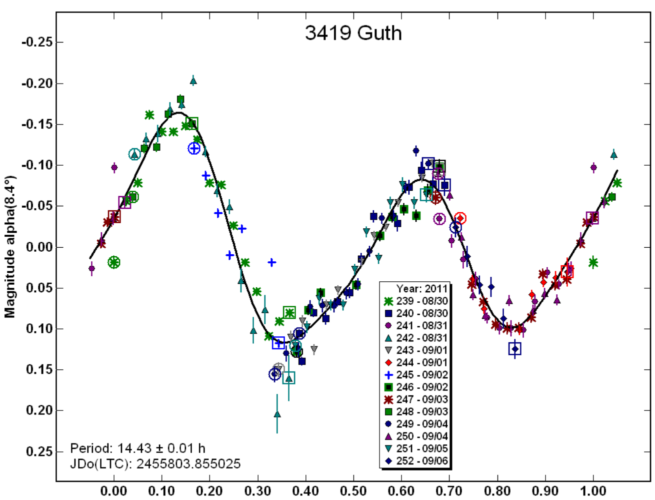
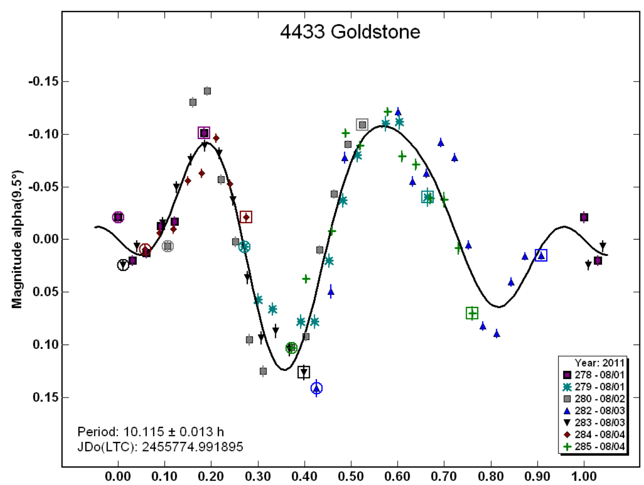
18 - 08/02
19 - 08/03
20 - 08/03
21 - 08/04
22 - 08/04


3419 Guth
Magnitude alpha(8.4°)
Period: 14.43 ± 0.01 h
JDo(LTC): 2455803.855025
Year: 2011
239 - 08/30
240 - 08/30
241 - 08/31
242 - 08/31
243 - 09/01
244 - 09/01
245 - 09/02
246 - 09/02
247 - 09/03
248 - 09/03
249 - 09/04
250 - 09/04
251 - 09/05
252 - 09/06


4433 Goldstone
Magnitude alpha(9.5°)
Period: 10.115 ± 0.013 h
JDo(LTC): 2455774.991895
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278 - 08/01
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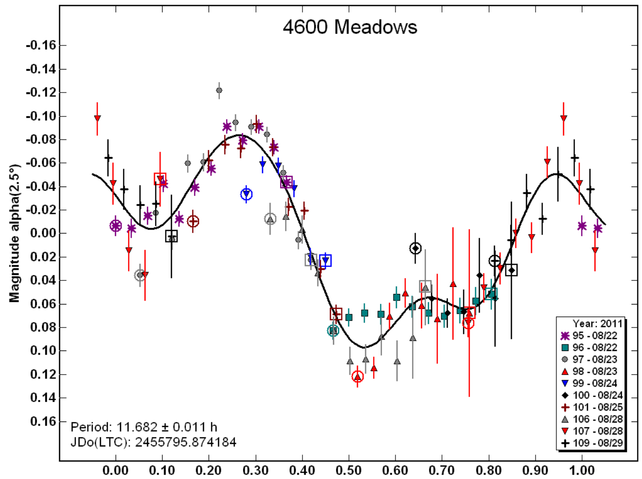
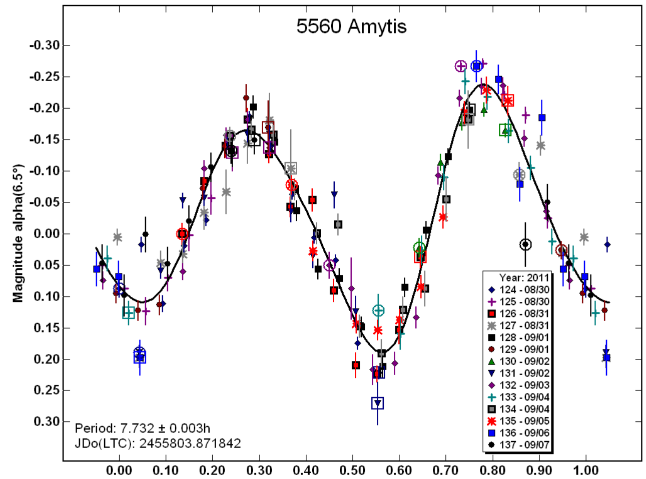
284 - 08/04
285 - 08/04


4600 Meadows
Magnitude alpha(2.5°)
Period: 11.682 ± 0.011 h
JDo(LTC): 2455795.874184
Year: 2011
95 - 08/22
96 - 08/22
97 - 08/23
98 - 08/23
99 - 08/24
100 - 08/24
101 - 08/25
106 - 08/28
107 - 08/28
109 - 08/29


5560 Amytis
Magnitude alpha(6.5°)
Period: 7.732 ± 0.003h
JDo(LTC): 2455803.871842
Year: 2011
124 - 08/30
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126 - 08/31
127 - 08/31
128 - 09/01
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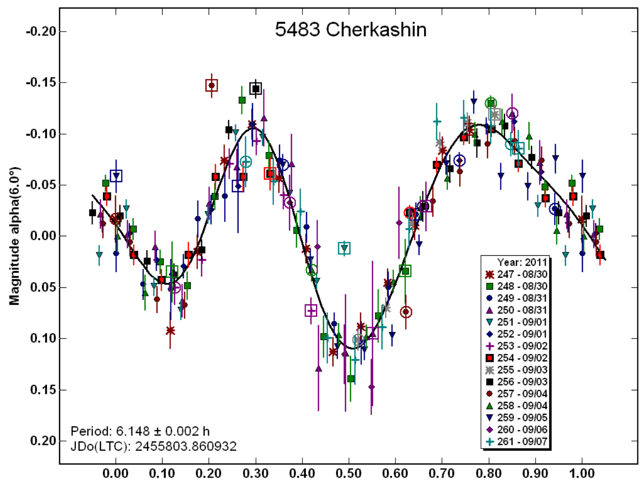
136 - 09/06
137 - 09/07


5483 Cherkashin
Magnitude alpha(6.0°)
Period: 6.148 ± 0.002 h
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Year: 2011
247 - 08/30
248 - 08/30
249 - 08/31
250 - 08/31
251 - 09/01
252 - 09/01
253 - 09/02
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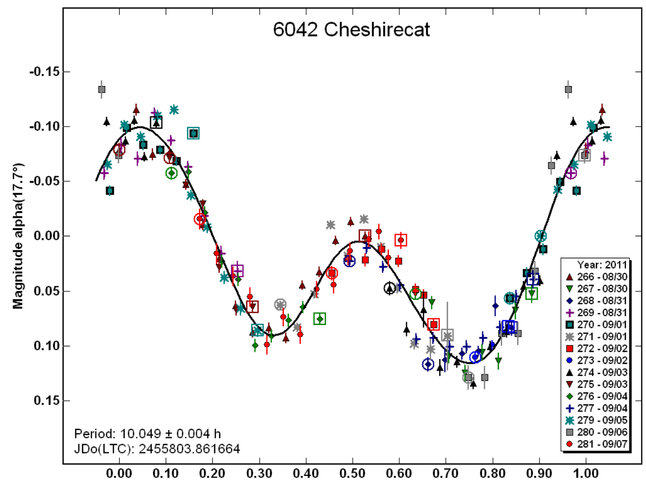
260 - 09/06
261 - 09/07


6042 Cheshirecat
Magnitude alpha(17.7°)
Period: 10.049 ± 0.004 h
JDo(LTC): 2455803.861664
Year: 2011
266 - 08/30
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268 - 08/31
269 - 08/31
270 - 09/01
271 - 09/01
272 - 09/02
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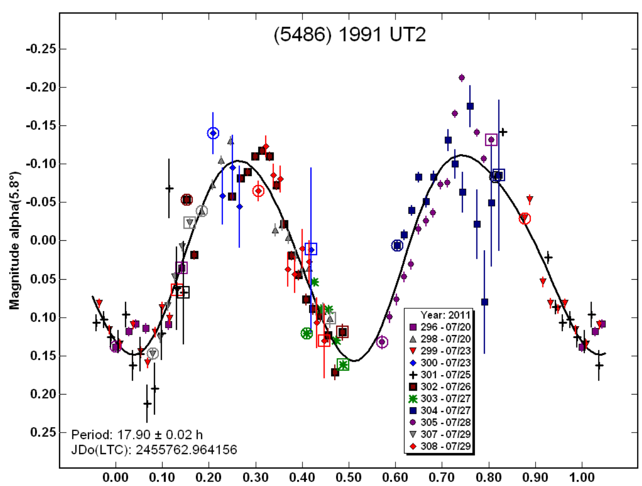
279 - 09/05
280 - 09/06
281 - 09/07


(5486) 1991 UT2
Magnitude alpha(5.8°)
Period: 17.90 ± 0.02 h
JDo(LTC): 2455762.964156
Year: 2011
296 - 07/20
298 - 07/20
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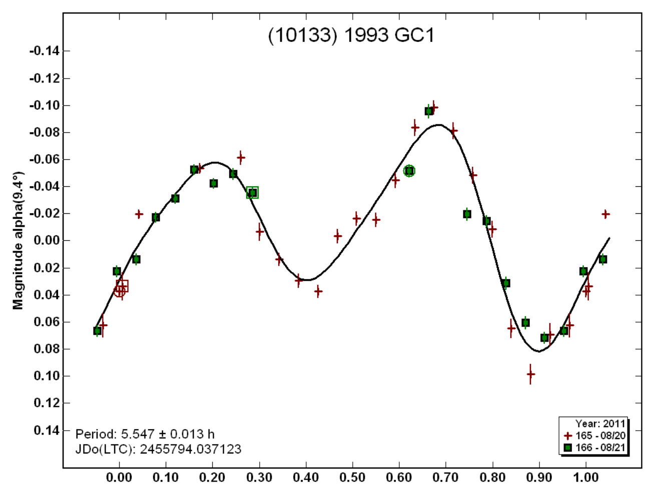
307 - 07/29
308 - 07/29


(10133) 1993 GC1
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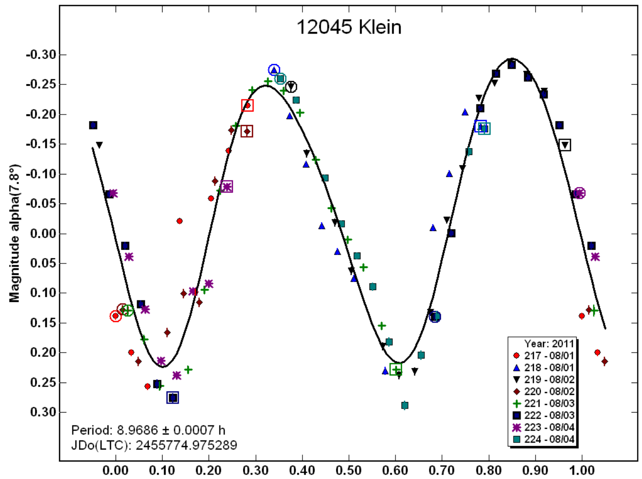
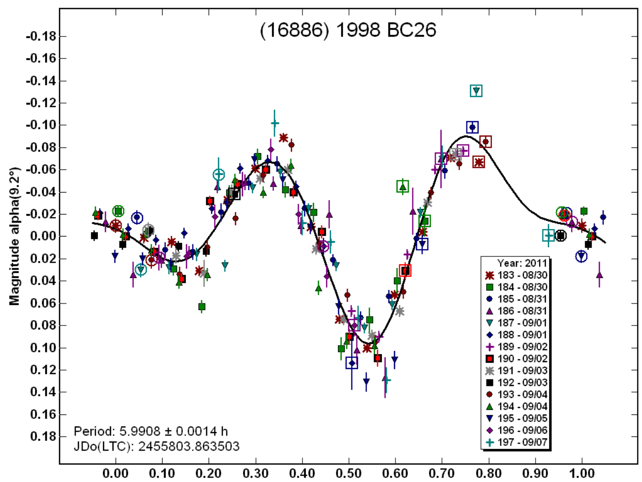
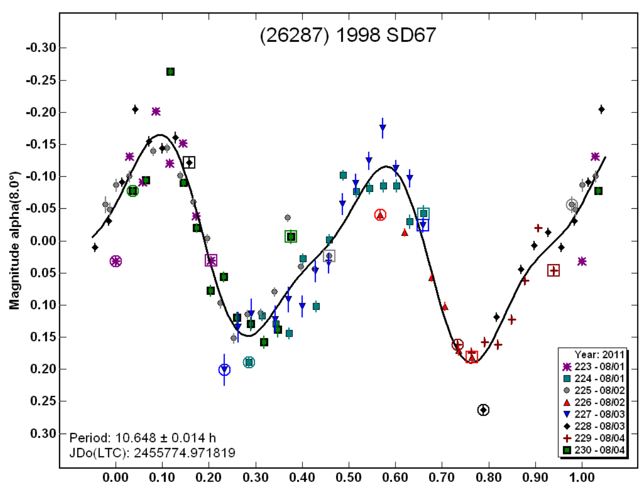
Year: 2011
165 - 08/20
166 - 08/21







ASTEROID LIGHTCURVE ANALYSIS AT THE VIA CAPOTE OBSERVATORY: 2011 APR–DEC

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(Received: 5 January)

Seven asteroids were observed and their lightcurves measured from 2011 April thru December at the Via Capote Observatory: 2573 Hannu Olavi (5.498 h), 2731 Cucula (61.69 h), 3033 Holbaek (233.3 h), (6192) 1990 KB1 (78.74 h), 6306 Nishimura (9.69 h), (23143) 2000 AZ177 (12.45 h), and 24260 Krivan (3.318 h).

The observations made during this campaign were guided, and obtained through a 0.4-m f/10 SCT. The CCD imager was an Apogee Alta U6 featuring a 1024x1024 array of 24-micron pixels. All observations were unfiltered at 1x binning yielding an image scale of 1.24” per pixel. All images were dark, flat field, and bias corrected. Images were measured using *MPO Canopus* (Bdw Publishing). Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors. See Warner (2007) and Stephens (2008) for a further discussion of this process. Target selections were made using the Collaborative Asteroid Lightcurve Link (CALL) web-site and “Lightcurve Opportunities” articles from the *Minor Planet Bulletin*. The results are summarized in the table below and include average phase angle information across the observational period. Individual lightcurve plots along with additional comments, as required, are also presented. All data reported here are available in ALCDEF compliant format at the IAU Minor Planet Center Light Curve Database (*http://minorplanetcenter.net/light_curve)*.

2573 Hannu Olavi. The results of the analysis reported here agree with those reported by Behrend (2011) and Owings (2012). However, there are several other candidate periods with low RMS values in the period spectrum, e.g., at 5.4 h.

2731 Cucula. Oey (2011) reported a period of 61.56 h and amplitude of 0.40 mag, both similar to the results here but with considerably fewer data points than obtained with this study. It is noteworthy that the Oey data set overlaps the final few sessions of data obtained here and then continues well past opposition. Owens (2012) reports a much shorter period of 26.886 h and an amplitude of 0.3 mag. Oey’s data overlaps much of the data obtained by Owens.

3033 Holbaek. 3033 Holbaek was challenging in that the period was very long and nearly commensurate with an Earth day. As expected, there are several candidate solutions in the period spectrum, including one with a monomodal lightcurve. Several segments of the lightcurve were observed twice with close data

#	Name	Date Range (mm/dd) 2011	Data Points	Phase	L_{PAB}	B_{PAB}	Per (h)	PE	Amp (m)	AE
2573	Hannu Olavi	05/31 – 06/15	282	15	220	2	4.932	0.001	0.35	0.10
2731	Cucula	06/14 – 08/07	866	18,3,4	220	5	61.69	0.02	>0.30	
3033	Holbaek	04/30 – 06/08	1146	14	216	5	233.3	0.1	1.2	0.05
(6192)	1990 KB1	06/26 – 07/20	690	15	303	2	78.74	0.03	0.95	0.1
6306	Nishimura	10/29 – 12/04	548	14	77	-5	9.690	0.001	0.41	0.05
(23143)	2000 AZ177	08/04 – 08/07	398	6	309	7	12.45	0.02	0.14	0.05
24260	Krivan	11/27 – 12/04	161	10	49	4	3.318	0.001	0.42	0.02

agreement, which would seem to reduce the likelihood that this object is tumbling.

It is noteworthy that no night-to-night zero point adjustments were applied to the data. The ability to internally link the nightly zero points using the tools in the photometric analysis package coupled with the rather large amplitude lightcurve made this project possible from just one observing station.

(6192) 1990 KB1. Behrend (2011) reports a provisional period of 11.1 h and amplitude of 0.12 mag. Higgins (2010) reports a much different period of 78.85 h and amplitude of 0.85 mag. The results obtained in this study agree well with the results reported by Higgins.

(23143) 2000 AZ177. The estimated period of the lightcurve was nearly commensurate with 0.5 earth day. This made complete observation of this object from a single station very time consuming. Other higher-priority targets prevented a more complete characterization for this apparition.

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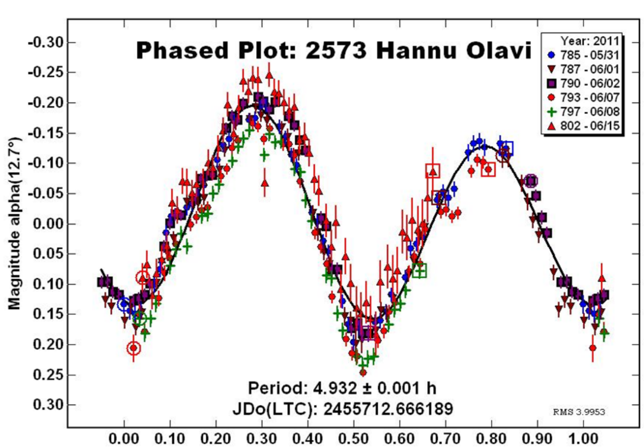

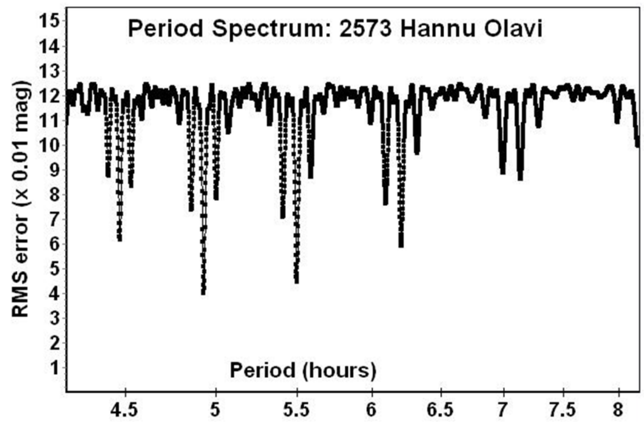

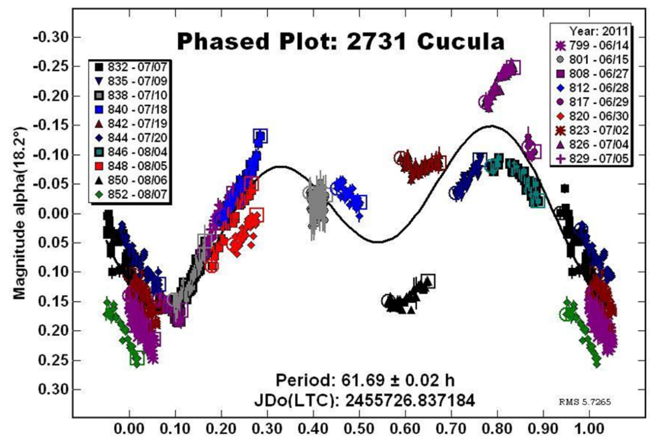

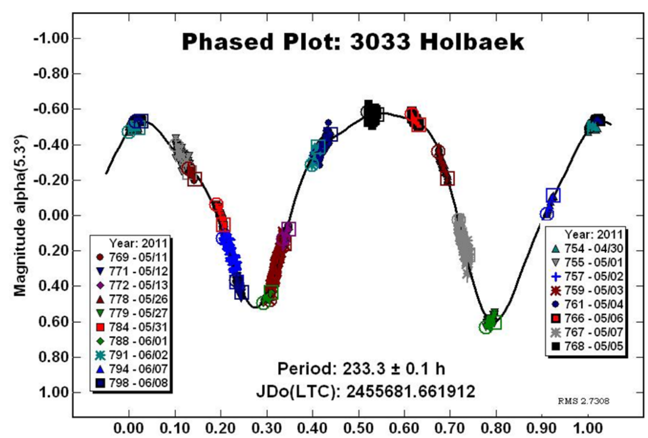

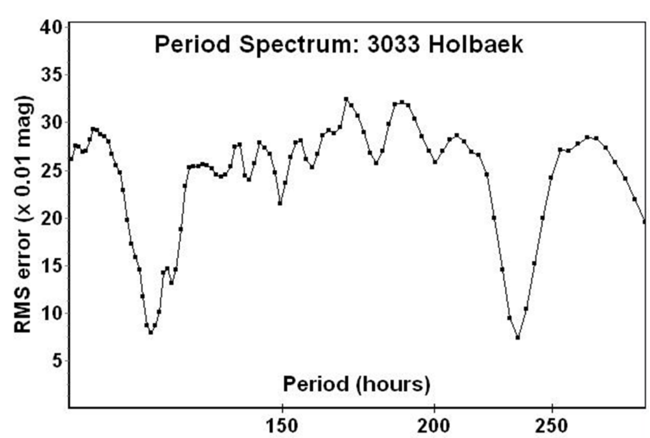

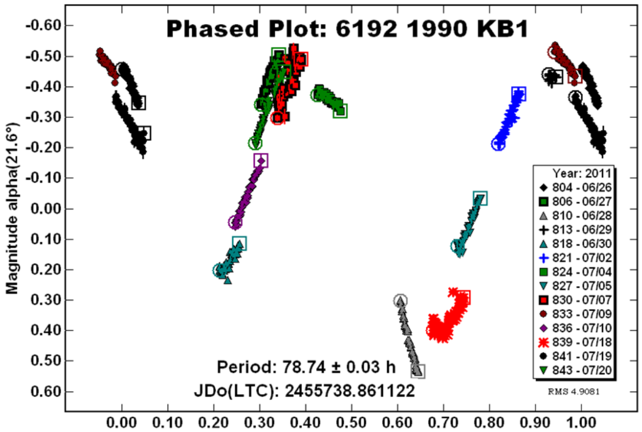

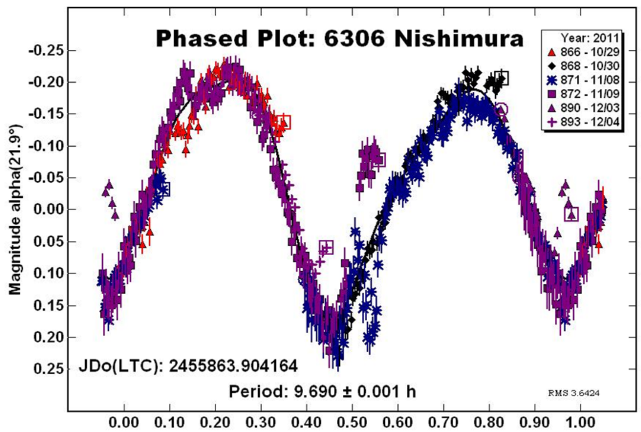

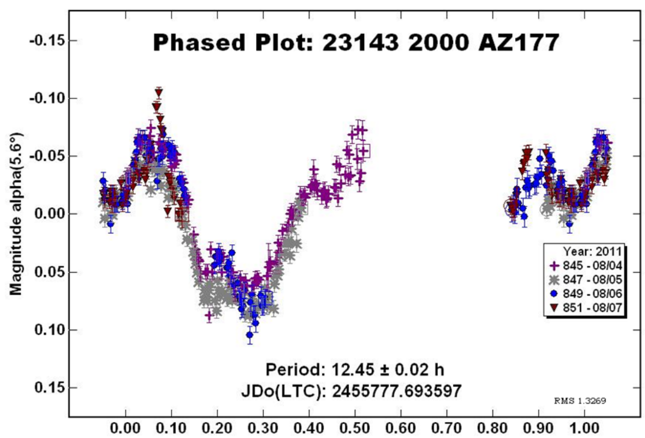

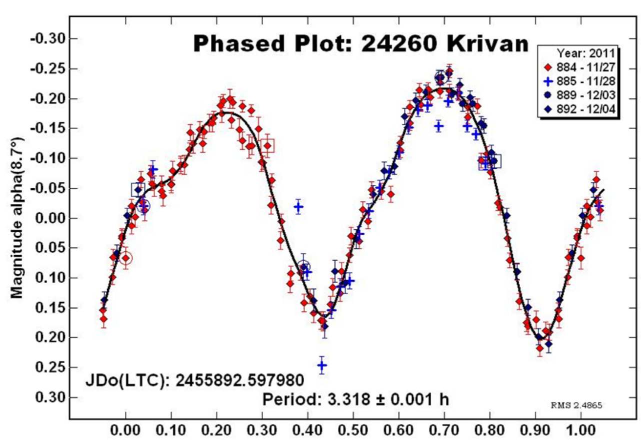

ROTATION PERIOD DETERMINATIONS FOR 31 EUPHROSYNE, 65 CYBELE, 154 BERTHA, 177 IRMA, 200 DYNAMENE, 724 HAPAG, 880 HERBA, AND 1470 CARLA

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Synodic rotation periods and amplitudes have been found for 31 Euphrosyne, 5.5296 ± 0.0001 h, 0.09 ± 0.01 mag; 65 Cybele, 6.0814 ± 0.0001 h, 0.08 ± 0.01 mag with an irregular lightcurve; 154 Bertha, 25.224 ± 0.002 h, 0.10 ± 0.01 mag with an irregular lightcurve; 177 Irma, 13.856 ± 0.001 h, 0.30 ± 0.03 mag; 200 Dynamene, 37.394 ± 0.002 h, 0.10 ± 0.01 mag with 4 unequal maxima and minima per cycle; 724 Hapag, 3.1305 ± 0.0001 h, 0.11 ± 0.01 mag; 880 Herba, 12.266 ± 0001 h, 0.13 ± 0.02 mag with one asymmetric maximum and minimum per cycle; and 1470 Carla, 6.1514 ± 0.0002 h, 0.25± 0.02 mag.

All observations published here were made at the Organ Mesa Observatory using a Meade 0.35-m LX-200 GPS Schmidt-Cassegrain, and SBIG STL-1001-E CCD. An Rc filter was used for 31 Euphrosyne and 200 Dynamene; a clear filter was used for fainter objects. Exposures were unguided. Image measurement finding only differential magnitudes and lightcurve analysis were done with *MPO Canopus*. Because of the large number of data points, the data for the lightcurves presented here have been binned in sets of three points with a maximum time interval between points no greater than 5 minutes. In each case, thorough examination of all local minima in the period spectrum ruled out all credible alias periods except twice the value reported here. Also in each case, the two halves of the lightcurve phased to the double-period looked identical within reasonable error of observation and shape changes which could be attributed to changing phase angle through the interval of observation. For the double-period to be the correct one, the object would need a shape which, although irregular, was highly symmetric over a 180 degree rotation. The probability of such a shape is not precisely zero but is sufficiently small that it may be safely rejected. Therefore, the correct period can be claimed to have been found for all objects reported here.

31 Euphrosyne. The Asteroid Lightcurve Data file (Warner *et al.*, 2011) states a secure period of 5.530 h based upon closely compatible measures by several previous observers. Additional observations were obtained on five nights from 2001 Sept. 24-Dec. 10 over a larger range of phase angles than ever previously sampled to provide data for lightcurve inversion modeling. These further refine the period to 5.5296 ± 0.0001 h, with amplitude 0.09 ± 0.01 mag at the 2011 apparition.

65 Cybele. The first period determination (Schober *et al.*, 1980) showed 6.07 h. Weidenschilling *et al.* (1987) agreed, but several consecutive subsequent period determinations by Weidenschilling *et al.* (1990), Gil-Hutton (1990), Drummond *et al.* (1991), De Angelis (1995), Schevchenko *et al.* (1996), and Behrend (2011) all suggested periods near 4.03 h. Pilcher and Stephens (2010), in the first dense lightcurve ever obtained, found 6.082 h and furthermore claimed that a period near 4 h was ruled out. New observations

made on 6 nights form 2011 Nov. 19 to 2012 Jan. 3 are completely consistent with Pilcher and Stephens (2010). They show a period of 6.0814 ± 0.0001 h, amplitude 0.08 ± 0.01 mag with an irregular lightcurve and completely rule out a period near 4 h.

154 Bertha. Previously published periods include >12 h (Harris and Young, 1989) with sparse photometry and no published lightcurve; 27.6 h (Kamel, 1998) based on a sparse published lightcurve; 22.30 h Warner (2007a) with a moderately dense lightcurve; and 18 h (Behrend, 2011). New observations on 10 nights from 2011 Sept. 19-Oct. 31 show a period 25.224 ± 0.002 h, amplitude 0.10 ± 0.01 mag with an irregular lightcurve. All previously reported periods are ruled out. With a period slightly greater than Earth synchronous, the phase of the lightcurve visible at a single location circulates slowly to the left. Observations were made at intervals of a few days until the entire lightcurve had been sampled through two complete circulations.

177 Irma. The only previously published lightcurve is by Wetterer *et al.* (1999), who reported a period of 14.208 h. This period was found from observations a month apart, for which the long interval between observations prevented accurately counting the intervening cycles. New observations well-distributed through 7 nights from 2011 Nov. 7-Dec. 16 enable a reliable counting of rotational cycles and show a unique period of 13.856 ± 0.001 h, amplitude 0.30 ± 0.03 mag.

200 Dynamene. The only previously published lightcurve is by Schober (1978) who combined irregular lightcurves on two consecutive nights, 1975 Dec. 5/6 and 6/7, to obtain partial phase coverage compatible with a period of 19 h. New observations on 11 nights form 2011 Oct. 9-Dec. 4 show a period 37.394 ± 0.002 h with 4 unequal maxima and minima per cycle, amplitude 0.10 ± 0.01 mag. A period near 19 h is ruled out.

724 Hapag. The Asteroid Lightcurve Data file (Warner *et al.*, 2011) shows no previous observations. Observations on 5 nights from 2011 Sept. 29-Nov. 1 show a period 3.1305 ± 0.0001 h, amplitude 0.11 ± 0.01 mag.

880 Herba. The only previous period determination is by Warner (2007b) who found 12.215 h. New observations on 6 nights 2011 from Sept. 23-Nov. 3 show a period 12.266 ± 0.001 h, amplitude 0.13 ± 0.02 mag with an asymmetric lightcurve with one maximum and minimum per cycle. Considering that the two data sets are at considerably different aspects, these two periods should be considered compatible.

1470 Carla. The Asteroid Lightcurve Data file (Warner *et al.*, 2011) shows no previous observations. Observations on five nights from 2011 Aug. 29-Sept. 25 show a period 6.1514 ± 0.0002 h, amplitude 0.25 ± 0.02 mag.

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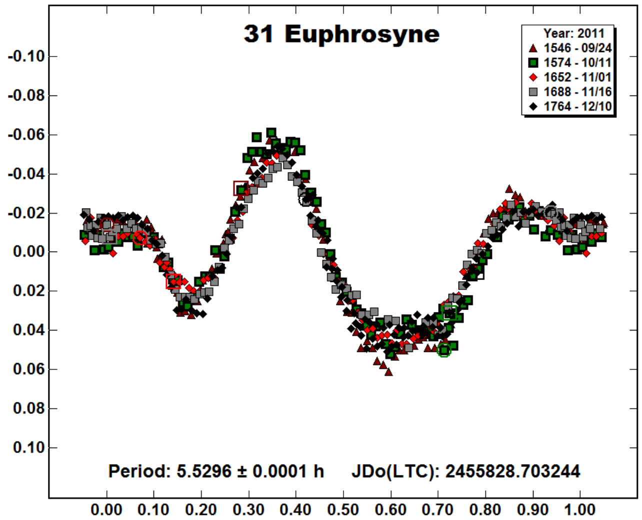
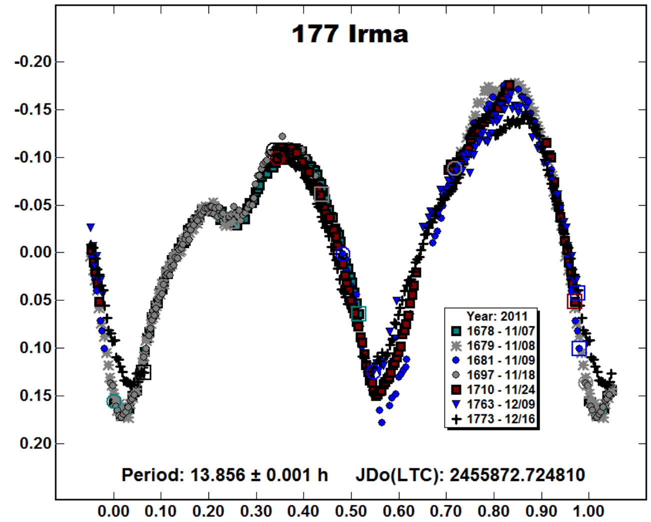
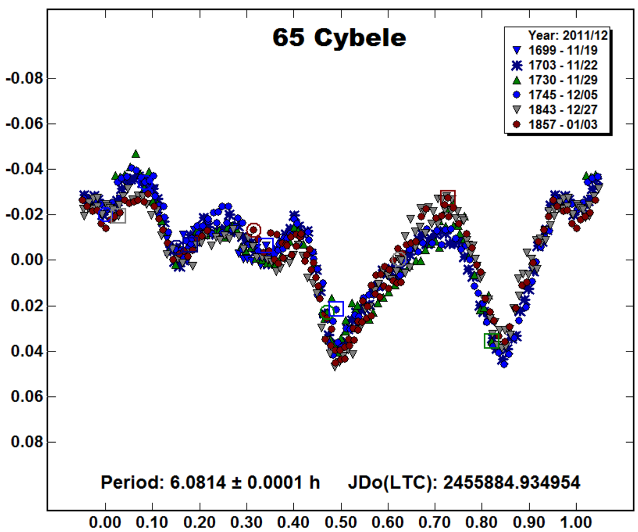
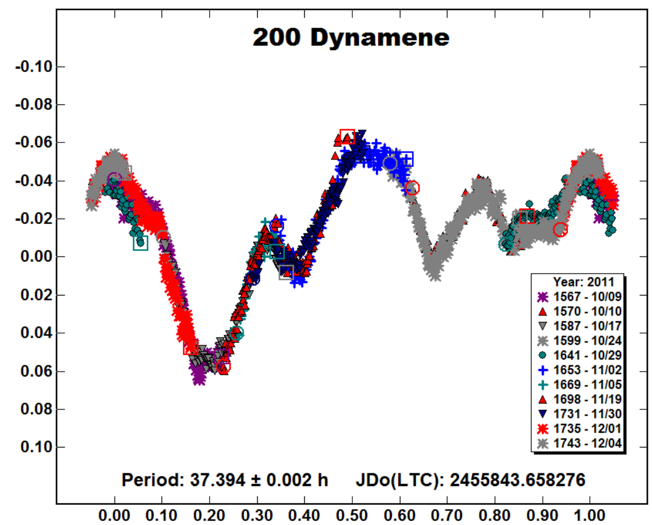
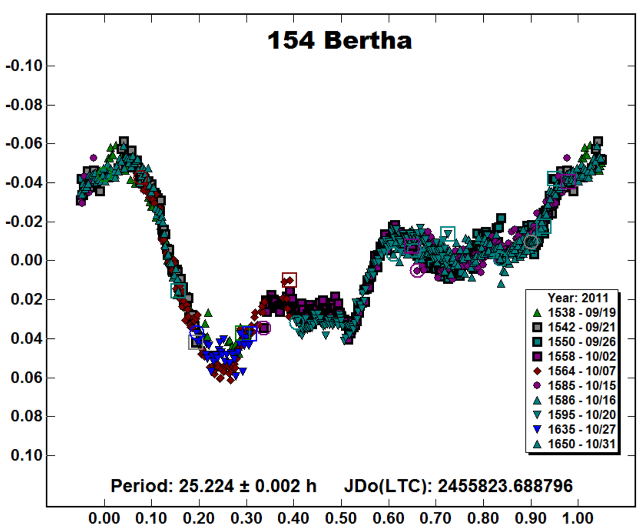
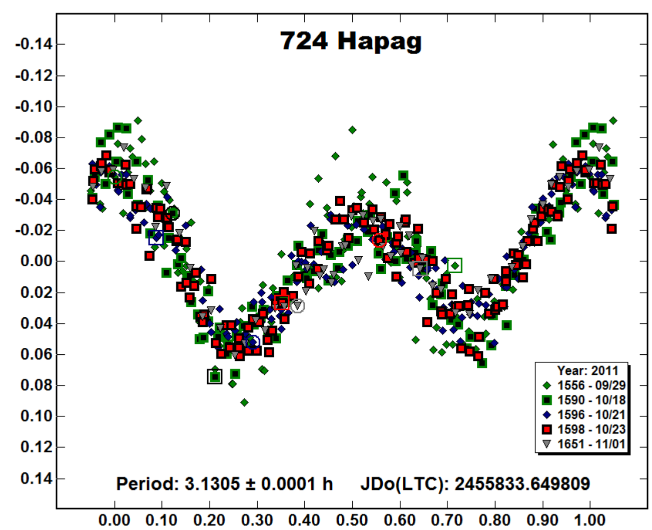

31 Euphrosyne
Year: 2011
1546 - 09/24
1574 - 10/11
1652 - 11/01
1688 - 11/16
1764 - 12/10
Period: 5.5296 ± 0.0001 h JDo(LTC): 2455828.703244

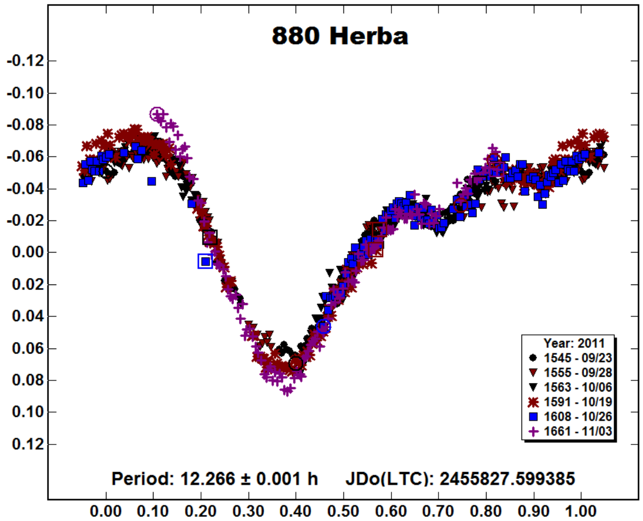

177 Irma
Year: 2011
1678 - 11/07
1679 - 11/08
1681 - 11/09
1697 - 11/18
1710 - 11/24
1763 - 12/09
1773 - 12/16
Period: 13.856 ± 0.001 h JDo(LTC): 2455872.724810

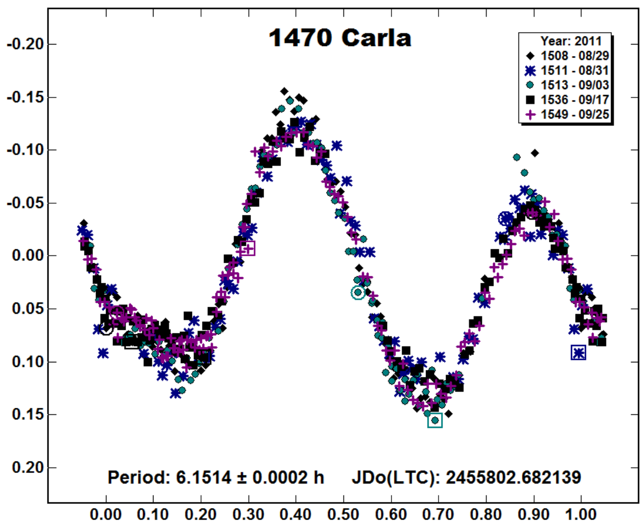

65 Cybele
Year: 2011/12
1699 - 11/19
1703 - 11/22
1730 - 11/29
1745 - 12/05
1843 - 12/27
1857 - 01/03
Period: 6.0814 ± 0.0001 h JDo(LTC): 2455884.934954


200 Dynamene
Year: 2011
1567 - 10/09
1570 - 10/10
1587 - 10/17
1599 - 10/24
1641 - 10/29
1653 - 11/02
1669 - 11/05
1698 - 11/19
1731 - 11/30
1735 - 12/01
1743 - 12/04
Period: 37.394 ± 0.002 h JDo(LTC): 2455843.658276


154 Bertha
Year: 2011
1538 - 09/19
1542 - 09/21
1550 - 09/26
1558 - 10/02
1564 - 10/07
1585 - 10/15
1586 - 10/16
1595 - 10/20
1635 - 10/27
1650 - 10/31
Period: 25.224 ± 0.002 h JDo(LTC): 2455823.688796


724 Hapag
Year: 2011
1556 - 09/29
1590 - 10/18
1596 - 10/21
1598 - 10/23
1651 - 11/01
Period: 3.1305 ± 0.0001 h JDo(LTC): 2455833.649809





ROTATION PERIOD AND H-G PARAMETERS DETERMINATION FOR 1188 GOTHLANDIA

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CCD observations of the main-belt asteroid 1188 Gothlandia were recorded during the period 2011 August to December. Analysis of the lightcurve found a synodic period of P = 3.4916 ± 0.0001 h and amplitude A = 0.59 ± 0.01 mag near opposition. The phase curve referenced to mean magnitude suggests the absolute magnitude and phase slope parameter H = 11.662 ± 0.014 and G = 0.153 ± 0.014. The phase curve referenced to maximum light suggests H = 11.425 ± 0.014 and G = 0.230 ± 0.015.

A partial spin/shape model using the lightcurve inversion method has been reported for 1188 Gothlandia by Hanus *et al*. (2011). The mean ecliptic latitude of the pole direction is stated $\beta = -63$ degrees with dispersion $\Delta = 19$ degrees. The negative ecliptic latitude of the pole direction indicates retrograde rotation. The ecliptic longitude of the pole direction is not yet known. The model includes the sidereal period $P = 3.491820$ h. The goal of our collaborative observing campaign was to obtain additional dense lightcurve data for use in improving the pole axis and shape models. Sparse data were also recorded throughout the wide range of phase angles.

Observations of 1188 Gothlandia were recorded by Baker at Indian Hill Observatory (IHO) using a 0.3-m Schmidt-Cassegrain Telescope (SCT) reduced to f/5.1 coupled with an SBIG ST-402ME CCD. Pilcher recorded observations at Organ Mesa Observatory (OMO) using a 0.35-m SCT at f/10 coupled with an SBIG STL-1001E CCD. Klinglesmith recorded observations at Etscorn Campus Observatory (ECO) using a 0.35-m SCT at f/11 coupled with an SBIG STL-1001E CCD. In addition to the instruments at our local observatories, Baker recorded images at Sierra Stars Observatory (SSO) using the robotic 0.61-m classical Cassegrain telescope and FLI Proline CCD. All images recorded during the campaign were calibrated with darks and flats.

A	B	C	D	E	F	G
Aug 27 – Sep 18	3.49157 ± 0.00002	2.9	-1.6	6.6	-0.4	0.168
Sep 26 – Oct 07	3.49176 ± 0.00006	7.6	0	8.7	0.6	0.110
Oct 14 – Oct 25	3.49163 ± 0.00005	9.4	1	11.3	1.7	0.173
Nov 02 – Nov 22	3.49150 ± 0.00003	12.2	2	17.4	2.8	0.260
Dec 01 – Dec 18	3.49138 ± 0.00004	20.3	3.1	26.3	3.5	0.353

Table I. Change in synodic period during apparition. A: First and last dates used in period determination. B: Synodic period and its error, in hours. C: Phase angle bisector (PAB) longitude on the first date. D: PAB latitude on the first date. E: PAB longitude on second date. F: PAB latitude on second date. G: Mean daily motion of PAB longitude for interval in A, degrees/day.

			Instrumental Photometry					Absolute Photometry						
Loc	**Date**	**α**	**LC**	**Mid UT**	**Obs**	**Filter**	**Amp**	**Dpt**	**UT**	**Filt**	**Obs**	**SNR**	**Std V**	**Error**
IHO	Aug 27	21.01	A	6:00	110	C	0.724	1	8:08	V	5	132	14.147	±0.033
IHO	Aug 30	19.70						2	4:43	V	5	162	13.687	±0.035
IHO	Sep 02	18.17						3	8:26	V	5	128	13.362	±0.024
IHO	Sep 18	9.10	B	5:00	110	V	0.642	4	4:30	V	5	256	12.988	±0.019
ECO	Sep 18	9.06	C	7:00	248	VR	0.643	5	6:09	V	10	148	13.093	±0.033
OMO	Sep 18	9.03	D	8:00	406	V	0.637	6	7:14	V	10	138	13.206	±0.028
IHO	Sep 25	4.53						7	4:21	V	5	308	12.569	±0.046
ECO	Sep 26	3.85	E	7:00	101	VR	0.752	8	4:39	V	10	191	12.628	±0.054
OMO	Sep 27	3.05	F	9:00	178	V	0.601	9	9:02	V	7	195	12.621	±0.036
SSO	Sep 28	2.40						10	8:06	V	3	353	12.976	±0.030
SSO	Sep 29	1.80						11	5:28	V	3	372	12.808	±0.040
SSO	Sep 30	1.07						12	7:56	V	3	397	12.548	±0.023
OMO	Oct 01	0.49	G	7:00	333	V	0.590	13	5:51	V	10	172	12.748	±0.034
ECO	Oct 01	0.44	H	9:00	126	VR	0.594	14	8:28	V	10	217	12.434	±0.033
SSO	Oct 01	0.42						15	9:06	V	6	441	12.530	±0.025
ECO	Oct 02	0.39	I	7:00	236	VR	0.720	16	5:33	V	10	167	12.281	±0.061
IHO	Oct 05	2.31	J	5:00	111	V	0.605	17	5:03	V	5	327	12.587	±0.032
IHO	Oct 07	3.60	K	4:00	105	V	0.612	18	2:55	V	5	298	12.585	±0.038
IHO	Oct 09	4.94						19	2:57	V	5	193	12.994	±0.034
ECO	Oct 13	7.59	L	7:00	148	VR	0.650	20	3:24	V	10	156	12.804	±0.040
ECO	Oct 14	8.24	M	7:00	224	VR	0.655	21	3:49	V	10	163	12.938	±0.033
SSO	Oct 14	8.34						22	7:30	V	3	373	12.789	±0.030
OMO	Oct 18	10.73	N	3:00	176	V	0.669	23	2:32	V	7	156	13.053	±0.032
SSO	Oct 22	13.23						24	6:02	V	3	347	13.036	±0.033
IHO	Oct 25	14.84	O	0:00	110	V	0.705	25	1:41	V	5	221	13.205	±0.030
SSO	Oct 28	16.57						26	6:06	V	3	252	13.576	±0.030
IHO	Oct 31	18.00						27	0:22	V	3	90	13.762	±0.032
IHO	Nov 02	19.01	P	3:00	114	V	0.728	28	1:41	V	5	191	13.489	±0.025
IHO	Nov 05	20.42						29	2:46	V	5	139	13.816	±0.025
OMO	Nov 11	22.95	Q	3:00	186	V	0.754	30	3:24	V	10	78	13.730	±0.029
SSO	Nov 15	24.44						31	5:01	V	3	159	14.461	±0.024
IHO	Nov 22	26.59	R	2:00	105	C	0.786	32	0:24	V	5	153	13.917	±0.027
OMO	Nov 24	27.15						33	2:03	V	12	111	14.046	±0.028
IHO	Dec 01	28.79	S	2:00	120	C	0.795	34	1:02	V	9	131	14.230	±0.030
OMO	Dec 18	31.23	T	3:00	212	C	0.833							
SSO	Dec 20	31.40						35	3:50	V	5	161	14.664	±0.021

Table II. Observation details.

The asteroid was observed at phase angles from 21.0 degrees pre-opposition on Aug 27 to 0.4 degrees at opposition on Oct 1 to 31.4 degrees post-opposition on Dec 20. We recorded at least one full rotation every week or two throughout the campaign. Bessel V filters were primarily used for the dense time series. During several sessions, the R filter was alternated with the V filter. V-R from those sessions shows no rotational variation, at least upon visual inspection. We switched to unfiltered imaging late in the apparition to improve the signal to noise ratio.

MPO Canopus software (BDW Publishing 2010) was used to perform differential photometry and period analysis. The data were binned in sets of 3 with a maximum time interval of 5 minutes. The bimodal composite lightcurve indicates period $P = 3.4916 \pm 0.0001$ h and amplitude $A = 0.59 \pm 0.01$ mag near opposition (Figure 1). The amplitude changed significantly as the phase angle changed during the several months of observation (Figure 2).

To study the change of synodic period through the entire interval of observation, we plotted five lightcurves from various smaller intervals. The mean daily motion of the longitude of the phase angle bisector was calculated for these intervals (Table I). This shows a negative correlation between daily motion and synodic period. The correlation is definitive of retrograde rotation, and is consistent with current models (Hanus *et al*. 2011 and Durech *et al*. 2009). In this case, the correlation is especially strong due to the short rotation period and large interval of observations. A rough approximation for sidereal period was made by extrapolating the correlation to zero daily motion (Figure 3).

Phase Curve and H-G Parameters

A complete description of the rationale and methodology of finding *H* and *G* values for an asteroid is provided by Buchheim (2010). This shows that extending the range of phase angles included in the study improves the accuracy of the *H* and *G* parameters. The large range of phase angles encountered here was especially favorable to achieving this goal. We used differential photometry to derive standard magnitudes for the asteroid from instrumental magnitudes recorded for the asteroid and comparison stars. Standard magnitude estimates for the comparison stars were calculated with (Dymock and Miles 2009)

$$V = 0.628(J\text{-}K) + 0.995r' \quad (1)$$

where V is the estimated standard V band magnitude, J and K are magnitude bands from the Two-Micron All-Sky Survey, and r' is a magnitude band from the Sloan Digital Sky Survey.

Depending on the number of stars in our various fields of view, 6 to 24 stars of the proper color were available for use as comparisons and whose calculated standard V magnitudes were reasonably consistent with their corresponding instrumental magnitudes. The comparison star selection and data reduction were performed with *Astrometrica* software (Raab 2010). The overall error stated for each data point (Table II) is a combination of the error as a function of the signal to noise ratio and the measure of the uncertainty in the comparison star magnitudes.

The observed standard magnitude for each data point was corrected for the varying brightness due to rotation by comparing the point on the lightcurve at the time of each observation with both mean magnitude and maximum light. Each dense time series in V yielded a sample of images from which a standard magnitude was derived. The lightcurve ephemeris utility in *MPO Canopus* was used to evaluate the individual lightcurve to determine the needed correction. Since the sparse observations were usually separated from the dense time series by several days or more, composite lightcurves were plotted from time series recorded before and after the sparse observations. These "bracketing" composite lightcurves produced good estimates of the amplitude, and the improved accuracy of the period was particularly important for determining an accurate estimate of the asteroid's place in the rotation cycle.

Brightness variance due to changing orbital geometry was also removed by calculating reduced magnitudes with

$$Vr = Vo - 5.0 \log(Rr) \quad (2)$$

where Vr is the reduced magnitude, Vo is the observed magnitude, R is the Sun-asteroid distance, and r is the Earth-asteroid distance, both in AU (Warner 2007). The Lightcurve Ephemeris and H-G Calculator utilities in *MPO Canopus* facilitated this process.

With rotation corrections referenced to mean magnitude, the phase curve indicates absolute magnitude $H = 11.662 \pm 0.014$, and phase slope parameter $G = 0.153 \pm 0.014$. Referenced to maximum light, the phase curve indicates absolute magnitude $H = 11.425 \pm 0.014$, and phase slope parameter $G = 0.230 \pm 0.015$. We note that the larger amplitude corrections referenced to maximum light at higher phase angles tend to reduce the slope of the curve, resulting in the corresponding increase in the G value (Figure 4).

The synodic period and amplitude were previously determined to be 3.4915 h and 0.78 mag (Hamanowa 2009). The Supplemental IRAS Minor Planet Survey (Tedesco *et al.* 2002) indicates the asteroid's absolute magnitude, phase slope parameter, geometric albedo and diameter to be 11.70, 0.15, 0.2401 and 12.40 km, respectively. Existing values for geometric albedo and diameter can be revised on the basis of new values for absolute magnitude and phase slope parameter (Harris and Harris 1997). Using our observed values for H and G referenced to mean magnitude, and the existing values for H, G and diameter from SIMPS, we calculated the geometric albedo and diameter for 1188 Gothlandia to be $p_V = 0.2476 \pm 0.0242$ and $D = 12.424 \pm 0.6$ km.

The observed amplitude near opposition can be used to calculate the equatorial elongation of the asteroid with the relation

$$a/b = 10^{(0.4dm)} \quad (3)$$

where a is the maximum equatorial radius, b is the minimum equatorial radius and dm is the amplitude of variation near minimum phase angle. We estimate dm to be 0.59 mag. Therefore the equatorial elongation is 1.72 using this relation, which must be expressed ≥ 1.72 since we do not know the viewing direction.

Acknowledgements

We wish to thank the folks at the Sierra Stars Observatory near Markleeville, CA for the use of their 0.61-m Classical Cassegrain robotic telescope during this project.

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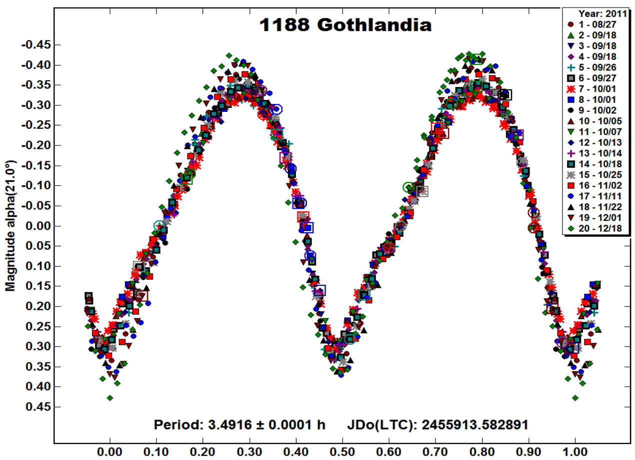

Figure 1. Composite lightcurve Aug - Dec 2011.

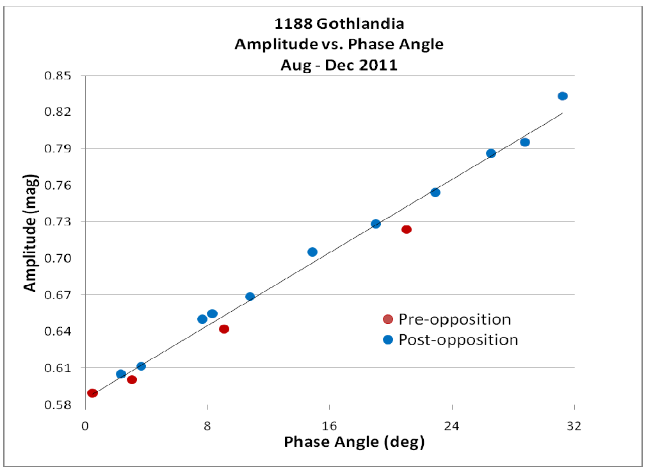

Figure 2. Amplitude from individual full rotation lightcurves recorded throughout the apparition.

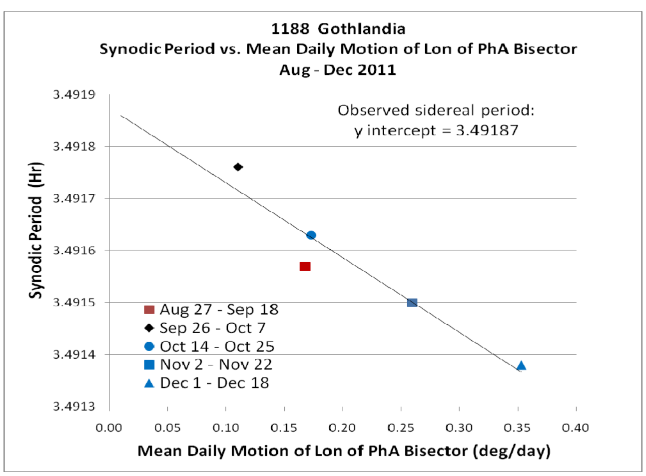

Figure 3. Change in synodic period during interval of observation.

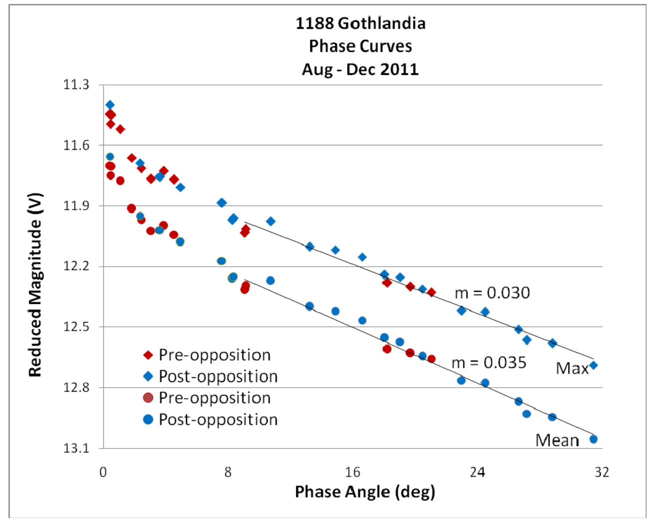

Figure 4. Phase curves referenced to both mean magnitude and maximum light. H-G values were calculated with *MPO Canopus*.

ASTEROID LIGHTCURVES FROM THE PRESTON GOTT OBSERVATORY

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Results of analysis of CCD photometry observations obtained at the Preston Gott Observatory of asteroids 970 Primula, 3015 Candy, 3751 Kiang, 6746 Zagar, 7750 McEwen, 10046 Creighton, and 19251 Totziens are presented.

The Preston Gott Observatory is the main astronomical facility of the Texas Tech University. Located about 20 km north of Lubbock, the main instrument is a 0.5-m f/6.8 Dall-Kirkam Cassegrain. An SBIG STL-1001E CCD was used with this telescope. All images were unfiltered and were reduced with dark frames and sky flats. Several of the asteroids observed on this occasion were asteroids that the author had observed at a previous opposition. Repeat observations was made for use in shape and spin axis modeling. Measurements were also made of any other asteroids that happened to be in the field of view. Other asteroids were chosen from Collaborative Asteroid Lightcurve Link (CALL) website maintained by Warner (2011).

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

#	Name	Date Range (2011)	Sessions	Per (h)	Error (h)	Amp	Error
970	Primula	Aug 19 - Oct 2	6	2.7768	0.0001	0.3	0.02
3015	Candy	Oct 30 - Nov 27	4	4.6249	0.0001	0.85	0.05
3751	Kiang	Jul 20 - Jul 29	7	8.2421	0.0018	0.55	0.05
6746	Zagar	Aug 1 - Aug 9	6	8.136	0.002	0.2	0.05
7750	McEwen	Jul 10 - Aug 22	13	27.8124	0.0012	0.65	0.02
10046	Creighton	Jun 6 - Jul 24	8	6.5698	0.0002	0.65	0.1
19251	Totziens	Jul 6 - Jul 25	7	18.446	0.005	0.1	0.02

970 Primula. Previous observations of this asteroid were made in 2003 December to early 2004 (Maleszewski and Clark 2004). Analysis of those data indicated a period of 2.721 h with an amplitude of 0.3 mag. The lightcurve was asymmetrical with one peak broader than the other. The recent observations basically confirm the period, the new analysis giving *P* = 2.7768 h. The amplitude was found to be the same as was the asymmetric lightcurve.

3015 Candy. Observations of this asteroid were made in 2005 December (Clark 2007). Those observations indicated a period of 4.625 h with an amplitude of 1.05 mag. Analysis of the most recent observations is in exact agreement with the period but show a slightly smaller amplitude of 0.9 mag.

6746 Zagar. Observations of this asteroid indicated a very asymmetrical lightcurve. The derived period was 8.136 h with an amplitude of 0.25 mag. However, one peak was substantially greater than the other. The minima were also unequal.

7750 McEwen. This asteroid also displayed an asymmetric lightcurve. Although the maxima were roughly equal, the minima were quite different. In addition, the widths of the peaks were different. The amplitude was about 0.65 mag and the period was a relatively long 27.8124 h.

Acknowledgments

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

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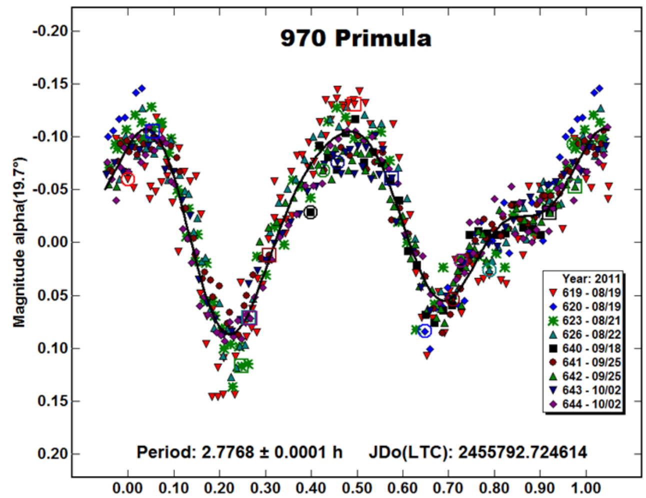

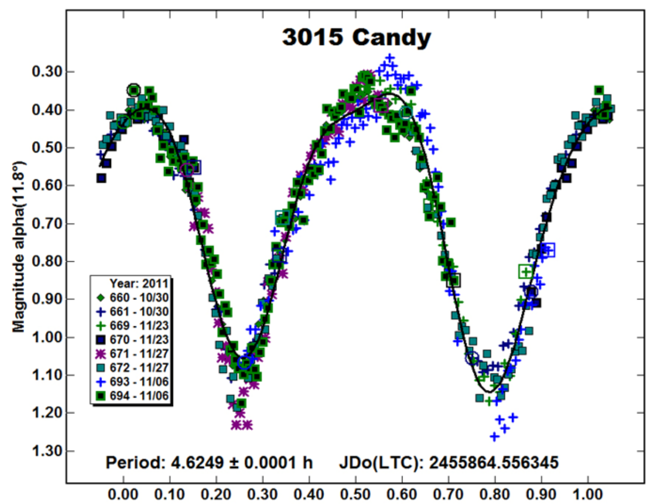

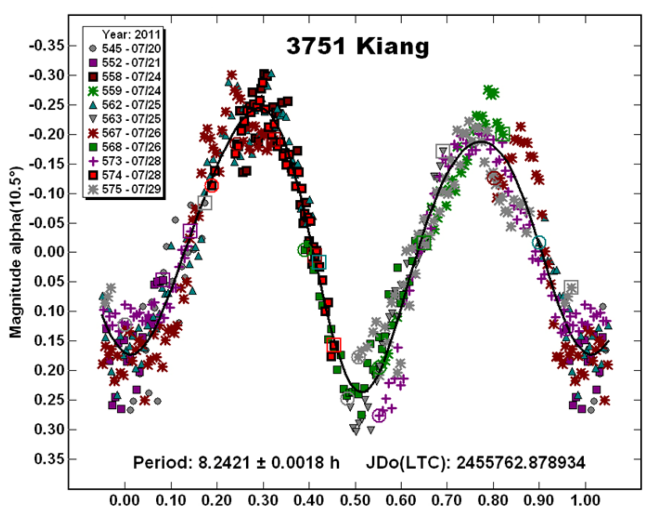

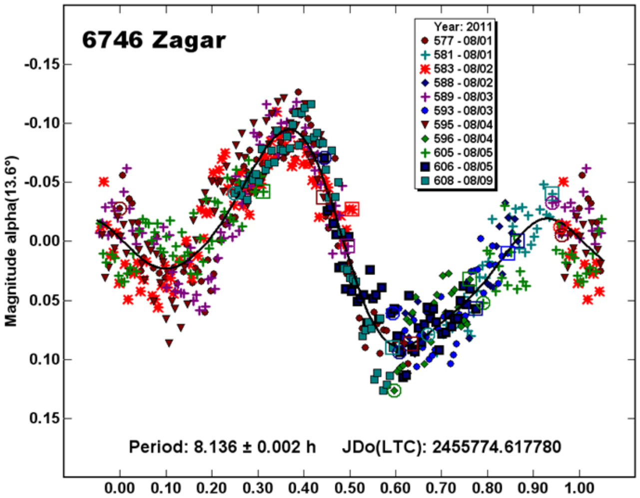

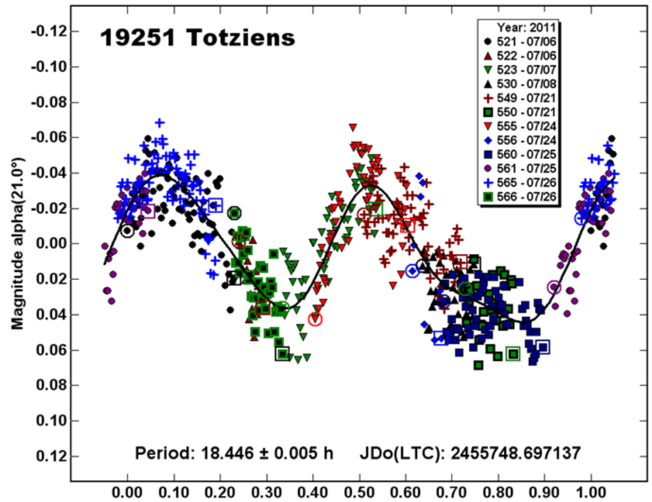

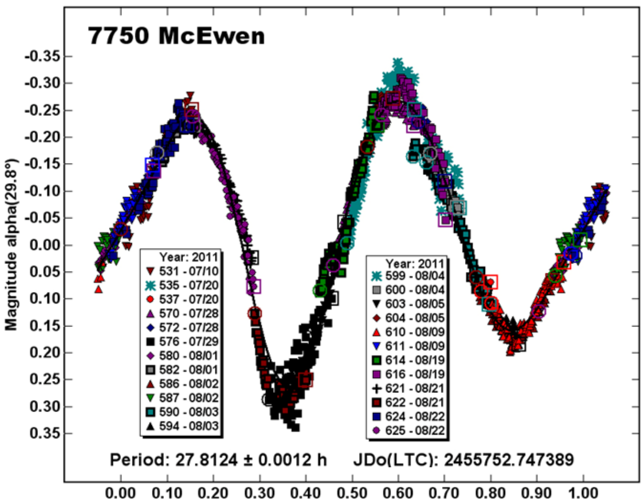

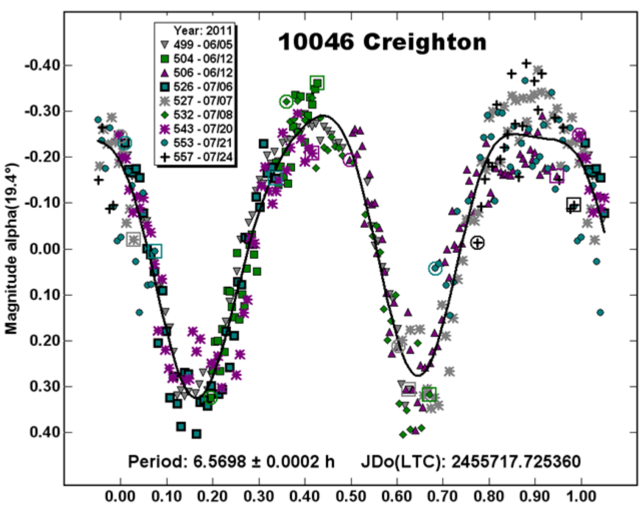

LIGHTCURVE DETERMINATION AT THE BIGMUSKIE OBSERVATORY FROM 2011 JULY- DECEMBER

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Lightcurves for eight asteroids were obtained at the Bigmuskie Observatory, Italy, during 2011 July-December: 613 Ginevra, 987 Wallia, 1718 Namibia, 1771 Makover, 2423 Ibarruri, 7750 McEwen, 6306 Nishimura, and (16959) 1998 QE17.

Thanks to many consecutive clear nights during 2011 July-December, the Bigmuskie Observatory worked to obtain lightcurves for eight asteroids. Because of this unusually long period of clear skies, it was possible to work even long-period asteroids and find secure results on these targets that are usually difficult to solve. The same hardware was used to obtain data for all eight asteroids: a Marcon f/8 0.3m Ritchey-Chretien equipped with an SBIG ST9 CCD camera. This setup provides a field of view of about 15x15 arcminutes and a resolution of 1.7 arcsec per pixel. An Rc filter was used for all the images. Every image was calibrated and measured with *MPO Canopus* v10 (Bdw Publishing) while *CCDsoft* V5 controlled the CCD camera. The Comp Star Selector utility in *MPO Canopus* was used to choose the comparison stars, making it possible to link the individual observing sessions to ±0.05 mag.

613 Ginevra. Two short sessions of about three hours were worked towards the end of 2011 September. When combined with four longer sessions recorded at the end of November, the analysis found a period of 13.024 ± 0.001 h and amplitude of 0.20 mag.

987 Wallia. Without a doubt, this asteroid produced the most complex and interesting lightcurve of all eight asteroids. A period of 10.52 h was reported in the list of potential lightcurve targets for 2011 July-Septemper on the CALL website (*http://www.MinorPlanet.info/call.html*). Period analysis of the

observations from six sessions found a period of 10.082 ± 0.001 h with an amplitude of 0.16 mag.

1718 Namibia. Analysis of the first six nights of observations indicated a period of 7.2 h, even if a less than perfect linkage between sessions near phase 0.60 was evident. After the seventh session, the period changed to 8.61 ± 0.01 h with an amplitude of 0.2 mag and a much better linkage of all seven sessions.

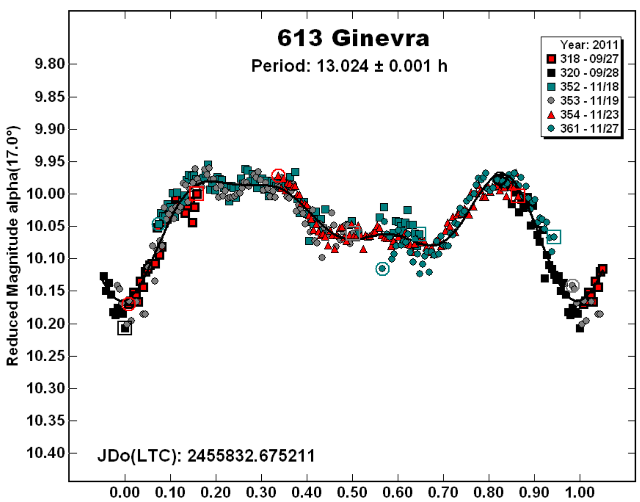
1771 Makover. Using data from four sessions, *MPO Canopus* found a period of 11.26 ± 0.01 h and an amplitude of 0.25 mag.

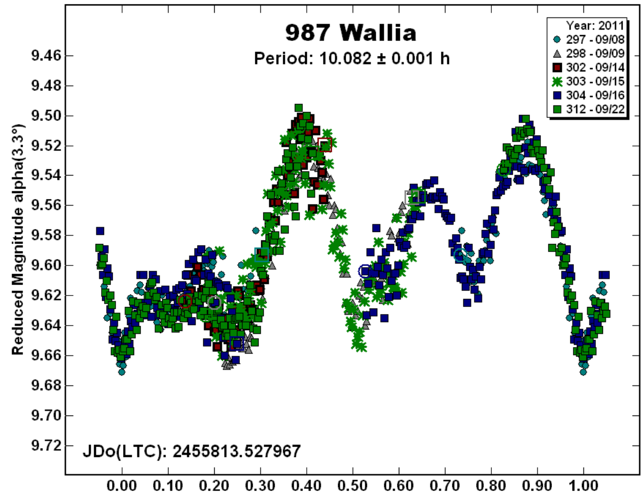
2423 Ibarruri. Data from 20 different sessions from Sep. 28 to Nov 17 were required to find the period 139.92 ± 0.01 h and an amplitude of 0.7 mag. Unfortunately, because of poor weather, the minimum at phase 0.50 was not covered .

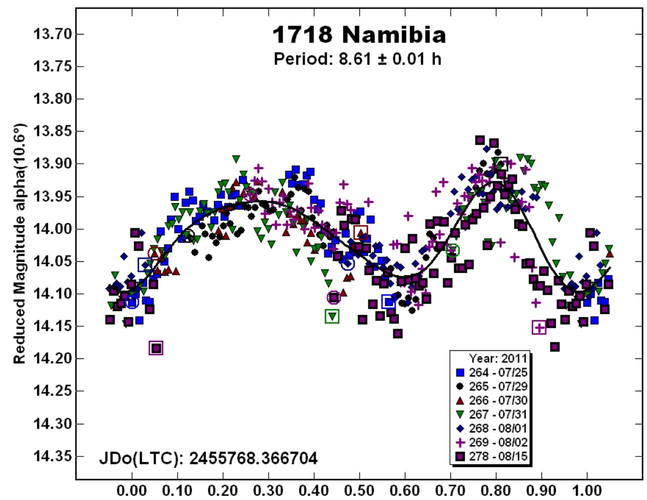
6306 Nishimura. After the first two sessions, analysis found a period around 8.5 h. After the third session, the period increased to 9.7 h and, after the fourth session, settled to 9.705 ± 0.005 h with an amplitude of 0.55 mag.

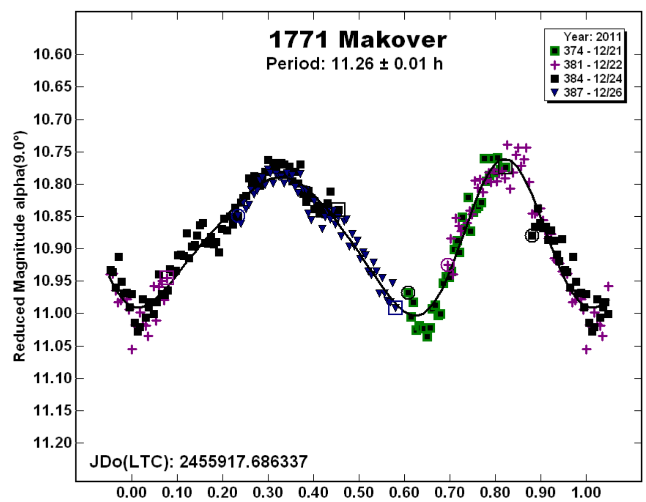
7750 McEwen. Using data from 10 nights, the solution of P = 27.80 ± 0.01 h and A = 0.6 mag appears to be secure, with no alias solutions and very good linkage between the sessions.

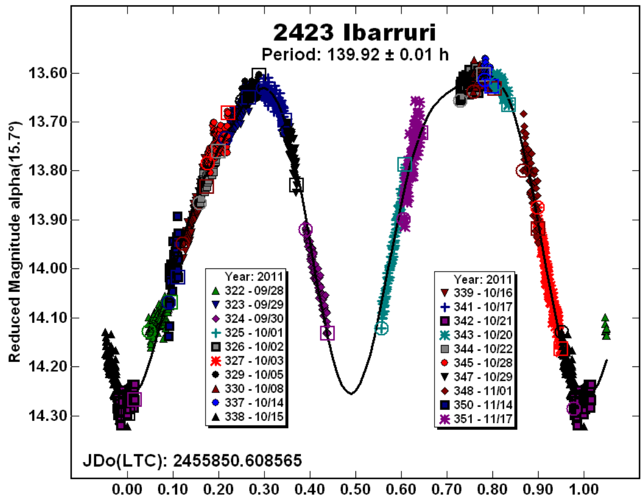
(16959) 1998 QE17. The short period of 3.227 ± 0.001 h with an amplitude of 0.35 mag was evident from the first session of Sept 26. The second sessions recorded on Oct 4 reduced the estimated error of the period.

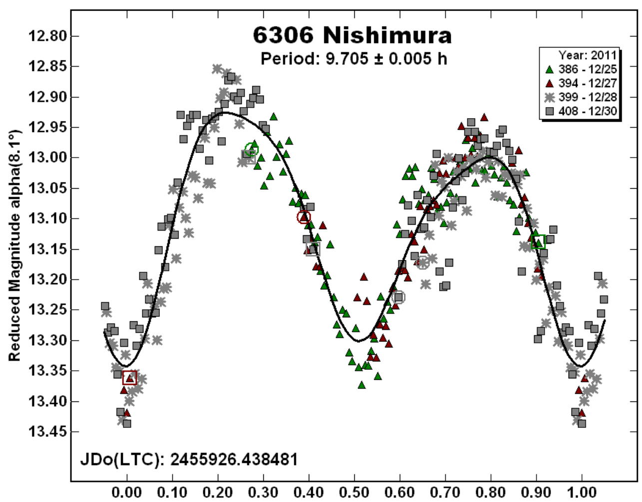


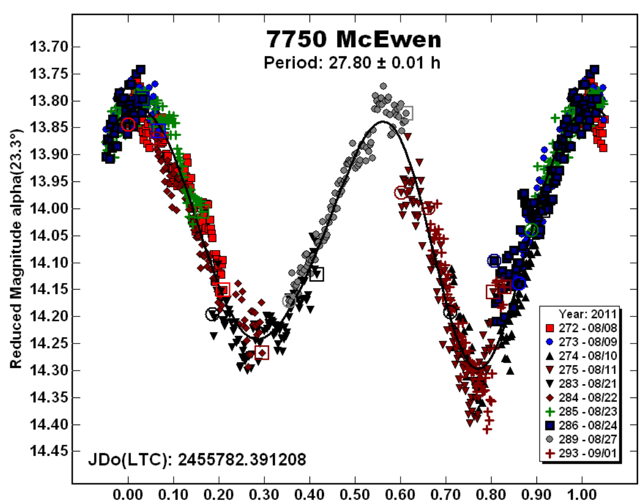


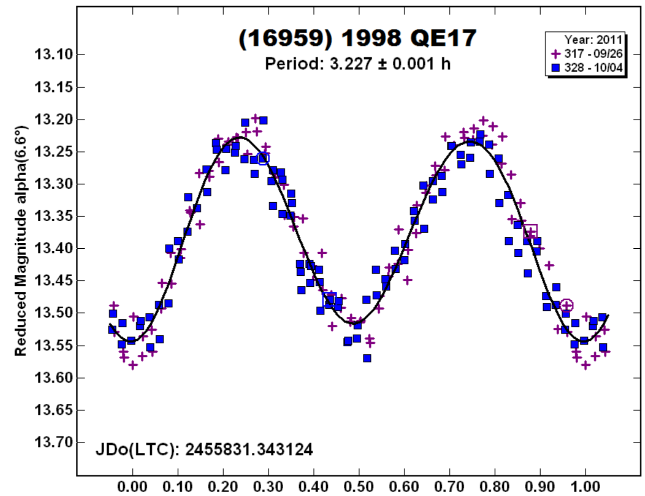












LIGHTCURVE PHOTOMETRY AND H-G PARAMETERS FOR 1077 CAMPANULA

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Photometric observations of main-belt asteroid 1077 Campanula ware made at two observatories over 10 nights from 2011 September-November. Analysis of the resulting data found a synodic period P = 3.85085 ± 0.00005 h with an amplitude AV = 0.24 ± 0.01 mag (corrected to zero phase). The measured absolute magnitude, H = 12.50 ± 0.02 mag, slope parameter G = 0.24 ± 0.03, and color index V-R = 0.40 ± 0.07 mag are consistent with a medium albedo M or S-type object. The diameter is estimated to be D = 9 ± 2 km.

The main-belt asteroid 1077 Campanula was reported as a lightcurve photometry opportunity in the *Minor Planet Bulletin* (Warner *et al.*, 2011). Observations were carried out from Balzaretto Observatory (A81) in Rome, Italy, and Bigmuskie Observatory (B88) in Mombercelli, Asti, Italy, over the period of 2011 September 17 to November 2, or a total span of 46 days and 10 observing nights (Table I). The equipment used for observations is reported in Table II. All images were calibrated with dark and flat-field frames. Measurements of the images were made with *MPO Canopus* (Warner, 2010) using differential photometry.

The V and R magnitudes were calibrated using the method described by Dymock and Miles (2009) and CMC-14 stars with near-solar color indexes selected by using Vizier (2011). The same method was also applied to the clear filter observations after conversion to V magnitudes using previously determined transformation coefficients. The observations in V and R band were acquired in alternating sequence (VRVR...).

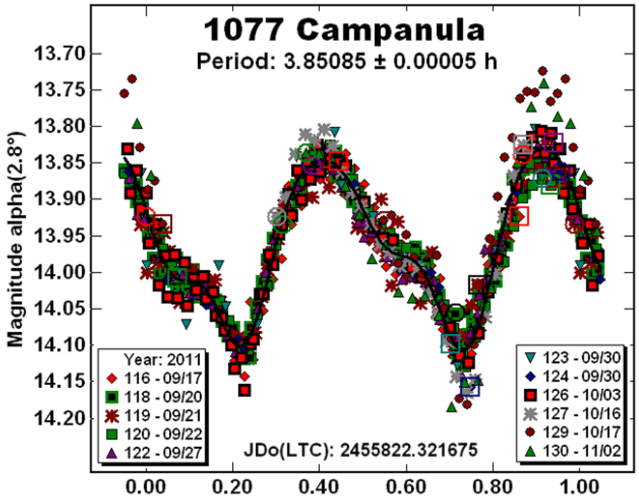

Figure 1. The lightcurve of 1077 Campanula shows a period of 3.85085 ± 0.00005 h with an amplitude of 0.24 ± 0.01 mag at zero phase angle.

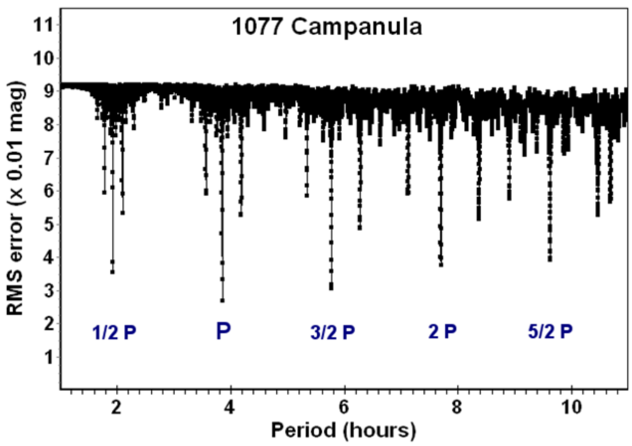

Figure 2. The period spectrum for Campanula shows the main period P and several harmonics.

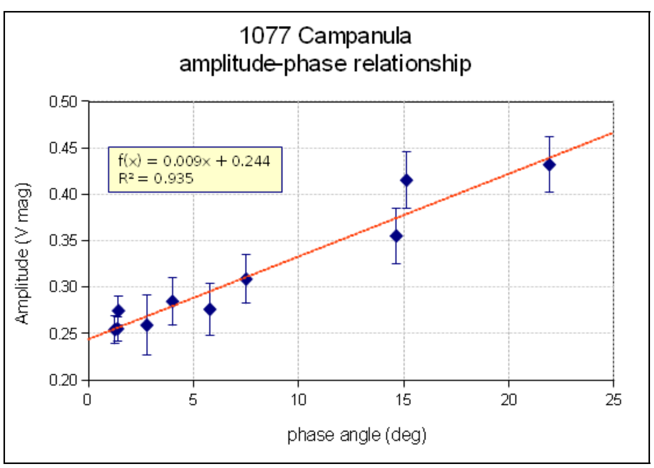

Figure 3. Amplitude-phase relationship

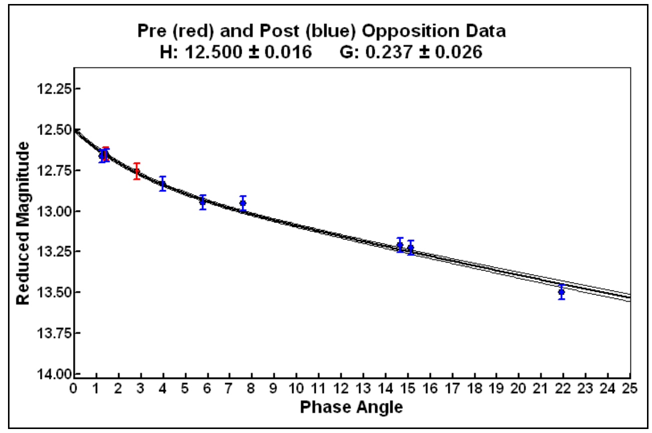

Figure 4. Visual reduced magnitude vs phase angle for estimate H_V = 12.50 ± 0.02 mag and G = 0.24 ± 0.03.

Period analysis was done using *MPO Canopus*, which implements the FALC analysis algorithm developed by Harris *et al.* (1989). Before starting analysis, the sessions were aligned by adjusting zero point values for each session via the CompAdjust form in *MPO Canopus*. Data analysis found a synodic period of *P* = 3.85085 ± 0.00005 h (Fig.1). The period spectrum (Fig. 2) covering a range of 1-11 h shows the main period *P* and several harmonics.

The amplitude of the lightcurve was measured for each session using a polynomial fit in *Peranso* (Vanmunster, 2007). The amplitudes were then plotted versus phase angle (Fig. 3), obtaining a linear-fit slope of s = 0.009 ± 0.001 mag deg^{-1} and intercept $A_V(0°)$ = 0.244 ± 0.008 mag and then m = s/A(0) = 0.037 deg^{-1}. This result agrees with the empirical formula by Zappala *et al.* (1990):

$$A(0°) = A(\alpha)/(1 + m\alpha) \tag{1}$$

where α is the solar phase angle and m is the slope parameter, which is 0.030 deg^{-1} for S-type objects.

The asteroid was observed in V and R band at Balzaretto Observatory on September 30. This allowed us to find the color index of V-R = 0.40 ± 0.07 (mean of 20 values). This value is consistent with a medium albedo M or S-type asteroid (Shevchenko and Lupishko, 1998).

The absolute magnitude (*H*) and slope parameter (*G*) were found using the H-G Calculator function of *MPO Canopus*. For each lightcurve, the V mag was measured as half peak-to-peak amplitude with *Peranso* (polynomial fit). Table III shows the data.

We found H = 12.50 ± 0.02 mag and G = 0.24 ± 0.03, the latter also being compatible with a medium albedo M or S-type asteroid (Shevchenko and Lupishko, 1998). For an S-type asteroid, the geometric albedo is p_V = 0.20 ± 0.07 (Shevchenko and Lupishko, 1998). Using this result and Eq. 2 (Pravec and Harris, 2007), this leads to an estimated diameter D = 9 ± 2 km.

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

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#	Date 2011	Observer	Phase Angle	Data points	Time span (h)	Filter
1	Sept 17	Franco	2.8°	79	7.2	C
2	Sept 20	Ferrero	1.4°	145	7.9	R
3	Sept 21	Ferrero	1.3°	73	3.7	R
4	Sept 22	Franco	1.4°	75	6.2	C
5	Sept 27	Ferrero	4.0°	86	6.0	R
6	Sept 30	Franco	5.8°	42	6.9	V,R
7	Oct 3	Franco	7.6°	73	6.1	C
8	Oct 16	Franco	14.6°	27	2.2	C
9	Oct 17	Ferrero	15.1°	30	2.0	R
10	Nov 2	Franco	21.9°	24	2.7	C

Table I. Observations list

Observer	Country	Telescope	CCD	Filters
Franco	Italy	SCT 0.20-m f/5.5	SBIG ST7-XME	Custom Scientific (Johnson V, Cousins R)
Ferrero	Italy	RC 0.30-m f/8	SBIG ST9	Astrodon Cousins R

Table II. Observers and equipment list

Year/Month/Day	UT	V mag	α(°)
2011 09 17	23:17	13.98	-2.79
2011 09 20	23:44	13.87	-1.39
2011 09 21	21:47	13.88	+1.26
2011 09 22	23:24	13.88	+1.43
2011 09 27	22:57	14.07	+3.99
2011 09 30	22:45	14.20	+5.77
2011 10 03	23:21	14.22	+7.57
2011 10 16	19:07	14.60	+14.63
2011 10 17	19:00	14.63	+15.13
2011 11 02	19:52	15.15	+21.92

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

ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2011 SEPTEMBER - DECEMBER

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Lightcurves for 42 asteroids were obtained at the Palmer Divide Observatory (PDO) from 2011 September to December: 92 Undina, 413 Edburga, 802 Epyaxa, 971 Alsatia, 1987 Kaplan, 3260 Vizbor, 3880 Kaiserman, 4172 Rochefort, 4217 Engelhardt, 4713 Steel, 4898 Nishiizumi, 5384 Changjiangcun, 5426 Sharp, 5427 Jensmartin, 6029 Edithrand, (6382) 1988 EL, 6485 Wendeesther, 6646 Churanta, 7829 Jaroff, (12453) 1996 YY, (16681) 1994 EV7, (20699) 1999 VJ144, (30019) 2000 DD, (32753) 1981 EB14, (46037) 2001 DF33, (57276) 2001 QP139, (59962) 1999 RL234, (63633) 2001 QR84, (71734) 2000 LX9, (84890) 2003 NP9, (96253) 1995 BY1, (105844) 2000 SH160, (106620) 2000 WL124, (114086) 2002 VG36, (114367) 2002 XA89, (134507) 1999 CR142, (138666) 2000 RX96, (178734) 2000 TB2, (203095), (303013) 2003 WC125, and 2000 YA. Two asteroids showed indications of being a binary asteroid. For the Hungaria asteroid 4217 Engelhardt, two, possibly three, potential mutual events (occultations and/or eclipses) were observed. No mutual events were observed for the Phocaea asteroid (46037) 2001 DF33 but a strong secondary period was found in the data with the lightcurve similar to that of a tidally-locked, slightly elongated satellite. New values for absolute magnitude (H) were found for several Hungaria asteroids using either derived or assumed values of G. These H values were compared against those used in the WISE mission to determine diameters and albedos. In all cases where the WISE results featured an unusually high albedo for the asteroid in question, the new value of H resulted in an albedo that was significantly lower and closer to the expected value for type E asteroids, which are likely members of the Hungaria collisional family.

CCD photometric observations of 42 asteroids were made at the Palmer Divide Observatory (PDO) from 2011 September to December. See the introduction in Warner (2010a) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling. The "Reduced Magnitude" in the plots is Cousins R corrected to unity distance by applying –5*log (rΔ) with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using *G* = 0.15 unless otherwise stated.

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

Readers are strongly encouraged to obtain the original references listed in the LCDB for their work and not rely only on the LCDB.

Also for brevity, references will be made to the NEOWISE (WISE for short) mission without giving the references every time. The general description of the data analysis and calibration is in Mainzer *et al.* (2011). The diameters of Hungaria asteroids from WISE referenced in this paper appeared in Masiero *et al.* (2011).

92 Undina. Photometry of this asteroid was done in support of radar observations by Michael Shepard for shape and spin axis modeling. The 2011 observations found a period of 15.89 h, which is in general agreement with past results.

413 Edburga. This asteroid was also observed in support of Shepard's radar observations. Behrend (2006), Warner (2010c), and Hanus *et al.* (2011) previously reported similar results.

802 Epyaxa. The 2011 observations at PDO confirmed earlier results by Warner (2009c) and Behrend (2009).

971 Alsatia. Stephens (2000) reported a period of 6.81 h while Behrend (2005) reported a period of 9.600 h. Observations were made at PDO to try to resolve the ambiguity. The subsequent analysis supports the longer period, finding P = 9.614 h with amplitude A = 0.29 mag.

1987 Kaplan. The author first observed this asteroid in 2000 (Warner, 2001) and found a period of 9.49 h. The images were remeasured a number of years later and the period was changed slightly to 9.46 h (Warner, 2011). The 2011 data found a period of 9.453 h, with amplitude of 0.65 ± 0.03 mag.

3260 Vizbor. Pravec *et al.* (2006) found a period of 64.1 h with an amplitude of A > 0.3 mag. Analysis of the 2011 PDO observations found a period of 72.12 h and amplitude of 0.64 mag. The data

#	Name	mm/dd 2011	Data Pts	α	L_{PAB}	B_{PAB}	Per (h)	PE	Amp (mag)	AE
92	Undina	11/14-11/18	550	5.4,4.2	63	-8	15.89	0.02	0.16	0.01
413	Edburga	11/14-11/18	215	16.,14.4	72	-17	15.78	0.02	0.53	0.02
802	Epyaxa	11/27-11/28	120	5.8	57	6	4.394	0.005	0.44	0.02
971	Alsatia	12/09-12/12	228	20.0,20.8	34	-11	9.614	0.003	0.29	0.02
1987	Kaplan	12/08-12/12	178	25.1,25.6	38	31	9.453	0.002	0.65	0.02
3260	Vizbor	09/24-10/21	441	14.9,2.7	30	5	72.12	0.02	0.64	0.02
3880	Kaiserman (H)	09/24-09/30	253	19.7	3	27	5.270	0.001	0.23	0.02
4172	Rochefort	11/03	74	2.5	44	3	3.68	0.02	0.40	0.02
4217	Engelhardt	12/08-12/19	451	23.9,25.7	39	25	3.0661*	0.0002	0.18	0.02
4713	Steel (H)	12/12-12-17	135	7.8	80	-12	5.193	0.002	0.28	0.02
4898	Nishiizumi (H)	10/19-10/20	165	8.2	30	12	3.291	0.002	0.29	0.01
5384	Changjiangcun (H)	11/24-11/27	178	20.0,20.5	10	1	12.509	0.005	0.68	0.02
5426	Sharp (H)	11/30-12/12	135	10.1,13.1	64	-13	4.56	0.01	0.25	0.02
5427	Jensmartin (H)	11/30-12/10	117	12.3,11.3	78	-18	5.812	0.002	0.64	0.02
6029	Edithrand (H)	12/18-12/26	159	9.9,9.5,10.0	86	-13	14.45	0.03	0.12	0.01
6382	1988 EL (H)	10/23-10/31	208	12.8,13.8	32	19	2.894	0.001	0.06	0.01
6485	Wendeesther (H)	09/28-10/22	424	25.2,29.8	351	25	74.82	0.05	1.00	0.05
6646	Churanta (H)	10/21-10/22	156	16.0	32	21	5.877	0.005	0.77	0.02
7829	Jaroff (H)	11/23-12/07	177	10.0,13.7	58	12	4.400	0.002	0.51	0.02
12453	1996 YY	10/23-10/24	138	5.0	38	12	10.00	0.02	0.33	0.02
16681	1994 EV7 (H)	12/27-12/28	171	22.3	94	33	5.317	0.005	0.81	0.02
20699	1999 VJ144	09/24-09/29	179	5.7,4.3	9	8	2.80	0.01	0.02	0.01
30019	2000 DD (H)	09/24-11/23	526	19.0,7.6,21.2	27	10	5.4741*	0.0004	0.08	0.01
32753	1981 EB14	09/24	44	12.8	30	5	15.	2.	0.60	0.05
34817	2001 SE116 (H)	11/24-11/27	132	23.3,23.6	45	28	6.380	0.005	0.82	0.03
46037	2001 DF33	09/11-09/25	196	19.4,22.8	323	14	2.6865*	0.0002	0.23	0.02
57276	2001 QP139	11/01	72	5.9	38	12	long		>0.1	
59962	1999 RL234	11/27-11/28	96	3.8,4.1	56	6	13.8	0.2	0.38	0.02
63633	2001 QR84	11/14-11/15	101	5.5,6.0	44	5	5.2	0.1	0.18	0.02
71734	2000 LX9 (H)	11/03-11/15	124	16.2,16.1,17.2	37	22	6.27	0.05	0.20	0.02
84890	2003 NP9 (H)	11/01-11/07	173	8.0,8.1	38	11	19.2	0.2	0.07	0.01
96253	1995 BY1	12/14	17	4.2	76	6	3.0	0.3	0.49	0.02
105844	2000 SH160 (H)	11/27-12/15	119	9.1,18.8	51	-5	38.26	0.02	1.45	0.10
106620	2000 WL124 (H)	12/14-12/28	427	5.1,12.7	76	4	104.5	0.5	0.58	0.03
114086	2002 VG36	09/24-09/30	69	15.6,13.0	29	5	22.	2.	0.75	0.10
114367	2002 XA89	11/28	38	8.9	50	-3	4.8	0.1	0.14	0.01
134507	1999 CR142	10/19	68	6.0	28	11	4.23	0.05	0.27	0.02
138666	2000 RX96 (H)	10/23-11/01	156	16.3,16.1,16.3	24	31	8.683	0.002	0.88	0.02
178734	2000 TB2	09/25	16	13.6	30	5	4.6	0.2	0.33	0.05
203095	2000 RO37	10/23-11/01	205	7.4,9.3	28	11	19.61*	0.02	0.31	0.02
303013	2003 WC123	12/14-12/15	46	5.4,5.9	76	5	3.8	0.1	0.21	0.02
	2000 YA	12/24	84	26.7,27.8	81	9	1.56	0.01	0.29	0.02

* (4217) Possible binary; orbital period of 36.03 h.
* (30019) Suspicious deviations that fit P = 33.05 h.
* (46037) Suspected binary with orbital period of 17.03 h.
* (203095) A period of 17.82 h is also possible

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

covered a phase angle range of 3°-15°. Assuming G = 0.15 and V-R = 0.45, a value of H = 12.80 ± 0.03 was found. This is 0.2 mag fainter than in the current MPCORB file and used in the WISE survey. Using the considerations outlined below for the discussion of 4898 Nishiizumi, this new value gives a corrected WISE diameter of 7.603 km and albedo of p_V = 0.2318 ± 0.0174, which is consistent with a type S asteroid.

4217 Engelhardt. The 2011 observations were follow-up to those by the author is 2004 (Warner, 2005a). The two periods from the two data sets are in agreement. On two occasions, what appeared to be a mutual event (occultation or eclipse) was observed. A third, weaker event may have also been captured. Analysis of the data found a main period of 3.0661 ± 0.0002 h with an amplitude of 0.18 ± 0.02 mag. When that period was subtracted, a secondary period – presumably the orbital period of a satellite – was found: P = 36.03 ± 0.01 h. Three plots are included below. The first shows the data without any period subtractions phased to P = 3.0661 h. The other two show the lightcurve when subtracting one of the two periods. The results are far from conclusive, but they are suggestive enough to make this a high-priority target at future apparitions.

4898 Nishiizumi. Analysis of observations in 2007 by the author (Warner, 2007c) found a period of 3.289 h. Analysis of the data from 2011 produced essentially the same period but with a slightly larger amplitude.

The WISE survey found a diameter of 2.178 km for this Hungaria asteroid when using H = 13.9. This produced an unusually high albedo of p_V = 0.994. In this case, observations were available at phase angles of ~8° and ~25° and so a new value of G could be computed and then a new value for H. If sufficient observations are not available to determine G definitively, then one can estimate a reasonable value for G based on either photometric colors converted to taxonomic class (e.g., Dandy *et al.* 2003) or actual taxonomic class. This information can be then be converted to a value for G (see Warner *et al.* 2009a, for a table giving average albedos and G for various taxonomic classes). Sources for color include, among others, the SDSS Moving Object Catalog (SDSS MOC, Ivezic *et al.* 2002) and LCDB (Warner *et al.* 2009a). Taxonomic information can come from Tholen (1984), SMASS II (Bus and Binzel 2001a, 2002b), or extended SMASS (DeMeo *et al.* 2009). It was from these sources that approximate values for G were determined for the other Hungarias discussed in this paper. In particular, a high albedo from WISE was taken to imply a type E asteroid (p_V = 0.46 ± 0.06, G = 0.43 ± 0.08, Warner *et al.* 2009a).

When a new value of H is found for thermally derived diameters and albedos, such as with WISE, one cannot simply use the new value of H and original diameter to find a new albedo. A strict recalculation involves using a detailed model of the object's reflected and thermally emitted flux components, e.g., the Standard Thermal Model (STM). In short, changing the original H used to compute a diameter changes not only the albedo but the original diameter as well. Harris and Harris (1997) developed a simple alternative to the rigorous treatment such that, with a new value of H, the G used to find that H, and the original diameter, a new value for the diameter and p_V can be determined.

Using G = 0.410 determined from the PDO observations of this asteroid found H_R = 14.31. Type E asteroids have an average V-R = 0.410 (Dandy *et al.* 2003), giving H = 14.72. Using the WISE parameters of G = 0.15 and diameter of D = 2.178 km, the new value for H, and applying the Harris and Harris correction (HH from here on) gives D = 2.030 km and p_V = 0.5545, which is within 2-sigma of the average for type E asteroids (Warner *et al.* 2009a) and making these results more in-line with expectations and not nearly as exceptional as the WISE results. Even though probably not justified, these results and others involving corrected diameters and albedos are given to the same precision as the original WISE data.

As a final note, the previously adopted value of H = 13.9 is what would be expected when assuming G = 0.15, the MPCORB default, and using observations exclusively at phase angles >15° (Alan Harris, private communications), thus pointing to the need for data at both low and high phase angles to determine accurate values for H and G, or at least using a better assumed value for G if there are data, e.g., taxonomic type or photometric colors, to support doing so.

5384 Changjiangcun. Previous observations by Warner (2007d) and Behrend (2007) found a period of about 12.51 h. The 2011 PDO data confirm these results. While being in the Hungaria region, where high-albedo type E objects are more likely expected (Warner *et al.* 2009, and references therein), this asteroid has a low albedo (Masiero *et al.* 2011; Usui *et al.* 2011), implying it is more likely a type C (or similar) interloper.

5427 Jensmartin. The results from analysis of the 2011 observations confirm the previously reported periods by Warner (2009a, 2010c). This was another Hungaria with an unexpectedly high albedo from WISE (p_V = 0.777), which assumed H = 13.4. Unfortunately, the phase angle for the asteroid was between 11 and 13 degrees during the entire apparition, so a definitive value for G could not be found. Regardless, using the approach outlined above and using G = 0.43, V-R = 0.41, and D = 3.158 km (from WISE), analysis of the PDO data give H = 14.41. The HH-corrected values are D = 2.953 km and p_V = 0.3487. The new albedo seems more reasonable; it is fairly certain that the H = 13.4 used in the WISE catalog is too bright. The MPCORB file currently gives H = 13.5.

6029 Edithrand. The results of analysis on data obtained in 2011 December are reasonably close to the previously reported period of 14.472 h (Warner, 2007d).

(6382) 1988 EL. This asteroid was previously observed by the author on three occasions (Warner, 2005b, 2007a, 2010b). Analysis of the 2011 data shows the same trend for a very low amplitude, A < 0.1 mag, and a period of P ~ 2.895 h. The range of phase angle coverage was small. However, a check of H derived from using several values of G found values for H similar to that used by WISE, which reported p_V = 0.19. This albedo is more consistent with a type S asteroid, a number of which are found in the Hungaria region (Warner *et al.* 2009b).

(6646) Churanta. The period of 5.877 h is consistent with the one previously found by the author (Warner 2007c). WISE results gave p_V = 1.0 when using H = 14.2. Even when using the default of G = 0.15, the PDO data give H = 14.9 (assuming V-R = 0.41) and HH-corrected values of D = 1.731 km and p_V = 0.646, the latter of which is still higher than expected for type E asteroids (Warner *et al.* 2009a). If G = 0.43 is assumed, then H = 15.2 and D = 1.759 km and p_V = 0.4746, or close to the average albedos for type E asteroids.

7829 Jaroff. The results of period analysis of the 2011 PDO data for this Hungaria member agree with those previously reported by the author (Warner, 2009b). The WISE results were p_V = 0.989 using H = 13.5. Using the PDO data, assuming G = 0.15 gives H = 13.94 and corrected values of D = 2.485 km and p_V = 0.7590.

Assuming $G = 0.43$ gives $H = 14.26$ and $D = 2.525$ km and $p_V = 0.5477$, or about 1.5-sigma above the average E-type albedos.

(16681) 1994 EV7. This Hungaria asteroid was observed by the author (Warner 2007c) in 2007 February. Analysis of that data set found a period of 5.3147 h. Analysis of the 2011 observations yielded a period of 5.317 ± 0.005 h with $A = 0.81$ mag.

(30019) 2000 DD. This Hungaria asteroid was previously observed by the author in 2006 (Warner 2007b), when a period of 6.242 h was reported. Follow-up observations at PDO in 2011 September-November found a different solution, $P = 5.4741$ h. In addition, a weak secondary period of 33.05 h was noted with two suspicious deviations on Oct. 23 and Nov. 3. However, Skiff (2011) observed the asteroid on Oct. 23 as well and his data do not show a similar deviation. His analysis of three nights of data found $P = 5.485 \pm 0.005$ h. A check of the original PDO images from 2011 and remeasuring them did not resolve the discrepancies, which can be considered at best as only as suspicious. Observations at future apparitions are strongly encouraged. A review of the original 2006 data found that they can be fit to a period of $P = 5.484$ h, in somewhat reasonable agreement with the more recent findings. For the sake of completeness, plots showing the 2006 data phased to the 5.484 h period as well as the result of subtracting out that period are included below along with plots of the 2011 data without any subtraction and then with one of the two periods subtracted.

(34817) 2001 SE116. Previous period analysis by the author (Warner 2007b, 2011) also found the same $P = 6.38$ h result.

(46037) 2001 DF33. Analysis of the data obtained for this outer main-belt asteroid shows a period of 2.6865 h as well as a second period of 17.03 h with $A \sim 0.1$ mag. The plots below show the lightcurve without subtracting the secondary period as well as the when each of the two periods are subtracted. The appearance of the longer period lightcurve is similar to that produced by a tidally-locked, slightly-elongated satellite. If so, the then orbital period of the object is also 17.03 h. Since there were no mutual events observed (occultations or eclipse), this should be considered a possible, maybe even probable, binary object but not a confirmed one.

(57276) 2001 QP139. This outer main-belt asteroid was in the same field as a planned target for a single night. Such “targets of opportunity” are measured whenever possible. Many times the data cover enough of a cycle to provide a reasonable estimate of the period and amplitude. In this case, however, the data show a steady trend upward and so only a limiting amplitude can be given.

(59962) 1999 RL234. This was another target of opportunity but, in this case, a follow-up night was possible and so a period solution, albeit a weak one, was possible.

(84890) 2003 NP9. The period solution of 19.2 h presented in the plot is weak due the low amplitude and not being able to follow the asteroid for a longer period of time. Several other periods are possible, including the double period of ~38.5 h, assuming a bimodal lightcurve. Given the amplitude and relatively low phase angle, a bimodal solution is not a certainty.

(96253) 1995 BY1; (114086) 2002 VG36; (114367) 2002 XA89; (134507) 1999 CR142; (303013) 2003 WC125. These were targets of opportunity.

(138666) 2000 RX96. This Hungaria asteroid was previously observed by the author in 2007 (Warner, 2007c). The periods reported then and now are in agreement. The WISE survey found an albedo of $p_V = 0.758$ using $H = 14.8$ and $G = 0.15$. Using the PDO data, assuming V-R = 0.41 and $G = 0.15$, then $H = 15.72$ and corrected values of $D = 1.525$ km and $p_V = 0.3913$; if $G = 0.43$ is assumed, then $H = 15.97$ and the corrected values are $D = 1.546$ km and $p_V = 0.3023$. Regardless of which solution set is adopted, the main point is that the value for H is significantly less (fainter) than the $H = 14.8$ used in the WISE analysis and the current value of $H = 15.0$ in the MPCORB file.

2000 YA. This near-Earth asteroid (NEA) had a close approach to Earth (~0.007 AU, or ~1M km) in late 2011 December. The only previously known photometry was in 2000 by Pravec *et al.* (2000), who reported a period of either 0.66 or 1.33 h. Analysis of radar observations (Benner *et al.* 2000) adopted a period of < 1.33 h, probably ~ 0.67 h. The PDO data indicate $P = 1.56$ h with $A = 0.29$ mag for a bimodal solution or $P = 0.78$ h, $A = 0.26$ mag for a monomodal solution. Pravec (private communications) could not fit the data from one apparition to the period found using the data from the other apparition. It’s hoped that the analysis of the radar observations from the 2011 apparition will resolve the ambiguities.

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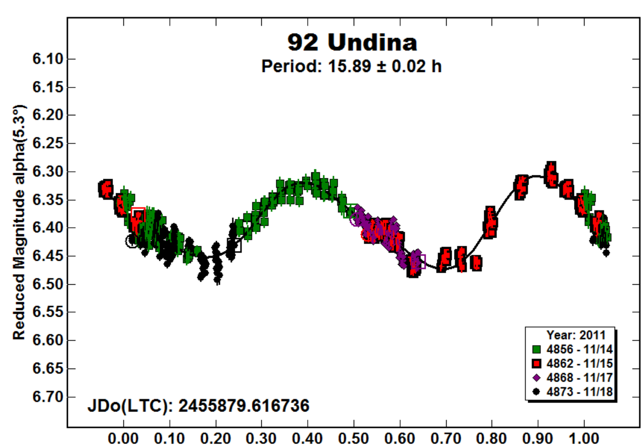
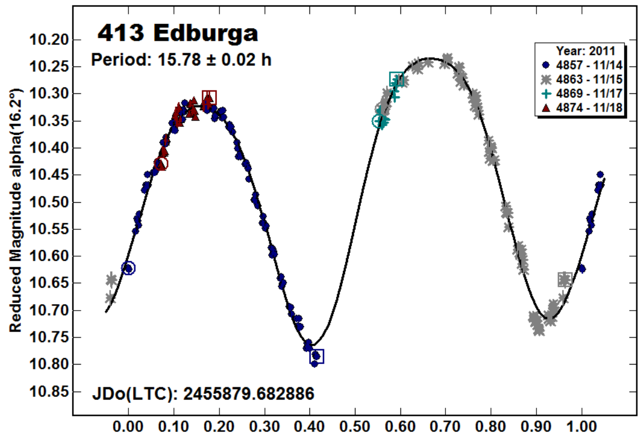
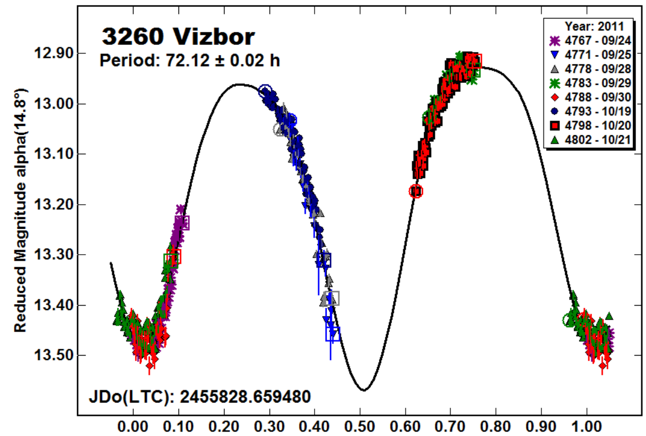
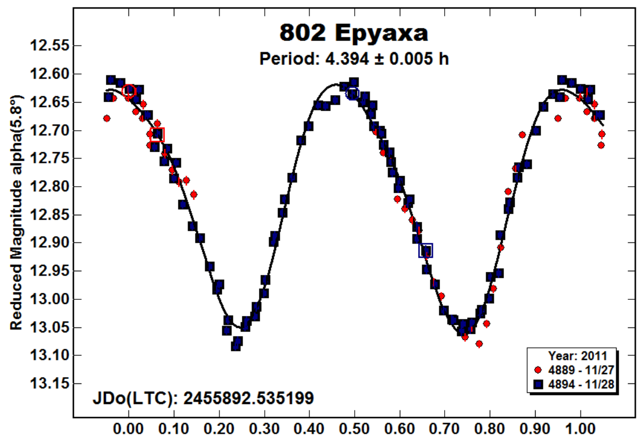
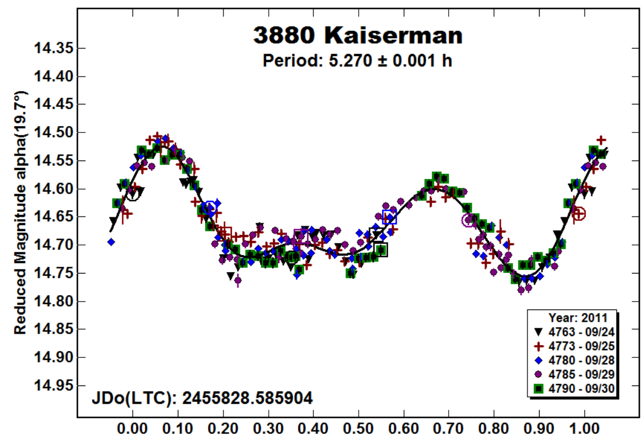
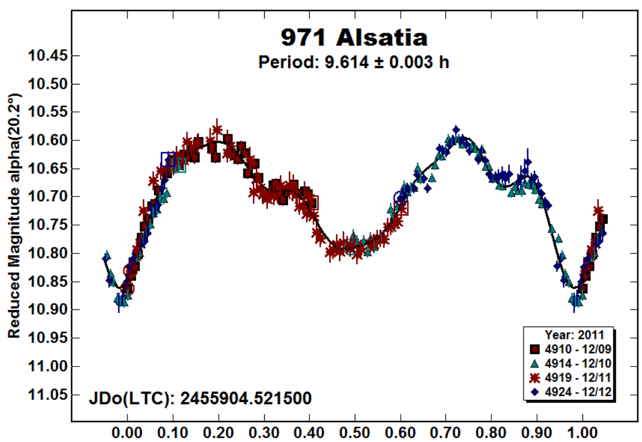


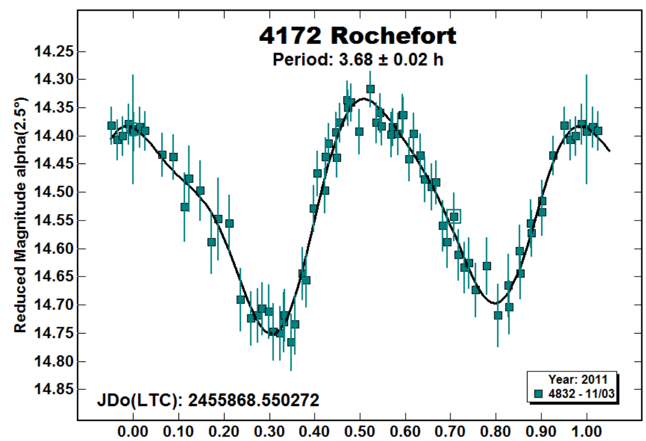

413 Edburga
Period: 15.78 ± 0.02 h
Year: 2011
4857 - 11/14
4863 - 11/15
4869 - 11/17
4874 - 11/18
Reduced Magnitude alpha(16.2°)
JDo(LTC): 2455879.682886

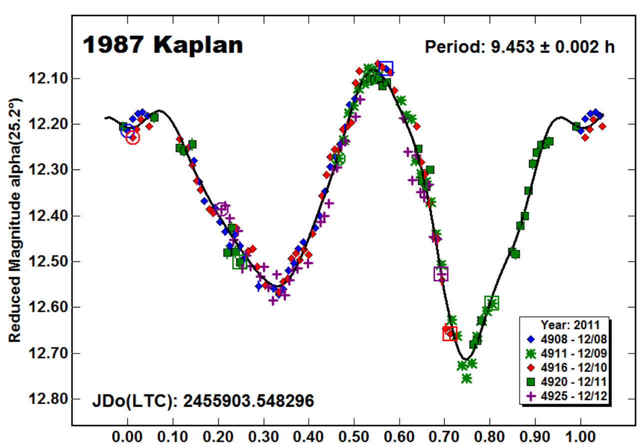

3260 Vizbor
Period: 72.12 ± 0.02 h
Year: 2011
4767 - 09/24
4771 - 09/25
4778 - 09/28
4783 - 09/29
4788 - 09/30
4793 - 10/19
4798 - 10/20
4802 - 10/21
Reduced Magnitude alpha(14.8°)
JDo(LTC): 2455828.659480

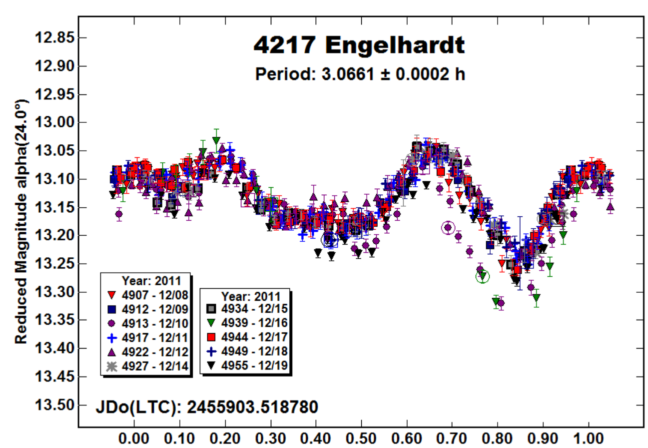

802 Epyaxa
Period: 4.394 ± 0.005 h
Year: 2011
4889 - 11/27
4894 - 11/28
Reduced Magnitude alpha(5.8°)
JDo(LTC): 2455892.535199

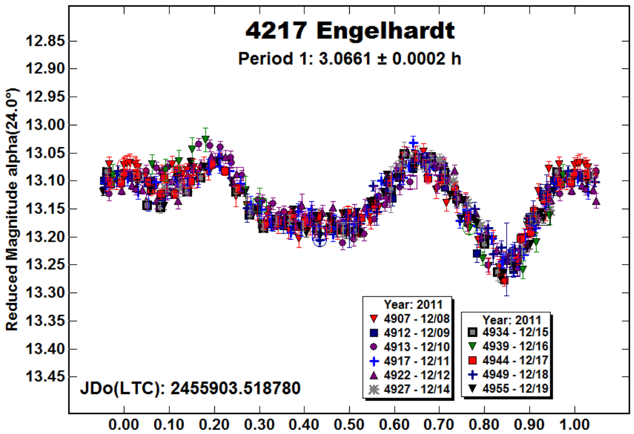

3880 Kaiserman
Period: 5.270 ± 0.001 h
Year: 2011
4763 - 09/24
4773 - 09/25
4780 - 09/28
4785 - 09/29
4790 - 09/30
Reduced Magnitude alpha(19.7°)
JDo(LTC): 2455828.585904

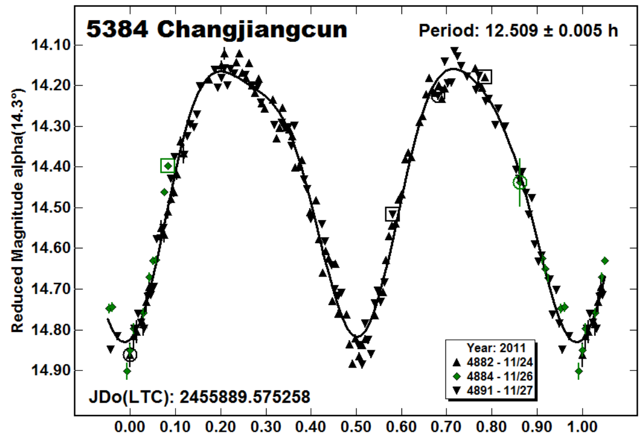

971 Alsatia
Period: 9.614 ± 0.003 h
Year: 2011
4910 - 12/09
4914 - 12/10
4919 - 12/11
4924 - 12/12
Reduced Magnitude alpha(20.2°)
JDo(LTC): 2455904.521500


4172 Rochefort
Period: 3.68 ± 0.02 h
Year: 2011
4832 - 11/03
Reduced Magnitude alpha(2.5°)
JDo(LTC): 2455868.550272


1987 Kaplan
Period: 9.453 ± 0.002 h
Year: 2011
4908 - 12/08
4911 - 12/09
4916 - 12/10
4920 - 12/11
4925 - 12/12
Reduced Magnitude alpha(25.2°)
JDo(LTC): 2455903.548296


4217 Engelhardt
Period: 3.0661 ± 0.0002 h
Year: 2011
4907 - 12/08
4912 - 12/09
4913 - 12/10
4917 - 12/11
4922 - 12/12
4927 - 12/14
Year: 2011
4934 - 12/15
4939 - 12/16
4944 - 12/17
4949 - 12/18
4955 - 12/19
Reduced Magnitude alpha(24.0°)
JDo(LTC): 2455903.518780


4217 Engelhardt
Period 1: 3.0661 ± 0.0002 h
Reduced Magnitude alpha(24.0°)
JDo(LTC): 2455903.518780
Year: 2011
4907 - 12/08
4912 - 12/09
4913 - 12/10
4917 - 12/11
4922 - 12/12
4927 - 12/14
Year: 2011
4934 - 12/15
4939 - 12/16
4944 - 12/17
4949 - 12/18
4955 - 12/19


5384 Changjiangcun
Period: 12.509 ± 0.005 h
Reduced Magnitude alpha(14.3°)
JDo(LTC): 2455889.575258
Year: 2011
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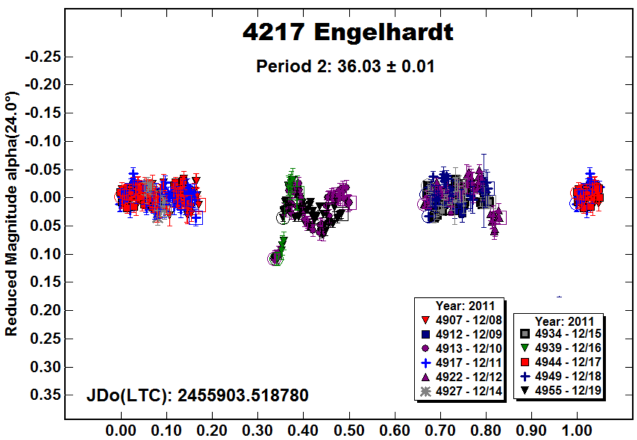
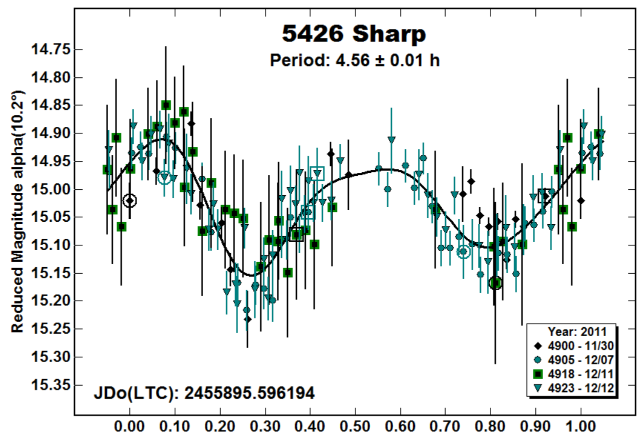
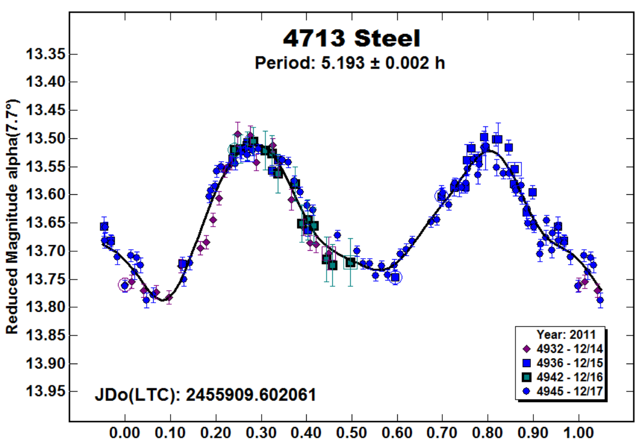
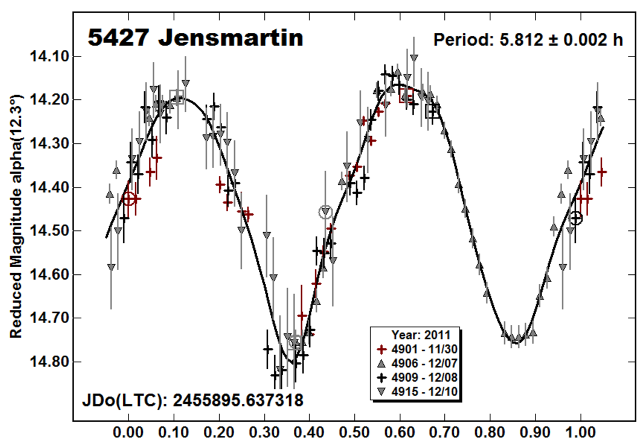
4884 - 11/26
4891 - 11/27


4217 Engelhardt
Period 2: 36.03 ± 0.01
Reduced Magnitude alpha(24.0°)
JDo(LTC): 2455903.518780
Year: 2011
4907 - 12/08
4912 - 12/09
4913 - 12/10
4917 - 12/11
4922 - 12/12
4927 - 12/14
Year: 2011
4934 - 12/15
4939 - 12/16
4944 - 12/17
4949 - 12/18
4955 - 12/19


5426 Sharp
Period: 4.56 ± 0.01 h
Reduced Magnitude alpha(10.2°)
JDo(LTC): 2455895.596194
Year: 2011
4900 - 11/30
4905 - 12/07
4918 - 12/11
4923 - 12/12


4713 Steel
Period: 5.193 ± 0.002 h
Reduced Magnitude alpha(7.7°)
JDo(LTC): 2455909.602061
Year: 2011
4932 - 12/14
4936 - 12/15
4942 - 12/16
4945 - 12/17


5427 Jensmartin
Period: 5.812 ± 0.002 h
Reduced Magnitude alpha(12.3°)
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Year: 2011
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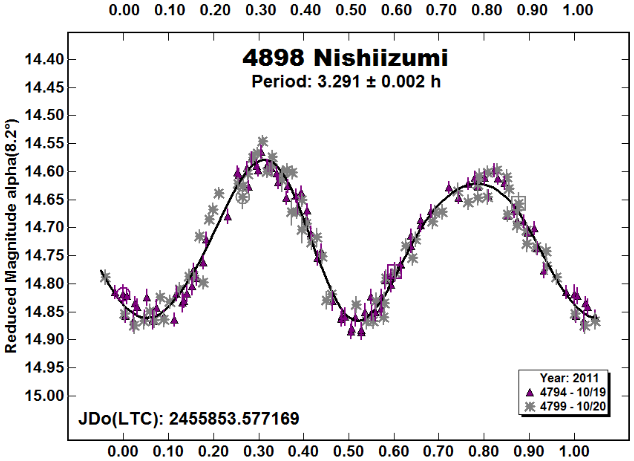
4906 - 12/07
4909 - 12/08
4915 - 12/10


4898 Nishiizumi
Period: 3.291 ± 0.002 h
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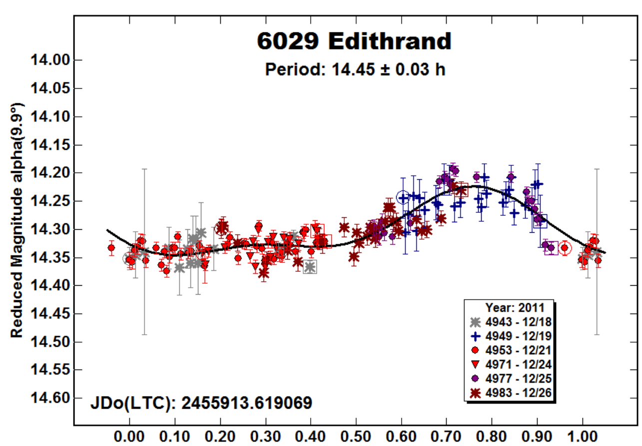
Year: 2011
4794 - 10/19
4799 - 10/20


6029 Edithrand
Period: 14.45 ± 0.03 h
Reduced Magnitude alpha(9.9°)
JDo(LTC): 2455913.619069
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4953 - 12/21
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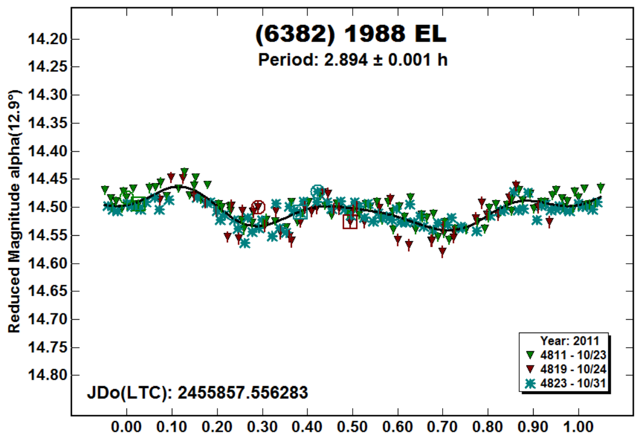
4983 - 12/26


(6382) 1988 EL
Period: 2.894 ± 0.001 h
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Year: 2011
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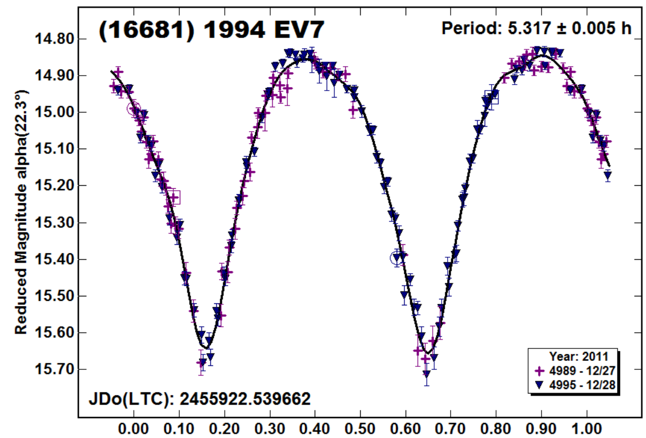
JDo(LTC): 2455857.556283


(16681) 1994 EV7
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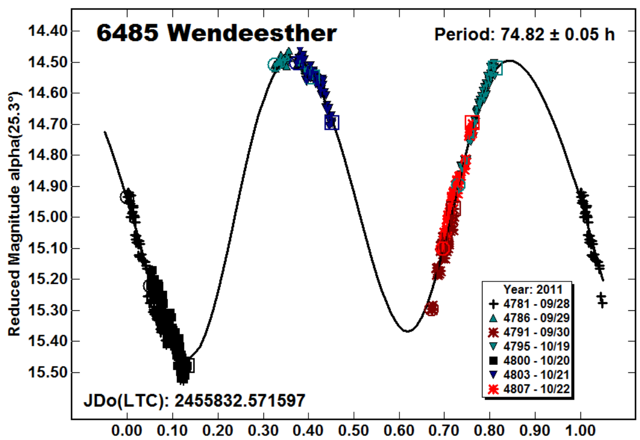
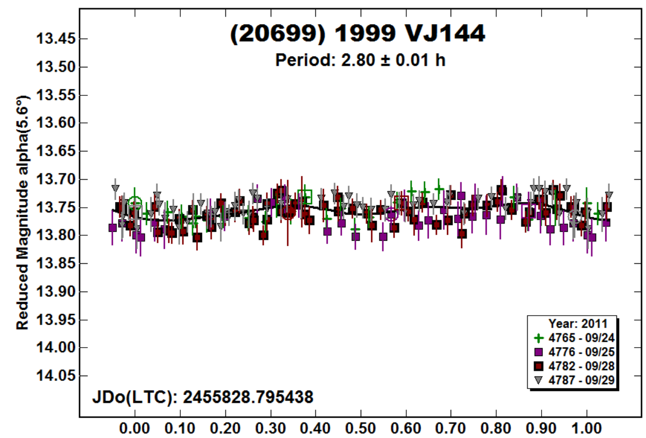

6485 Wendeesther
Period: 74.82 ± 0.05 h
Reduced Magnitude alpha(25.3°)
Year: 2011
4781 - 09/28
4786 - 09/29
4791 - 09/30
4795 - 10/19
4800 - 10/20
4803 - 10/21
4807 - 10/22
JDo(LTC): 2455832.571597


(20699) 1999 VJ144
Period: 2.80 ± 0.01 h
Reduced Magnitude alpha(5.6°)
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4776 - 09/25
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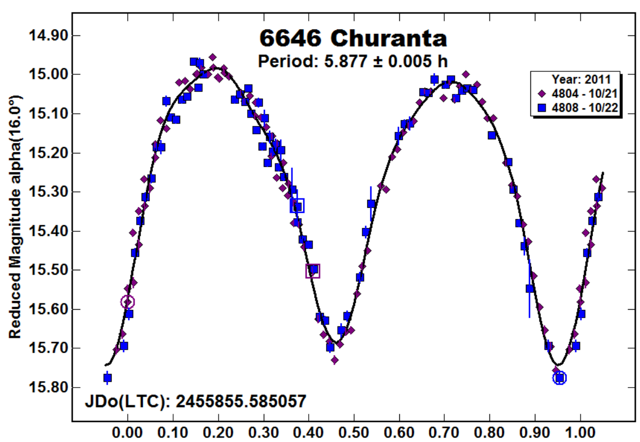
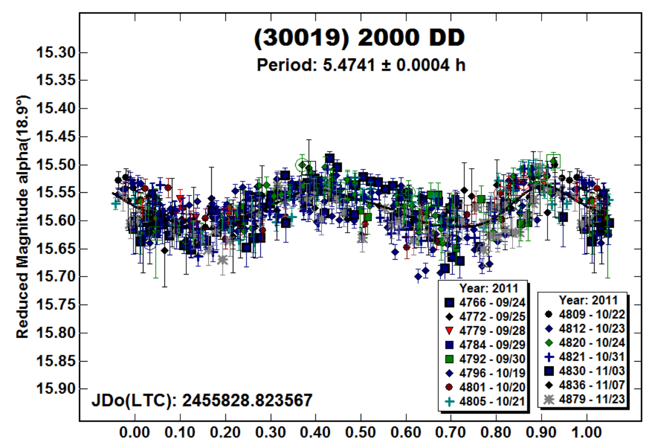
4787 - 09/29
JDo(LTC): 2455828.795438


6646 Churanta
Period: 5.877 ± 0.005 h
Reduced Magnitude alpha(16.0°)
Year: 2011
4804 - 10/21
4808 - 10/22
JDo(LTC): 2455855.585057


(30019) 2000 DD
Period: 5.4741 ± 0.0004 h
Reduced Magnitude alpha(18.9°)
Year: 2011
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4772 - 09/25
4779 - 09/28
4784 - 09/29
4792 - 09/30
4796 - 10/19
4801 - 10/20
4805 - 10/21
Year: 2011
4809 - 10/22
4812 - 10/23
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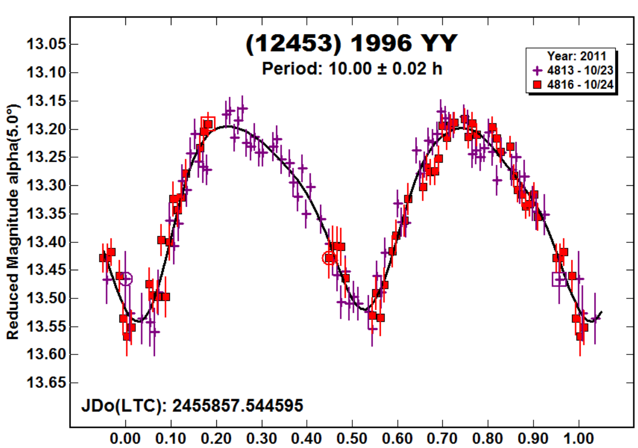
4821 - 10/31
4830 - 11/03
4836 - 11/07
4879 - 11/23
JDo(LTC): 2455828.823567


(12453) 1996 YY
Period: 10.00 ± 0.02 h
Reduced Magnitude alpha(5.0°)
Year: 2011
4813 - 10/23
4816 - 10/24
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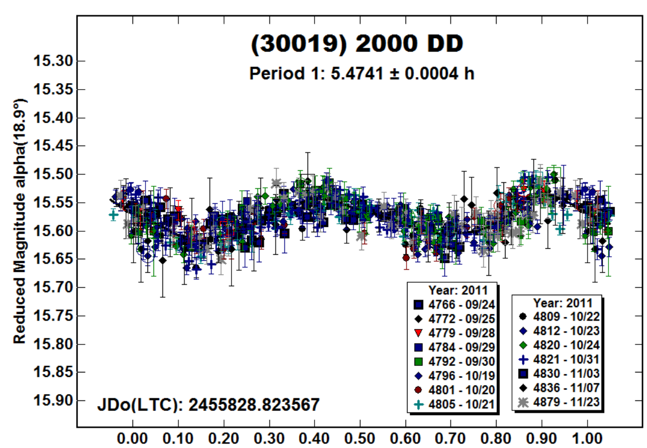
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Period 1: 5.4741 ± 0.0004 h
Reduced Magnitude alpha(18.9°)
Year: 2011
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4772 - 09/25
4779 - 09/28
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4792 - 09/30
4796 - 10/19
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4805 - 10/21
Year: 2011
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4830 - 11/03
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4879 - 11/23
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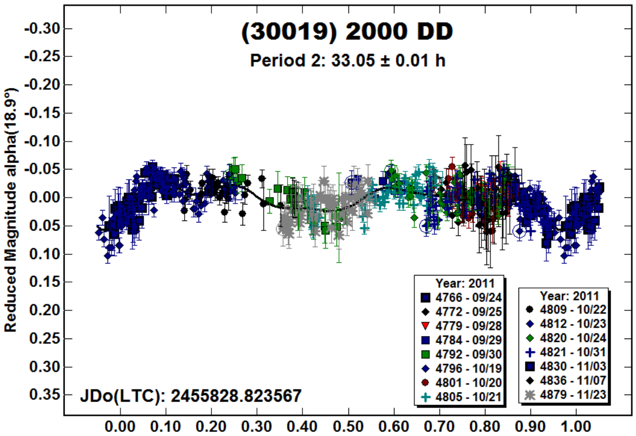
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Period 2: 33.05 ± 0.01 h
Reduced Magnitude alpha(18.9°)
Year: 2011
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4792 - 09/30
4796 - 10/19
4801 - 10/20
4805 - 10/21
Year: 2011
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4879 - 11/23
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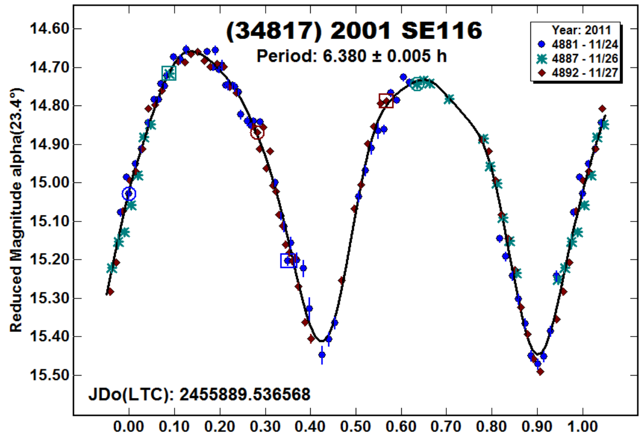
(34817) 2001 SE116
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Year: 2011
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4887 - 11/26
4892 - 11/27
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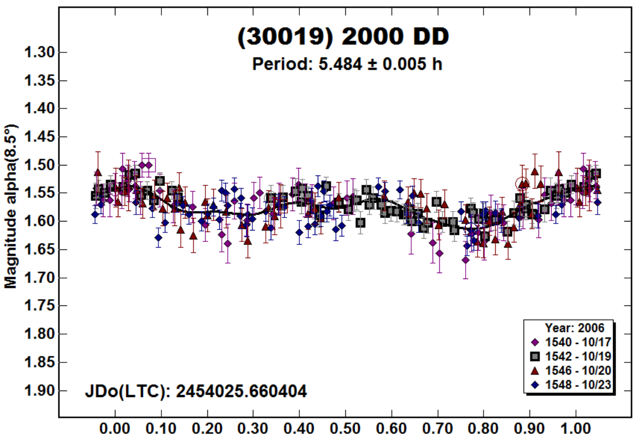
(30019) 2000 DD
Period: 5.484 ± 0.005 h
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Year: 2006
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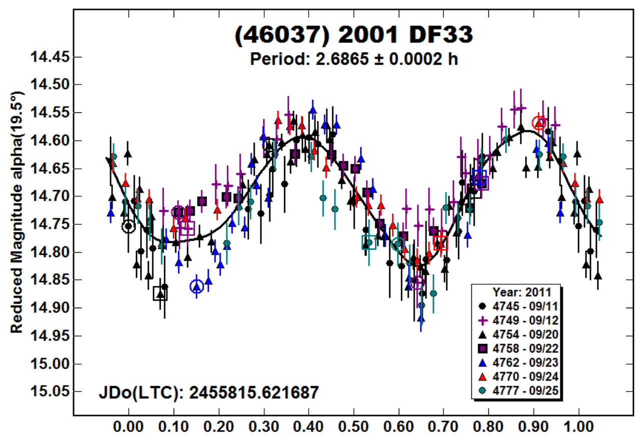
(46037) 2001 DF33
Period: 2.6865 ± 0.0002 h
Reduced Magnitude alpha(19.5°)
Year: 2011
4745 - 09/11
4749 - 09/12
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4758 - 09/22
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4770 - 09/24
4777 - 09/25
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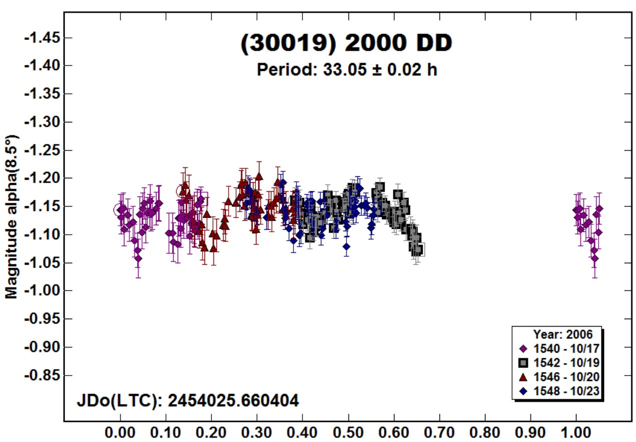
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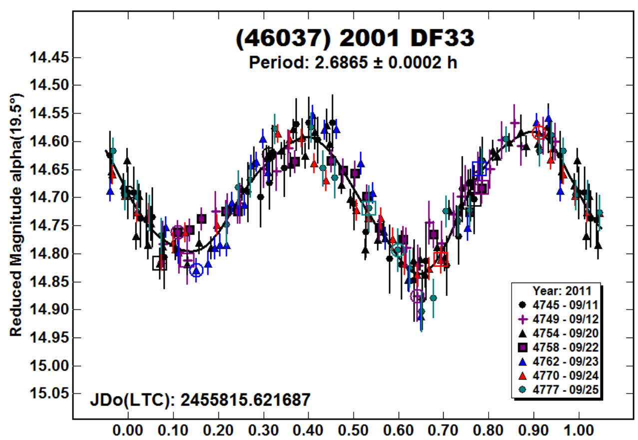
(46037) 2001 DF33
Period: 2.6865 ± 0.0002 h
Reduced Magnitude alpha(19.5°)
Year: 2011
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4758 - 09/22
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4770 - 09/24
4777 - 09/25
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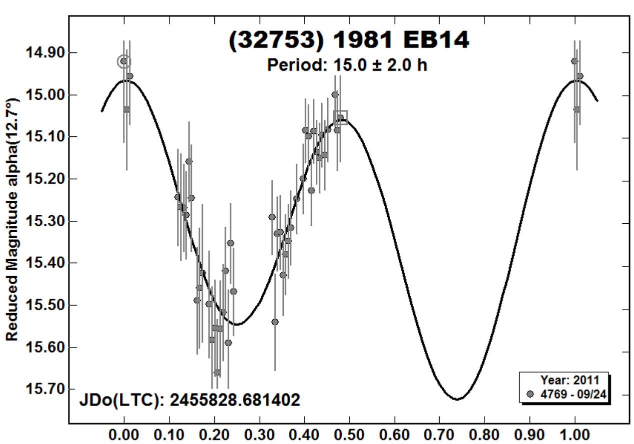
(32753) 1981 EB14
Period: 15.0 ± 2.0 h
Reduced Magnitude alpha(12.7°)
Year: 2011
4769 - 09/24
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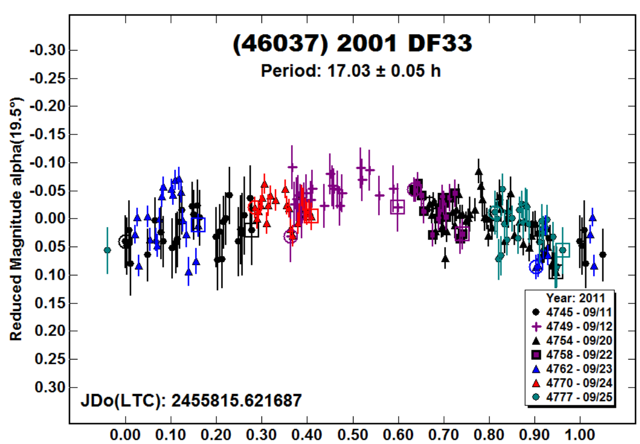
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Year: 2011
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4777 - 09/25
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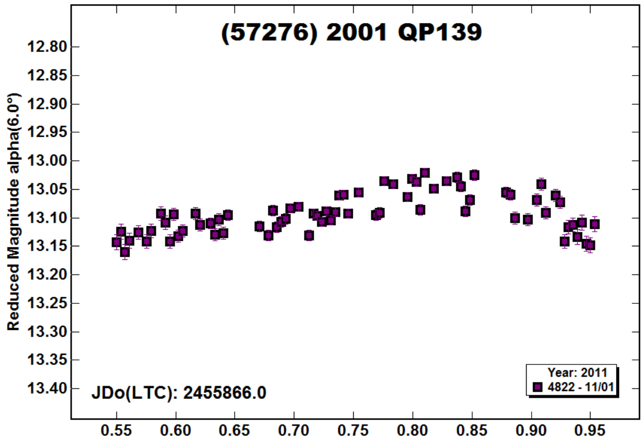
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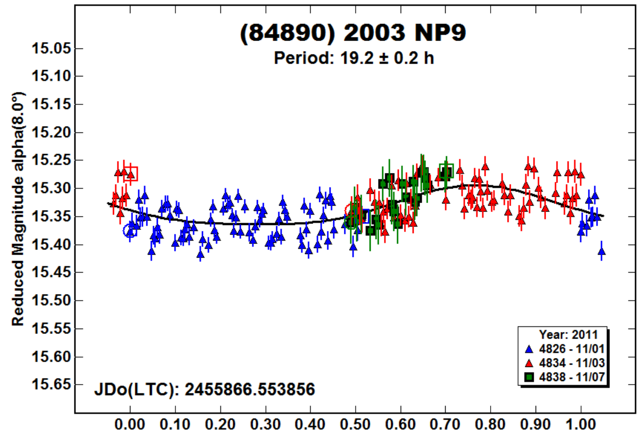
(84890) 2003 NP9
Period: 19.2 ± 0.2 h
Reduced Magnitude alpha(8.0°)
Year: 2011
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4834 - 11/03
4838 - 11/07
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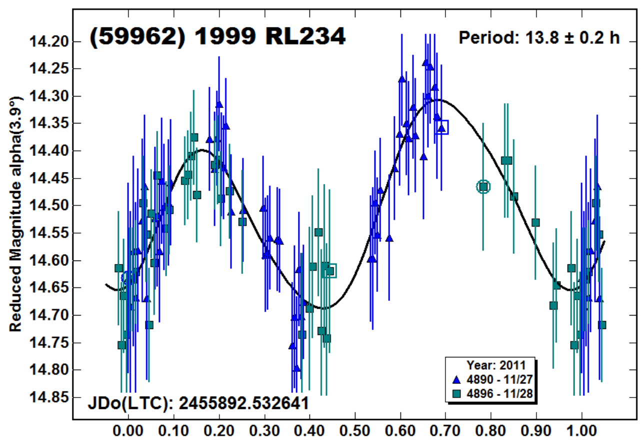
(59962) 1999 RL234
Period: 13.8 ± 0.2 h
Reduced Magnitude alpha(3.9°)
Year: 2011
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4896 - 11/28
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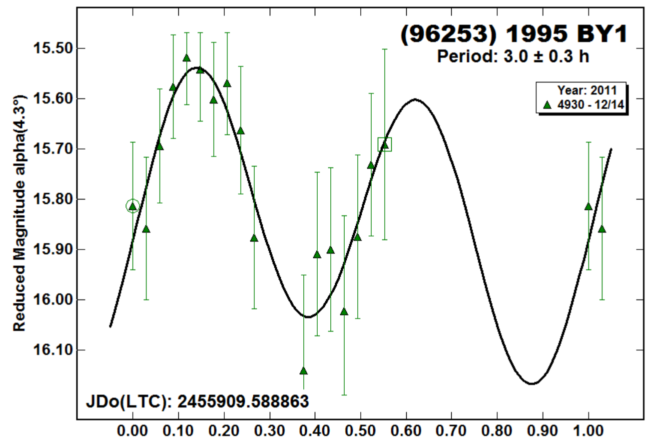
(96253) 1995 BY1
Period: 3.0 ± 0.3 h
Reduced Magnitude alpha(4.3°)
Year: 2011
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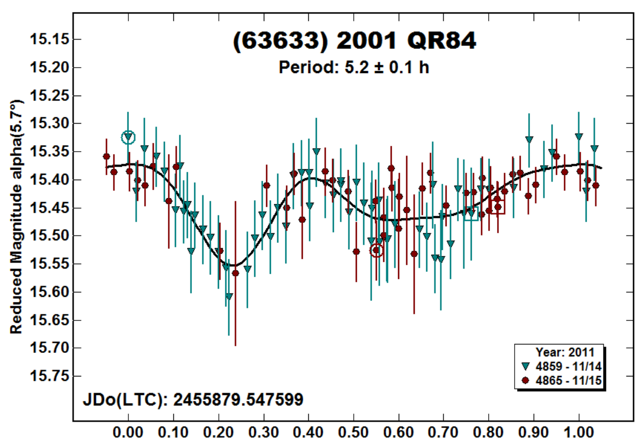
JDo(LTC): 2455909.588863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Year: 2011
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4865 - 11/15
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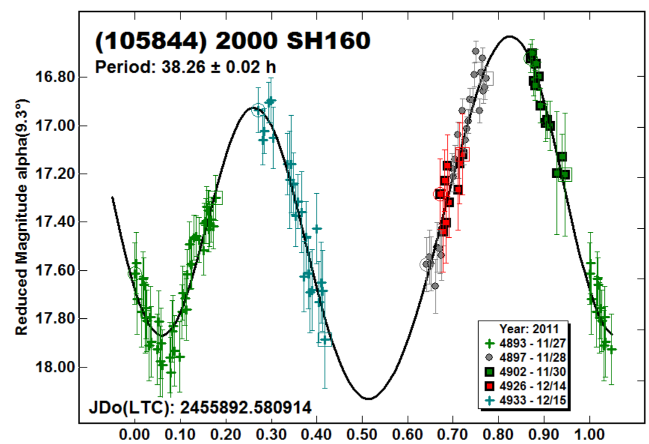
(105844) 2000 SH160
Period: 38.26 ± 0.02 h
Reduced Magnitude alpha(9.3°)
Year: 2011
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4897 - 11/28
4902 - 11/30
4926 - 12/14
4933 - 12/15
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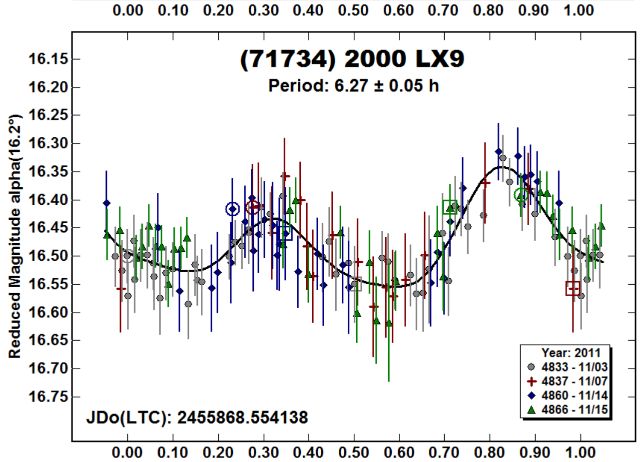
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Period: 6.27 ± 0.05 h
Reduced Magnitude alpha(16.2°)
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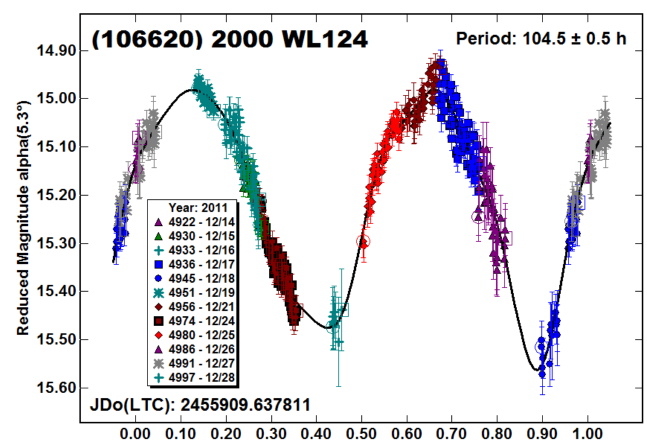
(106620) 2000 WL124
Period: 104.5 ± 0.5 h
Reduced Magnitude alpha(5.3°)
Year: 2011
4922 - 12/14
4930 - 12/15
4933 - 12/16
4936 - 12/17
4945 - 12/18
4951 - 12/19
4956 - 12/21
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4980 - 12/25
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4991 - 12/27
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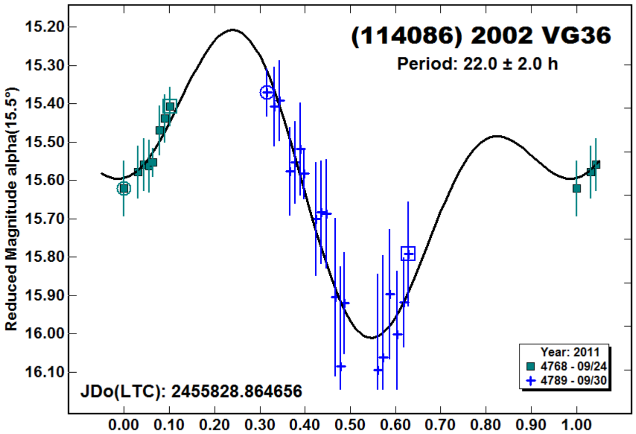
(114086) 2002 VG36
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4789 - 09/30
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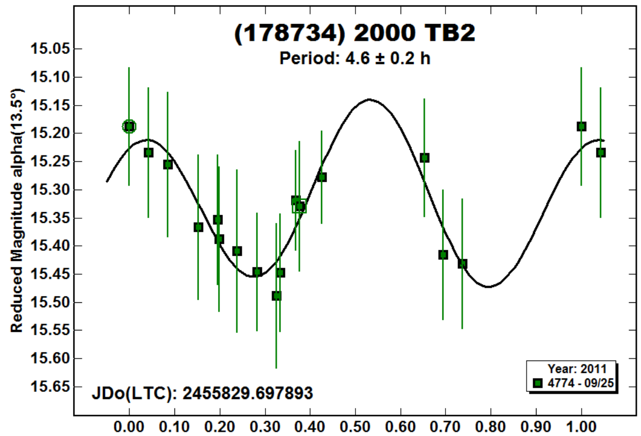
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Reduced Magnitude alpha(13.5°)
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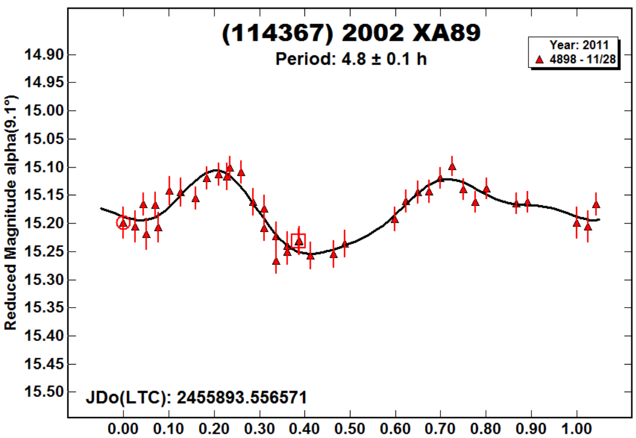
JDo(LTC): 2455829.697893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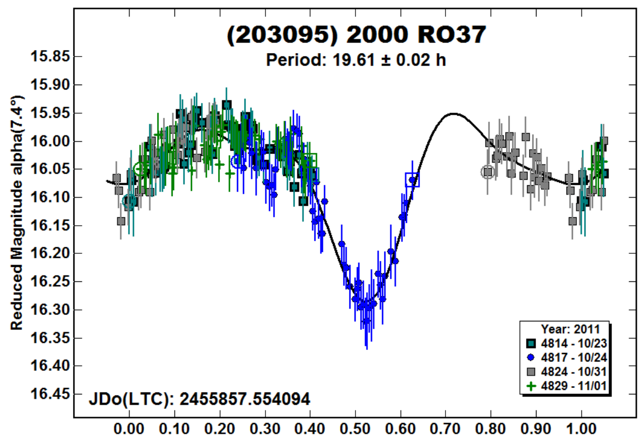
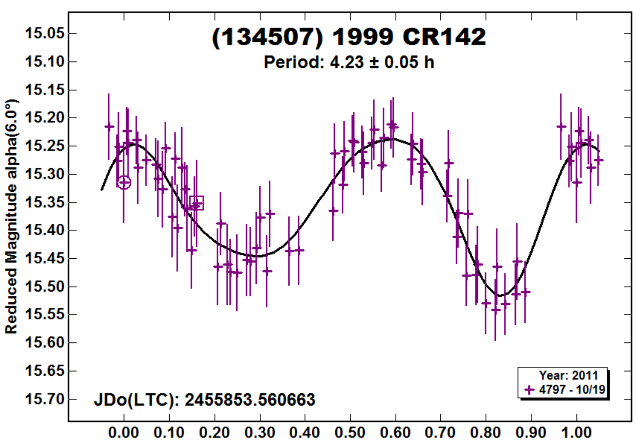
Period: 4.8 ± 0.1 h
Reduced Magnitude alpha(9.1°)
Year: 2011
4898 - 11/28
JDo(LTC): 2455893.556571


(203095) 2000 RO37
Period: 19.61 ± 0.02 h
Reduced Magnitude alpha(7.4°)
Year: 2011
4814 - 10/23
4817 - 10/24
4824 - 10/31
4829 - 11/01
JDo(LTC): 2455857.554094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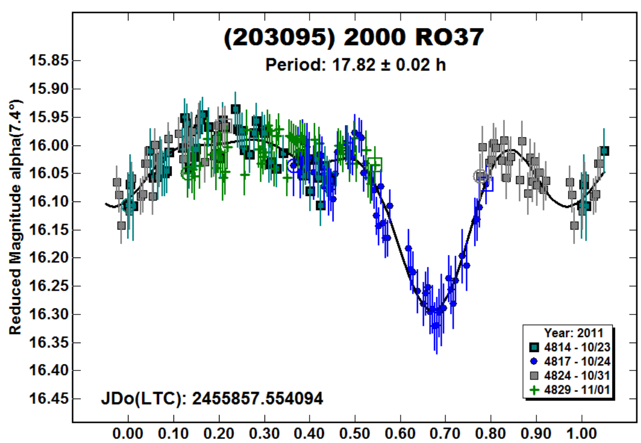
Period: 4.23 ± 0.05 h
Reduced Magnitude alpha(6.0°)
Year: 2011
4797 - 10/19
JDo(LTC): 2455853.560663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4817 - 10/24
4824 - 10/31
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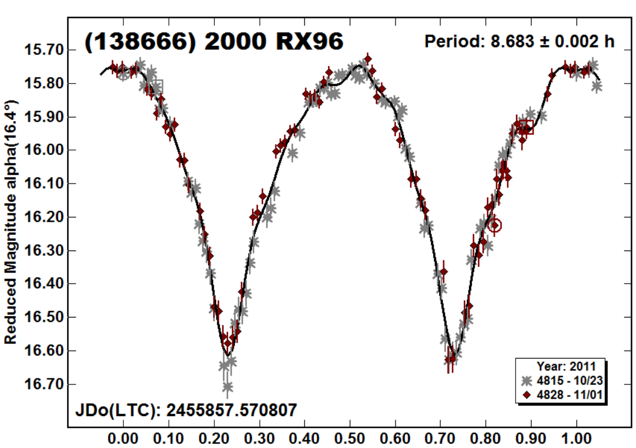
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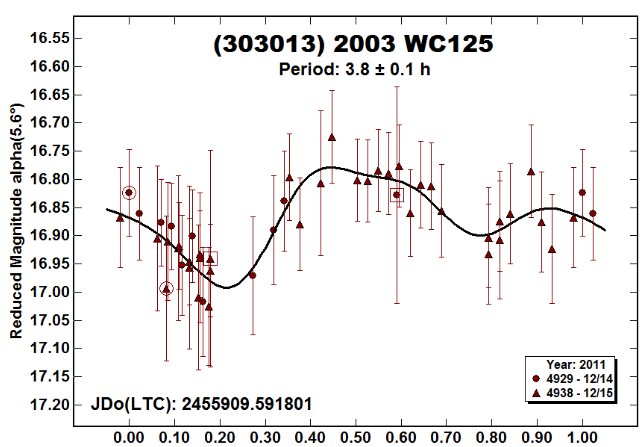
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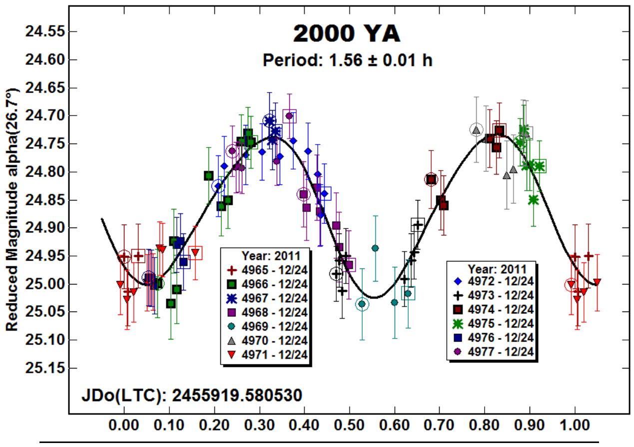

ASTEROIDS OBSERVED FROM GMARS AND SANTANA OBSERVATORIES: 2011 OCTOBER - DECEMBER

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(Received: 10 January)

Lightcurves of six asteroids were obtained from Santana Observatory and Goat Mountain Astronomical Research Station (GMARS): 555 Norma, 1028 Lydina, 1123 Shapleya, 1178 Irmela, 3436 Ibadinov, and 6042 Cheshirecat.

Observations at Santana Observatory (MPC Code 646) were made with a 0.30-m Schmidt-Cassegrain (SCT) with a SBIG STL-1001E CCD camera. All images were unguided and unbinned with no filter. Observations at GMARS (MPC Code G79) were made with a 0.4-m Schmidt-Cassegrain (SCT) with a SBIG STL-1001E. 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 et al. (1989). The asteroids were selected from the list of asteroid photometry opportunities published on the Collaborative Asteroid Lightcurve Link (CALL) website (Warner et al. 2011).

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

555 Norma. All images were acquired at Santana Observatory. Behrend (Behrend 2011) reported a period of 30.6 h based upon two nights of observations in April 2007 covering about 50 percent of the lightcurve. That lightcurve had an amplitude of about 0.25 mag. when the L_{PAB} was 187. The amplitude for the current opposition is only 0.06 magnitudes implying that we are viewing Norma nearly pole-on where the lightcurve may not be bimodal and surface features could dominate. The period spectrum shows two competing solutions of 16.60 h and 33.21 h which cannot be entirely eliminated. Observations should be obtained at its next opposition in April 2013.

1028 Lydina. All images were acquired at Santana Observatory. Lydina was previously reported to have a period of 15.69 h (Almeida 2003) based upon two nights of observations in November 1998. That period appears to be a 4:3 alias of this result. Behrend (Behrend 2011) reported a period of 48 h based upon three nights of observations in March 2007 covering the maxima.

1123 Shapleya. All observations were acquired at Santana Observatory. Wisniewski (Wisniewski 1995) observed Shapleya in January 1989 reporting a period > 20 h. Behrend (Behrend 2011) reported a period of 33.28 h based upon three nights of observations in February 2006, one of which had scatter of almost a magnitude.

1178 Irmela. Irmela was observed in 2010 at GMARS and Santana with the resulting period determined to be 11.989 ± 0.001 hr. This newly determined period obtained through data on consecutive nights is a 5/8 alias of the 19.17 h value reported by Binzel (1987) based on sparse sampling over three widely separated (non-consecutive) nights in May 1984.

3436 Ibadinov. Ibadinov does not have a previously reported period in the LCDB (Warner et al. 2010). It was a dim target found in the field of view of the primary target, 4138 Kalchas. A raw plot of 4 nights of observations spanning 8 nights suggests a period in excess of 7 days assuming a bimodal lightcurve.

6042 Cheshirecat. Observations for this object were completed on New Year's Eve in 2006. However, the results were never published.

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

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#	Name	mm/dd 2011/12	Data Pts	α	L_{PAB}	B_{PAB}	Per (h)	PE	Amp (mag)	AE
555	Norma	12/15 – 01/05	1,712	10.4, 1.9	108	-1	19.55	0.01	0.06	0.02
1028	Lydina	11/22 – 12/08	1,063	3.9, 0.5, 2.3	70	1	11.680	0.005	0.22	0.03
1123	Shapleya	10/17 – 11/18	2,351	6.0, 19.6	23	-8	52.92	0.01	0.38	0.03
1178	Irmela	2010/03/11 – 2010/03/14	591	1.9, 3.6	167	0	11.989	0.001	0.40	0.02
3436	Ibadinov	11/20 – 11/27	210	16.3, 15.0	107	-2	> 170	> 1.0		
6042	Cheshirecat	2006/12/20 – 2006/12/31	656	3.1, 9.0	83	-1	10.050	0.002	0.40	0.3

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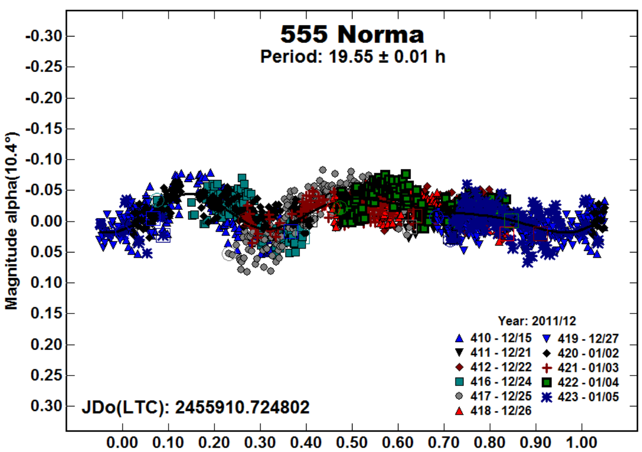

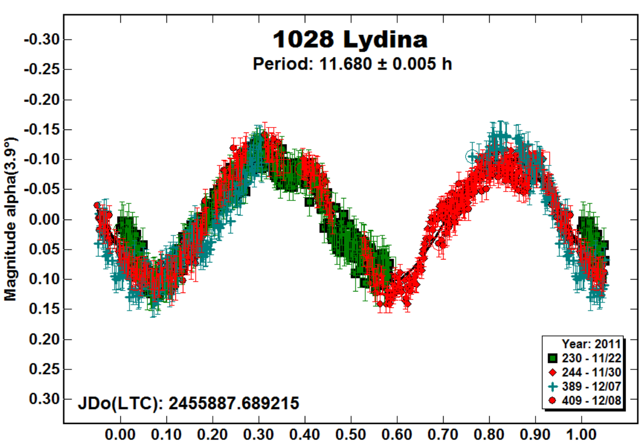

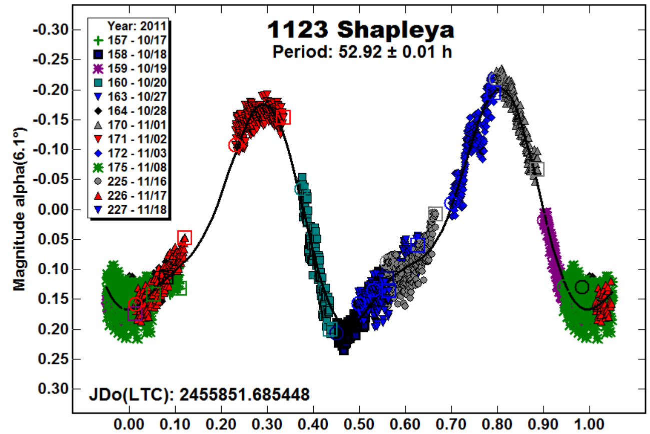

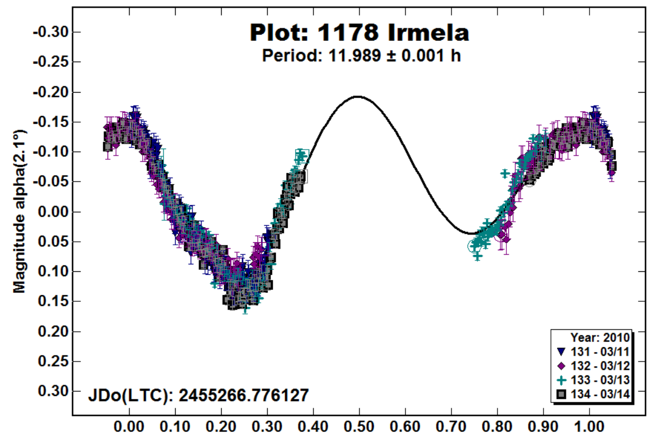

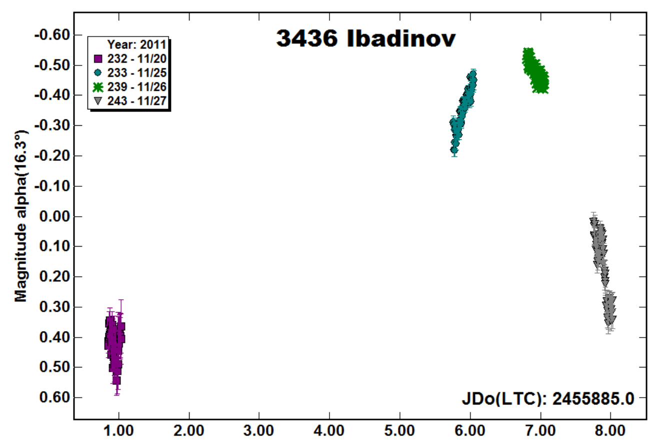

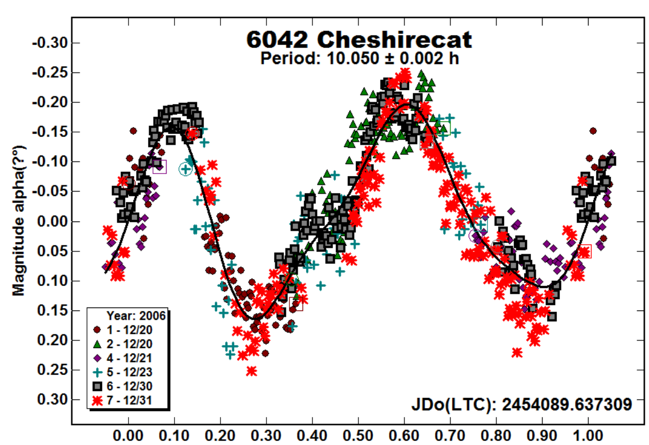

THE ENIGMATIC HUNGARIA ASTEROID 4868 KNUSHEVIA

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(Received: 12 January)

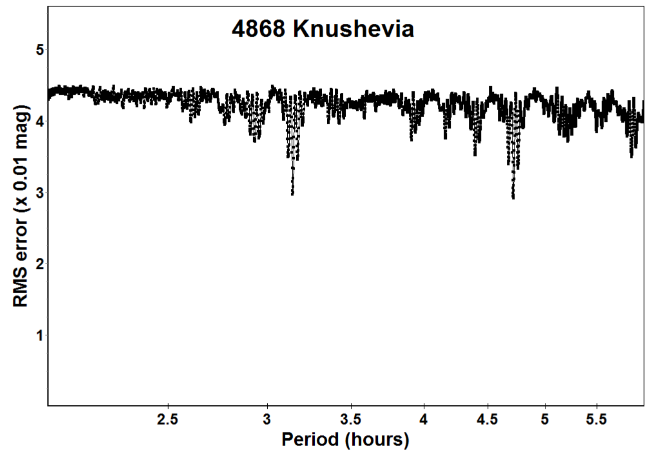
CCD photometry observations of the Hungaria asteroid 4868 Knushevia were made at the Palmer Divide Observatory and Hunters Hill Observatory in 2011 October. Period analysis favored two possible solutions, 3.143 h and 4.716 h, the latter being slightly favored despite having a more complex lightcurve. Attempts to fit data from two previous apparitions to either period failed.

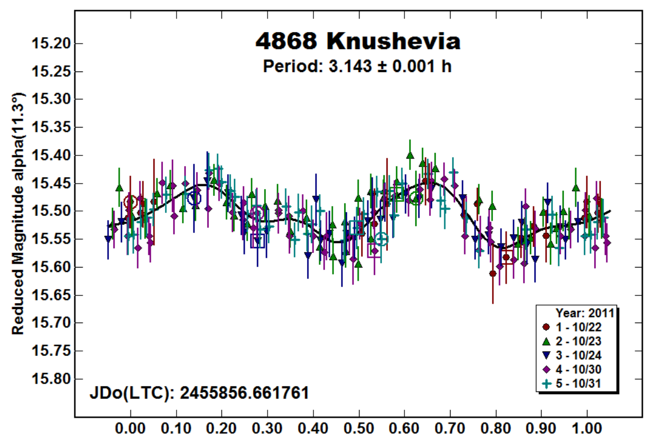
CCD photometry observations of the Hungaria asteroid 4868 Knushevia were made from 2011 October 22-31 at the Palmer Divide Observatory (PDO) and Hunters Hill Observatory (HHO). The asteroid had been previously observed by Warner (2009, 2010). Analysis of the data obtained in 2008 found a period of 4.45 h while that of the 2010 data found a period of 4.54 h. The 2011 campaign was run to try to find a definitive period. Instead, it only extended the ambiguities.

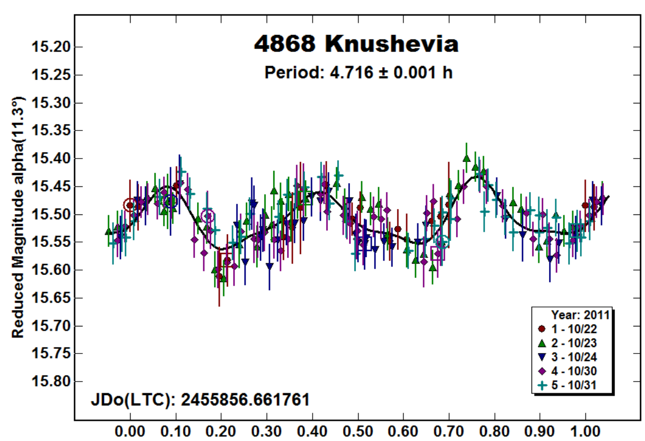
PDO observations by Warner were made with a 0.35-m Schmidt-Cassegrain (SCT) and FLI ProLine 1001E CCD camera. Exposures were unfiltered and 300 s. All frames were dark and flat field corrected. HHO observations by Higgins used 0.35-m SCT and SBIG STL-1001E CCD camera. Exposures were unfiltered and 240 s. All frames were dark and flat field corrected. *MPO Canopus* was used to measure all images and then do the period analysis. The entire data set was calibrated to a single internal system using J-K to BVRI conversions (Warner, 2007) on the comparison stars for each night to where merging the data from the two observatories required no zero point adjustment.

Initial analysis using only the PDO data could not find a unique solution, favoring a bimodal lightcurve of about 3.1 h or a trimodal, non-symmetric lightcurve of about 4.7 h, or almost exactly 1.5x the shorter solution. The addition of the HHO data refined the solutions but did not make one stand out over the other. The period spectrum (RMS fit versus period) shows that the two solutions are almost exactly equal. A review by Pravec with a more sophisticated set of analysis tools did not resolve the problem, although it precluded the presence of a second period, e.g., due to tumbling or an undetected satellite. Furthermore, attempts to fit the data from the previous apparitions to either of those found in 2011 either failed or were inconclusive.

This asteroid has oppositions just more than 18 months apart and so the oppositions in 2008 September and 2010 March were almost exactly 180° apart in viewing aspect (phase angle bisector longitude, PAB_L). Both showed lower amplitude than in 2011 October. The next opposition, 2013 April 28, is about six weeks later than the 2010 opposition and is hoped to be closer to an equatorial viewing aspect. The 2014 December 14 opposition is almost exactly 90° in PAB_L from the 2008 opposition, when the amplitude was lowest. This may be the best opportunity to determine the period once and for all, assuming observations and analysis during the 2013 apparition fail to do so.







Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35 and National Science Foundation grant AST-1032896. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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LIGHTCURVE ANALYSIS OF 6901 ROYBISHOP

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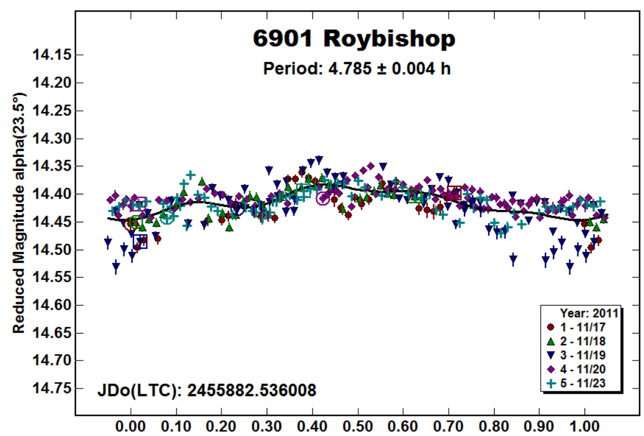
CCD photometry observations of the Hungaria asteroid 6901 Roybishop were made at the Palmer Divide Observatory and the Center for Solar System Studies in 2011 November. Data from a previous apparition gave indications of the asteroid having a satellite. The observations in 2011 did not provide any reasonable evidence that the asteroid was binary. Analysis of the data obtained over 4 nights found a synodic period of 4.785 ± 0.004 h and amplitude of only 0.04 ± 0.01 mag.

Observations in 2008 July-August by Warner (2009) of the Hungaria asteroid 6901 Roybishop hinted at the possibility that the asteroid might be binary. Two possible mutual events of 0.08 mag depth were observed and lead to a solution of an orbital period of 17.15 h and size ratio of Ds/Dp = 0.27 ± 0.02. However, the data set was not sufficient to confirm this analysis and so the asteroid was put on the list for future observations.

The 2011 campaign extended from 2011 November 17-23 at the Palmer Divide Observatory (PDO) and the Center for Solar System Studies (CS3). PDO observations by Warner were made with a 0.35-m Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD camera. Exposures were unfiltered and 240 s. All frames were dark and flat field corrected. CS3 observations by Coley used 0.35-m SCT and SBIG ST-10XE CCD camera. Exposures were unfiltered and 240 s. All frames were dark and flat field corrected.

MPO Canopus was used to measure all images and then do the period analysis. As in 2008, the asteroid showed a lightcurve with very low amplitude, 0.04 ± 0.01 mag. The period was found to be P = 4.785 ± 0.004 h. This is significantly different from the P = 4.682 h found with the 2008 data. In neither case could the data from one apparition be fit to the period from the other. However, the period spectrum (RMS fit versus period) for each showed that the adopted solution as judged by minimum RMS was barely significant. The observations in 2011 were calibrated to an internal system using J-K to BVRI conversions (Warner, 2007) on the comparison stars for each night. This presumably removed the possibility that the object is really a very slow rotator with large amplitude.

Save for one night of lesser quality data, there were no indications of mutual events (occultations and/or eclipses) during the five observing sessions. The phase angle bisector longitude (L_{PAB}) at the two apparitions differed by about 270° so, if nothing else, a presumption can be made that there were significantly different viewing aspects at the two apparitions. The flat lightcurve at both would seem to imply that the asteroid is nearly spheroidal in shape. The difference could also explain why events were not seen in 2011, i.e., the viewing geometry of the satellite orbit did not allow for events. For now, the asteroid remains a mystery and warrants observations at future apparitions.



Acknowledgements

Funding for observations at the Palmer Divide Observatory is provided by NASA grant NNX10AL35 and National Science Foundation grant AST-1032896. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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LIGHTCURVE ANALYSIS OF NEA 2005 YU55

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The near-Earth asteroid 2005 YU55 was observed in a coordinated campaign to obtain photometric data during the object's close approach to Earth in 2011 November. Analysis of more than 2500 data points found two possible synodic periods: P = 19.31 ± 0.02 h, A = 0.20 ± 0.02 mag and P = 16.34 ± 0.01 h, A = 0.24 ± 0.02 mag. Initial radar observations supported the shorter period but additional review now supports the longer period. In addition to finding a rotation period, the absolute magnitude was found to be H = 21.27 ± 0.05 and phase slope parameter G = –0.147 ± 0.014, the latter being consistent with a low albedo. Size estimates based on independent IR and radar observations ranged from ~310 to 400 meters, or – using H = 21.27 – yielding albeos in the range of 0.057-0.034.

The flyby of near-Earth asteroid 2005 YU55 in 2011 November provided an unusual opportunity to observe a low albedo asteroid, probably type C or a subtype (Moskovitz and Warner, 2011), in considerable detail. The asteroid had been previously observed by radar in 2009 (Benner, 2011), at which time a diameter of about 400 meters was determined. Unpublished photometric observations in 2010 by Warner lead to a rotation period on the order of 18 hours. The 2009 radar observations seemed to confirm this. This being the case, the likelihood was small for a single station being able to determine the rotation period from photometric observations during the brief time the asteroid was within reach of backyard telescopes. Accordingly, Warner and Stephens organized an observing campaign that would eventually include 8 observers in the U.S., Denmark, and Italy (see Table I).

In general, most observations were broken into "sessions", where a session was defined to be those data referenced against a given set of comparison stars in the same field as the asteroid. On the night of closest approach, 2011 Nov 9, the asteroid's sky motion was so fast that exposures were limited to between 5-10 seconds and, even with positioning the center of the field so that the asteroid crossed from one side to the other of a field about 20 arcminutes wide, a session included no more than 7-12 observations. Stephens alone obtained 46 sessions over 6 hours on Nov 9. Complicating the process more was that the asteroid was not exactly where predicted based on elements from the MPCORB file obtained early on Nov 9 (UT). By Nov 10, the asteroid's sky motion had slowed considerably such that Warner required *only* 17 sessions to cover almost 9 hours of observations. The observations on November 11-17 required fewer sessions, only one or two at the end of the range. Also, by Nov 10 the predicted and actual positions were in very close, if not exact, agreement.

Warner, Stephens, Brinsfield, Larsen, and Franco used *MPO Canopus* to measure their images, linking the zero points of the sessions to an internal system using 2MASS J-K magnitudes estimate BVRI magnitudes (see Warner, 2007). As such, not only did the observations from a single observer fit together reasonably well, the combined data set from the observers required only a minimum of minor zero point adjustments. This allowed finding a rotation period and lightcurve. The remaining data, those not already on the established system, could then be fit to the pre-determined curve to refine the results. Even with this approach, there was some uncertainty to the zero-point adjustments, which would prove critical during final analysis.

The initial analysis of the photometry found a period of about 16.3 h, as did a review of the first radar images by checking the amount of rotation of a feature over a known period (Marina Brozovic, private communications). However, subsequent radar data analysis (Michael Busch, Lance Benner, and Marina Brozovic, private communications) determined that a period of about 19.3 h was more likely. Warner revisited the photometry analysis and was able to force a solution by adjusting zero points of sessions from night-to-night, but keeping data within a given night from the same observer together. Because of the two, apparently reasonable and non-commensurate solutions, the possibility that the asteroid might be tumbling (non-principal axis rotation) has been raised. However, this and the actual rotation period can probably be determined only by careful and final analysis of the radar data, which is pending.

Using the data from Stephens on Nov 9 and Warner on Nov 10, 14-17, which covered phase angle 11°-70°, we determined an absolute magnitude of H_R = 20.887 ± 0.042 and a phase slope parameter of G = –0.147 ± 0.014. Assuming V-R = 0.38 (type C asteroid, Dandy *et al.*, 2003), nearly the same as the V-R = 0.37 used by Hicks *et al.* (2011), this gives H = 21.27 ± 0.05. This compares to H = 21.1 ± 0.1, G = –0.12 (Hicks *et al.*, 2011) and H = 21.2 (Bodewits *et al.*, 2011). Using the radar diameter of 400 meters (Lance Benner, private communications), this gives an albedo of p_V = 0.0343. Other observers using adaptive optics and/or IR observations reported smaller diameters of about 310 meters (Merline *et al.*, 2011; Mueller *et al.*, 2011). Using this value gives, using H = 21.27, p_V = 0.0571.

The final analysis of radar data is pending. When that is done, it's hoped that the various results for diameter and rotation period can

Observer	Location	Telescope	Camera	Filter	Dates Observed 2011 mm/dd UT
Warner	US	0.35m SCT 0.50m R-C	SBIG STL-1001E, FLI-1001E	No	11/9,10,14-17
Stephens	US	0.30m SCT	SBIG STL-1001E	No	11/9
Brinsfield	US	0.40m SCT	Apogee Alta U6	No	11/14,16,17
Larsen	Denmark	0.30m SCT	Orion SSDMI-2	No	11/11-13
Jacobsen	Denmark	0.40m Newtonian	Starlight Express SXVR-H16	No	11/15
Foster	US	0.33m reflector	SBIG STL-1K	No	11/9
Richmond	US	WIYN 0.9m	SITe S2KB	Rc	11/13
Franco	Italy	0.20m SCT	SBIG ST-7XME	No	11/9

Table I. List of observers, location, instrumentation, and dates observed. Not all data from each observer was used in the final analysis.

be resolved. Regardless, the 2011 campaign showed the importance of coordinating observations among professionals and amateurs and combining data sets obtained by a variety of means.

Acknowledgements

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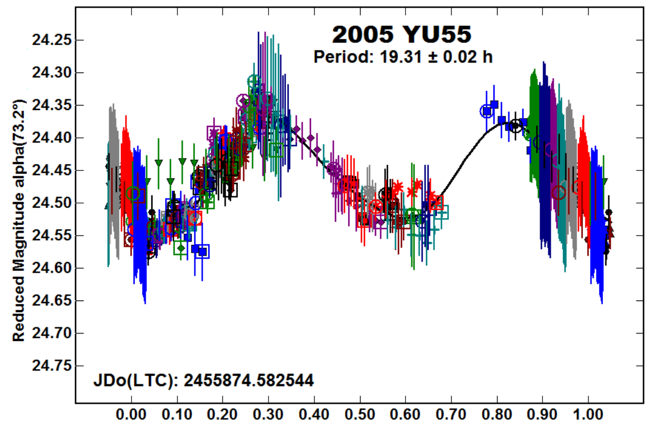

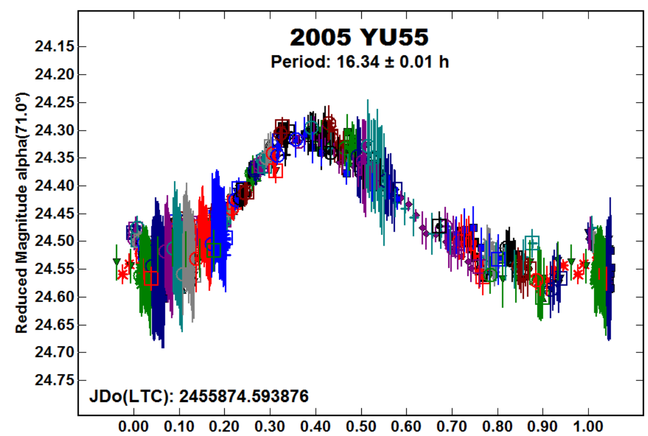

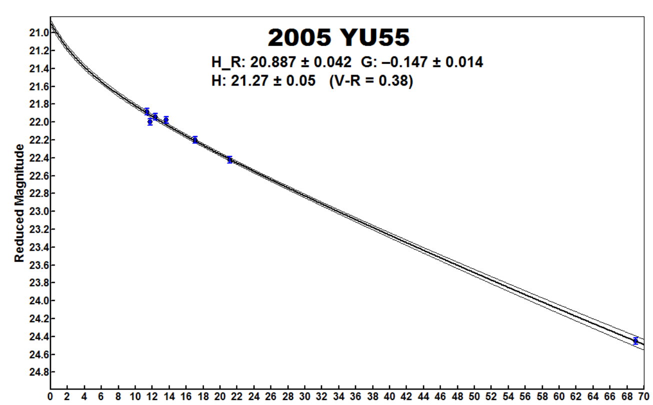

PHOTOMETRIC ANALYSIS OF THE VERY LONG PERIOD AND TUMBLING ASTEROID 1278 KENYA

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1278 Kenya is a long period main-belt asteroid. It was observed in collaboration among four photometrists located over two months at widely spaced locations. This asteroid is in non-principal axis (NPA) rotation, also known as tumbling. The primary period was determined to be 188 ± 1 h with a candidate second period of 127 ± 1 h. The quality of the tumbling solution is rated as PAR= –2, tending to –3.

(Editor's Note: The original version of this article was submitted 2011 September 1, but it was misplaced. The Editor assumes all responsibility for the unfortunate delay in publication.)

Observation of 1278 Kenya was initiated by Benishek who sent out an email invitation to join a global observing campaign. Previous observations by Behrend (2011) showed a period of $P > 24$ h with amplitude of 0.1 mag. Pilcher, Oey, and Higgins responded and developed a strategy that involved short sessions to be done as frequently as possible over a period that covered several months. This method of systematic observation would assure multiple coverage of the lightcurve of the slow rotator. Apart from the search for the synodic period, it is also known that such small object ($D \sim 22$ km based on $p_V = 0.18$ and $H = 10.8$) has a high probability to be a "tumbler" (Harris, 1994) or in non-principal axis rotation (NPAR). If in NPAR, the lightcurve will have deviations from the mean beyond those that can be explained by calibration error, amplitude-phase angle relation, and/or synodic effect (Oey, 2010). Once observational geometry had been accounted for, the data were sent to Pravec for further analysis to determine the nature of the NPA rotation.

Higgins performed his nightly routine by implementing a scheduling of targets observable on each clear night. The asteroid was a secondary target, with 2 to 9 data points obtained each night (Higgins, 2011). Oey also worked 1278 Kenya as a secondary target. As the long period nature of this very slow rotating asteroid became apparent, the length of each nightly session was limited to 1 hour, or about 10 data points per night. The number of data

Name	Sess	Session Numbers
Oey (Kingsgrove)	24	2,3,4,7,9,11,12,19,24,27, 31,52,64,69,72,74,82,83,86, 89,92,93,95,100
Pilcher	26	15,16,18,20,23,26,30,34,37, 42,48,51,57,61,63,65,67,70, 75,78,80,84,87,90,96,98
Benishek	12	1,5,6,8,10,35,49,53,55,73, 77,94
Higgins	7	13,28,32,41,44,56,59
Oey (Leura)	5	38,40,45,46,54

Table I. Corresponding observing sessions by authors

Obs	Telescope Camera	Scale "/pixel	Exp sec	Filter
Oey Kingsgrove	0.25-m f/11 SCT SBIG ST-9XE	1.45	300	Clear
Oey Leura	0.35-m f/7 SCT SBIG ST-8XME	1.54	180	Clear
Pilcher	0.35-m f/7 SCT SBIG STL-1001E	1.46	60	Clear
Benishek	0.41-m f/10 SCT ST-10XME	0.35	60	Clear
Higgins	0.36-m f/9.4 SCT SBIG STL-1001E	1.48	Varied	Clear

Table II. Equipment specifications.

points was to make sure that sufficient sampling was done per session. Benishek observed the asteroid by obtaining a complete night of data per session. This was usually done over a period of 4 to 6 hours. After a first, all-night session, Pilcher also limited individual sessions to 1 to 2 hours and obtained data on a large number of nights. All observers used *MPO Canopus* v10 software for data reduction and period analysis. *Canopus* incorporates the Fourier algorithm developed by Harris (Harris *et al.*, 1989). Oey, Higgins, and Benishek standardized their data by using the Comp Star Selector utility within the *Canopus* software. This method allows calibrating the nightly zero point by using solar-coloured comparison stars and Rc magnitudes derived from the 2MASS catalog (Warner, 2007) with an accuracy on the order of 0.03-0.05 mag (Stephens, 2008). Pilcher reduced his data by using differential photometry on local instrumental magnitude. Six images from each night were sent to Oey for calibrated data reduction as described above. Data reduced by Pilcher were then imported into the data set and the zero point was manually adjusted to coincide with the data reduced by Oey. Figure 3 shows the result of averaging five consecutive data points per point.

The observations ran from 2011 April 10 through June 26. The solar phase angle was 8.4° at the start, decreased to a minimum of 5.9°, and then increased 23.8° at the end of the campaign. The phase angle bisector longitude (L_{PAB}) shifted from 212.7° to 216.3° while the latitude (B_{PAB}) went from 12.3° to 8.6° during the period.

The synodic effect can be quantified by (Harris 1984):

$$|P_{syn} – P_{sid}| \sim \Delta(PAB) / \Delta(T) * P^2$$

Where Δ(PAB) is the change in the phase angle bisector during a change in time, Δ(T), and P is the rotation period measured in the same units of time as T (e.g., hours).

The maximum calculated value of $|P_{syn}-P_{sid}|$ was 0.79 h. The analysis in *MPO Canopus* found a synodic period of 187.89 ± 0.07 h. A realistic value of the period is $P = 188 \pm 1$ h. Looking closely at the single-periodic lightcurve (Figure 3), the seemingly random arrangement of the individual sessions along the mean could not be explained by the synodic effect or amplitude-phase angle relation alone. In fact, the light variations caused by this change in geometry were small and so the large variations in Figure 3 were judged to be due to the effect of tumbling. The data were analysed by Pravec, who found that 1278 Kenya was tumbling with a candidate second period P_2 = 127 ± 1 h. This second period should be accepted with caution since it is nearly 2:3 commensurate with the primary period of 188 h. Figure 1 shows the best fit with a third-order, 2-period Fourier series. The RMS residual is 0.022 mag, which is consistent with the calibration uncertainty associated with the method used. The tumbling solution is rated as PAR = –2, tending to –3 (see Pravec *et al.*, 2005). The relatively long campaign of 2.5 months provided sufficient data for a reliable detection of deviations indicating NPA rotation and providing candidate solution for both periods. Although the linear combinations of the harmonics of the main frequency are present, these harmonic signals are not strong enough for firm results, hence the PAR = –2/–3 instead of a PAR = –3 rating.

Extremely slow tumblers are difficult to solve beyond PAR = –2 from photometry data alone. Any attempt to obtain more data will likely not improve on the PAR rating unless other means of observation such as radar are used. Multiple apparition observations may improve this slightly but they probably will not be sufficient to describe the two periods of a tumbler uniquely.

If there are future opportunities to obtain favorable observations or perhaps another tumbling target with faster rotational period, then the following should be used to achieve optimum results:

1. Calibration accuracy should be limited to 0.02 mag or less.

2. A guideline for optimum sampling to the fourth harmonic is $2*(4f_1 + 4f_2)$ where $f_1 = 1/P_1$ and $f_2 = 1/P_2$. If a campaign is started without prior knowledge of P_2, than one can safely assume that $P_2 > P_1/3$. In the case with 1278 Kenya, the result is better than 1/9 or one point for every 6 hours. Then the optimum observation strategy would be one point (or a short session of a few points taken in quick succession, which will be averaged to effectively give one point of higher accuracy for analysis) at the beginning, middle and end of the night.

3. If a collaboration is established with observers at different longitudes, then there will be better sampling with more consistent coverage, as suggested in number 2 above, and this can also resolve a 24 h alias.

4. The duration of the campaign should be long enough for data to cover the period twice. In cases where the two periods are closely commensurate with one another, as with the case of 1278 Kenya, the duration of the campaign should be even longer.

Acknowledgements

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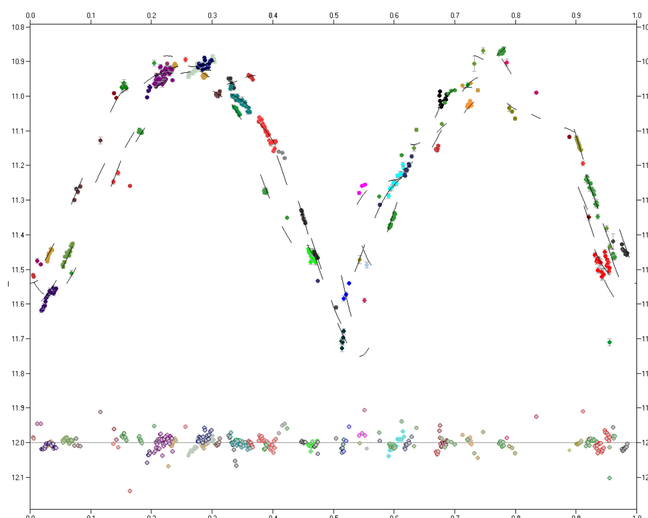


Figure 1. Lightcurve plot showing the best fit with third-order 2-period Fourier series. Data points are the average of the original 9 data points unless the separation of the original data points is greater than 1.88 h. The residuals are plotted along the arbitrary line at mag 12.0.

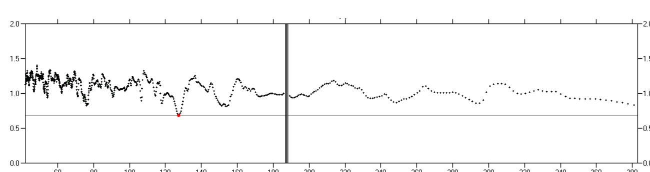


Figure 2. Period search spectrum for P_2.

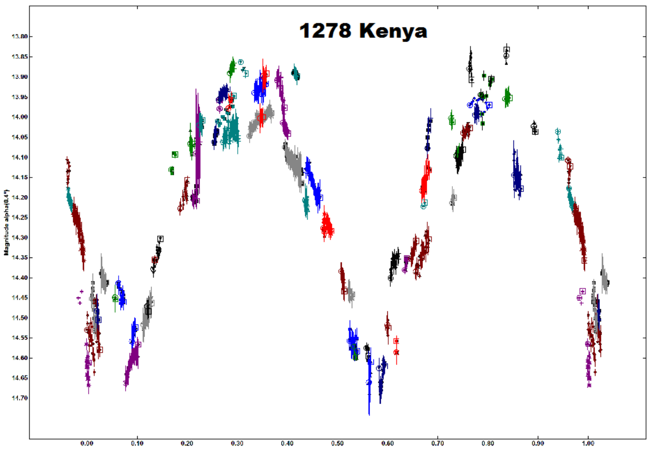
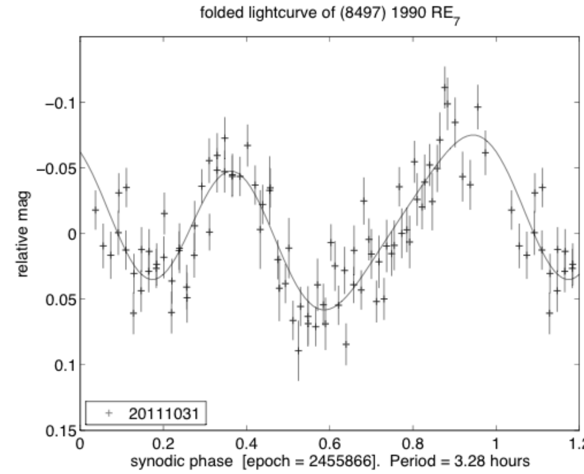
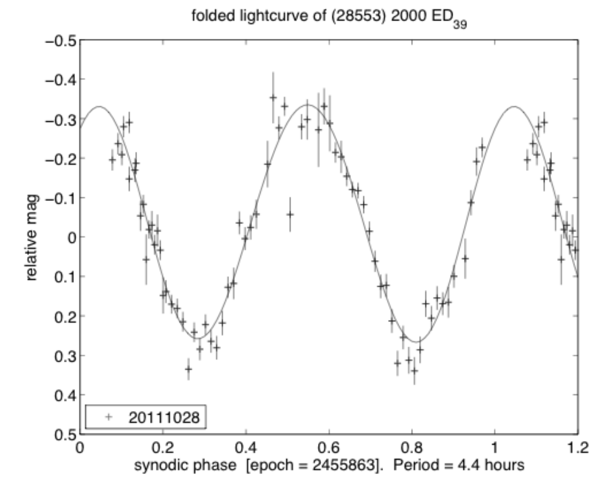


Figure 3. 1278 Kenya lightcurve plotted from single-period search in *MPO Canopus*. Data points were plotted with the average of 5 data points per point.





LIGHTCURVES AND SPIN PERIODS FROM THE WISE OBSERVATORY – OCTOBER 2011

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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.

Asteroid photometry has been done at the Wise Observatory since 2004. 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 is determined if possible. This paper presents photometric results of two 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 0.46-m Centurion telescope (Brosch *et al.* 2008) of the Wise Observatory (MPC 097). The 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'x50' with 3072x2048 pixels, with each pixel subtending 1.47 arcsec, unbinned. Observations were performed in "white light" with no filters (Clear). Exposure times were 180s, 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 observation date, the time span of the observation during that night, the number of images

Asteroid	Date	Time span [hours]	N	r [AU]	Δ [AU]	α [Deg]	L_{PAB} [Deg]	B_{PAB} [Deg]
(8497) 1990 RE_7	Oct 31, 2011	6.33	90	2.71	1.77	7.75	21.9	5.7
(28553) 2000 ED_{39}	Oct 28, 2011	4.83	70	2.04	1.06	5.72	43	1.6

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

Asteroid name	Period [hours]	U	Amplitude [mag]	H by MPC [mag]
(8497) 1990 RE_7	4.40 ± 0.07	3	0.60 ± 0.05	13.3
(28553) 2000 ED_{39}	3.28 ± 0.09	+2	0.15 ± 0.05	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.

obtained, the object's heliocentric distance (r), geocentric distance (Δ), phase angle (α), and the Phase Angle Bisector (PAB) ecliptic coordinates (L_{PAB}, B_{PAB}).

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 ~380 local comparison stars per field. The brightness of these stars remained constant to ±0.02 mag. Astrometric solutions were obtained using *PinPoint* (*www.dc3.com*) and the asteroids were identified in the MPC web database. Analysis for the lightcurve period and amplitude was done by 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 two asteroids, with reliability code of 2 to 3, are reported here. See Warner *et al.* (2009) for a discussion of the "U code" definitions in the Asteroid Lightcurve Database (LCDB). The two objects are main-belt asteroids with an absolute magnitude of 13.3 and 15.4 mag. Neither of the asteroids has published photometric measurements. Since these asteroids were not the prime targets of our observing campaign, they were observed only for one night. Therefore, the spin results, which are averaged on 3.8 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*). The folded lightcurves are presented on a relative magnitude scale.

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ERRATUM

*Oey et al. (2012). "Asteroid Rotational Lightcurve Analysis of 918 Itha and 2008 Konstitutsiya." MPB **39**, 1-2.*

The text description for the period of 918 Itha should read: "3.47393 ± 0.00006 hr". The abstract and lightcurve figure in the original article report the correct value.

A TRIO OF TUMBLING HUNGARIA ASTEROIDS

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During the course of the Hungaria asteroids survey at the Palmer Divide Observatory, three objects observed in early 2011 appear to be in non-principal axis rotation (NPAR, or "tumbling"): (6461) 1993 VB5, (14764) 7072 P-L, and (36316) 2000 LC12. Assuming the true periods of principal axis rotation and precession have been found, two of the three objects, 6461 and 36316, appear to be "slow rotators", with both periods being >24 h. The periods for 14764, however, are <16 h. While no definitive solutions are available, the results are still useful for studying the nature of tumbling asteroids, which are an increasingly critical element in the development of theories regarding the effects of thermal effects (e.g., YORP) on the evolution of spin rates and states among asteroids.

CCD observations at the Palmer Divide Observatory of three Hungaria asteroids in early 2011 showed them likely to be in non-principal axis rotation (NPAR, or "tumbling"). For a discussion of tumbling asteroids and the analysis of their lightcurves, see Pravec *et al.* (2005). The exact mechanics that create tumbling have yet to be fully understood. The YORP effect, a thermal process of re-radiating absorbed sunlight preferentially from the warmer afternoon side, is the likely cause of the excess of slow rotators (see Vokrouhlický *et al.*, 2007, Rossi *et al.*, 2010). Tumbling can persist for times comparable to the age of small asteroids with slow rotation (*P* > 24 h, common to many tumblers > 2-3 km in size), but may or may not be excited by slow rotation per se. The observed excess of slow rotators among the NEA and Hungaria populations (~30% of the Hungarias) along with the cause and role of tumbling are matters of continuing investigation, which can be well-served by studying in more detail whether most slow rotators are tumbling or just some of them. This requires detailed observations (*dense lightcurves*) capable of detecting signs of even small amplitude tumbling, i.e., objects that may be just entering or leaving their tumbling state.

Such an effort requires calibrated data, i.e., data put onto a common magnitude system, although it does not necessarily have to be referenced to a standard system such as that based on Landolt fields. At the least, the data from one observing session to another must be referenced against a common zero point with sufficient precision such that any small amplitude variations can be separated from calibration errors. At the Palmer Divide Observatory, a system using stars from the 2MASS catalog and conversion formulae to go to the Johnson-Cousins BVRcIc system are used to meet this goal. See Warner (2007) and Stephens (2008) and references therein for more information about this process. For general information about the observing program and instruments, see Warner (2011) and references therein.

Before discussing the individual results, it is important to note that in many cases, especially if data are from a single observing station, the periods found for that of principal axis rotation and precession ("wobble") may or may not be the true periods. This is particularly true if the derived or potential periods are commensurate with 24 h. In general, the combined result can be closely given as the linear combination of two frequencies (1/period). For example,

$$I * f1 \pm J * f2$$

Where I and J are integers. Therefore, in the cases below, the parameter I and/or J may not be equal to 1. The lightcurve of a tumbler is not a simple sum of two Fourier curves. Instead, it is the product of the two curves representing the two rotation actions. This means, for example, that subtracting the curve due to principal axis rotation from the combined lightcurve will *not* necessarily yield the second curve, the one due to precession. The analysis software used at PDO, *MPO Canopus*, is capable of handling only summed curves, as might be the case for a binary asteroid where the combined lightcurve is the sum of the rotation curves for the primary and satellite. Therefore, in cases where tumbling is suspected, the data are handed to Pravec and Kušnirák who have the necessary software to analyze the more complex data set.

The often highly-complex combination of the rotation and wobble lightcurves and, as a result, the rare instances when the combined lightcurve repeats itself, do not often allow giving a unique amplitude for one or both periods. Therefore, any amplitude for the combined lightcurve of a tumbling asteroid is often only an estimate of the range of the possible extremes when the two curves are combined.

(6461) 1993 VB5. This asteroid was observed from 2011 March 3 to April 28 with 717 data points collected using a 0.35-m and the 0.5-m telescopes at PDO. A single-period solution of about 220 h was found but it was very apparent that the data were not repeating from cycle to cycle, a good indication of tumbling. Therefore, the data were given to Pravec and Kušnirák for analysis. Two possible periods were found: ~47 h and ~74 h (see Figures 1 and 2). By themselves, the plots of the data using these periods are anything but convincing. Again, it should be noted that the true periods may be integral fractions or multiples of these two periods.

The estimated diameter of this asteroid is 3.8 km. Using a rule of thumb proposed by Harris (1994), the *damping time* for a period of ~68 h exceeds the age of the Solar System, with *damping time* being the time it takes for the natural tendency of an object to take it from tumbling to principal axis rotation. However, this is only an estimate and does not take into account the YORP timescale, which is the time it takes for an asteroid to be slowed sufficiently to make tumbling possible. Thus, a particular asteroid may have been in a slow rotation state for only a fraction of its lifetime, so a shorter damping time scale may be appropriate to consider. On the other hand, at a faster spin rate damping is faster, so the excitation into a tumbling state may have occurred after slow rotation was reached.

(14764) 7072 P-L. This Hungaria asteroid was observed from 2011 May 9 through June 16 with 346 data points collected using one of the 0.35-m telescopes. A period search found what appeared to be, on first glace, a reasonable solution of 28.59 h (see Figure 3). However, this solution serves to illustrate some important points when reviewing period solutions provided by software. Note that the phase angle of the observations is relatively low (~17°) and that the amplitude of the curve is nearly 0.8 mag. Simply put, there is no physical shape, viewed at a low phase angle, that can produce a lightcurve dominated by other than the second harmonic with an amplitude larger than around 0.4 magnitudes. The reasoning for this is the topic of a paper by Harris *et al.* (in preparation) and is based on analysis done by Russell (1906) and subsequent works. In the face of such a curve and circumstances, it's quite certain that the asteroid is tumbling.

Analysis by Pravec and Kušnirák found two possible periods, ~10 h and ~14 h. It's interesting to note that the second period is nearly commensurate with the 28 h period found when doing a single period search. It has happened before that the two periods of a tumbling asteroid are such that the combined lightcurve closely repeats itself at some interval and that single period analysis "latches onto" this commensurate period. All this is to say that "Just because the computer says it's true, doesn't mean that it is." Lightcurve data analysis requires the consideration of several factors to determine if a period and subsequent lightcurve found by software makes sense, let alone if they might be close to the true results.

The estimated size of the asteroid is 3 km. Even the 14 h period is well under a damping time of only 100 My. This would seem to indicate that one or both of the periods reported here might be integral fractions of the true periods or that the asteroid was observed on a likely repeat visit to a slow rotation state after going through one more YORP cycles, and thus the time in its current slow rotation state may be much shorter than its collisional lifetime.

(36316) 2000 LC12. This asteroid was observed from 2011 May 3 to June 16 with 694 data points collected using one of the 0.35-m telescopes. Single-period and dual-period tumbling analysis found a period of about 56 h (Figure 4). There were insufficient data, however, to find a second period for tumbling. However, given the approximate extreme amplitude of 1.2 mag (or 0.6 mag if the data from May 8 are excluded), the second period must be on the order of one-half to two times the one period, or between 26 and 112 h. This is because, as a "rule of thumb", the two periods of a tumbling asteroid cannot be separated by more than a factor of about the inverse amplitude of the variation. So, if the variation is about 1 mag, the two periods must be approximately the same. If the amplitude is about 0.1 mag, the two periods can differ by about a factor of 10. The paper by Black *et al.* (1999) provides the theoretical basis for this "rule of thumb", although it is not mentioned explicitly in the text.

The estimated diameter of 3.3 km and 56 h period are compatible for tumbling, i.e., the period for a damping time of 4.5 Ga is ~63 h, and so it's not entirely unexpected that this asteroid might be tumbling. Whether or not this is its first time doing so is a matter for conjecture.

Conclusion

Tumbling asteroids are difficult to work in the sense that they require significant amounts of observing time, both on a given night and over a period of many days, if not weeks and even months. To establish tumbling with some certainty, it is necessary to have good data over what appears to be a single cycle of the lightcurve, the test being that on the second cycle (and subsequent ones) the lightcurve does not repeat itself to within the errors of observation, changing synodic rate over an apparition, and/or changing amplitude due to significantly different phase angle and/or phase angle bisector viewing aspects over the apparition. As noted above, it's also required that data be placed on at least an internal system with, preferably, 0.02 mag or better precision. This requires extra work at the telescope and then at the computer.

As we move past the stages of building a large, general pool of rotation rates and look to support evolving theories involving the creation and development of the Solar System, tumbling asteroids become a critical element of the puzzle, as do their oft-common partners, slow rotators. However, the importance of this work really cannot be overstated and so the extra efforts required to observe and to analyze these objects properly is more than justified.

Acknowledgements

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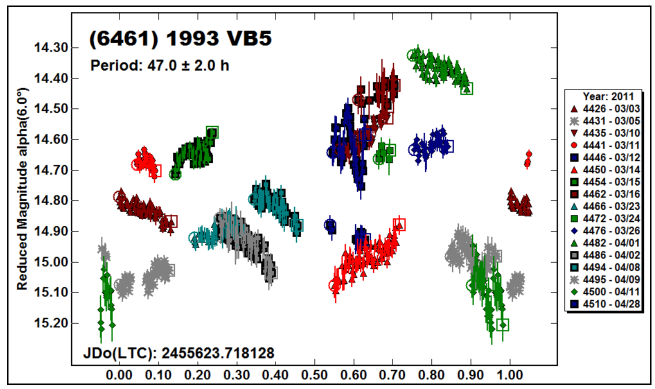

Figure 1. The data for (6461) 1993 VB5 forced to 47 h, one of two possible periods for non-principal axis rotation (NPAR).

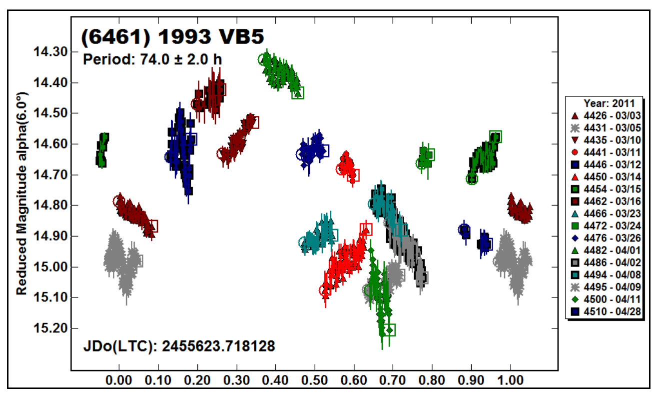

Figure 2. The data for (6461) 1993 VB5 forced to 74 h, one of two possible periods for non-principal axis rotation (NPAR).

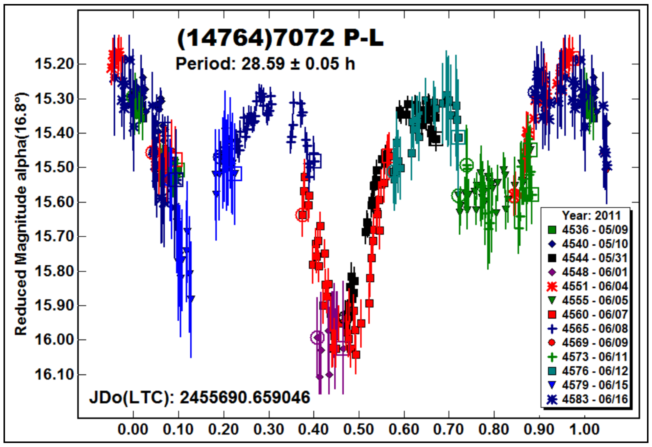

Figure 3. The data for (14764) 7072 P-L phased to a period of 28.59 h. See the text for a discussion of the plot.

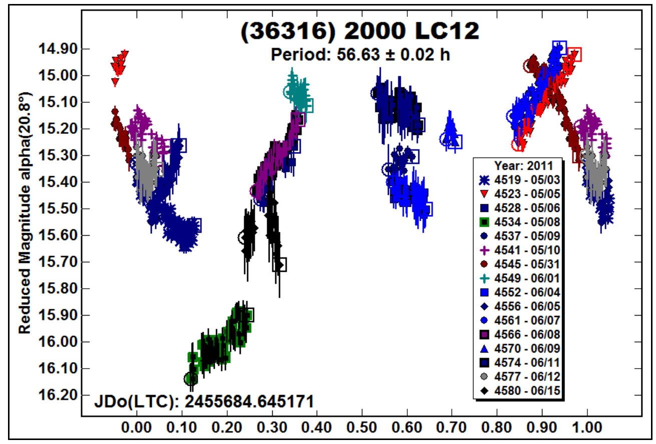

Figure 4. The data for (36316) 2000 LC12 phased to a possible period of non-principal axis rotation.

LIGHTCURVES OF 1940 WHIPPLE AND (6823) 1988 ED1

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Lightcurve measurements of two asteroids observed from the Shed of Science Observatory are reported: 1940 Whipple, P = 6.953 ± 0.003 h, A = 0.25 ± 0.05 mag; (6823) 1988 ED1, P = 2.546 ± 0.001 h, A = 0.19 ± 0.07 mag.

Photometry observations of two asteroids were made at the Shed of Science with an f/8.5 0.35-m Schmidt Cassegrain (SCT) and SBIG ST10XE CCD camera. The image scale was 0.94 arcsec/pixel. Exposures were made through a Celestron UHC LPR filter. All images were dark and flat field corrected. Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique and its comp star selector utility to link sessions. Period analysis with light-time corrected data was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al.* 1989).

1940 Whipple. Analysis of the data found a period P = 6.953 ± 0.003 h and amplitude A = 0.25 ± 0.05 mag. These results do not fit the earlier results of P = 5.78 h reported by Behrend and Roy (2007).

(6823) 1988 ED1. Analysis of observations over four nights indicates a period of P = 2.546 ± 0.001 h, A = 0.25 ± 0.05 mag. The period is slightly longer than reported by Bennefeld (2011) and Stephens (2008). Bennefeld observed over three nights within seven days. His lightcurve appears to be of good quality and suggests a period of P = 2.541 h. Stephens observed this asteroid over a month and also found a period of P = 2.541 h, but his results have a scatter of nearly 0.15 mag throughout the period. The data here were taken over three weeks and show a much more definitive curve.

Acknowledgements

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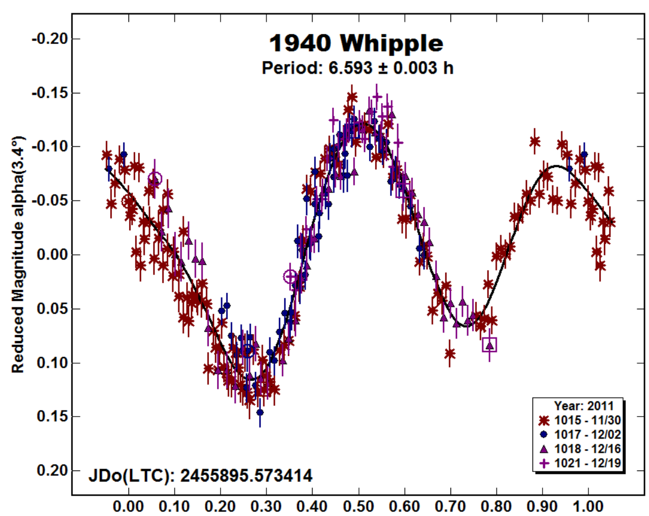

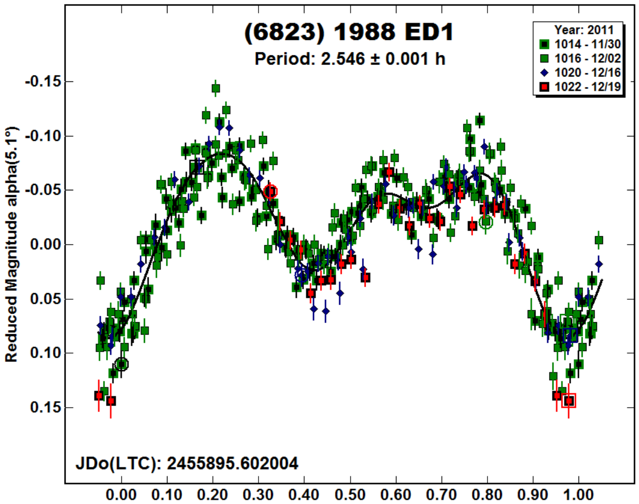

LIGHTCURVE ANALYSIS OF 3080 MOISSEIEV

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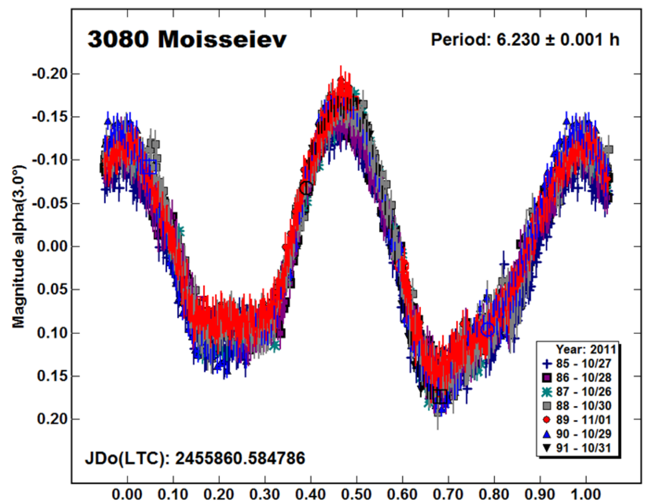
The lightcurve for main-belt asteroid 3080 Moisseiev was determined from data obtained 2011 October 26 through November 1. The analysis of the data found a synodic period of P = 6.230 ± 0.001 h and amplitude A = 0.40 ± 0.01 mag.

The main-belt asteroid, 3080 Moisseiev, was named after Nikolaj Dmitrevich Moisseiev (1902-1955), a professor at Moscow University. Moisseiev was the founder of the Moscow school of celestial mechanics (Schmadel 2003). The authors collaborated to observe the asteroid in late 2011 to determine its rotation period and lightcurve amplitude.

Observations at the Phillips Academy Observatory were conducted with a 0.4-m f/8 DFM Engineering telescope using an SBIG 1301-E CCD camera with a 1280 x 1024 array of 16-micron pixels. The resulting image scale was 1.0 arcsecond per pixel. Exposures were 180 s working at –25° C. All images were dark and flat field corrected, guided and unbinned. R and C filters were used. Observations at the Lenomiya Observatory were conducted with a Celestron CPC1100 0.28-m Schmidt-Cassegrain with a focal length of 1.943 m, and a ratio of f/6.3 using a focal reducer. The CCD camera was an SBIG ST8XME. Exposures were 40 seconds, unfiltered, guided, at –15° C, and binned 2x2, resulting in an array of 765 x 510 at 18-micron per pixels and 1.92 arcseconds per pixel. All images were dark and flat field corrected. Observations at the Etscoren Campus Observatory were conducted with a Celestron C-14 using an SBIG STL1001E CCD with 1024x1024 array of 24-micron pixels. The resulting image scale was 1.25 arcsecond per pixel. Exposures were 120 s working at –25º C. Images were unbinned and a clear filter was used. All images were unguided and dark and flat field corrected. Data reduction was done with IDL procedures written by Klinglesmith. After flat field correction, the images were aligned before being measured with *MPO Canopus* (Bdw Publishing).

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. Data merging and period analysis was also done with *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris *et al.* (1989). The combined data set from all observers was analyzed by Martinez. He found a best fit of 6.230 ± 0.001 h with amplitude of 0.40 ± 0.01 mag. The final data set contained 2,102 points. A search of the Asteroid Lightcurve Database (LCDB; Warner *et al.* 2009) and other sources did not reveal any previously reported lightcurve results for 3080 Moisseiev.



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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2012 APRIL-JUNE

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

We present four lists of "targets of opportunity" for the period 2012 April-June. For background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188. In the first three sets of tables, "Dec" is the declination, "U" is the quality code of the lightcurve, and "α" is the solar phase angle. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

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

Objects with U = 1 should be given higher priority when possible. *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. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

The first list is an *abbreviated list* of those asteroids reaching $V \leq 15.0$ 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 target list generator on the CALL web site allows you to create custom lists for objects reaching $V \leq 17.0$ during any month in the current year, e.g., limiting the results by magnitude and declination.

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

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 spin axis and/or shape modeling. Those doing work for modeling should contact Josef Ďurech at the email address above and/or visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site for existing data and models:

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

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

Future radar targets:
http://echo.jpl.nasa.gov/~lance/future.radar.nea.periods.html

Past radar targets:
http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html

Arecibo targets:
http://www.naic.edu/~pradar/sched.shtml

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

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

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

Once you've analyzed your data, it's important to publish your results. Papers appearing in the *Minor Planet Bulletin* are indexed in the Astrophysical Data System (ADS) and so can be referenced by others in subsequent papers. It's also important to make the data available at least on a personal website or upon request.

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Lightcurve Opportunities

#	Name	Brightest Date	Mag	Dec	U	LCDB Data Period	Amp
3070	Aitken	4 01.1	14.8	- 3			
2333	Porthan	4 02.7	14.8	+ 3	2	27.78	0.58
3776	Vartiovuori	4 03.3	14.8	+14	2	7.7	0.12
	2011 UF305	4 03.9	15.7	+77			
326	Tamara	4 10.9	11.6	+ 3	2+	14.45	0.11-0.27
2689	Bruxelles	4 11.2	14.7	- 7			
2738	Viracocha	4 14.0	14.9	-11			
4106	Nada	4 14.2	14.4	- 3			
2104	Toronto	4 21.3	14.4	-29	2+	8.96	0.32
874	Rotraut	4 21.5	13.9	- 6	2	14.58	0.24
5237	Yoshikawa	4 24.6	14.9	-12			
2364	Seillier	4 24.4	14.7	-11	2	6.7	0.10
2826	Ahti	4 26.0	15.0	-14	1	>24.	0.10
19774	2000 OS51	4 28.6	14.4	-32			
3161	Beadell	5 05.9	14.9	-38			
3339	Treshnikov	5 08.1	15.0	+ 0			
756	Lilliana	5 11.9	13.4	- 5	2	9.26	0.56-0.9
1315	Bronislawa	5 11.7	13.9	-19	2	9.56	0.16
4408	Zlata Koruna	5 15.5	14.9	-17			
2962	Otto	5 17.4	14.0	-21	1	15.24	0.09
4059	Balder	5 24.2	14.8	-20			
6212	1993 MS1	5 27.7	14.9	-15			
5380	Sprigg	5 29.8	14.6	-20			
8278	1991 JJ	5 29.3	14.5	-24			
14002	1993 LW1	5 30.5	14.9	-25			
6535	Archipenko	5 30.1	15.0	-46			
3306	Byron	5 31.3	14.3	-16			
19793	2000 RX42	5 31.1	15.0	-17			
1393	Sofala	5 31.1	14.3	-24	1	7.8	0.03
596	Scheila	5 31.1	11.6	-22	2	15.87	0.06
6742	Biandepei	6 01.5	14.6	-16			
3784	Chopin	6 03.7	14.8	-14	1+	12.72	0.06
51367	2000 UD104	6 05.5	14.7	-37			
541	Deborah	6 06.5	13.3	-25	2+	13.91	0.07
4724	Brocken	6 07.6	14.4	-17			
5633	1978 UL7	6 10.0	14.4	-23			
	2005 GO21	6 14.0	14.7	-43			
1492	Oppolzer	6 14.7	14.7	-13			
2229	Mezzarco	6 15.5	15.0	-27			
2724	Orlov	6 15.4	15.0	-17			
1677	Tycho Brahe	6 19.9	14.7	-48			
1954	Kukarkin	6 21.1	14.4	-28			
1791	Patsayev	6 21.3	14.6	-15			
7276	Maymie	6 22.7	15.0	-27			
6193	Manabe	6 23.2	14.7	-34			
3301	Jansje	6 23.1	14.3	-16			
2404	Antarctica	6 26.0	14.8	-22			
29451	1997 RM1	6 26.1	14.9	-37			
4340	Dence	6 28.0	14.1	-41	2	7.56	0.11
3836	Lem	6 29.3	14.8	-25			

Low Phase Angle Opportunities

#	Name	Date	α	V	Dec	Period	Amp	U
62	Erato	4 02.1	0.79	3.7	-02	9.2213	0.12-0.15	3
47	Aglaja	4 06.5	0.59	1.9	-08	13.178	0.02-0.17	3
37	Fides	4 07.5	0.33	1.0	-08	7.3335	0.10-0.25	3
341	California	4 13.4	0.43	3.1	-08	8.74	0.07	1
1132	Hollandia	4 19.6	0.18	3.5	-11	5.568	0.35	3
435	Ella	4 19.8	0.16	3.7	-12	4.623	0.30-0.45	3
252	Clementina	4 19.9	0.61	3.7	-10	10.862	0.44	2
66	Maja	4 21.6	0.61	3.5	-14	9.733	0.2 -0.45	3
1186	Turnera	4 22.4	0.93	3.5	-10	12.066	0.34	2+
149	Medusa	4 23.9	0.59	3.3	-12	26.023	0.56	3
1650	Heckmann	4 25.0	0.65	3.5	-12	14.893	0.06-0.12	3
210	Isabella	5 02.3	0.44	3.4	-17	6.672	0.09-0.35	3
245	Vera	5 06.2	0.53	2.9	-15	14.38	0.26	3
713	Luscinia	5 08.8	0.74	4.0	-15	8.28	0.21	3
1315	Bronislawa	5 11.7	0.35	3.9	-19	9.	0.02	1
418	Alemannia	5 17.0	0.85	3.4	-22	4.671	0.14-0.27	3
596	Scheila	5 31.1	0.16	1.7	-22	15.877	0.06	2
503	Evelyn	5 31.2	0.10	3.1	-22	38.7	0.30-0.5	2
321	Florentina	6 04.0	0.72	4.0	-25	2.871	0.31-0.42	3

Low Phase Angle Opportunities (continuted)

#	Name	Date	α	V	Dec	Period	Amp	U
128	Nemesis	6 06.5	0.15	1.2	-23	39.	0.10	3
541	Deborah	6 06.5	0.77	3.5	-25	13.91	0.07	2+
570	Kythera	6 07.2	0.38	3.7	-21	8.120	0.15-0.18	2
104	Klymene	6 16.7	0.76	3.3	-26	8.984	0.3	3
1248	Jugurtha	6 19.2	0.81	3.3	-26	12.910	0.70-1.4	3
86	Semele	6 27.8	0.37	3.0	-24	16.634	0.18	3
171	Ophelia	6 27.9	0.09	2.7	-23	6.66535	0.14-0.46	3
449	Hamburga	6 28.6	0.35	3.2	-24	18.263	0.08	2+

Shape/Spin Modeling Opportunities

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

Occultation Profiles Available

#	Name	Brightest Date	Mag	Dec	LCDB DATA Period	Amp	U
476	Hedwig	4 05.3	12.2	-22	27.33	0.13	3
47	Aglaja	4 06.6	11.8	-08	13.178	0.02-0.17	3
580	Selene	5 01.2	15.0	-11	9.47	0.27	3-
324	Bamberga	5 06.4	11.7	-31	29.43	0.07-0.12	3
124	Alkeste	5 17.1	10.9	-16	9.921	0.08-0.15	3
78	Diana	5 17.5	11.9	-33	7.2991	0.02-0.30	3
81	Terpsichore	5 19.8	13.3	-29	10.943	0.10	3
238	Hypatia	6 07.1	12.6	-05	8.8745	0.12-0.17	3
205	Martha	6 13.2	13.1	-10	39.8	0.10-0.50	2
568	Cheruskia	6 26.2	14.0	-12	13.209	0.10-0.44	3
18	Melpomene	6 28.1	9.3	-08	11.570	0.10-0.32	3

Inversion Modeling Candidates

#	Name	Brightest Date	Mag	Dec	LCDB Data Period	Amp	U
685	Hermia	4 04.2	14.7	-09	50.44	0.90	3
455	Bruchsalia	4 04.7	13.7	+09	11.838	0.12	2+
1139	Atami	4 06.9	15.0	-13	27.446	0.43	3
1503	Kuopio	4 12.0	13.8	-27	9.957	0.77	3
2865	Laurel	4 17.2	14.5	-31	21.5	0.15	2
1148	Rarahu	4 28.7	14.5	+01	6.5447	0.94	3-
714	Ulula	5 02.4	12.2	-20	6.998	0.48-0.63	3
400	Ducrosa	5 09.5	14.4	-33	6.87	0.62	3-
877	Walkure	5 10.0	14.5	-12	17.424	0.33-0.44	3-
1102	Pepita	5 12.4	13.6	-12	5.1054	0.32-0.55	3
367	Amicitia	5 16.3	13.0	-17	5.05	0.25-0.67	3
1035	Amata	5 22.8	14.7	-42	9.081	0.44	3
263	Dresda	5 24.7	14.1	-20	16.809	0.32-0.40	3
440	Theodora	5 28.8	14.1	-24	4.828	0.43	3
321	Florentina	6 04.1	14.0	-25	2.871	0.31-0.42	3
3169	Ostro	6 04.1	14.8	+00	6.483	0.42-1.2	3
1482	Sebastiana	6 07.9	14.5	-23	10.489	0.57-0.75	3
1010	Marlene	6 09.4	14.4	-21	31.06	0.32	2
138	Tolosa	6 13.4	10.9	-26	10.101	0.18-0.45	3
4077	Asuka	6 16.6	14.7	-28	7.919	0.40	3-
104	Klymene	6 16.8	13.2	-26	8.984	0.3	3
974	Lioba	6 29.2	13.5	-25	38.7	0.37	3

Radar-Optical Opportunities

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

MPC: *http://www.minorplanetcenter.org/iau/MPEph/MPEph.html*
JPL: *http://ssd.jpl.nasa.gov/?horizons*

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

(144411) 2004 EW9 (2012 March-April, H = 17.1)
Pravec *et al.* (http://www.asu.cas.cz/~ppravec/neo.htm) found a period of almost 50 h for this asteroid, a 1.4 km NEA. There were no signs of tumbling based on data taken over a period of several months in 2004. The H value is based on the Pravec reductions and assuming V-R = 0.45.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
03/25	12 46.4	-28 47	0.65	1.60	17.6	16.9	152	159	+0.05	+34
03/30	12 38.4	-29 28	0.60	1.57	17.4	16.1	154	108	+0.42	+33
04/04	12 29.0	-29 58	0.56	1.53	17.1	16.0	155	46	+0.89	+33
04/09	12 18.3	-30 16	0.52	1.49	17.0	17.1	154	40	-0.93	+32
04/14	12 06.5	-30 20	0.49	1.45	16.8	19.3	151	107	-0.44	+32
04/19	11 54.1	-30 07	0.46	1.41	16.7	22.6	147	155	-0.05	+31
04/24	11 41.5	-29 38	0.43	1.37	16.7	26.6	142	121	+0.06	+31
04/29	11 29.2	-28 53	0.41	1.33	16.6	31.2	137	63	+0.46	+31

2004 FG11 (2012 April, H = 20.9, PHA)
The observing window for this 0.2 km NEA will be open for only a few days at the beginning of April, as a waxing moon moves closer each day. There are no lightcurve parameters in the Lightcurve Database (LCDB) for this object.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	15 11.5	+04 54	0.15	1.12	18.6	33.6	142	109	+0.62	+50
04/02	15 19.0	+06 15	0.14	1.11	18.4	35.2	140	98	+0.72	+49
04/03	15 28.0	+07 53	0.13	1.10	18.2	37.3	138	88	+0.81	+48
04/04	15 39.1	+09 51	0.11	1.08	18.0	40.0	136	78	+0.89	+47
04/05	15 53.1	+12 16	0.10	1.07	17.9	43.5	133	70	+0.95	+45
04/06	16 11.0	+15 16	0.09	1.06	17.7	48.1	128	63	+0.99	+42
04/07	16 34.7	+18 57	0.08	1.05	17.6	54.2	122	59	-1.00	+38
04/08	17 06.5	+23 23	0.07	1.03	17.5	62.2	114	58	-0.98	+33

1998 HE3 (2012 April-May, H = 21.7, PHA)
The LCDB has no parameters for this NEA and potentially hazardous asteroid. The estimated size is 130 meters. Given the size, there is potential for it to be a super fast rotator and/or tumbler. It will pass the Earth by about 0.03 AU on May 10 with its closest predicted approach being 0.024 AU in 2059.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/25	15 47.9	-10 36	0.12	1.11	18.4	21.4	156	160	+0.12	+33
04/27	15 40.0	-09 49	0.10	1.10	18.0	18.5	160	136	+0.27	+35
04/29	15 29.4	-08 47	0.09	1.09	17.6	15.2	163	109	+0.46	+38
05/01	15 15.0	-07 22	0.08	1.08	17.1	11.8	167	79	+0.67	+41
05/03	14 54.6	-05 22	0.06	1.07	16.6	10.2	169	47	+0.86	+46
05/05	14 24.8	-02 22	0.05	1.06	16.3	14.4	165	16	+0.98	+53
05/07	13 39.6	+02 14	0.04	1.05	16.1	25.9	153	38	-0.99	+63
05/09	12 30.7	+08 52	0.03	1.03	16.3	44.8	134	85	-0.88	+71

2010 KX7 (2012 May, H = 21.8, PHA)
Based on current predictions, this 130-meter NEA will have a 0.033 AU flyby in 2142. It has been observed at only two apparitions, so high-accuracy and precision astrometry may be needed prior to the radar observations to assure successful observations. This one definitely favors those in the Southern Hemisphere during its two-week observing window. Unfortunately, the moon will be past first quarter, heading for full.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/01	18 08.0	+15 01	0.05	1.03	17.2	58.6	119	118	+0.67	+16
05/03	17 36.7	+01 41	0.04	1.04	16.6	45.0	133	87	+0.86	+17
05/05	16 58.7	-14 31	0.04	1.04	16.0	30.2	149	48	+0.98	+17
05/07	16 14.7	-30 11	0.04	1.05	15.9	21.4	158	12	-0.99	+15
05/09	15 27.2	-42 06	0.05	1.05	16.3	24.1	155	37	-0.88	+12
05/11	14 40.2	-49 43	0.06	1.06	16.9	30.9	148	70	-0.70	+9
05/13	13 57.9	-54 10	0.07	1.06	17.4	36.9	141	97	-0.49	+7
05/15	13 22.2	-56 39	0.08	1.07	17.9	41.5	136	118	-0.29	+6

2001 CQ36 (2012 May, H = 22.7)
Whiteley *et al.* (2002) reported only that the period might be long for 2001 CQ36. It’s a 90-meter NEA, so it’s not surprising that it’s not very bright even when only 0.03 AU from Earth in late May. Again, the Southern Hemisphere observers have the best (only) chance to cover this. Keep in mind the possibility of being a superfast rotator (less than 2 h) and tumbling.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/15	19 09.4	-32 41	0.06	1.05	18.3	48.7	129	66	-0.29	-18
05/17	19 25.2	-34 06	0.05	1.04	18.1	50.4	127	86	-0.14	-21
05/19	19 45.2	-35 41	0.05	1.04	17.9	52.8	125	105	-0.03	-26
05/21	20 11.1	-37 24	0.04	1.03	17.7	56.3	122	122	+0.00	-31
05/23	20 45.2	-39 03	0.04	1.03	17.6	61.2	117	136	+0.04	-38
05/25	21 30.2	-40 15	0.03	1.02	17.5	68.0	110	144	+0.14	-47
05/27	22 27.6	-40 11	0.03	1.02	17.6	77.0	101	146	+0.31	-58
05/29	23 33.8	-37 52	0.03	1.01	17.8	88.1	90	143	+0.52	-70

2007 LE (2012 June, H = 19.1, PHA)
2007 LE will flyby Earth on June 2 at a distance of about 7.1 million km, or about 19 lunar distances. The sky motion at the time will be very large, so getting good photometry may be difficult and might be better done a few days later but, by then, the asteroid will be well south of the celestial equator. There are no lightcurve parameters in the LCDB for the 450-meter NEA.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/01	15 47.4	+33 33	0.05	1.04	14.7	54.5	123	58	+0.83	+52
06/03	15 37.8	+06 57	0.05	1.06	14.0	32.1	146	27	+0.97	+46
06/05	15 30.6	-16 21	0.06	1.07	14.0	19.3	160	28	-1.00	+32
06/07	15 25.1	-31 48	0.07	1.08	14.6	21.6	157	57	-0.91	+21
06/09	15 20.9	-41 25	0.09	1.10	15.3	27.0	151	83	-0.74	+13
06/11	15 17.8	-47 36	0.11	1.11	15.9	31.0	146	106	-0.54	+8
06/13	15 15.5	-51 47	0.13	1.12	16.4	33.8	142	125	-0.35	+5
06/15	15 14.0	-54 45	0.15	1.14	16.8	35.7	139	138	-0.18	+3

2003 KU2 (2012 June-July, H = 17.7)
Given some of the other radar targets this month, this is a behemoth: almost 0.9 km, assuming an albedo of 0.2. The LCDB has no entries for the asteroid.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/10	19 37.0	-16 10	0.40	1.36	17.5	24.9	146	39	-0.64	-17
06/13	19 44.4	-16 07	0.36	1.33	17.3	24.7	147	75	-0.35	-19
06/16	19 52.8	-16 06	0.33	1.30	17.0	24.6	148	108	-0.11	-21
06/19	20 02.5	-16 05	0.29	1.28	16.7	24.7	148	142	+0.00	-23
06/22	20 14.0	-16 05	0.26	1.25	16.4	25.2	149	176	+0.06	-25
06/25	20 28.0	-16 05	0.23	1.22	16.2	26.0	148	149	+0.27	-28
06/28	20 45.3	-16 03	0.20	1.19	15.9	27.6	147	112	+0.60	-32
07/01	21 07.4	-15 55	0.18	1.17	15.6	30.1	145	73	+0.89	-37

(153958) 2002 AM31 (2012 June-July, H = 18.1)
There are no lightcurve parameters in the LCDB for 2002 AM31, an NEA with estimated size of 0.7 km. It will miss planet Earth by 0.035 AU on July 22. The ephemeris does not extend that far because, by the time of closest approach, the solar elongation will

be only 90°, making photometry difficult. However, astrometric observations before the approach may be beneficial to the radar teams for pointing at the object.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/10	18 09.6	-03 27	0.26	1.26	16.8	18.9	156	60	-0.64	+8
06/15	18 10.8	-01 38	0.23	1.23	16.4	19.2	157	117	-0.18	+8
06/20	18 11.9	+00 29	0.20	1.20	16.1	20.4	156	159	+0.00	+9
06/25	18 13.1	+03 03	0.16	1.17	15.7	22.9	154	116	+0.27	+10
06/30	18 15.0	+06 19	0.13	1.13	15.3	26.6	150	55	+0.81	+11
07/05	18 18.3	+10 51	0.11	1.11	14.9	31.8	145	37	-0.98	+12
07/10	18 24.9	+17 50	0.08	1.08	14.4	39.3	138	86	-0.60	+14
07/15	18 40.0	+30 18	0.06	1.05	14.0	51.2	126	118	-0.16	+16

1685 Toro (2012 June-July, H = 14.2)

This Apollo member is sometimes called "Earth's second satellite." It has resonances with both Earth and Venus that cause it to have close approaches to Earth twice every eight years, this being one of those years. The solar elongation is never very large, meaning that photometry runs are kept short. The period is about 10.1 h, so a single station will have to obtain a number of sessions to get good coverage of the full lightcurve.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/10	22 04.7	-07 34	0.64	1.36	15.7	44.8	109	2	-0.64	-46
06/15	22 17.8	-04 56	0.59	1.33	15.4	46.0	110	59	-0.18	-47
06/20	22 32.0	-01 54	0.53	1.30	15.2	47.4	110	114	+0.00	-48
06/25	22 47.4	+01 35	0.48	1.26	15.0	49.2	110	172	+0.27	-49
06/30	23 04.8	+05 38	0.44	1.23	14.8	51.6	109	123	+0.81	-48
07/05	23 24.6	+10 18	0.40	1.19	14.6	54.6	107	56	-0.98	-47
07/10	23 47.8	+15 38	0.37	1.16	14.5	58.3	104	11	-0.60	-45
07/15	00 15.5	+21 36	0.34	1.12	14.4	63.0	100	55	-0.16	-40

2201 Oljato (2012 June-August, H = 16.8)

This NEA of about 1.8 km size is thought to have a period on the order of 24 h or more. This makes it a prime candidate for a coordinated photometry campaign, providing enough observers can be found in the Southern Hemisphere.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/15	21 46.4	-16 28	0.77	1.56	16.9	34.1	121	71	-0.18	-46
06/25	21 29.6	-18 19	0.78	1.66	16.8	25.8	135	160	+0.27	-43
07/05	21 08.7	-20 15	0.81	1.76	16.8	17.1	149	16	-0.98	-39
07/15	20 46.0	-21 59	0.86	1.86	16.7	8.5	164	118	-0.16	-34
07/25	20 24.2	-23 19	0.94	1.95	16.7	2.0	176	108	+0.35	-30
08/04	20 05.8	-24 11	1.04	2.04	17.2	6.8	166	38	-0.96	-26
08/14	19 52.1	-24 38	1.17	2.13	17.8	12.2	154	161	-0.14	-24
08/24	19 43.4	-24 48	1.32	2.21	18.3	16.3	142	60	+0.44	-22

IN THIS ISSUE

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

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* * * * *

The deadline for the next issue (39-3) is April 15, 2012. The deadline for issue 39-4 is July 15, 2012.