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LIGHTCURVE ANALYSIS OF EXTREMELY CLOSE NEAR-EARTH ASTEROID – 2012 DA14

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In this paper we present one of the first lightcurves of near-Earth asteroid 2012 DA14. This is a very interesting near-Earth asteroid, which approached the Earth at a very close distance on Feb. 15 2013. From our measurements we find a rotational period of 9.485 ± 0.144 h with an amplitude of 1.79 mag.

All observations reported here were carried out at Russian remote ISON-NM observatory (NM, USA) in visible light with 0.45-m astrograph f/2.8 and FLI ML09000-65 camera mounted in prime focus. The unbinned image scale is 1.95 arcsec/pixel. All images were dark and flat field corrected. Analysis of the images and results for the rotation period were carried out by the *MPO Canopus* package (Bdw Publishing).

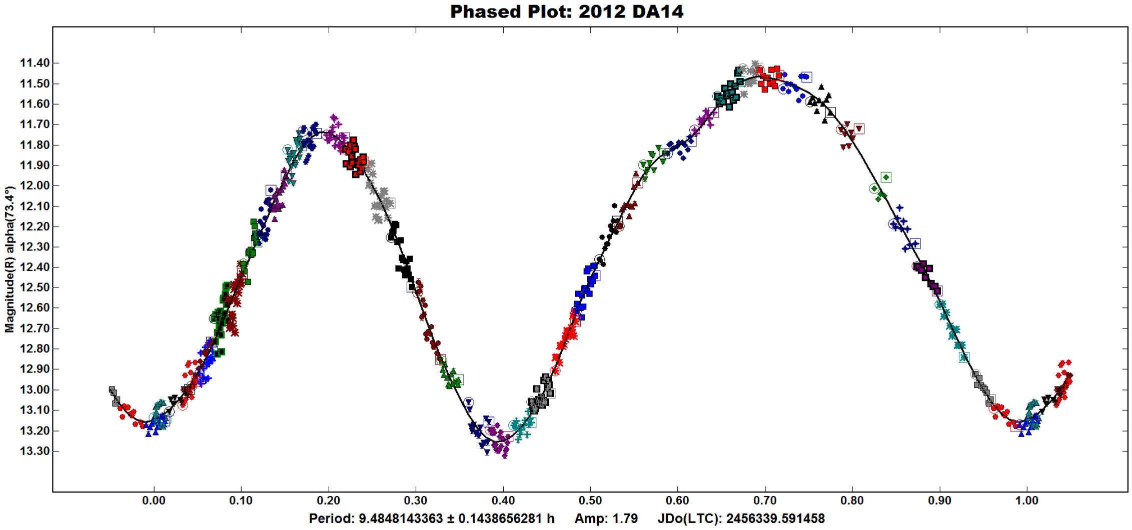
Asteroid 2012 DA14 is a near-Earth object (Aten category, *q* = 0.8289, *a* = 0.9103, *e* = 0.0894, *i* = 11.6081). Before the current close approach, 2012 DA14 had orbital elements within the Apollo category (*q* = 0.8894, *a* = 1.0018, *e* = 0.1081, *i* = 10.3372). Parameters of the orbit make this asteroid an interesting target for a possible space mission. Asteroid 202 DA14 was discovered on Feb 23 2012 by the La Sagra Sky Survey, LSSS (MPC code J75).

An extremely close approach to the Earth (0.00022 AU or ~34 000 km) occurred 2013 Feb 15.80903. We observed this asteroid after its close approach, 2013 Feb 16, from 02:11:35 UT to 12:17:43 UT (Table1). Our total observational interval was 10 h 16 min, i.e. ~108% of the rotation period.

UT	*Δ*	*r*	*phase*	*mag*
02:11:35	0.0011	0.988	73.5	11.8
12:18:43	0.0026	0.988	80.9	14.0

Table I. Photometric observations of 2012 DA14.

We found our data fit a rotation period that is relatively long for the objects with the same size: P = 9.485 ± 0.144 h with an extremely high lightcurve amplitude of 1.79 mag.



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****Editor's Note:*** *This manuscript was received on February 20, one of the earliest reported lightcurve results for 2012 DA14. Unfortunately due to an error by the Editor, this article was omitted from the processing for MPB 40-3. The Editor offers his apology for the delay in publishing these results.*

LIGHTCURVE PHOTOMETRY, H-G PARAMETERS AND ESTIMATED DIAMETER FOR 1412 LAGRULA

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Photometric observations of main-belt asteroid 1412 Lagrula were made over ten nights during 2013 March and April, with filtered system. The resulting synodic period is 5.9176 ± 0.0001 h with an amplitude of 0.28 ± 0.05 mag. The color index V-R = 0.37 ± 0.05 mag. The measured absolute visual magnitude, Hv = 11.81 ± 0.04 mag. and the slope parameter, G = 0.135 ± 0.049, are consistent with a low albedo object, e.g., type C. The diameter is estimated to be D = 23 ± 3 km.

The main-belt asteroid 1412 Lagrula was reported as a lightcurve photometry opportunity, for 2013 March, in Minor Planet Call *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*. All the observations were carried out from C62 Eurac Observatory in Bolzano (Italy), during ten observing nights, using a 0.30m reflector telescope, reduced to f/4.0 and a QHY9 CCD camera. Before each session, the observers synchronized the computer's clock with atomic clock time, via Internet NTP servers. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2012). The derived synodic period was P = 5.9176 ± 0.0001 h (Fig.1) with a amplitude of A = 0.28 ± 0.05 mag.

All filtered images (V Johnson, R Cousins) were calibrated with dark and flat-field frames. The V and R band frames were acquired in sequence changing alternatively the filters (VR VR VR). This allowed us to find the color index of V-R = 0.37 ± 0.05 mag (mean of 40 values). This value is typical of a C-type asteroid (Shevchenko and Lupishko, 1998). Assuming C-type, the geometric albedo is Pv = 0.06 ± 0.02 (Shevchenko and Lupishko, 1998). The absolute magnitude (H) and slope parameter (G) ware found using the H-G Calculator function of MPO Canopus. Seven values obtained pre- and post-opposition of the asteroid, using the maximum values of the lightcurve. We obtained Hv = 11.810 ± 0.040 mag. and the slope parameter G = 0.135 ± 0.049 (Fig. 2).

From this, we can estimate a diameter of D = 23 ± 3 km using the expression (Pravec and Harris, 2007):

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

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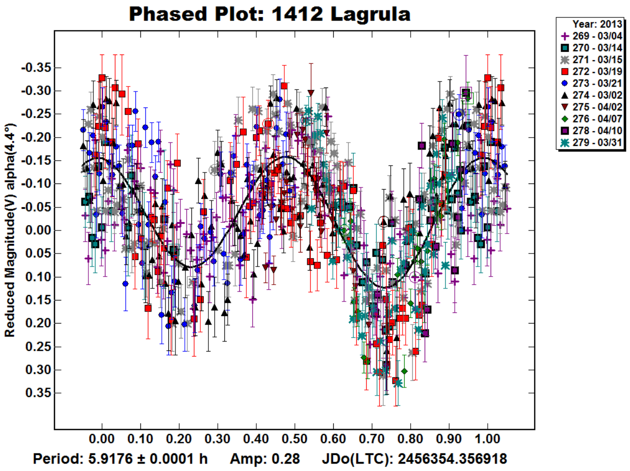

Figure 1. The lightcurve of 1412 Lagrula with a period of 5.9176 ± 0.0001 h and an amplitude of 0.28 ± 0.05 mag.

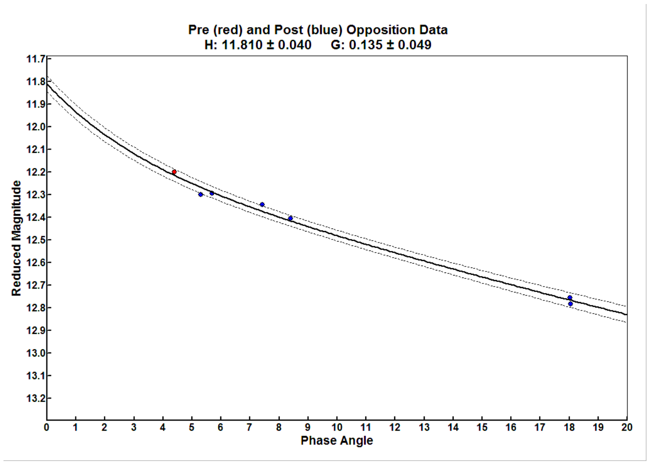

Figure 2. Visual reduced magnitude vs. phase angle for Hv = 11.810 ± 0.040 mag. and the slope parameter, G = 0.135 ± 0.049

ROTATION PERIOD DETERMINATIONS FOR 26 PROSERPINA, 31 EUPHROSYNE, AND 681 GORGO

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Synodic rotation periods and amplitudes have been found for 26 Proserpina 13.109 ± 0.001 hours, 0.20 ± 0.01 mag. and 31 Euphrosyne 5.5293 ± 0.0001 hours, 0.10 ± 0.01 mag. Both results for these low numbered objects are consistent with previous findings. A new result for 681 Gorgo is a period of 6.4606 ± 0.0001 hours, amplitude 0.42 ± 0.02 mag.

Observations to produce these determinations have been made at the Organ Mesa Observatory with a 35.4 cm Meade LX200 GPS S-C and SBIG STL 1001-E CCD. Photometric measurement and lightcurve construction are with *MPO Canopus* software. All exposures are 60 second exposure time, unguided, R filter for the bright objects 26 Proserpina and 31 Euphrosyne and clear filter for much fainter 681 Gorgo. To reduce the number of points on the lightcurves and make them easier to read data points have been binned in sets of 3 with maximum time difference 5 minutes.

26 Proserpina. Warner et al. (2013) state a period of 13.110 hours based on several independent and consistent determinations. New observations were obtained on six nights 2013 Mar. 10 - Apr. 30 to contribute to a lightcurve inversion model. These provide a good fit to a lightcurve phased to 13.109 ± 0.001 hours with amplitude 0.20 ± 0.01 magnitudes. This is fully consistent with previous determinations.

31 Euphrosyne. Warner et al. (2013) state a period of 5.530 hours based on several independent and consistent determinations. New observations were obtained on four nights 2013 Jan. 28 - Apr. 17 to contribute to a lightcurve inversion model. These provide a good fit to a lightcurve phased to 5.5293 ± 0.0001 hours, amplitude 0.10 ± 0.01 magnitudes. This is fully consistent with previous determinations.

681 Gorgo. Warner et al. (2013) list no previous period determinations. Observations on 4 nights 2013 Apr. 11 - May 7 provide a good fit to a lightcurve with period 6.4606 ± 0.0001 hours, amplitude 0.42 ± 0.02 magnitudes.

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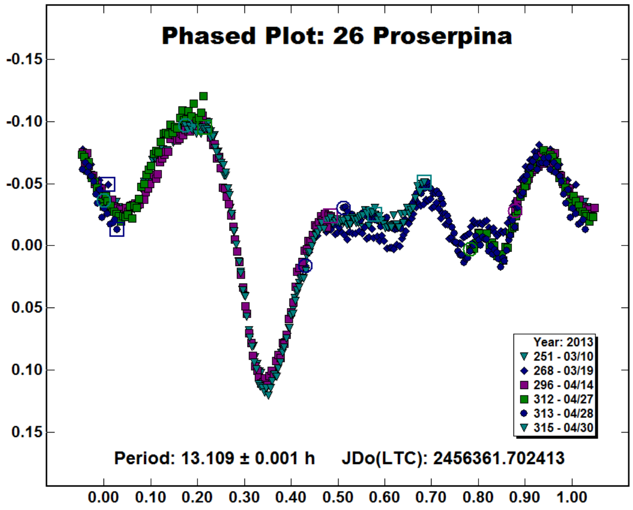

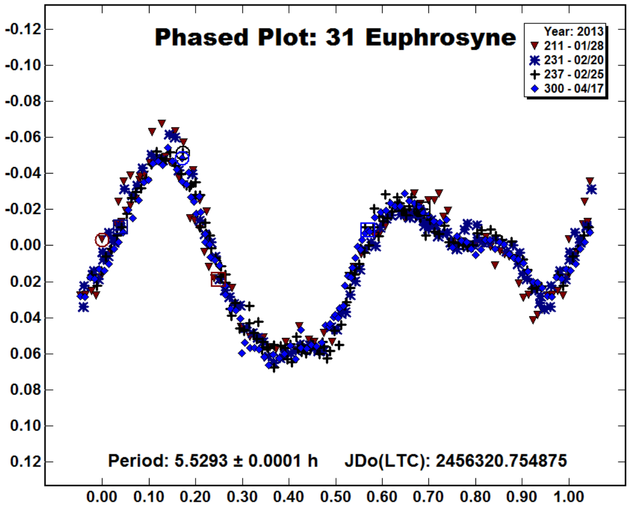

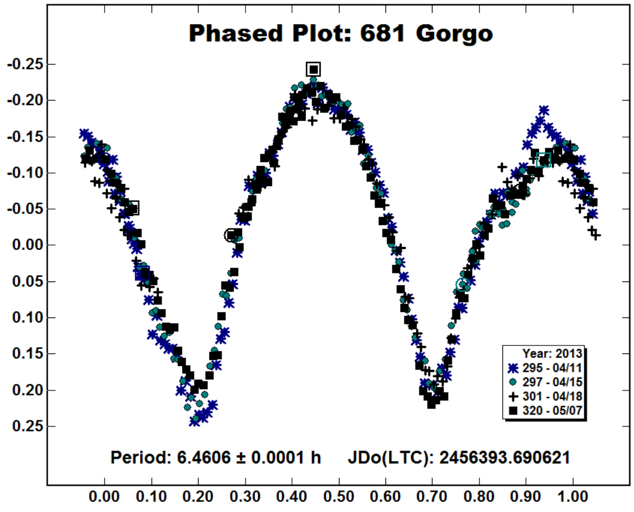

PERIOD DETERMINATION FOR 4527 SCHOENBERG

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The main-belt asteroid 4527 Schoenberg (1982 OK) has been observed between June 28 and July 1, 2012 at Maidanak astronomical observatory of the Ulugh Beg Astronomical Institute (UBAI), Uzbekistan Academy of Sciences. On the basis of data analysis it is found a synodic rotation period of 2.6928±0.0384 hour (0.1122±0.0016 day) and lightcurve amplitude of 0.31±0.05 mag.

4527 Schoenberg (1982 OK) was discovered at Anderson Mesa station on Jul 24, 1982 by E. Bowell and named after Austrian composer Arnold Schoenberg. This object is a main-belt asteroid with an orbital period of 3.35 years (MPC, 2013). However in the minor planet lightcurve database (LCDB; Warner *et al.*, 2009), there is no reference to it.

All observational data reported here were obtained using the Maidanak observatory's 60-cm Zeiss-600 telescope. Observations were carried out for period June 28 – July 1, 2012. We have used 1kx1k FLI IMG1001E CCD camera with resolution of 0.67 arcsec/pixel and FOV – 10.7' x 10.7' and Bessel R filter. The temperature of the camera was set at –30°C. Image acquisition was done with *MaxIm DL*. All images were reduced with master bias, dark, and flat frames. All calibration frames were created using *IRAF* (Image Reduction and Analysis Facility). And all instrumental star magnitudes were also obtained using *IRAF*. Asteroid's magnitudes have been corrected to 'unity distance' using by Mag(reduced)=Mag(observed)-5*log(rR), where r and R is geocentric distance and heliocentric distance to the asteroid and differential magnitudes were calculated using reference stars from the UCAC2 catalog.

LS periodogram (Scargle J.D., 1982) was used for period analysis of the photometric data. Analysis of the data provided a synodic rotation period of P = 2.6928±0.0384 h with an amplitude of 0.31 ± 0.05 mag.

Acknowledgements

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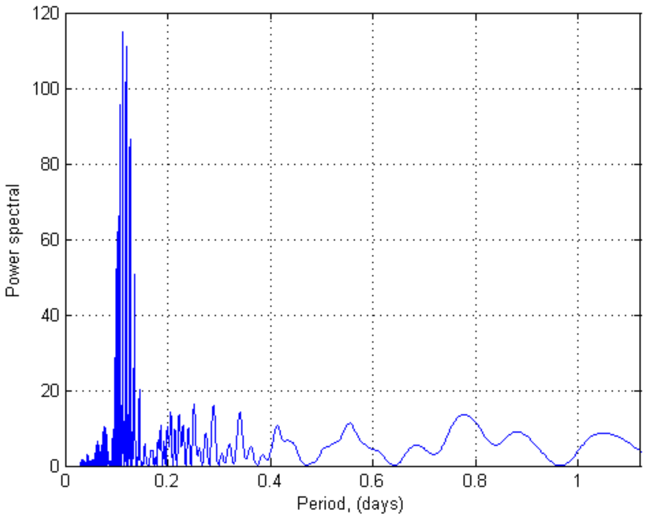

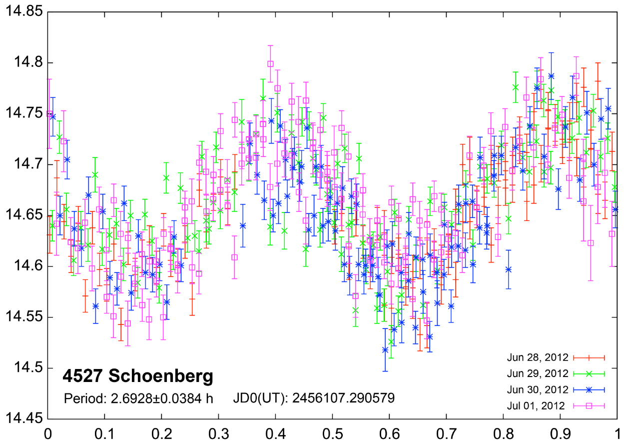

INVERSION MODEL CANDIDATES

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We present lightcurves for ten asteroids that were selected because they are potential candidates for lightcurve inversion modeling.

The observations of asteroid lightcurves were obtained at the Etscorn Campus Observatory (ECO, 2013). We used 3 Celestron 14-inch SCT telescopes on Software Bisque Parmount ME mounts (SB, 2013). Two of the telescopes used SBIG STL 1001E CCDs that have 1024 x 1024 24 micron pixels. The third C-14 used a SBIG ST10xme with an Optic 0.5x focal reducer. The ST10xme is binned 2x2 providing an image of 1092 by 736 13.6 micron pixels. The pixel size for the STL 1001E cameras is 1.25 arc seconds/pixel. This provides a 22 x 22 arc minute field of view. The ST10 XME pixel size is 1.28 arc seconds/pixel. This provides a 20 x 16 arc minute field of view. The asteroid images were obtained through either an R or clear filter. Exposure times varied between 3 and 5 minutes depending on the brightness of the object. Each evening a series of 11 dome flats were obtained and combined into a master flat with a median filter. The telescopes were controlled with Software Bisque's TheSky6 (SB, 2013) and the CCDs were controlled with CCDsoft V5 (SB, 2013). The images were dark subtracted and flat field corrected using image processing tools within MPO Canopus version 10.4.1.9 (BDW 2013). The multi-night data sets for each asteroid were combined with the FALC routine (Harris et. al., 1989) within Canopus to provide synodic periods for each asteroid.

Inversion Model Candidates

We have observed 10 asteroids suggested in the papers by Warner et. al. (2013a, 2013b) that would benefit from another lightcurve at a new set of solar phase angle bisectors. The results from the last 3 months worth of observations are given below. The information about discovery and designations were taken from the JPL Small-Body Database Browser (2013). The individual sessions for each lightcurve will be placed in the Minor planet Center lightcurve data base (ALCDEF, 2013).

158 Koronis is a main-belt asteroid discovered by V. Knorre at Berlin on 1876 Jan 04. It is also known as 1955 HA1, A893 PA and A911 HB. It was observed on 8 nights between 2013 Apr 15 and 2013 May 03. We obtained a synodic period of 14.206 ± 0.002 h and an amplitude of 0.31 ± 0.03 mag. According to the lightcurve database several observers have reported periods ranging between 14.18 and 14.218 hours (LCDB, 2013). Our synodic period is in agreement with the work of Slivan et.al. (2003).

461 Saskia is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1900 Oct 22. It is also known as 1900 FP, 1955 CT, A917 XE and A924 DB. It was observed on 10 nights between 2013 Apr 24 and 2013 May 30. We obtained a synodic period of 7.348 ± 0.001 h with an amplitude of 0.26 ± 0.05 mag. Others have obtained synodic periods of 7.34 h (Buchheim, 2006) and 7.349 h (Behrend 2007).

604 Tekmessa is a main-belt asteroid discovered by J. H. Metcalf at Traunton on 1906 Feb 16. It is also known as 1906 TK, A894 BA, A911 BC and A915 WG. It was observed on 6 nights between 2013 May 08 and 2013 May 26. We obtained a synodic period of 5.560 ± 0.001 h with an amplitude of 0.49 ± 0.05 mag. Others have obtained synodic periods of 5.55959 h (Behrend, 2006) and 5.5596 h (Baker et. al., 2011).

966 Muschi is a main-belt asteroid discovered by W. Baade at Bergedorf on 1921 Nov 09. It is also known as 1921 KU. It was observed on 7 nights between 2013 Apr 16 and 2013 Jun 03. We obtained a synodic period of 5.348 ± 0.0001 h with an amplitude of 0.44 ± 0.05 mag. Others have obtained synodic periods of 5.355 h (Stephens, 2004), 5.35531 h (Durech, 2009), 5.3558 h (Behrend, 2009)

1378 Leonce is a main-belt asteroid discovered by F. Rigaux at Uccle on 1936 Feb 21. It is also known as 1936 DB, 1958 FG, 1962 KB, A915 RC and A915 WA. It was observed on 6 nights between 2013 Apr 28 and 2013 May 12. We obtained a synodic period of 4.325 ± 0.001 h with an amplitude of 0.63 ± 0.05 mag. Others (Behrend, 2002 and 2007) have obtained synodic periods of 4.3250 h and 4.3586 h.

1396 Outeniqua is a main-belt asteroid discovered by C. Jackson at Johannesburg on 1936 Aug 09. It is also known as 1936 PF, 1930 XV, 1933 SL, 1949 HG1, 1950 TO2, !957 WE1, 1977 TB4 and A912 HF. It was observed on 3 nights between 2013 Apr 20 and 2013 Apr 28. We obtained a synodic period of 3.082 ± 0.001 h with an amplitude of 0.47 ± 0.05 mag. Others have obtained synodic periods of 3.081 h (Warner, 2006) and 3.08158 h (Behrend, 2006).

1860 Barbarossa is a main-belt asteroid discovered by P. Wild at Zimmerwald on 1973 Sep 28. It is also known as 1973 SK, 1935 GG, 1943 FD, 1948 PE1, 1948 QE, 1951 EA2, 1952 OC1, 1960 MA, 1971 BM1, 1972 JO and A911 QA. It was observed on 6 nights between 2013 May 07 and 2013 May 26. We obtained a synodic period of 3.255 ± 0.001 h with an amplitude of 0.35 ± 0.05 mag. Others have obtained synodic periods of 3.255 h (Di Martino, 1994) and 3.254 h (Behrend, 2005).

2276 Warck is a main-belt asteroid discovered by by E. Delporte at Uccle on 1933 Aug 18. It is also known as 1933 QA, 1948 TY, 1951 MB and 1977 RK3. It was observed on 7 nights between 2013 May 07 and 2013 Jun 04. We obtained a synodic period of 4.435 ± 0.001 h with an amplitude of 0.25 ± 0.10 mag. Rene Roy obtained a period of 4.054 (Behrend, 2002).

2911 Miahelena is a main-belt asteroid discovered by H. Akikoski at Turku on 1938 Apr 08. It is also known as 1938 GJ, 1928 DL, 1952 HQ1, 1952 HZ1, 1971 HK, 1975 EF2 and 1977 TE6. It was observed on 5 nights between 2013 May 19 and 2013 Jun 04. The sessions (32 and 37) done on the UT night of 2013 May 19 were done with two different telescopes and CCDs. The lightcurves overlap perfectly. We obtained a synodic period of 4.202 ± 0.001 h with an amplitude of 0.62 ± 0.05 mag. Brinsfield (2008) obtained synodic period of 4.19 h.

3332 Raksha is a main-bet asteroid discovered by L. Chernykh on 1978 Jul 04. It is also known as 1978 NT1, 1936 FT, 1950 TC4, 1952 CB, 1962 TH, 1970 PP, 1974 OR and 1878 RF1. We observed it for 6 nights from 2013 Apr 16 through 2013 May 23. We obtained a period of 4.806 ± 0.002 h and an amplitude of 0.36 ± 0.07 mag. It has been observed by P. Antonini who obtained a period of 4.806456 ± 0.0006 h. (Behrend, 2009). Our period of 4.806 ± 0.002 h is in good agreement. Our amplitude of 0.36 ± 0.07 mag. is slightly larger than Antonini's value of 0.31 mag.

In order to compare our results with other epochs of observation, the table below lists the solar phase angle bisectors PABL and PABB for the observations presented in this paper.

asteroid	dates (2013)	PABL	PABB
158 Koronas	04/15-05/03	194	-1.2
461 Saskia	04/24-05/30	230	1.7
604 Tekmessa	05/08-05/26	190	-0.4
966 Muschi	04/16-06/03	185	16.2
1378 Leonce	04/28-05/12	201	1.4
1396 Outeniqua	04/20-04/28	189	-1.9
1860 Barbarossa	05/07-05/26	197	12.0
2276 Warck	05/07-06/04	219	0.6
2911 Miahelena	05/19-06/04	231	12.6
3332 Raksha	04/16-05/23	154	7.7

Acknowledgements

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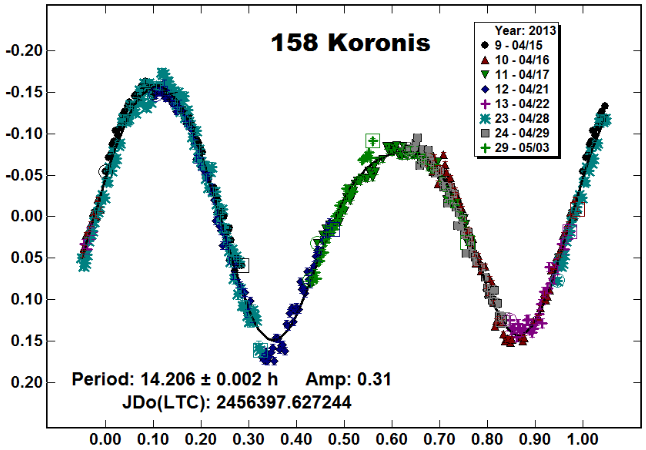

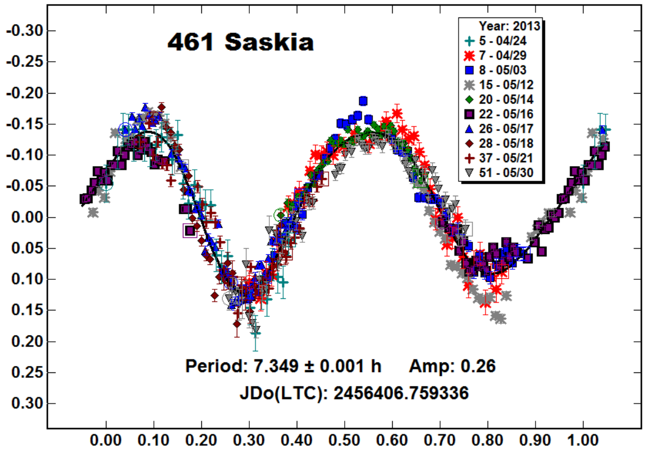

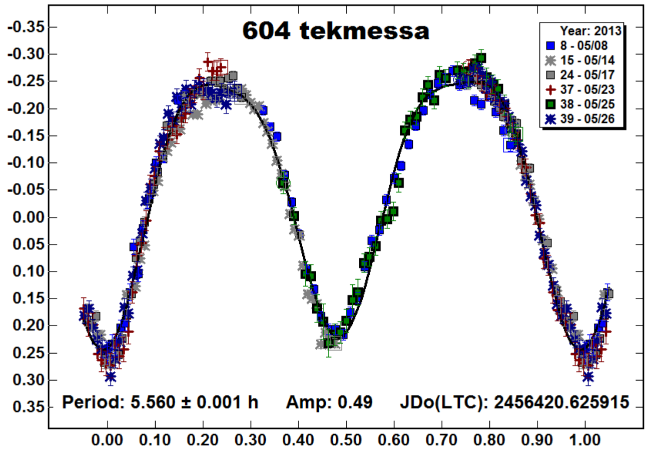

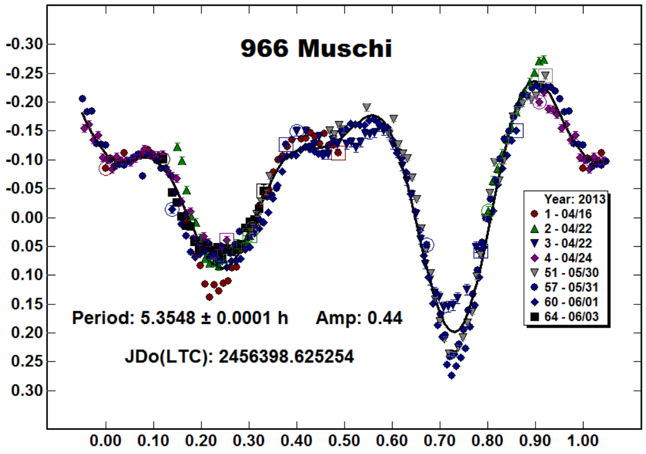

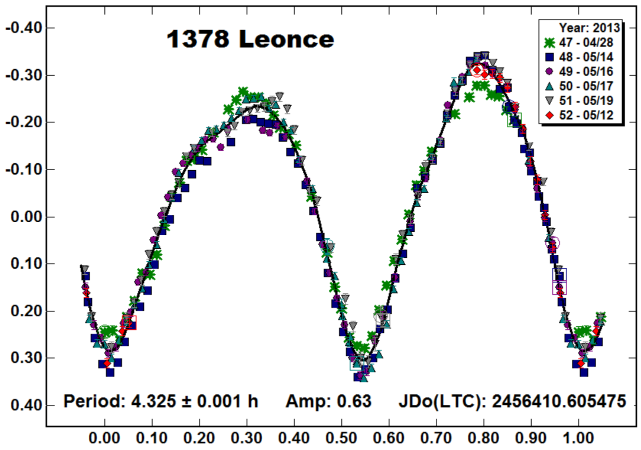
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49 - 05/16
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52 - 05/12
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-0.30
-0.20
-0.10
0.00
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0.30
0.40
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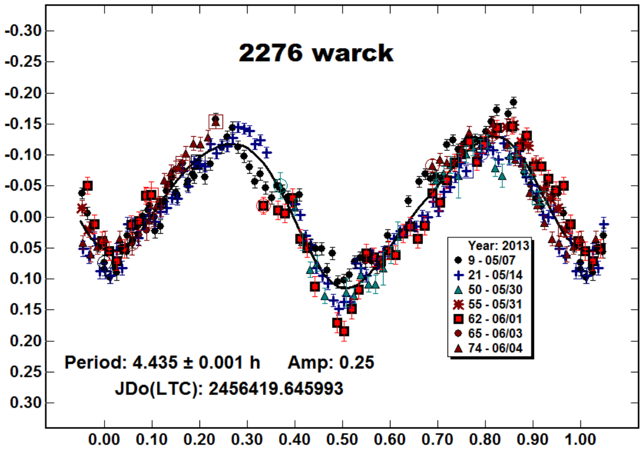
2276 warck
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9 - 05/07
21 - 05/14
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0.30
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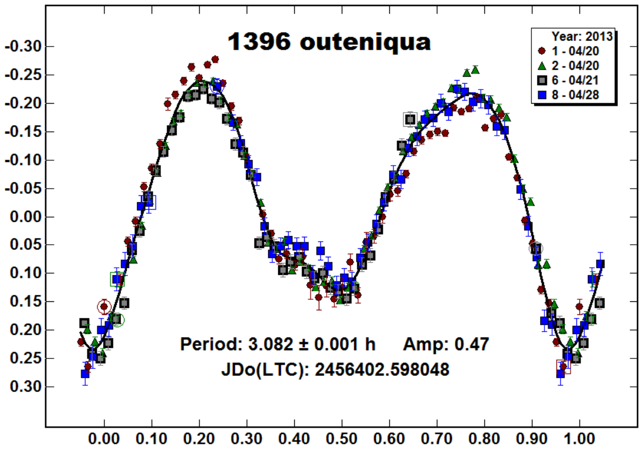
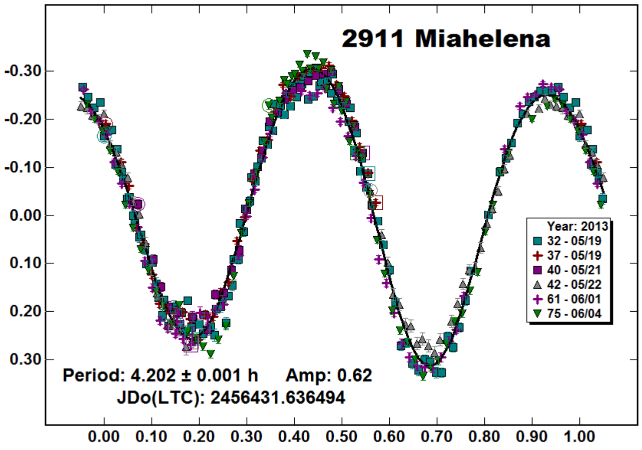
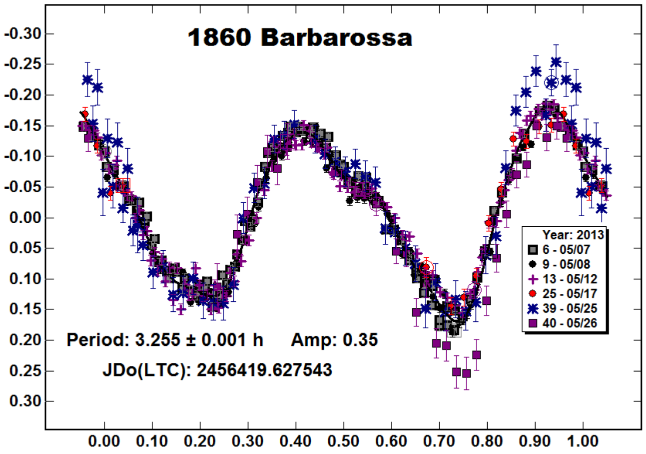
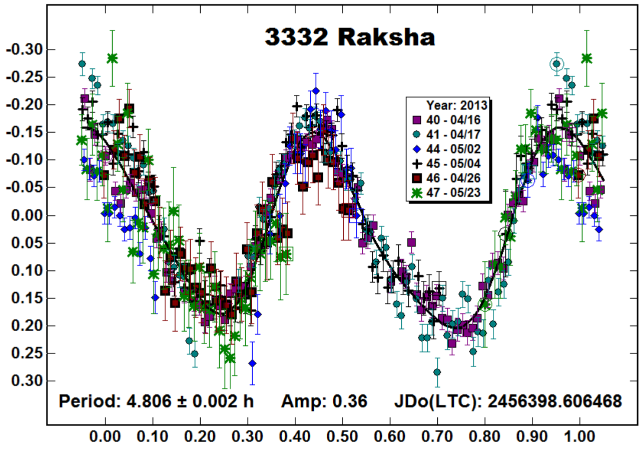

1396 outeniqua
Year: 2013
1 - 04/20
2 - 04/20
6 - 04/21
8 - 04/28
Period: 3.082 ± 0.001 h Amp: 0.47
JDo(LTC): 2456402.598048
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


2911 Miahelena
Year: 2013
32 - 05/19
37 - 05/19
40 - 05/21
42 - 05/22
61 - 06/01
75 - 06/04
Period: 4.202 ± 0.001 h Amp: 0.62
JDo(LTC): 2456431.636494
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


1860 Barbarossa
Year: 2013
6 - 05/07
9 - 05/08
13 - 05/12
25 - 05/17
39 - 05/25
40 - 05/26
Period: 3.255 ± 0.001 h Amp: 0.35
JDo(LTC): 2456419.627543
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


3332 Raksha
Year: 2013
40 - 04/16
41 - 04/17
44 - 05/02
45 - 05/04
46 - 04/26
47 - 05/23
Period: 4.806 ± 0.002 h Amp: 0.36 JDo(LTC): 2456398.606468
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

ROTATIONAL PERIOD OF ASTEROID 6479 LEOCONNOLLY

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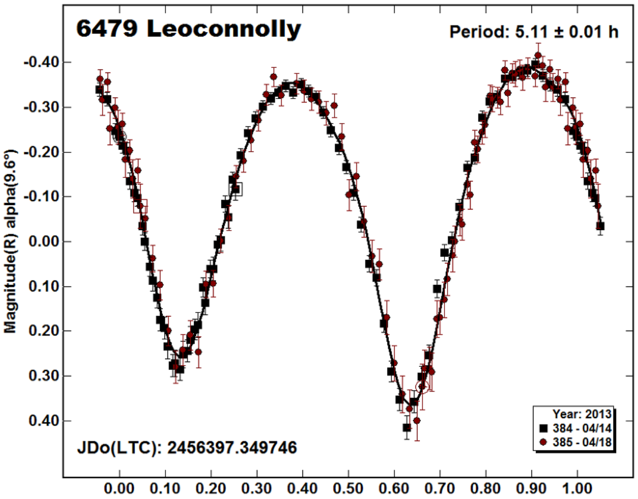
(Received: 16 June)

Photometric observations of the main-belt asteroid 6479 Leoconnolly were made over two nights in 2013 April. Lightcurve analysis shows a synodic period of 5.11 ± 0.01 h with an amplitude of 0.75 ± 0.03 mag.

The main-belt asteroid 6479 Leoconnolly was selected from the "Potential Lightcurve Targets" web site (Warner, 2012a). Observations on two 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 a 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, 2012b).

The derived synodic period was P = 5.11 ± 0.01 h with an amplitude of A = 0.75 ± 0.03 mag.



The lightcurve of 6479 Leoconnolly with a period of 5.11 ± 0.01 h and an amplitude of 0.75 ± 0.03 mag.

References

Warner, B.D. (2012a). "Potential Lightcurve Targets." *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*

Warner, B.D. (2012b). MPO Software, *MPO Canopus* version 10.4.1.9. Bdw Publishing. *http://minorplanetobserver.com/*

ROTATION PERIOD DETERMINATION FOR 730 ATHANASIA

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(Received: 16 June Revised: 15 July)

The synodic rotation period and amplitude have been found for 730 Athanasia 5.7345 ± 0.0002 hours, 0.14 ± 0.02 magnitudes, with a slightly unsymmetrical bimodal lightcurve. The period spectrum between 2.5 hours and 12.5 hours is presented, and the plausibility of all local minima in the period spectrum as potential alias periods is investigated.

Observations to produce these determinations have been made at the Organ Mesa Observatory with a 35.4 cm Meade LX200 GPS S-C and SBIG STL 1001-E CCD, unguided, clear filter, 60 second exposures. Photometric measurement and lightcurve construction are with *MPO Canopus* software. To reduce the number of points on the lightcurves and make them easier to read data points have been binned in sets of 3 with maximum time difference 5 minutes.

Warner et al. (2013) state no previous observations of 730 Athanasia. At its 2013 June opposition this object was very faint, about V magnitude 15.3, but much brighter than at any time for the next 10 years. Its observation was therefore accorded high priority by the author. For an object this faint the lightcurves are necessarily noisy. For a very faint object in a moderately dense Milky Way star field contamination of the measuring aperture by background stars is a problem. Star subtraction routines were used for measuring all sessions. However for stars of brightness comparable to that of the asteroid star subtraction may not be complete. Significant upward bumps of a time duration comparable to that required for the target measuring aperture to cross a star were found in several cases. A search of the original images showed that at the corresponding times the target did pass close to stars. The affected data points were deleted from the data set. Also there may have been stars too faint to be apparent in visual inspection of the images, and therefore which were not included in the star subtraction routine. These would also produce upward bumps in the lightcurve. However, no bumps are clearly apparent.

Observations were obtained on 10 nights 2013 May 9 - June 12. Data from these provide a good fit to a slightly asymmetric bimodal lightcurve phased to period 5.7345 ± 0.0002 hours, amplitude 0.14 ± 0.02 magnitudes. Several small clusters of discordant data points appear, but these do not show any systematic trend. They are a consequence of the low SN ratio of data for a very faint object, with possible contributions from very faint field stars.

For a difficult target a careful search for possible alias periods should be made. A period spectrum between 2.5 hours and 12.5 hours, including the half period and double period to the suggested 5.7345 hour solution, is shown. It contains many local minima, each of which was carefully examined. All of those except the half period, 3/2 period, and double period contain misfits sufficient to rule them out. Lightcurves phased to 5.7345 hours and 8.6016 hours are presented, which show two and three maxima and minima per cycle, respectively. The lightcurve of the most likely period, 5.7345 hours, is a slightly asymmetric bimodal one. If the two halves were nearly identical this would be strong evidence in favor of the half period. The lightcurve is noisier due to the faintness of the target than for a typical medium amplitude lightcurve for a brighter target. And the symmetry is greater than in many asteroid lightcurves for which the bimodal solution is considered secure. Each of the ten sessions covered most of the bimodal lightcurve; so there is multiple coverage of all phases. The overall trend shows sufficient asymmetry that the half period seems highly unlikely. And the scatter in the half period, 2.8672 hours, lightcurve is significantly greater than for the bimodal lightcurve

The two halves of the quadrimodal lightcurve for the double period at 11.469 hours are nearly identical. This rotation period requires a shape model irregular but also symmetric over a 180 degree rotation. The probability of such a shape model for a real asteroid is not exactly zero, but is extremely small and may be reasonably rejected. The double period lightcurve shows that adjacent maxima have different heights but alternate maxima have the same height. This provides further evidence against the half period with only one maximum and minimum per cycle, in which case all maxima in the double period lightcurve would have the same height.

The lightcurve phased to 8.6016 hours contains three maxima and minima with a noise level only very slightly greater than that in the bimodal lightcurve. Two of the maxima are nearly identical and would require a possible but very unlikely shape model symmetrical over a 120 degree rotation to represent the actual period.

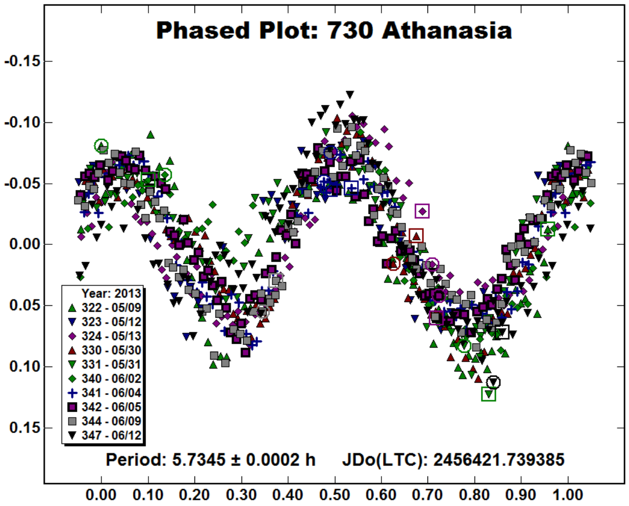
The noise in the data for this very faint object has been significantly compensated by the large number of data points and multiple coverage of all phases. This improves the reliability of the most likely period of 5.7345 hours.

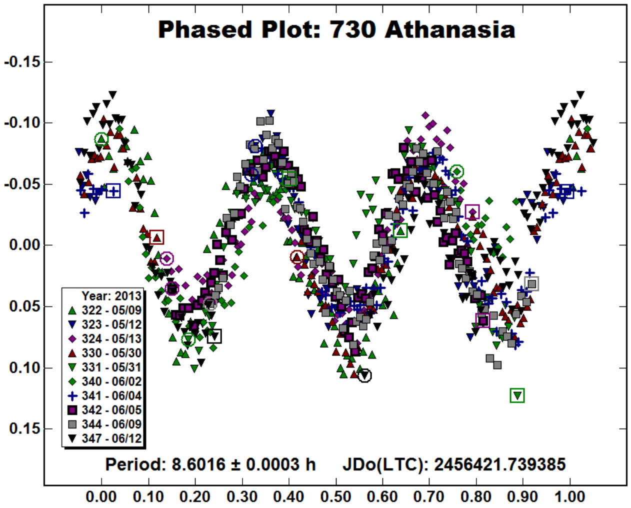
Acknowledgment

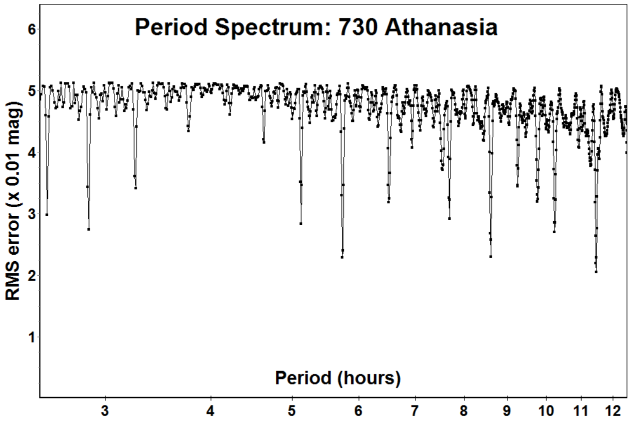
The author thanks Alan W. Harris for several helpful suggestions that greatly improved this paper.

Reference:

Warner, B.D., Harris, A.W., and Pravec, P., "Asteroid Lightcurve Data Files, Revised 2013 March 1." *http://www.minorplanet.info/lightcurvedatabase.html*







LIGHTCURVE FOR (152756) 1999 JV3

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(Received: 25 June)

CCD photometric observations of the Apollo asteroid (152756) 1999 JV3 were obtained from Lowell Observatory in May 2013. A synodic period of 2.845 ± 0.001 h with an amplitude of 0.32 ± 0.02 was found.

Observations of (152756) 1999 JV3 were requested by Lance Benner because it was a target of the radar program at Arecibo and Goldstone (private communication). No previous periods are reported in the Lightcurve Database (Warner 2012).

Observations at Lowell Observatory (MPC 688) were made using the 42-inch (1.05-m) Hall telescope. All images were unbinned and R filters were used. Data and period analysis was done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989).

The phase angle over the short observing run ranged from 34 to 43 degrees and the average phase angle bisector Longitude (L_{PAB}) was 254.

Acknowledgements

French and Stephens were visiting astronomers at Lowell Observatory. This research was supported by National Science Foundation grant AST-1212115.

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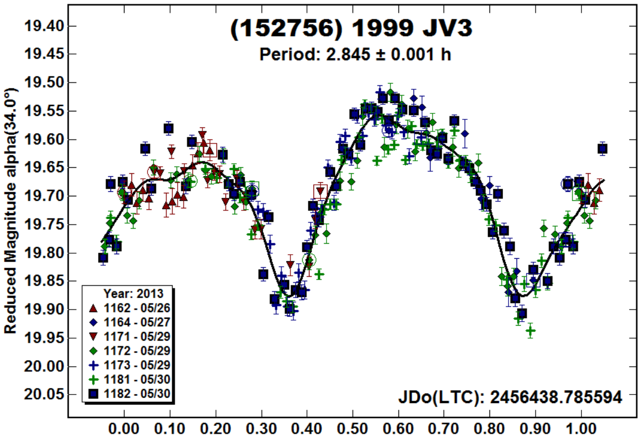
Harris, A.W., Young, J.W., Bowell, E., Martin, L. J., Millis, R. L., Poutanen, M., Scaltriti, F., Zappala, V., Schober, H. J., Debehogne, H, and Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* 77, 171-186.

Warner, B.D. (2012). The Asteroid Lightcurve Database (LCDB) website. *http://www.minorplanet.info/lightcurvedatabase.html*.



ROTATION PERIOD DETERMINATION FOR 498 TOKIO

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(Received: 6 June)

For 498 Tokio a synodic rotation period of 41.85 ± 0.01 hours and amplitude 0.23 ± 0.02 magnitude have been found with CCD photometry.

Observations by Pilcher were made at the Organ Mesa Observatory with a Meade 35 cm LX200 GPS S-C, SBIG STL-1001E CCD, clear filter, unguided exposures, MPOSC3 and APASS calibration magnitudes. Martinez used a Celestron CPC 1100 28 cm Schmidt Cassegrain, SBIG ST8XME CCD, clear filter, differential photometry only.

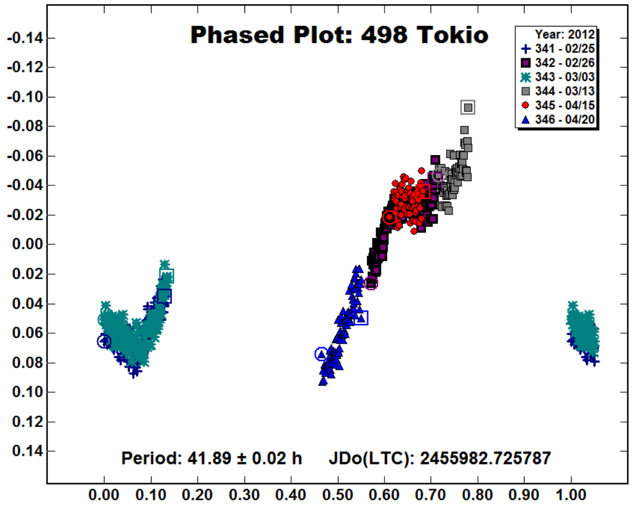
MPO Canopus software was used by both observers to measure the images photometrically, share data, adjust instrumental magnitudes up or down to produce the best fit, and prepare the lightcurves. Due to the large number of data points acquired the lightcurves have been binned in sets of three data points with a maximum of five minutes between points.

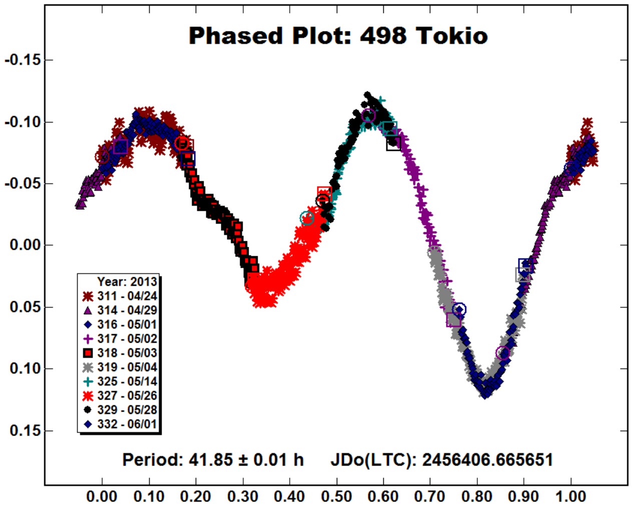
Earlier period determinations are by Gil-Hutton (1995), 30 hours; and by Behrend (2012), 24.82 hours; both based on fragmentary lightcurves. Author Martinez obtained sessions on 6 nights 2012 Feb. 25 - Apr. 20, but was unable to find a period from these data. Author Pilcher inspected these data and also was unable to find a period. At the next opposition author Pilcher obtained data on ten nights 2013 Apr. 24 - June 1. These revealed a period much longer than those for which the 2012 data were searched and provided a good fit with full phase coverage to a lightcurve phased to 41.85 ± 0.01 hours, amplitude 0.23 ± 0.02 magnitudes, and an unsymmetrical bimodal lightcurve. With this well defined period the 2012 data were reexamined. Within a trial period range from 37 to 47 hours the instrumental magnitudes were adjusted until a best fit (minimum Fourier residual) was obtained at 41.89 ± 0.02 hours with about 50% phase coverage. Although this is not a completely independent determination, its consistency with the period of 41.85 ± 0.01 hours found from the 2013 data, rather than perhaps a period up to 5 hours different, improves the confidence of the solution.

References

Behrend, R. (2012). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Gil-Hutton, R. (1995). "Photoelectric Photometry of Asteroids 184 Dejopeja, 498 Tokio, and 690 Wratislavia." *Rev. Mexicana Astron. Astrof.* **31**, 19-21.





ROTATIONAL PERIOD OF ASTEROID 2050 FRANCIS

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(Received: 17 June)

Photometric observations of the main-belt asteroid 2050 Francis were made over three nights during 2013 May and June. Analysis shows a synodic period of 3.069 ± 0.001 h with an amplitude 0.20 ± 0.03 mag.

The main-belt asteroid 2050 Francis was selected from the "Potential Lightcurve Targets" web site (Warner, 2012a). Observations on three nights were carried out from Balzaretto Observatory (A81) in Rome (Italy) using a 0.20-m Schmidt-Cassegrain (SCT) reduced to *f*/5.5 equipped with a SBIG ST7-XME CCD camera, and from F. Fuligni Observatory (D06), near Rome (Italy), using a 0.35-m *f*/10 Meade Advanced Coma Free (ACF) telescope and SBIG ST8-XE CCD camera with Bessel R filter. All images were calibrated with dark and flat-field frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012b).

The derived synodic period was $P = 3.069 \pm 0.001$ h (Fig.1) with an amplitude of $A = 0.20 \pm 0.03$ mag.

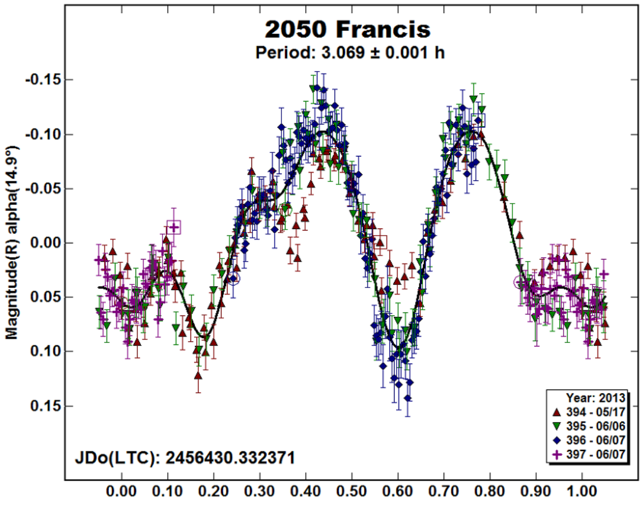

Figure 1. The lightcurve of 2050 Francis with a period of 3.069 ± 0.001 h and an amplitude of 0.20 ± 0.03 mag.

References

Warner, B.D. (2012a). "Potential Lightcurve Targets." *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*

Warner, B.D. (2012b). MPO Software, *MPO Canopus* version 10.4.1.9. Bdw Publishing, *http://minorplanetobserver.com/*

A TROOP OF TROJANS: PHOTOMETRY OF 24 JOVIAN TROJAN ASTEROIDS

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(Received: 20 June)

Lightcurves for 24 Jupiter Trojan asteroids were obtained from Cerro Tololo Inter-American Observatory, Lowell Observatory and the Center for Solar System Studies from September 2012 to May 2013.

The Jovian Trojan asteroids are found in orbits near the stable L4 and L5 Langrange points of Jupiter's orbit. They formed further from the Sun than main-belt asteroids and their composition and collisional history appears to be different. As of 2012 15 April, 3402 had been found in the L4 (preceding) region and 1758 in the L5 region. As yet, the rotation properties of Trojan asteroids are poorly known relative to those of main-belt asteroids, due to the lower albedo and greater distance of the Trojans. Here we report lightcurve data for 24 Trojans. Most are in the 50 – 100 km diameter size range.

Observations at the Center for Solar System Studies (CS3) were made by Stephens and Coley with three telescopes, either 0.4-m or 0.35-m SCTs, two using a SBIG STL-1001E CCD Cameras and the other using a SBIG ST-9e CCD camera. All images were unbinned with no filter. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989).

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

Observations at Lowell Observatory (MPC 688) were made using either the 0.8-m or the Perkins 1.8-m telescopes. All images taken at Lowell were unbinned; V and R filters were used. Data and period analysis was done using *MPO Canopus*.

The results are summarized in Table I. 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) or using the APASS (AAVSO Photometric All-Sky Survey Release 7). Diameters (Dia) are from the WISE/NEOWISE database (Grav 2012).

With the exception of 5285 Krethon, these targets were selected because they had no previously published rotational results.

2146 Stentor. With an amplitude less than 0.1 mag., the lightcurve is not necessarily bimodal. Monomodal or three or more extrema lightcurves cannot be ruled out.

3391 Sinon. 21 February was observed at CS3. All of the other nights were observed at Lowell using the 31-inch.

4902 Thessandrus. It was clear from early in the observing run that this was the longest period Jovian Trojan yet found. With a rotational period of about a month, it has a high probability of tumbling since the dampening time will exceed the age of the solar system (Pravec 2005). The object was followed for almost two months and the second rotation was markedly different than the first rotation. Petr Pravec (private communication) looked at the data and reported a fit for two periods of 738 h and 510 h, with uncertainties of about 20 hours.

5285 Krethon. Observations were acquired at CS3. Duffard *et al.* (2008) reported a period of 20.84 h. The website containing the lightcurve is no longer available. Our observations could not be phased to the 20.84 h period. Aliases of 16 h and 24 h are not viable solutions.

5436 Eumelos. 27-28 February and 01 March were observed at Lowell using the 0.8-m. Observations were then continued at CS3 after the Lowell observing run was over.

7152 Euneus. Observations were obtained on three consecutive nights and the amplitude did not vary more than 0.01 mag. A period cannot be determined at this opposition and the asteroid should be re-observed at a future opposition.

8125 Tyndareus. Observations over three consecutive nights did not vary more than 0.05 mag. in amplitude. Since observations started very late in the Trojan season, there were not enough available nights to determine a rotational period if it were extremely long.

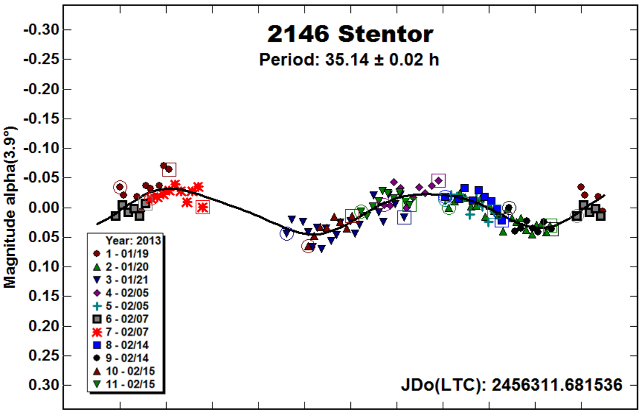
(11351) 1997 TS25. This asteroid has an extremely long rotational period. Despite its size suggesting the damping time is similar to the age of the solar system, no evidence of tumbling was found outside of the catalog star error bars.

13229 Echion. Observations on 06 March were obtained using the 72-inch Perkins telescope at Lowell. The rest of the observing run was lost to a winter storm, so observations were completed at CS3 using the 0.4-m telescope.

(24451) 2000 QS104. Initial observations were obtained at CTIO. When sufficient observations were not obtained to determine a period, they were completed at CS3.

Name	Dates	Obs.	Obs.	Pts	Dia	Phase	L_{PAB}	B_{PAB}	Per.	P.E.	Amp.	AE
2146 Stentor	01/19 – 02/16/13	RDS DRC	CS3	578	51	3.9, 1.0, 2.5	137	5	35.14	0.02	0.08	0.02
3391 Sinon	02/21 – 02/28/13	RDS LMF LHW	LWLL CS3	208	38	2.5, 3.9	142	5	8.14	0.01	0.72	0.03
4068 Menestheus	01/05 – 01/18/13	RDS	CS3	382	68	4.6, 3.9	116	-18	14.341	0.001	0.40	0.03
4501 Eurypylos	03/17 – 4/01/13	RDS	CS3	156	46	4.2, 6.8	158	-9	6.054	0.001	0.24	0.02
4902 Thessandrus	01/21 – 03/16/13	RDS	CS3	1645	51	3.0, 1.3, 8.1	134	-6	738	10	Tumb	
5041 Theotes	03/14 – 03/18/13	DRC	CS3	106		4.4, 5.1	155	9	6.52	0.01	0.35	0.03
5123 1989 BL	02/17 – 02/18/13	RDS	CS3	168	42	4.0, 4.2	132	8	9.88	0.01	0.40	0.02
5284 Orsilocus	02/10 – 02/13/13	RDS	CS3	264	50	3.1, 3.2	141	15	10.31	0.01	0.12	0.02
5285 Krethon	03/04 – 03/22/13	RDS	CS3	210	50	1.9, 4.3	163	10	12.04	0.01	0.46	0.03
5436 Eumelos	02/27 – 03/14/13	RDS LMF LHW	CS3 LWLL	375	38	5.1, 7.9	136	-8	38.41	0.02	0.68	0.03
6545 1986 TR6	03/17 – 3/31/13	RDS	CS3	166	51	4.8, 7.1	156	-12	16.26	0.01	0.31	0.03
7152 Euneus	01/20 – 01/22/13	RDS	CS3	208	40	3.5, 3.1	135	2	Undet			
8125 Tyndareus	04/01 – 04/03/13	RDS	CS3	97	27	5.9, 6.2	162	-5	Undet		<.05	
11351 1997 TS25	03/29 – 5/01/13	DRC	CS3	326	34	4.8, 9.1	167	-12	513.7	1.3	0.53	0.1
12052 Aretaon	09/08 – 09/19/12	RDS	CS3	161	39	2.6, 4.1	341	11	8.05	0.01	0.17	0.02
13229 Echion	03/06 – 03/13/13	LMF FV DRC	CS3 Lwll	204		2.4, 3.9	155	0	8.46	0.01	0.33	0.04
15436 1998 VU30	02/26 – 02/28/13	RDS	CS3	156	88	5.4, 5.7	136	-16	8.97	0.01	0.29	0.03
15440 1998 WX4	01/05 – 01/19/13	RDS	CS3	321	63	5.2, 2.6	131	5	Undet			
15502 1999 NV27	9/20 - 9/22/12	LMF DLR RDS	CTIO	90	53	3.9, 4.2	342	11	15.03	0.03	0.10	0.01
15535 2000 AT177	03/01 – 03/02/13	RDS	CS3	115	40	2.0, 2.2	152	-1	6.01	0.01	0.26	0.03
18046 1999 RN116	09/08 – 11/03/12	RDS	CS3	181	43	1.9, 9.3	352	-6	36.00	0.03	0.13	0.02
19020 2000 SC6	09/16 – 09/21/12	LMF DLR RDS	CTIO	141	43	5.3, 4.9	7	-19	9.82	0.01	0.43	0.02
21601 1998 XO89	04/04 – 04/12/13	RDS	CS3	256	55	6.1, 7.1	174	-22	12.65	0.01	0.30	0.02
24451 2000 QS104	9/20 – 11/04/12	RDS LMF DLR	CTIO CS3	225	41	3.2, 2.3, 7.9	5	-9	40.68	0.04	0.03	0.01

Table I: Observing results.


2146 Stentor
Period: 35.14 ± 0.02 h
Magnitude alpha(3.9°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2013
1 - 01/19
2 - 01/20
3 - 01/21
4 - 02/05
5 - 02/05
6 - 02/07
7 - 02/07
8 - 02/14
9 - 02/14
10 - 02/15
11 - 02/15
JDo(LTC): 2456311.681536
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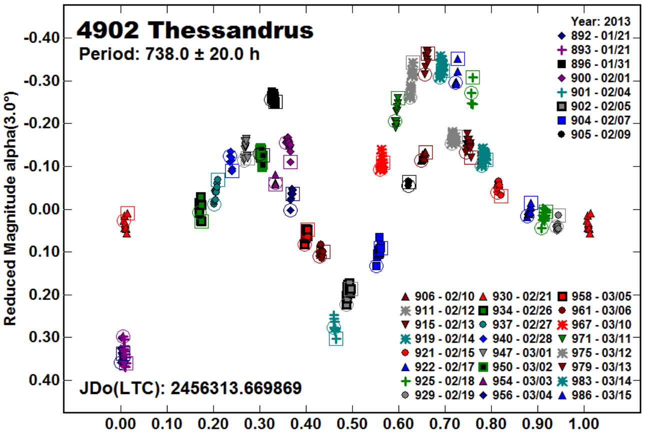
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


4902 Thessandrus
Period: 738.0 ± 20.0 h
Reduced Magnitude alpha(3.0°)
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
Year: 2013
892 - 01/21
893 - 01/21
896 - 01/31
900 - 02/01
901 - 02/04
902 - 02/05
904 - 02/07
905 - 02/09
906 - 02/10
911 - 02/12
915 - 02/13
919 - 02/14
921 - 02/15
922 - 02/17
925 - 02/18
929 - 02/19
930 - 02/21
934 - 02/26
937 - 02/27
940 - 02/28
947 - 03/01
950 - 03/02
954 - 03/03
956 - 03/04
958 - 03/05
961 - 03/06
967 - 03/10
971 - 03/11
975 - 03/12
979 - 03/13
983 - 03/14
986 - 03/15
JDo(LTC): 2456313.669869
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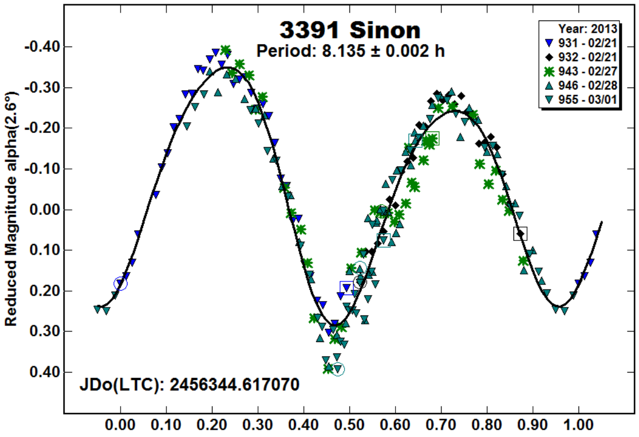
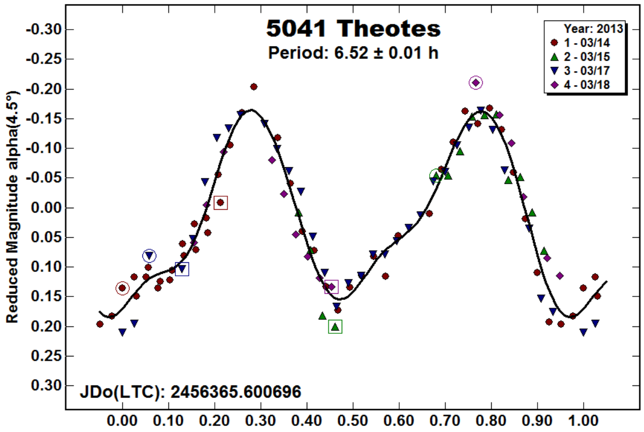
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


3391 Sinon
Period: 8.135 ± 0.002 h
Reduced Magnitude alpha(2.6°)
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
Year: 2013
931 - 02/21
932 - 02/21
943 - 02/27
946 - 02/28
955 - 03/01
JDo(LTC): 2456344.617070
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


5041 Theotes
Period: 6.52 ± 0.01 h
Reduced Magnitude alpha(4.5°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2013
1 - 03/14
2 - 03/15
3 - 03/17
4 - 03/18
JDo(LTC): 2456365.600696
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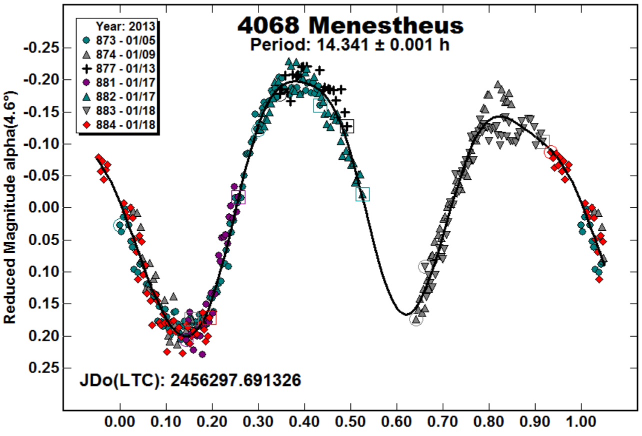
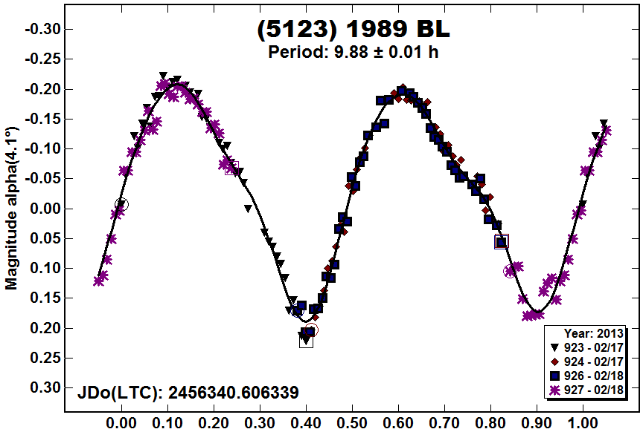
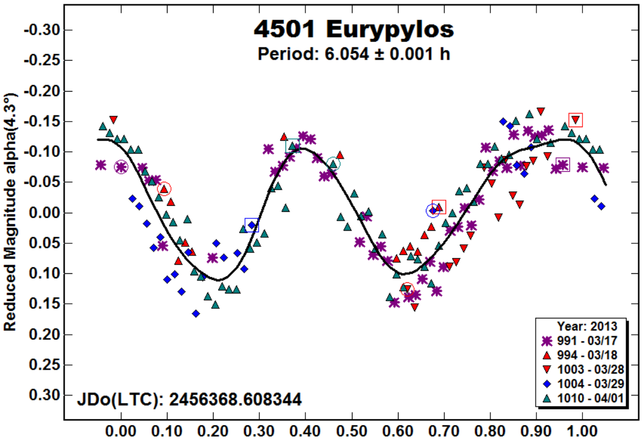
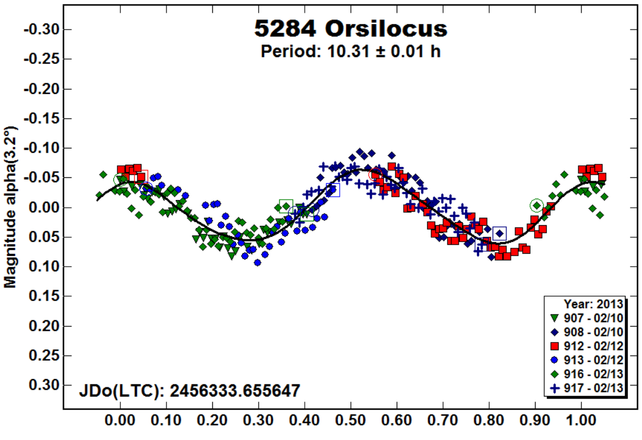
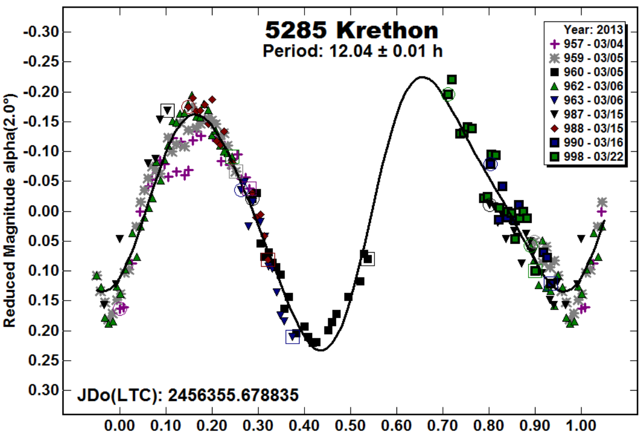
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

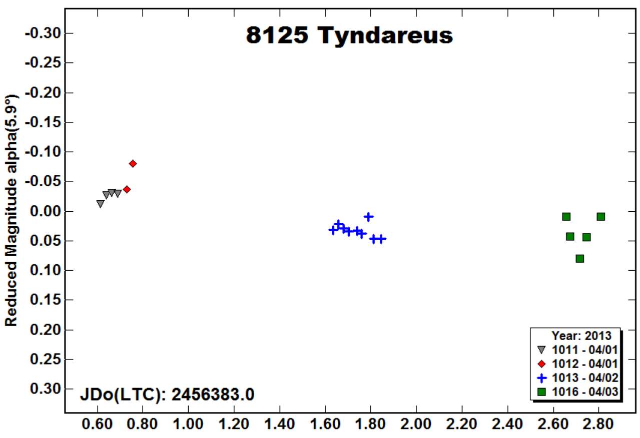

4068 Menestheus
Period: 14.341 ± 0.001 h
Reduced Magnitude alpha(4.6°)
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Year: 2013
873 - 01/05
874 - 01/09
877 - 01/13
881 - 01/17
882 - 01/17
883 - 01/18
884 - 01/18
JDo(LTC): 2456297.691326
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

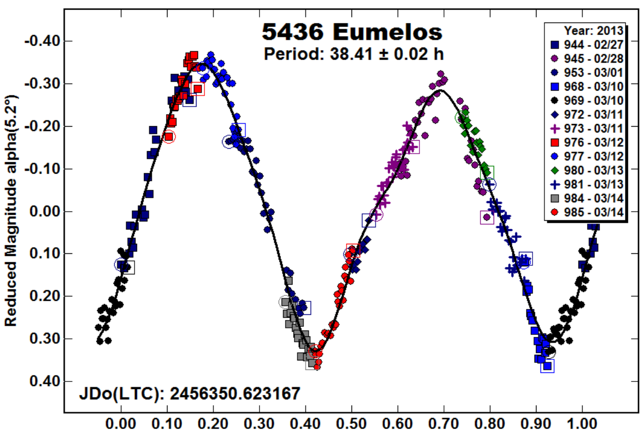

(5123) 1989 BL
Period: 9.88 ± 0.01 h
Magnitude alpha(4.1°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2013
923 - 02/17
924 - 02/17
926 - 02/18
927 - 02/18
JDo(LTC): 2456340.606339
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

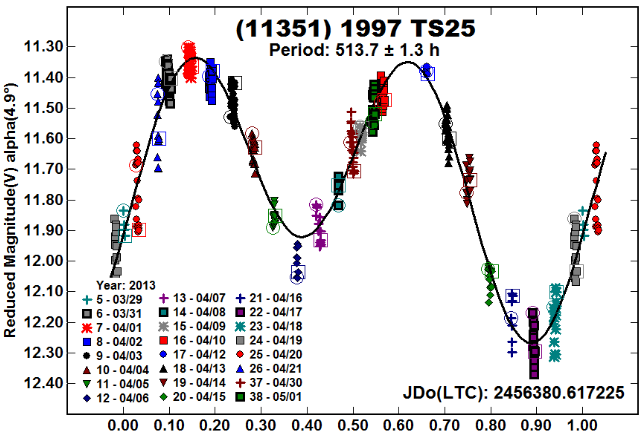

4501 Eurypylos
Period: 6.054 ± 0.001 h
Reduced Magnitude alpha(4.3°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2013
991 - 03/17
994 - 03/18
1003 - 03/28
1004 - 03/29
1010 - 04/01
JDo(LTC): 2456368.608344
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

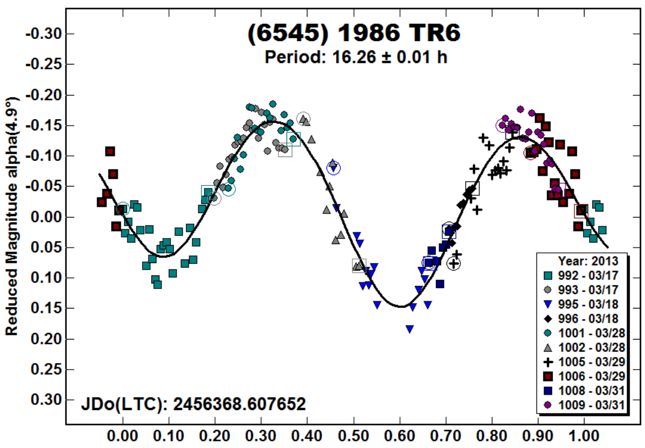

5284 Orsilocus
Period: 10.31 ± 0.01 h
Magnitude alpha(3.2°)
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Year: 2013
907 - 02/10
908 - 02/10
912 - 02/12
913 - 02/12
916 - 02/13
917 - 02/13
JDo(LTC): 2456333.655647
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

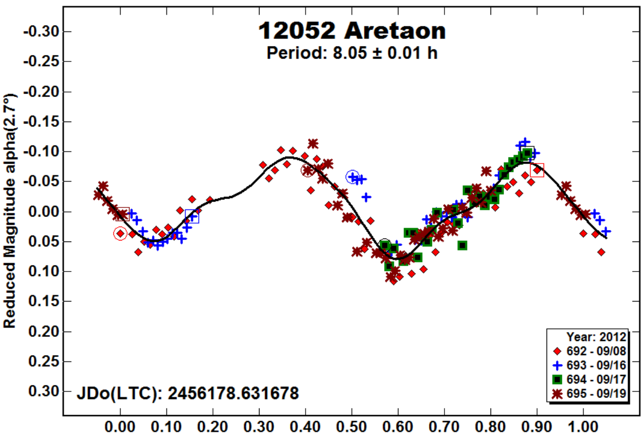

5285 Krethon
Period: 12.04 ± 0.01 h
Reduced Magnitude alpha(2.0°)
JDo(LTC): 2456355.678835
Year: 2013
957 - 03/04
959 - 03/05
960 - 03/05
962 - 03/06
963 - 03/06
987 - 03/15
988 - 03/15
990 - 03/16
998 - 03/22
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

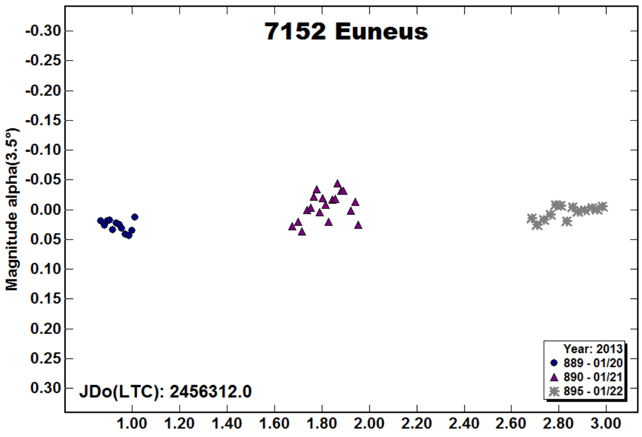

8125 Tyndareus
Reduced Magnitude alpha(5.9°)
JDo(LTC): 2456383.0
Year: 2013
1011 - 04/01
1012 - 04/01
1013 - 04/02
1016 - 04/03
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.20 2.40 2.60 2.80

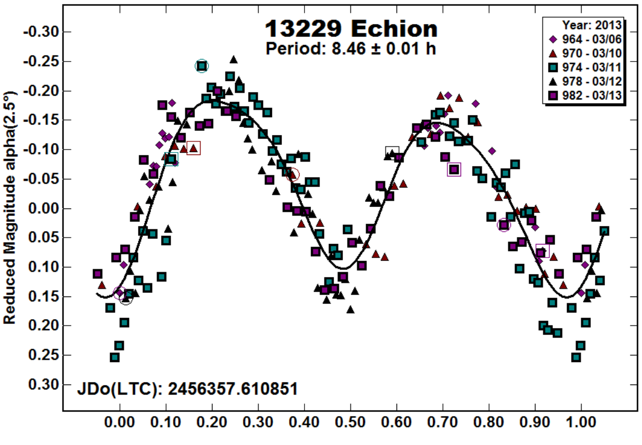

5436 Eumelos
Period: 38.41 ± 0.02 h
Reduced Magnitude alpha(5.2°)
JDo(LTC): 2456350.623167
Year: 2013
944 - 02/27
945 - 02/28
953 - 03/01
968 - 03/10
969 - 03/10
972 - 03/11
973 - 03/11
976 - 03/12
977 - 03/12
980 - 03/13
981 - 03/13
984 - 03/14
985 - 03/14
-0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

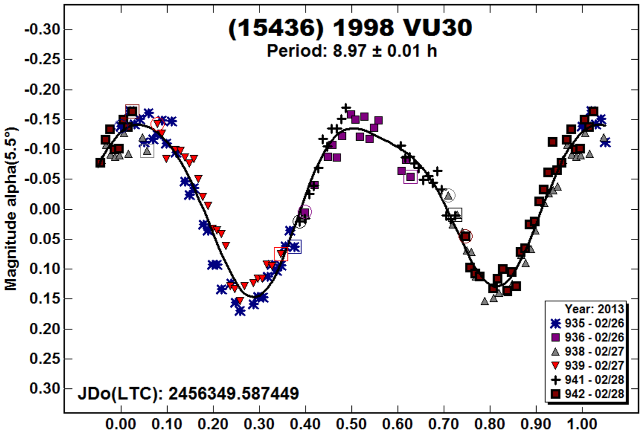

(11351) 1997 TS25
Period: 513.7 ± 1.3 h
Reduced Magnitude(V) alpha(4.9°)
JDo(LTC): 2456380.617225
Year: 2013
5 - 03/29
6 - 03/31
7 - 04/01
8 - 04/02
9 - 04/03
10 - 04/04
11 - 04/05
12 - 04/06
13 - 04/07
14 - 04/08
15 - 04/09
16 - 04/10
17 - 04/12
18 - 04/13
19 - 04/14
20 - 04/15
21 - 04/16
22 - 04/17
23 - 04/18
24 - 04/19
25 - 04/20
26 - 04/21
37 - 04/30
38 - 05/01
11.30 11.40 11.50 11.60 11.70 11.80 11.90 12.00 12.10 12.20 12.30 12.40
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

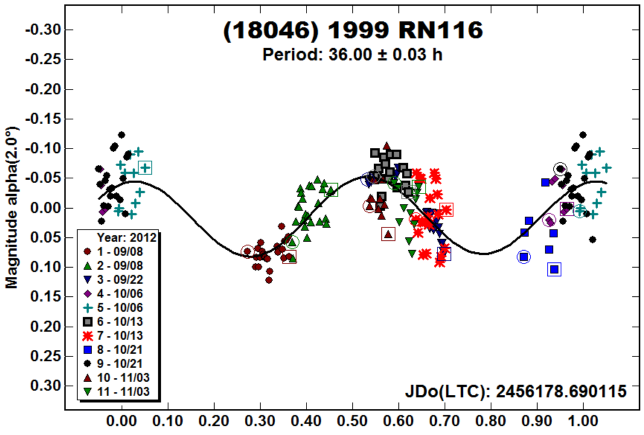

(6545) 1986 TR6
Period: 16.26 ± 0.01 h
Reduced Magnitude alpha(4.9°)
JDo(LTC): 2456368.607652
Year: 2013
992 - 03/17
993 - 03/17
995 - 03/18
996 - 03/18
1001 - 03/28
1002 - 03/28
1005 - 03/29
1006 - 03/29
1008 - 03/31
1009 - 03/31
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

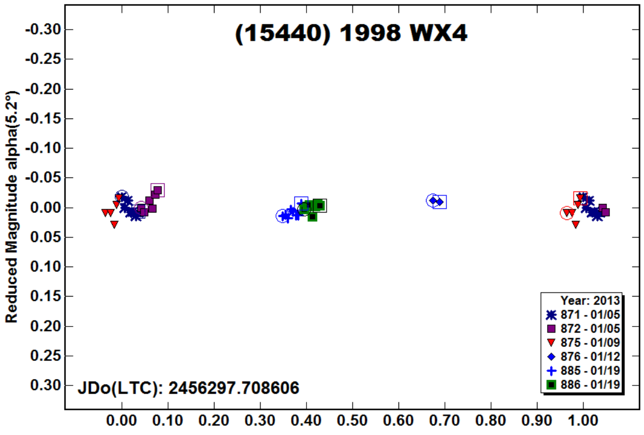

12052 Aretaon
Period: 8.05 ± 0.01 h
Reduced Magnitude alpha(2.7°)
JDo(LTC): 2456178.631678
Year: 2012
692 - 09/08
693 - 09/16
694 - 09/17
695 - 09/19
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

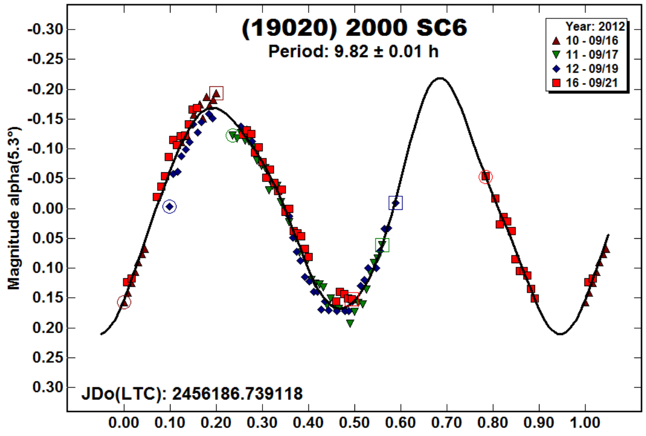

7152 Euneus
Magnitude alpha(3.5°)
JDo(LTC): 2456312.0
Year: 2013
889 - 01/20
890 - 01/21
895 - 01/22
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
1.00 1.20 1.40 1.60 1.80 2.00 2.20 2.40 2.60 2.80 3.00

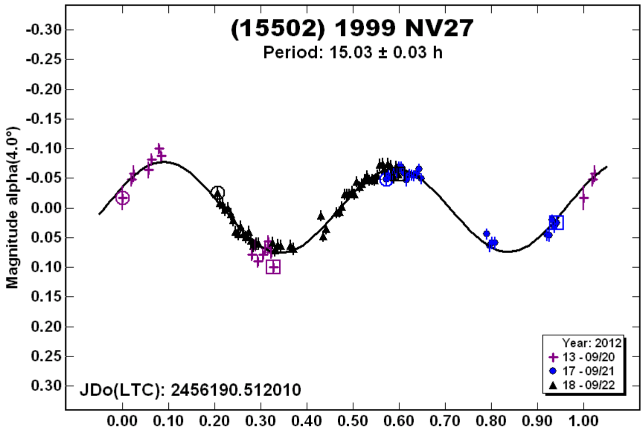

13229 Echion
Period: 8.46 ± 0.01 h
Reduced Magnitude alpha(2.5°)
JDo(LTC): 2456357.610851
Year: 2013
964 - 03/06
970 - 03/10
974 - 03/11
978 - 03/12
982 - 03/13
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

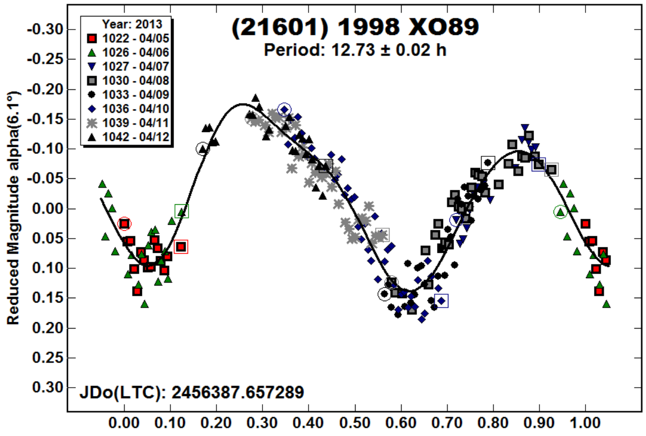

(15436) 1998 VU30
Period: 8.97 ± 0.01 h
Magnitude alpha(5.5°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456349.587449
Year: 2013
935 - 02/26
936 - 02/26
938 - 02/27
939 - 02/27
941 - 02/28
942 - 02/28


(18046) 1999 RN116
Period: 36.00 ± 0.03 h
Magnitude alpha(2.0°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456178.690115
Year: 2012
1 - 09/08
2 - 09/08
3 - 09/22
4 - 10/06
5 - 10/06
6 - 10/13
7 - 10/13
8 - 10/21
9 - 10/21
10 - 11/03
11 - 11/03


(15440) 1998 WX4
Reduced Magnitude alpha(5.2°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456297.708606
Year: 2013
871 - 01/05
872 - 01/05
875 - 01/09
876 - 01/12
885 - 01/19
886 - 01/19


(19020) 2000 SC6
Period: 9.82 ± 0.01 h
Magnitude alpha(5.3°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456186.739118
Year: 2012
10 - 09/16
11 - 09/17
12 - 09/19
16 - 09/21


(15502) 1999 NV27
Period: 15.03 ± 0.03 h
Magnitude alpha(4.0°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456190.512010
Year: 2012
13 - 09/20
17 - 09/21
18 - 09/22


(21601) 1998 XO89
Period: 12.73 ± 0.02 h
Reduced Magnitude alpha(6.1°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456387.657289
Year: 2013
1022 - 04/05
1026 - 04/06
1027 - 04/07
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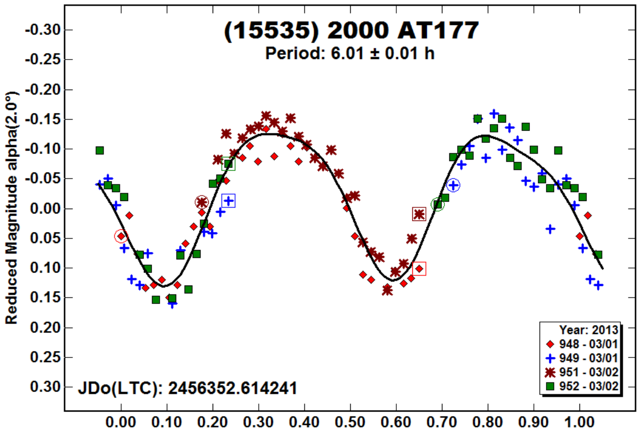
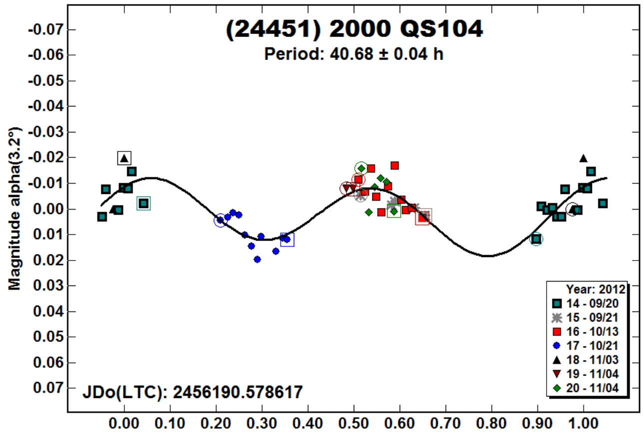
1036 - 04/10
1039 - 04/11
1042 - 04/12


(15535) 2000 AT177
Period: 6.01 ± 0.01 h
Reduced Magnitude alpha(2.0°)
-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456352.614241
Year: 2013
948 - 03/01
949 - 03/01
951 - 03/02
952 - 03/02


(24451) 2000 QS104
Period: 40.68 ± 0.04 h
Magnitude alpha(3.2°)
-0.07 -0.06 -0.05 -0.04 -0.03 -0.02 -0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
JDo(LTC): 2456190.578617
Year: 2012
14 - 09/20
15 - 09/21
16 - 10/13
17 - 10/21
18 - 11/03
19 - 11/04
20 - 11/04

Period Analysis

To avoid observation bias, asteroids were followed even if they were long period. Three had to be abandoned for the current observing season due to their low amplitude light curves.

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French, Stephens and La Rocca were visiting astronomers at Lowell Observatory and at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory, operated by the Association of Universities for Research in Astronomy, under contract with the National Science Foundation. The Cerro Tololo 0.9-m telescope is operated by the SMARTS Consortium. French, Vilas and Stephens were visiting astronomers at Lowell Observatory. This research was supported by National Science Foundation grant AST-1212115.

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A PLETHORA OF PHOCAEA ASTEROIDS

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(Received: 29 June)

CCD photometric observations of three Phocaea family asteroids were obtained from the Center for Solar System Studies in 2013 June. 5040 Rabinowitz has a period of 4.691 ± 0.001 h and an amplitude of 0.35 ± 0.02 mag. while 6487 Tonyspear has a period of 74.91 ± 0.02 h and an amplitude of 1.24 ± 0.02 mag., and (70126) 1999 NT2 has a period of 5.41 ± 0.01 h and an amplitude of 0.83 ± 0.03 mag.

The Center for Solar System Studies (CS3) recently started operations. Its participants have a history of studying asteroid families such as Jovian Trojans or Hungarias. When program members of targeted families are not observable, alternative targets such as Near-Earth Objects or the Phocaea family will be selected. No previous periods for these asteroids are reported in the Lightcurve Database (Warner 2013).

Stephens used either a 0.4-m or 0.35-m SCT with a FLI-1001e, SBIG STL-1001E CCD camera while Coley used a 0.35-m SCT with a SBIG ST-9e CCD camera. All images were unbinned with no filter and had Master flats and darks applied to the science frames prior to measurement. Measurements were made using *MPO Canopus*, which employs differential aperture photometry to produce the raw data. Period analysis was done using *MPO Canopus*, which incorporates the Fourier analysis algorithm (FALC) developed by Harris (1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted to approximate Cousins R magnitudes based on 2MASS J-K colors (Warner 2007). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

5040 Rabinowitz. This asteroid was observed by Coley and Stephens in a crowded star field, which increased the scatter in the plot from dim field stars in the background. Because of this, slight deviations from the Fourier curve were not considered compelling evidence of attenuation events. The average phase angle over the observing run was 21 degrees and the average phase angle bisector Longitude (L_{PAB}) was 271 degrees.

6487 Tonyspear. This asteroid observed by Stephens was also in a crowded star field. The lightcurve profiles with U-shaped maxima and V-shaped minima, the long rotational period and the 'shoulders' on the deepest minimum are suggestive that the asteroid might be a contact binary. The average phase angle over the observing run was 29 degrees contributing to the large amplitude of 1.24 mag. The average phase angle bisector Longitude (L_{PAB}) was 281 degrees.

(70126) 1999 NT2. Also embedded deep in the Milky Way, this asteroid was observed by Stephens. The first night had the densest coverage of observations as it passed in front of a dark nebula near Bernard 133. Subsequent nights were hampered by the dense star fields with over half the images lost to background stars. The Phase Angle was 13 degrees and the phase angle bisector Longitude (L_{PAB}) was 282 degrees.

Acknowledgements

The purchase of the FLI-1001E CCD camera by Stephens was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society.

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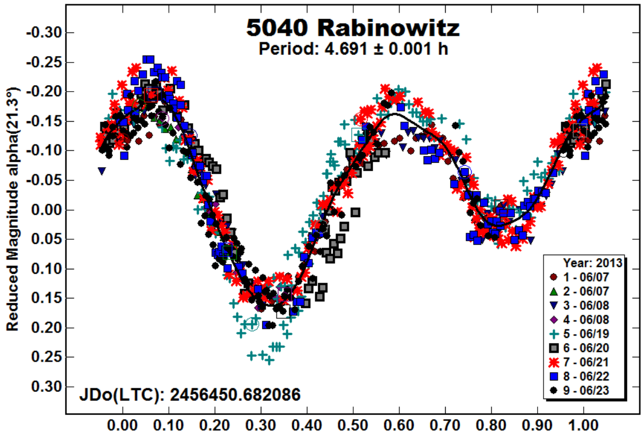

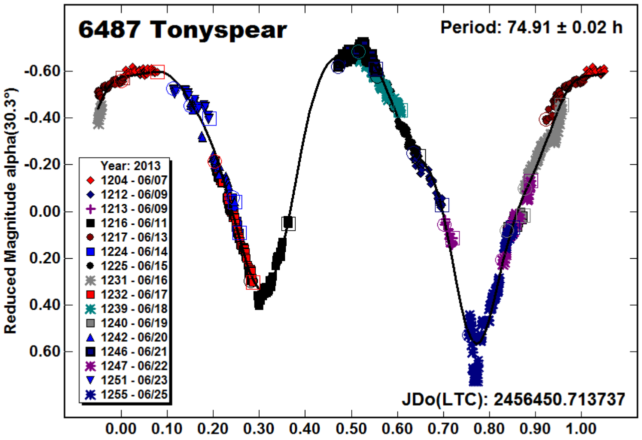

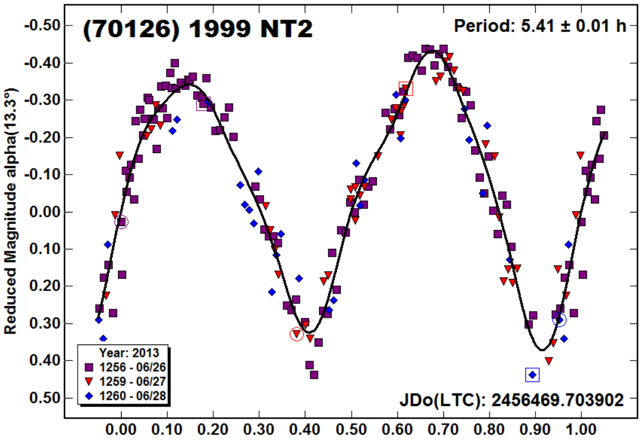

LIGHTCURVE PHOTOMETRY, H-G PARAMETERS, AND ESTIMATED DIAMETER FOR 15621 ERIKHOVLAND

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Photometric observations of main-belt asteroid 15621 Erikhovland were made over seven nights during May and June 2013 with a filtered system. The resulting synodic period is 5.3426 ± 0.0001 h with a high amplitude of 0.81 ± 0.02 mag. The color index V-R = 0.33 ± 0.03 mag. The measured absolute visual magnitude, Hv = 12.14 ± 0.09 mag. and the slope parameter, G = 0.08 ± 0.09, are consistent with a low albedo object, e.g., type C. The diameter is estimated to be D = 20 ± 3 km.

The main-belt asteroid 15621 Erikhovland was reported as a lightcurve photometry opportunity, for May 2013, in MPC Call (*http://www.minorplanet.info/PHP/call_OppLCDBQuery.php)*. All the observations were carried out from C62 Eurac Observatory in Bolzano (Italy), during eight observing nights, using a 0.30m reflector telescope, reduced to f/4.0 and a QHY9 CCD camera. Before each session, the observers synchronized the computer's clock with atomic clock time, via Internet NTP servers. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2012). The derived synodic period was P = 5.3426 ± 0.0001 h (Fig.1) with an amplitude of A = 0.81 ± 0.02 mag.

All filtered images (V Johnson, R Cousins) were calibrated with dark and flat-field frames. The V and R band frames were acquired in sequence changing alternatively the filters (VR VR VR). This allowed us to find the color index of V-R = 0.33 ± 0.05 mag (mean of 30 values). This value is typical of a C-type asteroid (Shevchenko and Lupishko, 1998). Assuming C-type, the geometric albedo is pv = 0.06 ± 0.02 (Shevchenko and Lupishko, 1998). The absolute magnitude (Hv) and slope parameter (G) ware found using the H-G Calculator function of MPO Canopus. Seven values obtained pre- and post-opposition of the asteroid, using the maximum values of the lightcurve. Unfortunately, there are no V values at small phase angles, near 0°, which are necessary for an optimal fit. We obtained Hv = 12.14 ± 0.09 mag. and the slope parameter G = 0.08 ± 0.09 (Fig. 2).

From this, we can estimate a diameter of D = 20 ± 3 km using the expression (Pravec and Harris, 2007):

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

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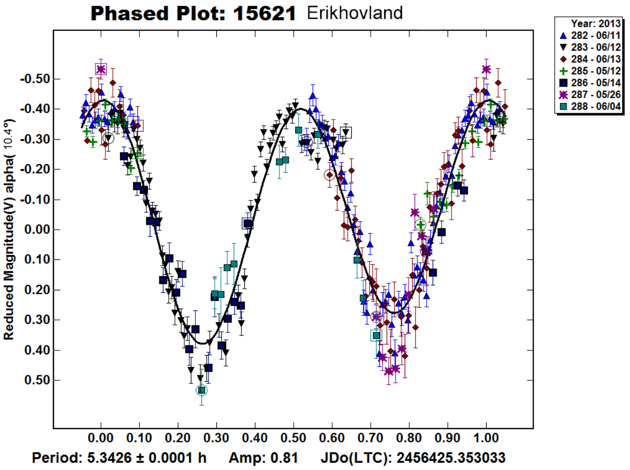

Figure 1. The lightcurve of 15621 Erikhovland with a period of 5.3426 ± 0.0001 h and an amplitude of 0.81 ± 0.02 mag.

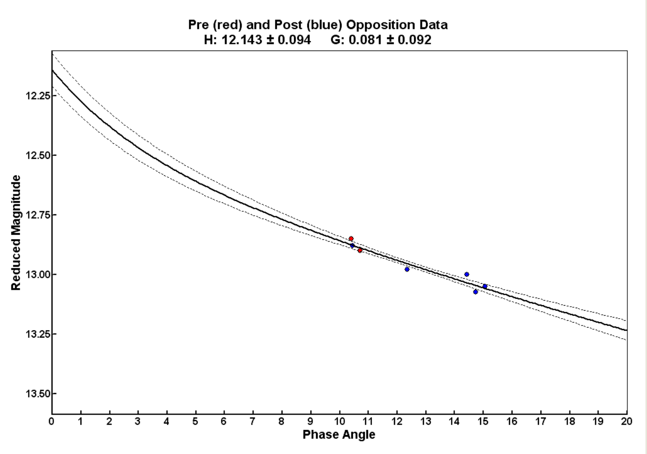

Figure 2. Visual reduced magnitude vs. phase angle for Hv = 12.14 ± 0.09 mag. and the slope parameter, G = 0.08 ± 0.09

LIGHTCURVE OF THE POTENTIALLY HAZARDOUS ASTEROID (163249) 2002 GT

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Photometric observations of the potentially hazardous asteroid (PHA) (163249) 2002 GT were made on 2013 June 16 and 17, before the object's relatively close approach to the Earth. Analysis of the resulting data found a synodic period P = 3.77 ± 0.01 h with an amplitude A = 0.36 ± 0.03 mag.

The Apollo class potentially hazardous asteroid (PHA) (163249) 2002 GT was discovered by Spacewatch at Kitt Peak on 2002 April 3. Due to its relatively close approach to the Earth, it was scheduled as a radar target from Arecibo and/or Goldstone in 2013 June. The JPL Small-Body Database Browser reported an absolute magnitude $H = 18.3$, or an estimated diameter from 0.6 (medium albedo) to 1.3 km (low albedo).

The asteroid was observed at San Marcello Pistoiese (MPC Code 104) for two nights on 2013 June 16 and 17, for a total of 491 unfiltered images, each of 45 seconds exposure. Data were collected with a 0.60-m *f*/4 reflector and Apogee Alta 1024x1024 CCD camera. This combination gave a field of view of 35x35 arcmin and a pixel scale of 2 arcsec/pixel. All images were calibrated with dark and flat-field frames. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2012) at Balzaretto Observatory (A81).

The derived synodic period was $P = 3.77 \pm 0.01$ h with an amplitude of $A = 0.36 \pm 0.03$ mag. While the period spectrum shows two nearly equal solutions, the bimodal solution is much more likely given the large amplitude of the lightcurve.

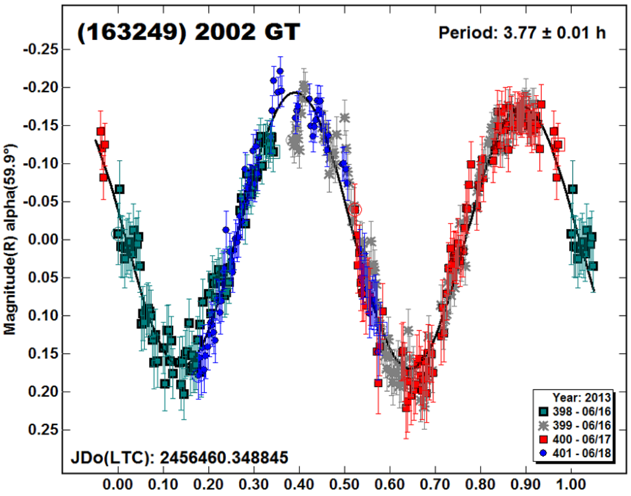

Figure 1. The lightcurve of PHA (163249) 2002 GT with a period of 3.77 ± 0.01 h and an amplitude of 0.36 ± 0.03 mag.

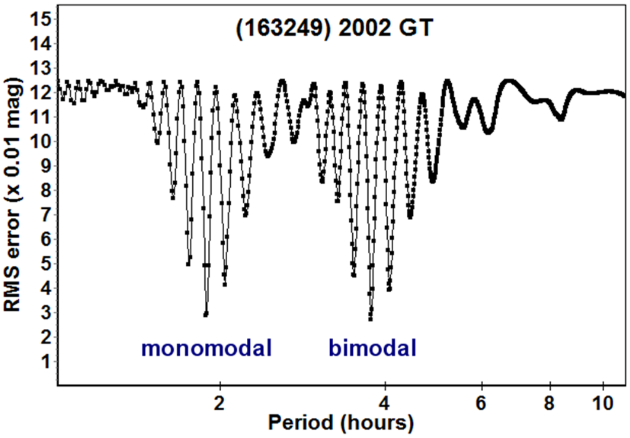

Figure 2. The period spectrum for (163249) 2002 GT shows minimums for the monomodal and bimodal solutions.

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LIGHTCURVE OF (4507) 1990FV

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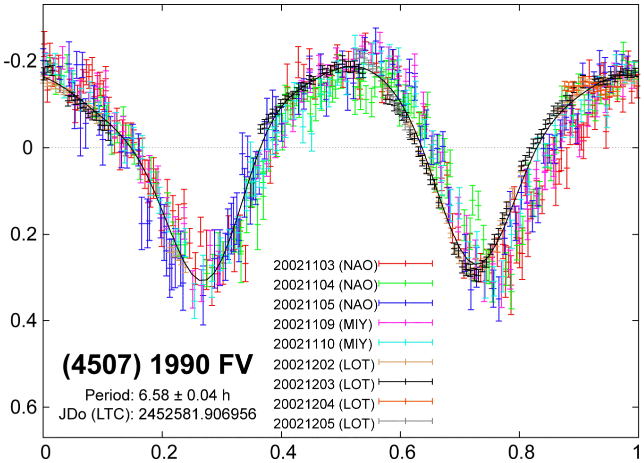
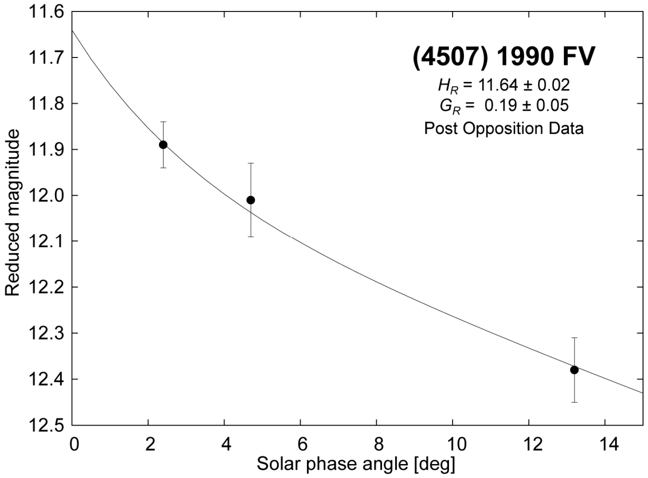
We observed the main-belt asteroid (4507) 1990 FV from 2002 November to December at three observatories in eastern Asia. Its synodic rotation period turned out to be 6.58 ± 0.04 h and its lightcurve amplitude was 0.40 ± 0.03 mag when reduced to zero solar phase angle. Since our observations covered a relatively large solar phase angle range (2.3-13.7 degrees), we were able to make a phase curve to estimate the absolute magnitude (H) and slope parameter (G) in the R band: $H_R = 11.64 \pm 0.02$, $G_R = 0.19 \pm 0.05$.

(4507) 1990 FV is a main-belt asteroid with an orbital period of 4.87 years. It was discovered on 1990 March 19 at Fujieda, Japan (MPC code 898), by Hitoshi Shiozawa and Minoru Kizawa (MPC 16363). This asteroid was once considered a major member of the young Karin asteroid family (Nesvorný *et al.*, 2002). However, later numerical recalculation (Nesvorný and Bottke, 2004) and detailed spectroscopic observation (Vernazza *et al.,* 2006) eliminated the possibility that this asteroid is a member of the Karin family, putting it in the interloper category.

There are two references about this asteroid in the minor planet lightcurve database (Warner *et al.,* 2009; LCDB). One of them is a recent report by Hanuš *et al.* (2013) which uses observational data obtained from Catalina Sky Survey from 2003 November to 2009 May. In Hanuš *et al.* (2013), our presentation abstract at an IAU symposium is cited (Yoshida *et al.* 2005; ACM 2005) as a literature of the rotational period of this asteroid. Another reference in LCDB is our own publication, Yoshida *et al.* (2004). However, Yoshida *et al.* (2004) does not contain any information on the lightcurve or on the rotational period of this asteroid. Also, Yoshida *et al.* (2005) that is cited in Hanuš *et al.* (2013) was published just electronically, and currently the abstract file is not available on the symposium webpage. This kind of confusion is also seen in Harris *et al.* (2012) whose data are summarized on the PSI asteroid database. Our observations for this asteroid were carried out from 2002 November to December, about a year before Catalina Sky Survey's first observation for this asteroid (Hanuš *et al.,* 2013) took place. Therefore we believe that it is worth officially publishing the lightcurve and its period analysis results for this asteroid based on our own observations for rectifying the existing reference records, as well as for aiming at making a new lightcurve reference for future studies.





The photometric observations of this asteroid were made at three different observatories in eastern Asia, just after an opposition of this asteroid. The Mitaka headquarter of National Astronomical Observatory of Japan ("NAO" in the table below), the Miyasaka Observatory in Japan ("MIY"), and the Lulin Observatory in Taiwan ("LOT"). At the Mitaka headquarter of National Astronomical Observatory of Japan (MPC code 388), we used a 0.5-m *f*/1.2 Mitaka Kohki GNF-50 telescope with an SBIG ST-1001E CCD camera. The CCD of this camera has 1024x1024 24x24-µm pixels and 24.6x24.6-mm array dimension. The resulting field of view is 14.0x14.0 arcmin and the plate scale is 0.82 arcsec/pixel. At the Miyasaka Observatory (MPC code 366), we used a 0.25-m *f*/6 Takahashi MT-250 with an SBIG ST-6 CCD camera. The CCD of this camera has 375x242 23x27 µm pixels and 8.63x6.53 mm array dimension. The field of view is 19.8x15.0 arcmin and the plate scale is 3.17x3.72 arcsec/pixel. At the Lulin Observatory (MPC code D35), we used a 1.0-m *f*/8 telescope with an Apogee AP8 CCD camera. The CCD of this camera has 1024x1024 24x24-µm pixels and 24.6x24.6-mm array dimension. The field of view is 10.6x10.6 arcmin and the plate scale is 0.62 arcsec/pixel.

Dates of observations and relative orbital circumstances of the asteroid with respect to the Earth and the Sun are summarized in a table as follows. The Sun-asteroid distance is r while Δ is the Earth-asteroid distance, both in AU. The ecliptic longitude and latitude of the asteroid are λ and β, and α is the solar phase angle (deg). "Obs" denotes the observatory name.

UT Date	r	Δ	λ	β	α	Obs
2002 Nov 03	2.882	1.894	34.4	-0.8	2.28	NAO
2002 Nov 04	2.882	1.896	34.2	-0.8	2.69	NAO
2002 Nov 05	2.882	1.898	33.9	-0.8	3.10	NAO
2002 Nov 09	2.881	1.910	33.1	-0.7	4.73	MIY
2002 Nov 10	2.881	1.913	32.9	-0.7	5.13	MIY
2002 Dec 02	2.879	2.057	29.6	-0.3	12.85	LOT
2002 Dec 03	2.878	2.067	29.5	-0.3	13.16	LOT
2002 Dec 04	2.878	2.075	29.4	-0.3	13.41	LOT
2002 Dec 05	2.878	2.084	29.3	-0.3	13.69	LOT

We used an *R* band filter for our lightcurve observations. All the telescopes were driven at the sidereal tracking rate with the exposure time limited by the moving rate of asteroid as well as by the seeing size during the observing periods. We chose a single exposure time of two to eight minutes so that the asteroid had an appearance of a point source. The brightness of the asteroid was measured relative to that of a field star located on the same frame. We chose the field stars from the USNO-A2.0 star catalogue. We corrected the magnitude of the asteroid using the extinction curve obtained on each of the observing nights, using our own observation result of the Landolt standard stars taken at several air masses.

To construct synthesized lightcurves of the asteroid from the observational data, we followed a sequence proposed by Harris and Lupishko (1989). We employed two different algorithms to examine periodicities in the lightcurve data: Lomb's Spectral Analysis (Lomb, 1976; LSA) and the WindowCLEAN Analysis (Roberts *et al.,* 1987; WCA). After the frequency analysis was done, we fit the lightcurve with a Fourier series. Paying attention to different zero-levels of the lightcurves derived from different observing runs, we combined the lightcurves of multiple observing runs based on these zero-levels, and then obtained final synthesized lightcurve.

Both the WCA and LSA frequency analyses of the lightcurve detected a clear peak at the rotation period of 6.58 ± 0.04 h. We estimated the peak-to-peak variation of the lightcurve reduced to zero solar phase angle, $A(0)$, using the empirical relationship advocated by Zappalà *et al.* (1990): $A(\alpha) = A(0)\ (1+m\alpha)$ where $A(\alpha)$ is raw peak-to-peak variation magnitude of lightcurve when the solar phase angle is α. For S-type asteroids such as (4507) 1990 FV, the parameter m is empirically determined as 0.030. From our observations, the reduced lightcurve amplitude was determined as 0.40 ± 0.03 at α=0.

We fitted our observational results of this asteroid with the *H-G* magnitude system approved by IAU. Absolute magnitude H is usually defined by asteroid brightness in the V band. However, since our observations were carried out in the R band, we calculated and designated H and the slope parameter G as H_R and G_R. Our analysis gave $H_R = 11.64 \pm 0.02$ and $G_R = 0.19 \pm 0.05$.

Acknowledgements

We thank Hung-Chin Lin for checking out the instrument details at Lulin Observatory. Some part of the data analysis was performed at CfCA/ADC at NAO. This study is supported by the JSPS program for Asia-Africa academic platform (2009-2011).

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ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2013 MAY-JUNE

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Lightcurves for eleven asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 May and June. The asteroids were a mostly a mix of Hungaria and Phocaea members along with some outer main-belt asteroids. New data failed to remove the existing rotation period ambiguity for the Hungaria asteroid 1355 Magoeba, although the number of possibilities may have been reduced. A new period is proposed for 4436 Ortizmoreno, 8.24 h (or 16.48 h), superseding the one reported by Birlan *et al*. (1996). The Hungaria member 26074 Carlwirtz may be a binary with a primary rotation period of $P_1 = 2.5493 \pm 0.0003$ h and a satellite orbital period of $P_{orb} = 16.11 \pm 0.02$ h. The Phocaea member (125742) 2001 XT117 shows signs of a low amplitude precision period, i.e., it is possibly in non-principal axis rotation (NPAR).

CCD photometric observations of eleven asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2013 May and June. See the introduction in Warner (2010b) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling.

These are the first observations to be made at PDS after the telescopes were moved from Colorado to the CS3 site in Landers, CA. All the telescopes are fully robotic, with custom software and equipment allowing fully-unattended control of all aspects of observing, from opening/closing the roof, acquiring images, and transferring those images back to processing computers in Colorado. It's anticipated that the new location will allow an additional 60-80 observing nights per year beyond what was possible at the now closed Palmer Divide Observatory site in Colorado.

In the plots below, the "Reduced Magnitude" is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0.

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

1355 Magoeba. Finding the period for this enigmatic Hungaria asteroid has been a challenge over the years, mostly because the lightcurve amplitude rarely rises above 0.10 mag and is often <0.05 mag. Warner (2007) observed 1355 in 2006 and reported a period of 32.9 h with an amplitude of 0.22 mag. That was subsequently revised (Warner, 2010a) to 31.65 h and 0.10 mag. New observations in late 2009 lead to a shorter period of 5.946 h, which was based on the assumption of a bimodal lightcurve. Additional observations (Warner, 2011), lead to a period of 5.99 h, but the 0.06 mag amplitude made that solution ambiguous.

The new observations in 2013 from CS3-PDS did not resolve the ambiguities. The period spectrum below shows that a number of like-probability solutions were possible; one of those was 2.977 h, or about the half-period of the ~5.9 h solution. The first lightcurve in the set below shows the 2013 data phased to the 2.977 h solution. When plotting the data for the double period to look for symmetry in the shape, a period of about 5.2 h was favored over 5.9 h. The 2013 data were forced to the half-period, which found 2.644 h. This is the second lightcurve in the Magoeba set. Note that the shape of the two 2013 lightcurves is essentially identical. By simple visual inspection, it is not possible to tell which solution is the right one, if either.

The best data set prior to 2013 from PDO was late 2009. These data were forced to periods near 2.97 and 2.64 h. These are shown in the third and fourth lightcurves in the series. The fit to 2.97 h is noticeably the better of the two. For this reason, it's suggested that a period of 2.97 h (or 5.94 h) be adopted for this asteroid. Now that there are data from four apparitions with a useful distribution in phase angle bisector longitudes, it might be possible to apply lightcurve inversion techniques to see which period gives a more probable model. Then again, it may take a few more years of trying before this mystery's riddle is solved.

2150 Nyctimene. 2013 was the fourth apparition at which this Hungaria was observed by the author (Warner 2007; 2008; 2012). The period of 6.124 ± 0.005 h is in good agreement with the earlier results. The amplitude of the asteroid has ranged from 0.59 to 0.66 mag. Not only does this indicate an elongated ellipsoidal body with an a/b ratio of about 1.8:1 (assuming an equatorial view) but that the spin axis has a small-to- modest obliquity, i.e., it is mostly upright with reference to the ecliptic plane.

4436 Ortizmoreno. Birlan *et al*. (1996) reported a period of 6.656 h for this outer main-belt asteroid with an amplitude of 0.40 mag. The 2013 data could not be fit to this period, the analysis finding a period of 8.24 ± 0.02 h and an amplitude of 0.09 mag if a monomodal solution is presumed. Since the low phase angle and amplitude combine to make this assumption unreliable, the double-period of 16.48 h with a bimodal lightcurve cannot be formally excluded. Lightcurves for both periods are shown below.

4497 Taguchi. None of the previous periods for this inner main-belt asteroid agreed with one another, although two were similar. Almeida *et al*. (2004) found 3.563 h; Clark (2006) found 5.343 h; and Behrend (2008) reported a period of 3.49 h, which is similar to the Almeida finding. It's worth noting that Clark's result is almost exactly 1.5x the Almeida period, possibly indicating that the longer period was a result of *rotational aliasing*, which is a miscount of the rotations within the data set. For example, if a lightcurve is nearly symmetrical and the two data sets are taken several days apart and at least one lightcurve doesn't cover even a half-cycle, then opposing halves of the lightcurve may be mistaken as being from the same half.

Analysis of the CS3-PDS data found a period of 3.563 ± 0.003 h and amplitude of 0.11 mag. There appears to be enough asymmetry in the lightcurve to presume that the solution is not ambiguous and, furthermore, it agrees exactly with the Almeida *et al*. solution.

5211 Stevenson. No previously reported period could be found for this Phocaea member.

(8893) 1995 KZ. No previously reported period was found for this Phocaea member.

(19204) 1992 ME. Previous work on this Phocaea member includes Stephens (2006), who reported a period of 3.17 h, and Pravec *et al.* (2006), who found the period to be >10 h. The 2013 data show a monomodal lightcurve with an amplitude of only 0.10 mag and period of 19.5 ± 0.1 h. Other than forcing the period to the double, i.e., 39 h, and a bimodal solution, there were no other likely periods. This would seem to confirm the Pravec *et al*. result but it should not be considered definitive.

(24778) 2000 WC145. This appears to be the first time a period has been found for this outer main-belt asteroid. The period was nearly an integral ratio with an Earth-day; so, even over a span of eight days, there are some small gaps in the lightcurve. Despite this and the slightly noisy data, the solution is considered secure.

(26074) Carlwirtz. This Hungaria asteroid seems to be a probable new binary discovery. The first lightcurve in the series below shows the data forced to a period of 2.5492 ± 0.0003 h with no subtraction. There is considerable scatter about the mean Fourier curve. When a secondary period of 16.11 h is subtracted from the data, a considerably better fit is achieved. This is shown in the second lightcurve of the set. The third lightcurve in the set shows the secondary period after subtracting the primary period from the data. It shows no obvious signs of *mutual events* that would be the result of occultations and/or eclipses involving a satellite. Instead, it appears to be a bimodal lightcurve with an amplitude of 0.09 mag. The period is nearly 2:3 of an Earth-day. This made it difficult for a single station to fill in the missing pieces of the lightcurve.

(41185) 1999 VJ200. This outer main-belt member was a *target of opportunity*, meaning it was in the same field as a planned target. It was well below 18th magnitude and so the data have significant error bars. A second night was given to see if a reasonable period could be derived. The apparent amplitude of 0.39 mag gives some credence to the solution of 4.97 ± 0.03 h but many other solutions are possible with adjustments to the nightly zero points of the data from two nights (second lightcurve in set). Using only the data from the first night, 2013 June 19, which appears to show most of a bimodal lightcurve cycle, a second-order Fourier solution finds a period of 3.92 ± 0.15 h and amplitude of 0.39 ± 0.03 mag (first lightcurve in set). Given the significantly larger error bars on the second night (June 20) and doubts about the fit of the data from two nights, the adopted period is 3.92 h – with the understanding that it could differ from the true period by considerably more than the stated error of 0.15 h.

(125742) 2001 XT117. This asteroid is a member of the Phocaea group. No previously reported period could be found. The base period of 60.8 ± 0.2 h seems secure. However, there are some indications that the asteroid may be a tumbler, i.e., in non-principal axis rotation (NPAR; see Pravec *et al*. 2005). Those indications are slight misfits of some sessions that overlapped with others, e.g., session 6184 (2013 June 8) has a steeper slope and higher maximum than the data from other sessions around the same rotation phase. There are similar indications around 0.9 rotation phase. The small deviations would seem to indicate that the amount of "wobble" is small and that maybe the asteroid is just coming into or out of its NPAR state.

Acknowledgements

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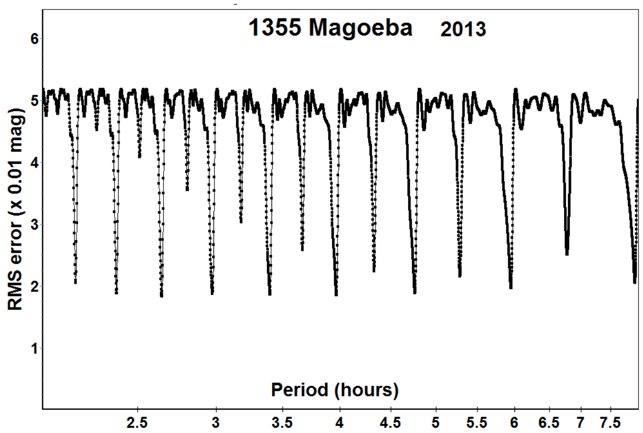
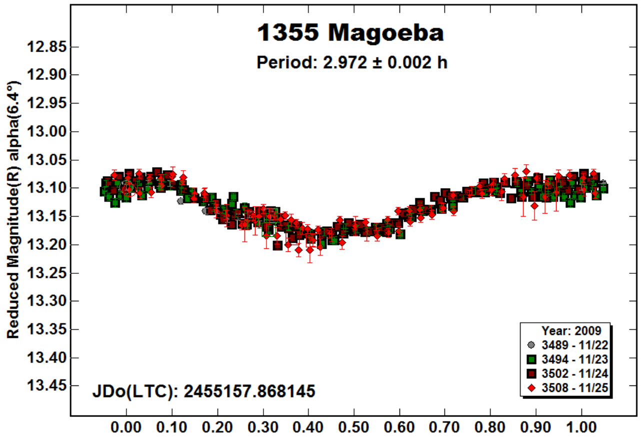
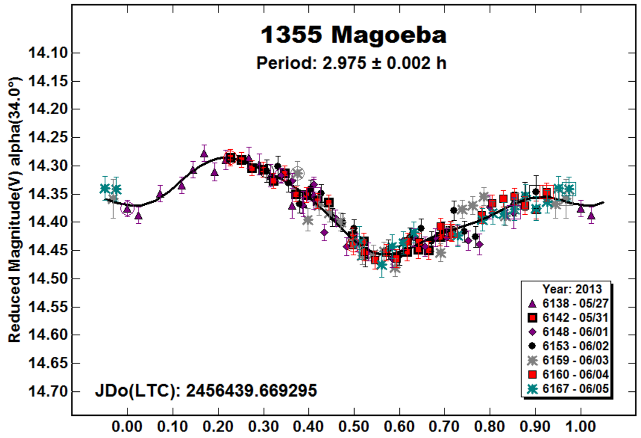
Number	Name	2013 (mm/dd)	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
1355	Magoeba (H)	05/27-06/05	127	33.9,34.6	187	-10	2.977	0.005	0.15	0.01
		11/22-11/25^	259	5.7,7.2	56	-8	2.972	0.002	0.10	0.01
2150	Nyctimene (H)	05/27-06/07	272	28.2,29.7	193	+4	6.124	0.005	0.66	0.02
4436	Ortizmoreno (H)	05/31-06/05	310	6.4,7.7	235	+11	8.24	0.02	0.09	0.01
4497	Taguchi (H)	05/31-06/03	207	7.8,8.8	231	+7	3.563	0.003	0.11	0.01
5211	Stevenson	06/09-06/14	240	24.1,25.0	226	+34	14.18	0.01	0.33	0.02
8893	1995 KZ	06/04-06/14	668	21.0,22.2	245	+33	22.27	0.02	0.39	0.02
19204	1992 ME	06/03-06/08	332	22.3,21.0	262	+27	19.55	0.10	0.08	0.01
24478	2000 WC145	06/15-06/23	326	17.7,18.9	238	+31	16.13	0.03	0.43	0.03
26074	Carlwirtz (H)	06/06-06/19	330	30.7,31.8	227	+33	2.5493*	0.0003	0.11	0.01
41185	1999 VJ200	06/19-06/20	74	12.2,12.4	241	+21	3.92	0.15	0.39	0.03
125742	2001 XT117	06/04-06/19	712	20.4,22.6	244	+21	60.8#	0.2	1.15	0.05

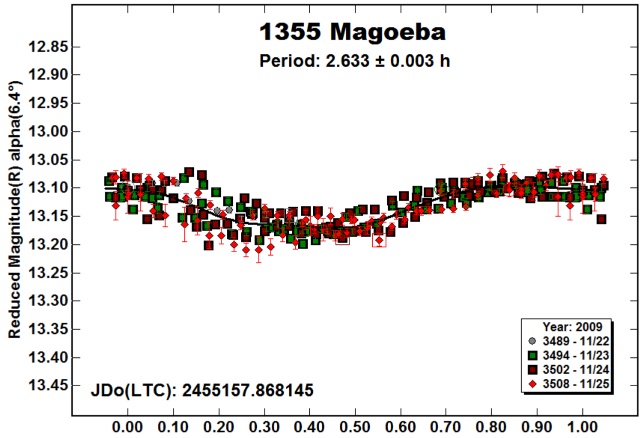
^2009 *period of binary primary #dominant period of a tumbler

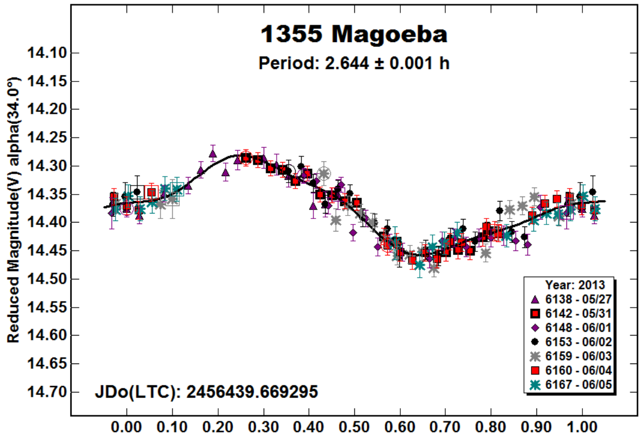
Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not 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).

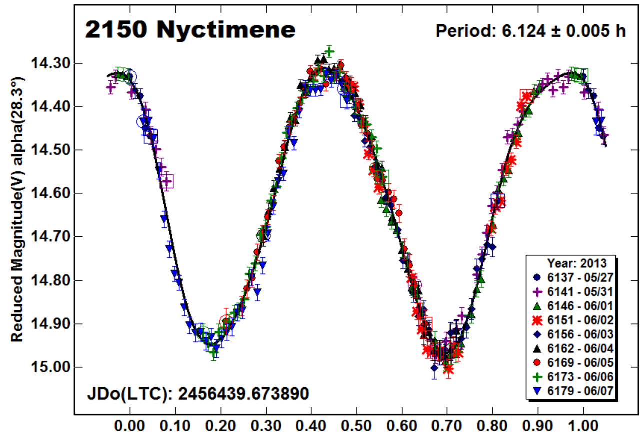


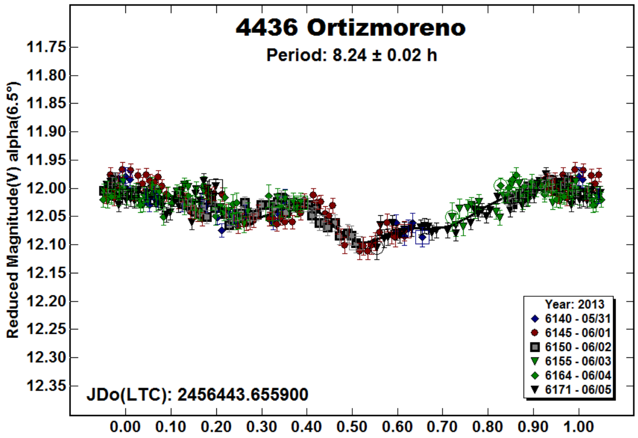


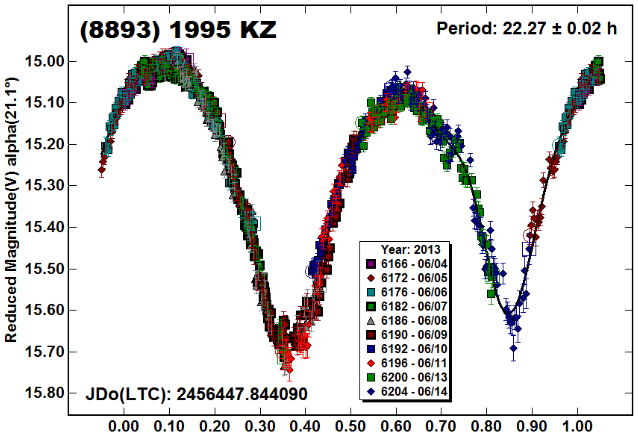


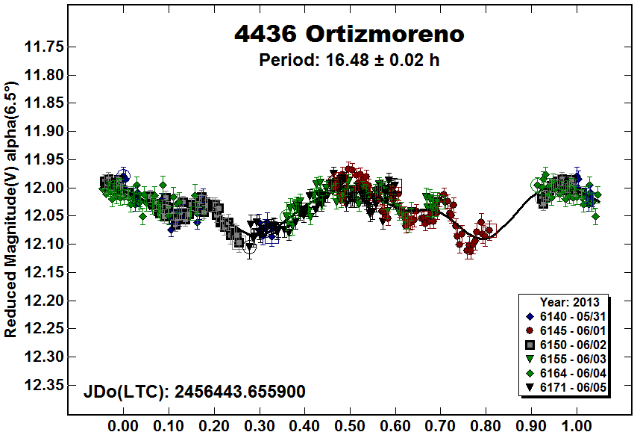


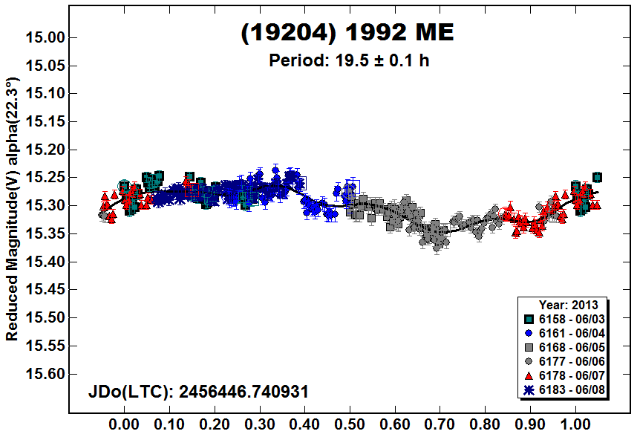





4436 Ortizmoreno
Period: 8.24 ± 0.02 h
Reduced Magnitude(V) alpha(6.5°)
11.75
11.80
11.85
11.90
11.95
12.00
12.05
12.10
12.15
12.20
12.25
12.30
12.35
Year: 2013
6140 - 05/31
6145 - 06/01
6150 - 06/02
6155 - 06/03
6164 - 06/04
6171 - 06/05
JDo(LTC): 2456443.655900
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(8893) 1995 KZ
Period: 22.27 ± 0.02 h
Reduced Magnitude(V) alpha(21.1°)
15.00
15.10
15.20
15.30
15.40
15.50
15.60
15.70
15.80
Year: 2013
6166 - 06/04
6172 - 06/05
6176 - 06/06
6182 - 06/07
6186 - 06/08
6190 - 06/09
6192 - 06/10
6196 - 06/11
6200 - 06/13
6204 - 06/14
JDo(LTC): 2456447.844090
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


4436 Ortizmoreno
Period: 16.48 ± 0.02 h
Reduced Magnitude(V) alpha(6.5°)
11.75
11.80
11.85
11.90
11.95
12.00
12.05
12.10
12.15
12.20
12.25
12.30
12.35
Year: 2013
6140 - 05/31
6145 - 06/01
6150 - 06/02
6155 - 06/03
6164 - 06/04
6171 - 06/05
JDo(LTC): 2456443.655900
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(19204) 1992 ME
Period: 19.5 ± 0.1 h
Reduced Magnitude(V) alpha(22.3°)
15.00
15.05
15.10
15.15
15.20
15.25
15.30
15.35
15.40
15.45
15.50
15.55
15.60
Year: 2013
6158 - 06/03
6161 - 06/04
6168 - 06/05
6177 - 06/06
6178 - 06/07
6183 - 06/08
JDo(LTC): 2456446.740931
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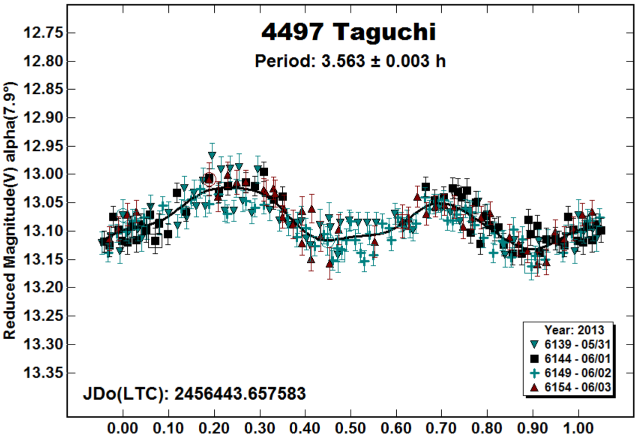
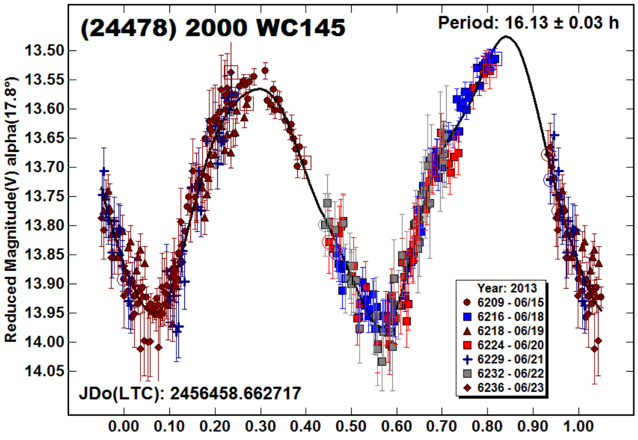

4497 Taguchi
Period: 3.563 ± 0.003 h
Reduced Magnitude(V) alpha(7.9°)
12.75
12.80
12.85
12.90
12.95
13.00
13.05
13.10
13.15
13.20
13.25
13.30
13.35
Year: 2013
6139 - 05/31
6144 - 06/01
6149 - 06/02
6154 - 06/03
JDo(LTC): 2456443.657583
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(24478) 2000 WC145
Period: 16.13 ± 0.03 h
Reduced Magnitude(V) alpha(17.8°)
13.50
13.55
13.60
13.65
13.70
13.75
13.80
13.85
13.90
13.95
14.00
14.05
Year: 2013
6209 - 06/15
6216 - 06/18
6218 - 06/19
6224 - 06/20
6229 - 06/21
6232 - 06/22
6236 - 06/23
JDo(LTC): 2456458.662717
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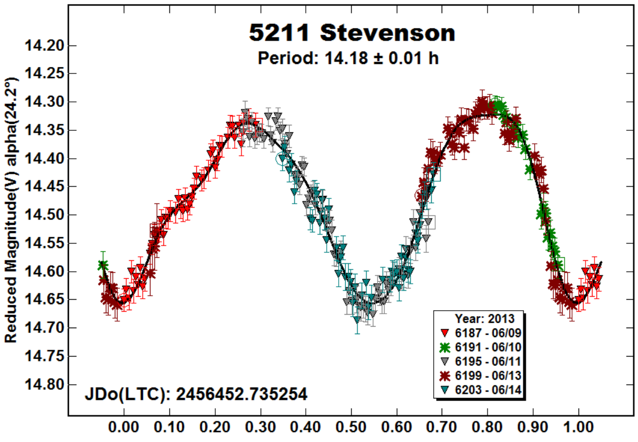
5211 Stevenson
Period: 14.18 ± 0.01 h
Reduced Magnitude(V) alpha(24.2°)
14.20
14.25
14.30
14.35
14.40
14.45
14.50
14.55
14.60
14.65
14.70
14.75
14.80
Year: 2013
6187 - 06/09
6191 - 06/10
6195 - 06/11
6199 - 06/13
6203 - 06/14
JDo(LTC): 2456452.735254
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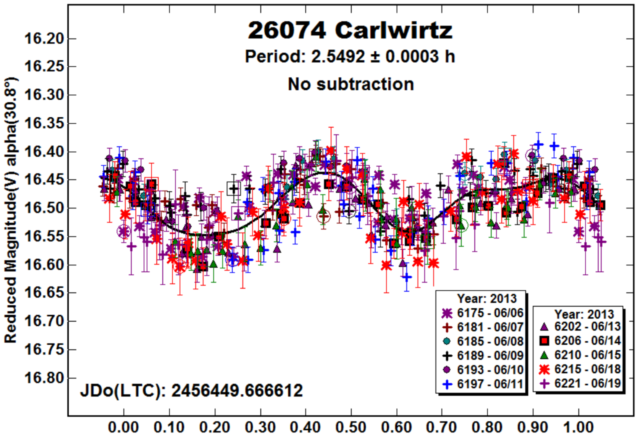
26074 Carlwirtz
Period: 2.5492 ± 0.0003 h
No subtraction
Reduced Magnitude(V) alpha(30.8°)
16.20
16.25
16.30
16.35
16.40
16.45
16.50
16.55
16.60
16.65
16.70
16.75
16.80
Year: 2013
6175 - 06/06
6181 - 06/07
6185 - 06/08
6189 - 06/09
6193 - 06/10
6197 - 06/11
Year: 2013
6202 - 06/13
6206 - 06/14
6210 - 06/15
6215 - 06/18
6221 - 06/19
JDo(LTC): 2456449.666612
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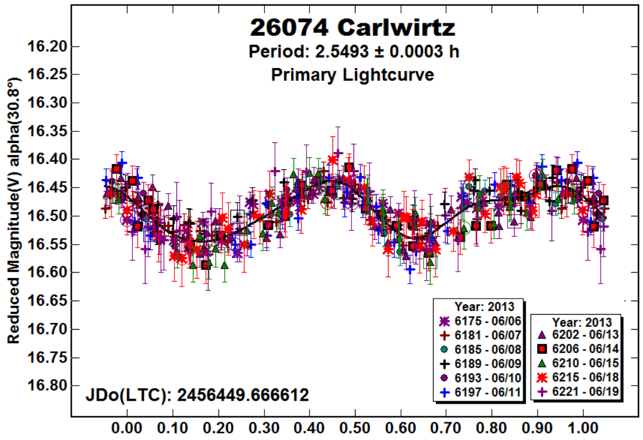

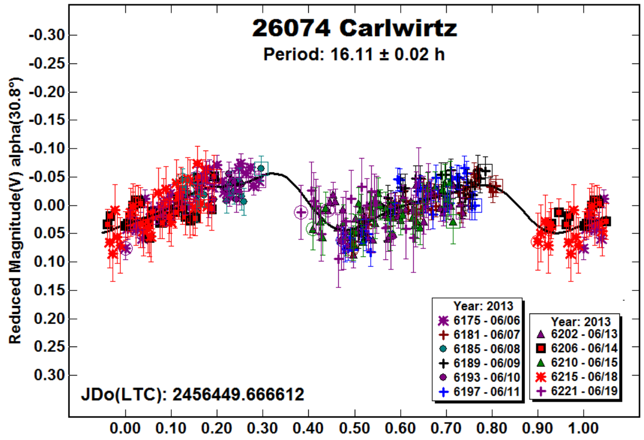

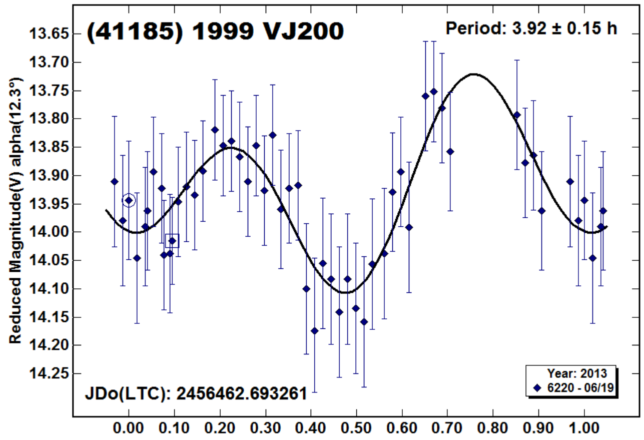

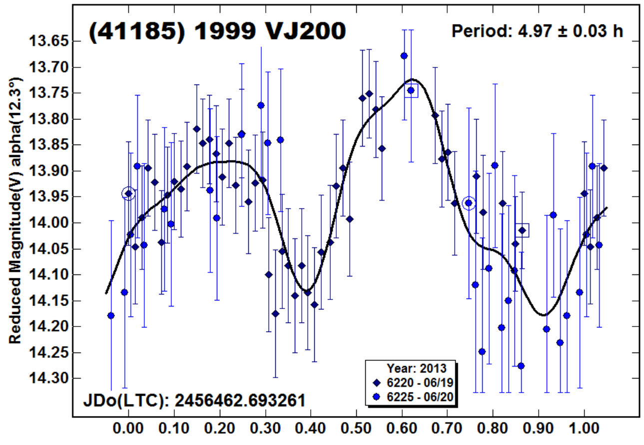

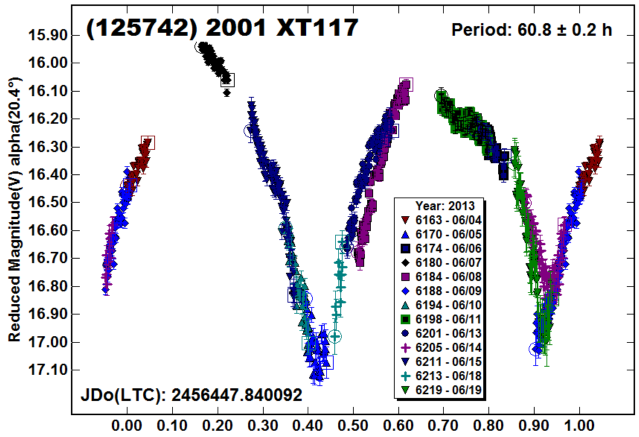

PHOTOMETRIC STUDY OF FOUR ASTEROIDS AT TEXAS A&M COMMERCE OBSERVATORY

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Lightcurves for four asteroids were measured at the Texas A&M University-Commerce Observatory from 2011 through 2013. The asteroids were: 1175 Margo, 2566 Kirghizia, 4106 Nada and (19977) 1989 TQ.

Photometric data was obtained at the Texas A&M University-Commerce Observatory using a 0.41-m Meade LX-200 telescope on a Paramount German equatorial mount. Images were taken with an SBIG STL-11000 CCD Camera. Images were 5 minutes each through a clear filter and the telescope was guided using an external CCD camera connected to a piggybacked refractor. The image scale was 0.424 arc-seconds per pixel.

Dark frames of equal length exposures were subtracted from each image as they were taken. Image calibration was done using *Maxim DL*. Flat field images were obtained nightly through the same clear filter using an LED panel placed in front of the telescope. The images were all calibrated and aligned before using the *MPO Canopus* v10.2.1.0 program for the photometric measurements (Warner, 2011). Standard stars were all chosen on the images with high (>200) S/N ratios. When the target asteroid passed near background stars the observations were deleted. Star subtraction methods did not provide high enough quality photometry.

1175 Margo. Observations of the asteroid were obtained on the following two nights in 2011; November 29 and December 1. The total number of observations was 109. The period determined was 6.01 ± 0.02 h and the peak amplitude variation was 0.32 magnitudes. These values agree to within the errors with 6.015 ±

0.001 found by Brinsfield (2010). However, Oliver et al. (2008) determined a period of 11.99 ± 0.03 h. Since the period of Margo is an integer value of the Earth's 24 hour period it is difficult to distinguish which period is correct. This asteroid needs more observations before the period is convincingly determined.

2566 Kirghizia. Observations of the asteroid were obtained on the following three nights in 2013: February 14, 15 and 19. The total number of observations was 104. The period determined was 4.451 ± 0.006 h and the peak amplitude variation was 0.55 magnitudes. A search of the Astrophysics Data System and the Asteroid Lightcurve Database did not find any previously reported lightcurve results.

4106 Nada. Observations of the asteroid were obtained on the following five nights in 2012: April 17, 18, 19, 24 and 25. The total number of observations was 147. The period determined was 5.832 ± 0.006 h and the peak amplitude variation was 0.48 magnitudes. These values agree to within the errors with both Owings (2013) who reported 5.8330 ± 0.0001 h and Stephens (2012) who reported 5.832 ± 0.002 h.

(19977) 1989 TQ. Observations of the asteroid were obtained on the following seven nights in 2012: August 23, September 7, 11, 12, 13, 19 and 20. The total number of observations was 237. The period determined was 8.566 ± 0.004 h and the peak amplitude variation was 1.33 magnitudes. A search of the Astrophysics Data System and the Asteroid Lightcurve Database did not find any previously reported results.

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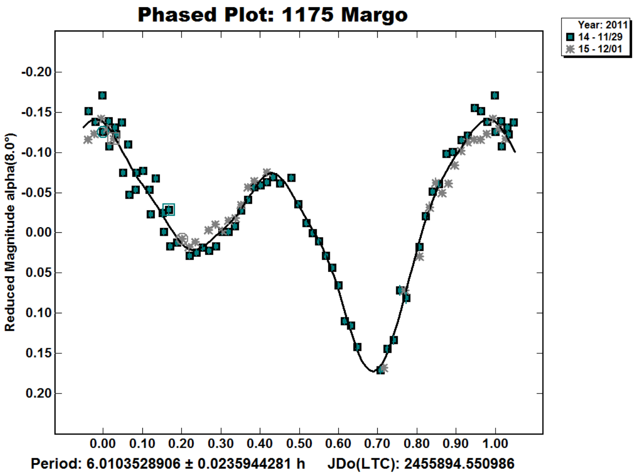

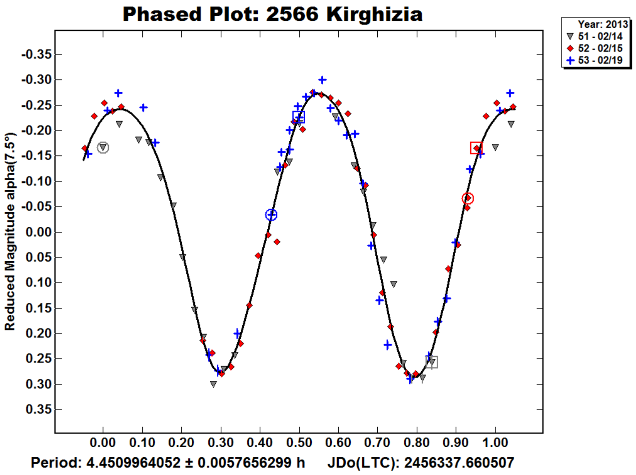

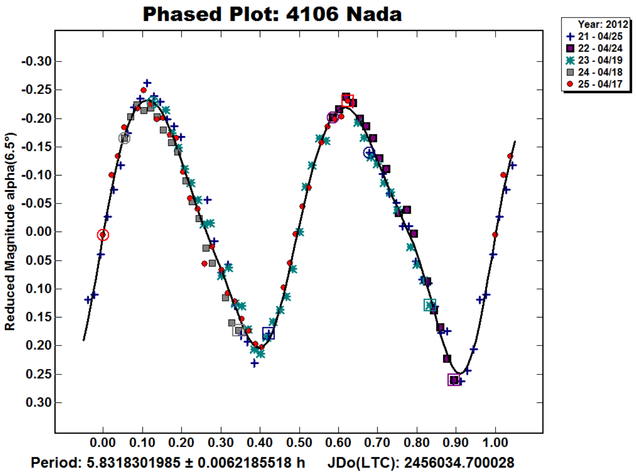

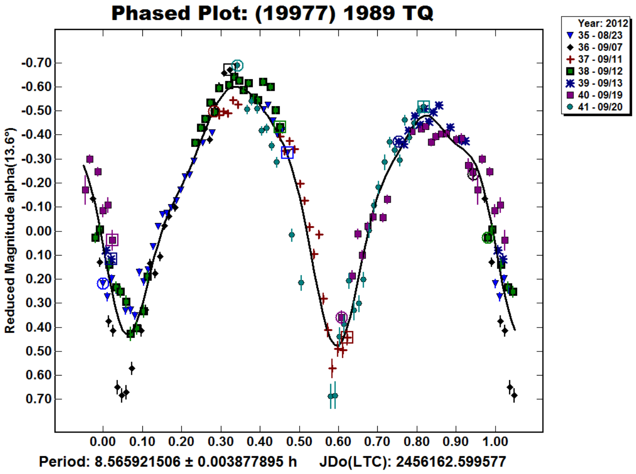

PERIOD DETERMINATION FOR THE SLOW ROTATOR 2546 LIBITINA

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(Received: 5 July)

Period and amplitude results for asteroid 2546 Libitina were determined from observations during 2013. The synodic rotation period was found to be 132.71 ± 0.07 h and the lightcurve amplitude was 0.35 ± 0.03 mag.

The main-belt asteroid 2546 Libitina was discovered in 1950 and named after the ancient Roman goddess of funerals and burial. It appeared on the CALL web site as an asteroid photometry opportunity due to reaching a favorable apparition and having no defined lightcurve parameters. CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) in 2013, April 9 to 23, using a 0.3-m Meade LX-200R reduced to f/6.9. The CCD imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536 x 1024 array of 9-micron pixels and 23 x 16 arcminute field-of-view. Exposures were 90 s working at –10C, unfiltered, binned 2x2, yielding an image scale of 1.77 arcseconds per pixel. The camera was off-axis guided by means of a SX Lodestar camera and *PHD Guiding* (Stark Labs) software. Image acquisition was done with *MaxIm DL5* (Diffraction Limited). All images were dark and flat-field corrected and then measured using *MPO Canopus* (Bdw Publishing) version 10.4.0.20 with a differential photometry technique. The data were light-time corrected. Night-to-night zero point calibration was accomplished by selecting up to five comp stars with near solar colors according to recommendations by Warner (2007) and Stephens (2008). Period analysis was also done with *MPO Canopus*, which incorporates the Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989).

A total of 13 nights were exclusively devoted to observe this asteroid over a total span of 15 days. About 72 hours of effective observation and more than 2,600 data points were required in order to solve the lightcurve. Over the span of observations, the phase angle varied from 8.8º to 8.5º to 9.8º, the phase angle bisector ecliptic longitude from 203.9º to 204.9º, and the phase angle bisector ecliptic latitude from –13.7º to -14.1º. The rotational period was determined (for the first time) to be 132.71 ± 0.07 h along with a peak-to-peak amplitude of 0.35 ± 0.03 mag. Neither clear evidences of tumbling nor binary companion were seen in the lightcurve.

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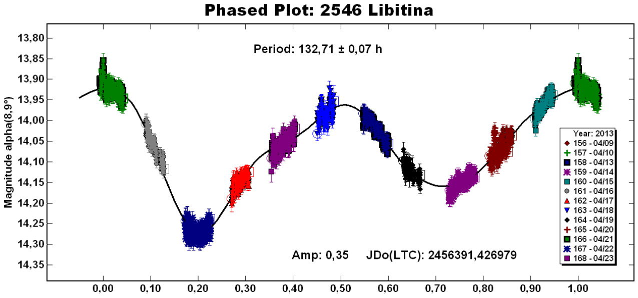

LIGHTCURVE OF 3422 REID USING STAR SUBTRACTION TECHNIQUES

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Lightcurves measurements obtained in June 2013 for asteroid 3422 Reid suggest 2.91 ± 0.02 h as an update to the rotation period. The observed amplitude was 0.52 ± 0.05 mag. A significant reduction in the point-to-point scatter within the lightcurve was achieved when star subtraction were employed to eliminate the contaminating effects of background stars.

3422 Reid was discovered on 1978 July 28 at Perth Observatory, in Perth, Australia, and given the designation 1978 OJ. Since its discovery, only one lightcurve had been measured (Krotz *et al.* 2010), but it did not cover a full rotation cycle and so it was possible that the reported period of 3.22 h was not precise. The purpose of the observations obtained at Isaac Aznar Observatory (IAO) was to find the rotation period as accurately as possible. Images were obtained using a Meade 0.35-m LX200 ACF *f*/6.4, an unfiltered Santa Barbara Instrument Group (SBIG) CCD ST9-XE working at –10°C, and SBIG A08 adaptive optics. The image scale was 1.86 arcseconds per pixel. Exposure time was 60 seconds. The observations were made on the night of 2013 June 22, when the asteroid was approximately mag 15.3. Image calibration was done using master twilight flats and darks. The calibration frames were created using *MaximDL* and *MPO Canopus* was used to measure the processed images.

Using a data set of 88 points, first analysis found a period of 2.99 ± 0.01 h with an amplitude of 0.48 ± 0.05 mag. This period was slightly shorter than the 3.22 h obtained by Krotz *et al.* (2010). Figure 1 shows the lightcurve from the first analysis. Because the asteroid was passing a dense field star at the time, the shape of the lightcurve changed abruptly around 0.30 to 0.55 rotation phase. This is a common problem in minor planet photometry, so it´s necessary to do a thorough review of the images in order to minimize background contamination effects on the curve shape and resulting the rotation period and amplitude.

Fortunately *MPO Canopus* V.10 has a star subtraction function that attempts to correct the increase in brightness when the asteroid and star images merge. Figure 2 shows the final lightcurve after using the star subtraction function. The shape is smoother than the previous curve as the point-to-point noise is reduced. The improved precision in the data yields a rotation period of 2.91 ± 0.02 h. The amplitude in the new lightcurve is 0.52 ± 0.05 mag. The star subtraction function also improved the RMS from Fourier analysis reducing from 5.52384 in Figure 1 to 2.44077 in Figure 2.

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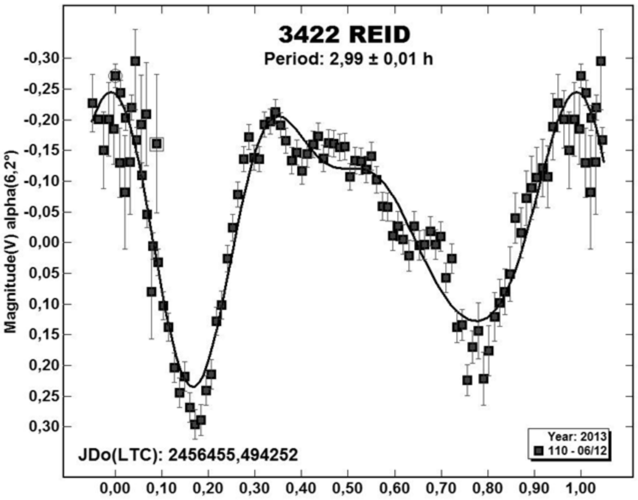

Figure 1: Preliminary lightcurve for 3422 Reid.

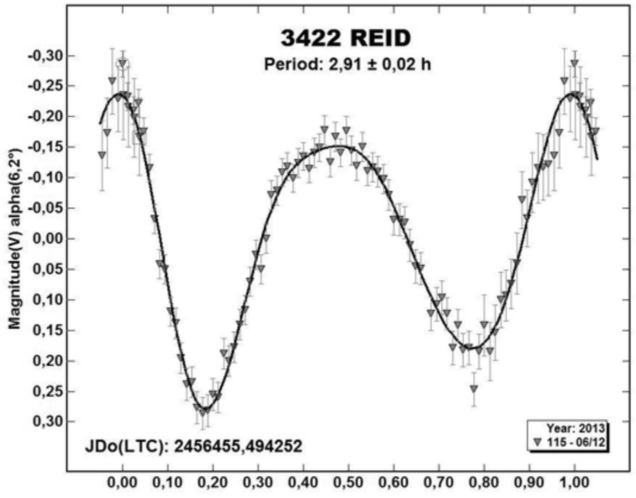

Figure 2: Final lightcurve for 3422 Reid using star subtraction.

ASTEROID LIGHTCURVE ANALYSIS AT ELEPHANT HEAD OBSERVATORY: 2013 APRIL –JULY

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(Received: 12 July)

Four main-belt asteroids were observed from Elephant Head Observatory during 2013 April to July: 319 Leona, 806 Gyldenia, 814 Tauris, and 2448 Sholokhov.

The synodic rotation rates for four main-belt asteroids were determined from the analysis of CCD photometric observations. These were conducted with a 0.25-m Schmidt-Cassegrain Telescope on a German Equatorial mount (GEM) using an SBIG STT-8300M CCD camera with 5.4-micron pixels binned at 4x4 with an image scale of 1.67 arcsec per pixel. A clear filter was used for all exposures, which were between 150 and 250 seconds each. All images were dark and flat-field corrected. All lightcurve data were submitted to the ALCDEF website at *http://minorplanetcenter.net/light_curve*.

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

319 Leona. A search for previous period determinations of 319 Leona found a value of 9.6 h (Behrend, 2006). New observations were obtained over nine nights in 2013 April. Analysis of the data found a period of 14.9 ± 0.1 h, amplitude 0.10 ± 0.03 mag. The newly determined period differs from that given in the asteroid lightcurve database (Behrend, 2006). The flatness of the lightcurve made it difficult to establish an accurate period. This asteroid needs further work.

806 Gyldenia. A search for previous period determinations of 806 found 14.45 h (Behrend 2005, 2006). New observations were obtained over eight nights in 2013 April. Analysis of the data found a period of 16.846 ± 0.007 h, amplitude 0.14 ± 0.02 mag. The newly determined period differs from that in Behrend of 14.45 h. Both lightcurves are plotted below for reference.

814 Tauris. A search for previous period determinations of 814 Tauris found 35.8 h (Debehogne *et al*., 1983). New observations were obtained over 14 nights from 2013 May to June. Analysis of the data found a period of 35.8 ± 0.1 h, amplitude 0.18 ± 0. The newly determined period is within experimental uncertainty with the Debehogne *et al*. result. This lightcurve did not receive complete coverage of the analyzed period.

2448 Sholokhov. A search for previous period determinations of 2448 Sholokhov found Warner (2005; 10.065 h). New observations were obtained over 11 nights from 2013 May to June. Analysis of the data found a period of 10.061 ± 0.002 h, amplitude

0.21 ± 0.02 mag. The newly determined period is within experimental uncertainty with Warner.

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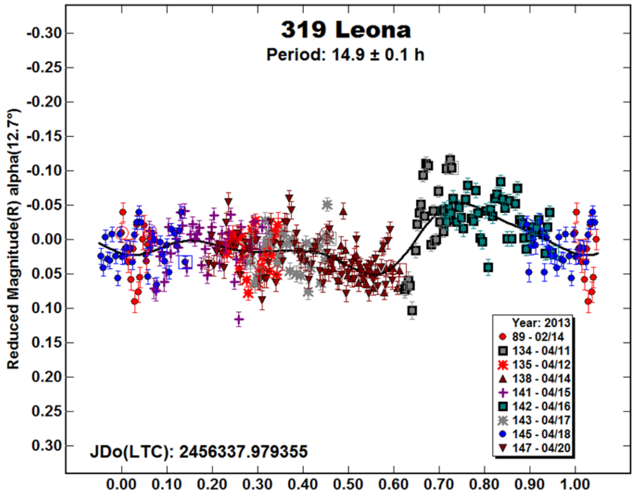

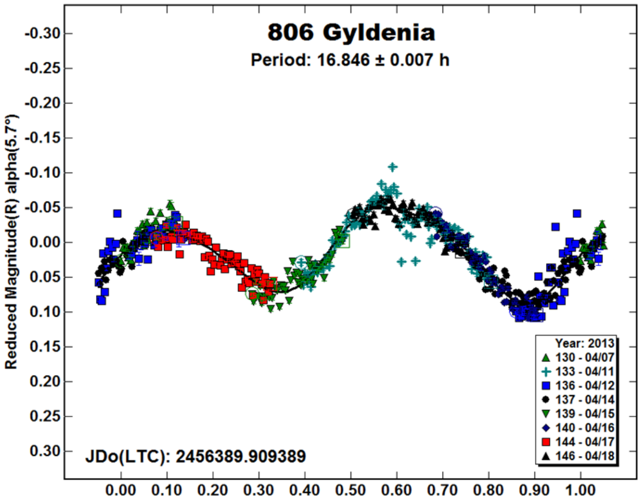

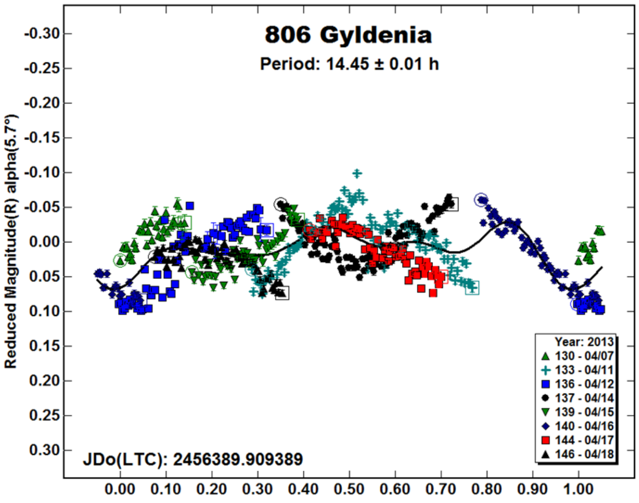

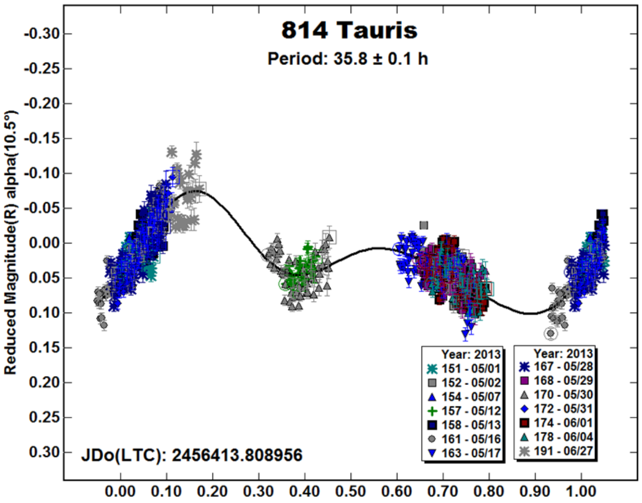

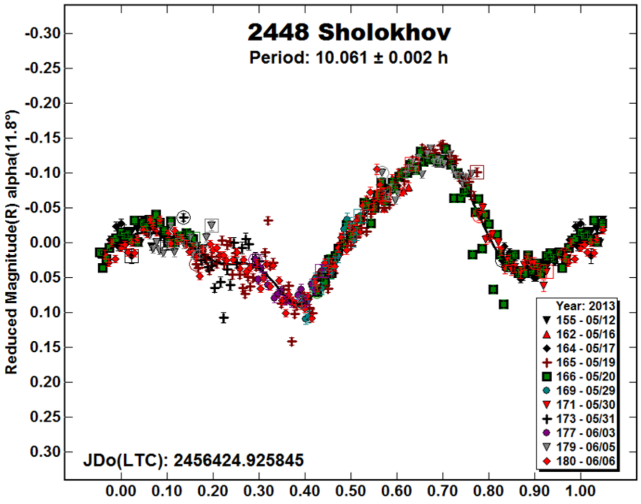

ASTEROID LIGHTCURVE ANALYSIS AT THE PALMER DIVIDE OBSERVATORY: 2013 FEBRUARY-MARCH. THE FINAL REPORT.

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Lightcurves for nine asteroids were obtained at the Palmer Divide Observatory (PDO) in 2013 February and March. These represent the final objects out of more than 1100 lightcurves measured at PDO over fourteen years. Of the nine objects reported here, six were Hungaria members, two were NEAs, and the remaining two were main belt members. Analysis of the data resulted in a revised rotation period for the Hungaria member 4531 Asaro. The near-Earth asteroid (5828) 1991 AM was found to be a possible binary system with an unusual lightcurve for the secondary period, while follow-up on known Hungaria binary 5899 Jedicke lead to a revised period for the primary and confirmation of the orbital period of the satellite.

CCD photometric observations of nine asteroids were made at the Palmer Divide Observatory (PDO) in 2013 February and March. See the introduction in Warner (2010b) for a discussion of equipment, analysis software and methods, and overview of the lightcurve plot scaling. These were the last observations to be made at PDO, which was razed soon after and the telescopes moved to the California desert where they will be operated remotely. From 1999 April through 2013 March, more than 1100 asteroid lightcurves were obtained and published as a result of work at PDO. Within these numbers are the primary discoveries of more than a dozen Hungaria binary asteroids as well as primary or co-discovery of nearly another dozen.

In the plots below, the "Reduced Magnitude" is Johnson V or Cousins R (indicated in the Y-axis title) corrected to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotational phase, ranging from 0.0 to 1.0.

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

4531 Asaro. This Hungaria was previously worked by Warner (2010), at which time the period was reported to be 5.736 h with an asymmetrical trimodal lightcurve and amplitude of 0.29 mag. The data obtained in 2013 produced a completely different period, 4.144 h, with a bimodal lightcurve of amplitude 0.19 mag. In most cases, if the phase angle is not too severe and assuming an object with a "normal" (potato-like) shape, the lightcurve with an amplitude of almost 0.3 mag should be bimodal and nearly symmetrical. Since this was not the case and the 2013 lightcurve seemed well-determined, even if its amplitude was 0.1 mag less, the original 2010 data were reanalyzed to see if they could be fit to a period near 4.14 h. This proved to be the case as a period of 4.15 h was found and, in fact, had a significantly lower RMS fit value than that for the original period. A plot showing the revised 2010 lightcurve is included below.

(5828) 1991 AM. Observations from 2013 February and March showed this near-Earth asteroid (NEA) to be a possible binary system. The primary lightcurve has a period is 2.6666 ± 0.0002 h and amplitude of 0.15 ± 0.01 mag. These are parameters that are consistent with a small binary system where the primary rotation rate increased to the point it shed mass and a satellite was formed. It is the shape of the secondary lightcurve that makes this an unusual object.

A typical lightcurve due to a satellite has either an upbowed or flat shape with drops from the general "curve" due to occultations or eclipses involving the satellite (so called *mutual events;* see the lightcurves for 5899 Jedicke below). If the viewing geometry isn't right to see these events, there will still be a secondary curve with the upbow shape due to rotation of the elongated satellite tidally-locked to its orbital period, or a bimodal curve, indicating a satellite's rotation that is not tidally-locked.

Two proposed solutions for a satellite are shown below along with a period spectrum. Neither of these fit well with the descriptions above and are not overly convincing. There seems to be little doubt that a second period is present: the lightcurve without subtracting one of the two long periods is almost indiscernible. However, the physical characteristics of the system remain a mystery and observations at future apparitions are strongly encouraged.

5899 Jedicke. This Hungaria was found to be a binary system by Warner *et al*. (2010a, 2010b). At that time, a primary rotation period of 3.66 h was found, but the amplitude was too low to eliminate other possible periods. The period of the mutual events (orbital period) was well-established, however, at 16.7 h. The 2013 data also showed a small amplitude for the primary. In both apparitions, the second period lightcurve, which showed pronounced mutual events, was easier to determine first. It was then subtracted from the data set to look for the primary period.

The result was that the period spectrum for the primary period in 2013 (see below) shows a somewhat significant preference for a period of about 2.75 h. Based on this, the PDO data from 2010, a subset of that used by Warner *et al.* in 2010, was reanalyzed such that the primary period was forced to between 2 and 3 h. The primary and orbital periods that came from that analysis are in close agreement with the 2013 results and the 3.66 h solution, while still present, was not as strong as one for 2.75 h. Therefore, it is proposed that a period of 2.748 h be adopted for the primary.

8024 Robertwhite. This appears to be the first reported period in the literature. The 0.95 mag amplitude implies an a/b ratio of about 2.5:1 for a triaxial ellipsoid at an equatorial view.

(33908) 2000 LL6. No previously reported period could be found.

(40203) 1998 SP27. This was follow-up to observations in 2009 (Warner 2010a). The periods from the two apparitions are in good agreement and the amplitudes essentially the same. Since the phase

Number	Name	2013 (mm/dd)	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
4531	Asaro (H)	03/18-03/19	142	10.9,10.2	190	+7	4.144	0.005	0.19	0.02
4531	Asaro (H)	10/18-10/31^	139	26.4,23.3	65	+22	4.15	0.01	0.29	0.03
5828	1991 AM (N)	02/19-03/15	273	24.8,55.2	145	+32	2.6666*	0.0002	0.15	0.01
5899	Jedicke (H)	03/02-03/15	384	13.5,14.9	166	+23	2.7481*	0.0004	0.05	0.01
5899	Jedicke (H)	02/03-03/04#	251	16.0,27.0	112	-1	2.730*	0.001	0.04	0.01
8024	Robertwhite (H)	03/18-03/19	137	5.6,4.9	184	+4	7.067	0.005	0.95	0.02
33908	2000 LL6 (H)	03/11-03/14	79	23.7,23.8	175	+36	5.91	0.01	0.25	0.02
40203	1998 SP27 (H)	03/18-03/19	168	22.3,22.2	181	+32	5.448	0.005	0.38	0.02
68216	2001 CV26 (N)	03/11-03/15	200	25.6,22.0	175	+19	2.4290	0.0002	0.21	0.01
88141	2000 WE174	03/11	56	9.8	165	+26	3.01	0.05	0.28	0.03
94608	2001 VR109	03/14-03/15	93	10.0,10.5	159	-6	6.02	0.05	0.60	0.04
^2009 #2010 *period of the primary										

Table I. Observing circumstances. Asteroids with (H) after the name are members of the Hungaria group/family. Asteroids with (N) after the name are near-Earth asteroids (q < 1.3 AU). The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range).

angle bisector longitudes (L_{PAB}) were about 100° apart, this could be interpreted to mean that the spin axis of the asteroid has a low to modest obliquity.

(68216) 2001 CV26. This NEA has been observed on numerous occasions (e.g., Hicks 2010; Polishook 2012; Hills 2013). All reported a period of about 2.4 h, in agreement with the 2013 results from PDO.

(88141) 2000 WE174. This outer main-belt asteroid was in the same field as 5899 Jedicke on one night. Despite having data covering more than one cycle, the period should be taken with some doubt given the large error bars and unusual shape of the lightcurve.

(94608) 2001 VR109. A member of the Flora group, 2001 VR109 was another *target of opportunity*. The large amplitude gave promise of finding a reasonable solution and a telescope was made available for a second night for additional observations.

Acknowledgements

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

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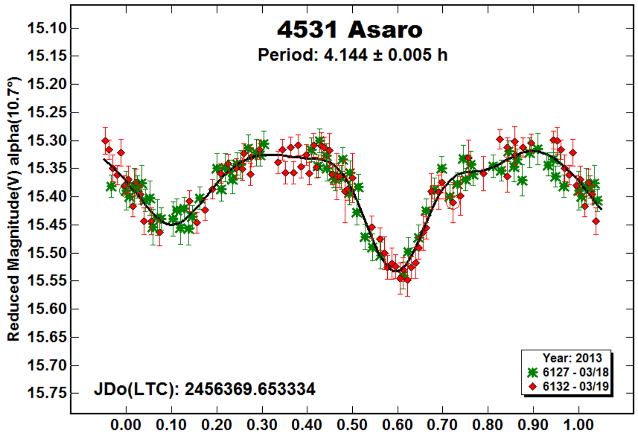
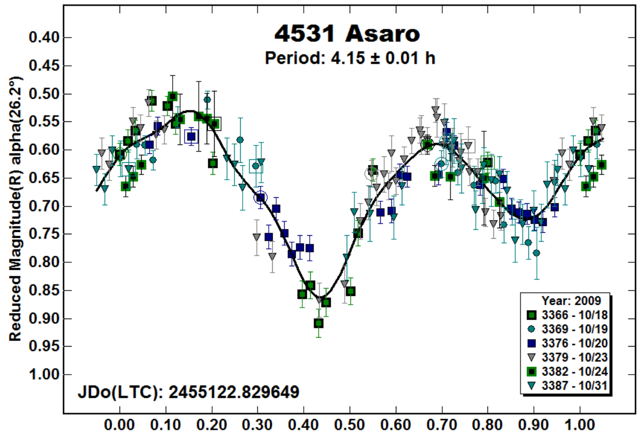
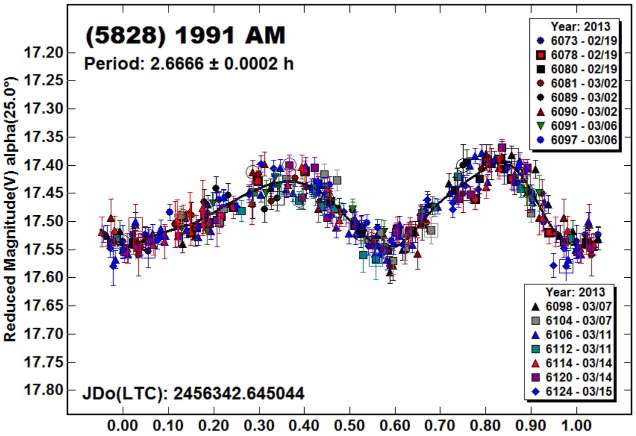
Editor's Note: *A hearty congratulations and "farewell and thank you" to the Palomar Divide Observatory. The lightcurve community looks forward to new results from these instruments forthcoming from their new location and ongoing contributions from the author.*



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6073 - 02/19
6078 - 02/19
6080 - 02/19
6081 - 03/02
6089 - 03/02
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6091 - 03/06
6097 - 03/06
Year: 2013
6098 - 03/07
6104 - 03/07
6106 - 03/11
6112 - 03/11
6114 - 03/14
6120 - 03/14
6124 - 03/15
17.20
17.25
17.30
17.35
17.40
17.45
17.50
17.55
17.60
17.65
17.70
17.75
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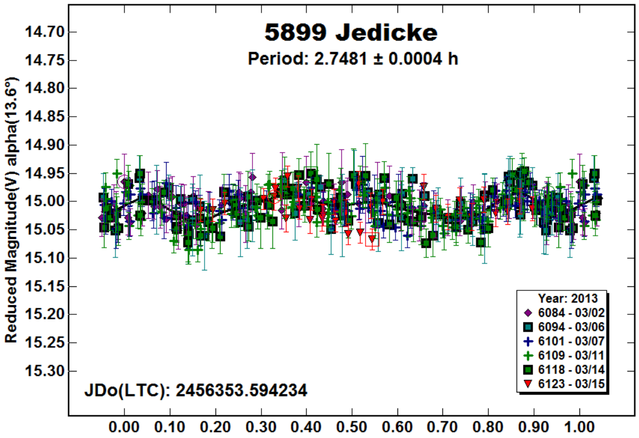
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6101 - 03/07
6109 - 03/11
6118 - 03/14
6123 - 03/15
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14.75
14.80
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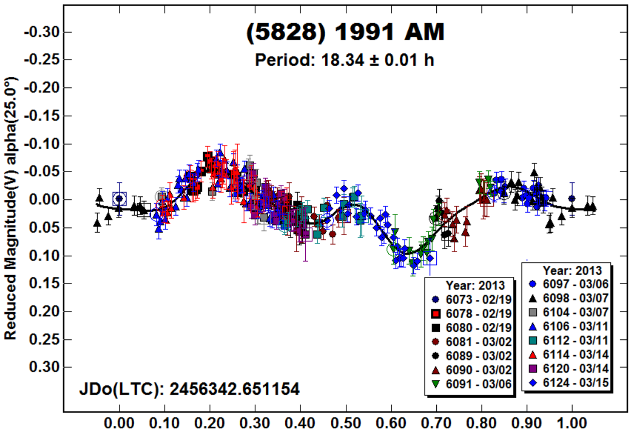
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Year: 2013
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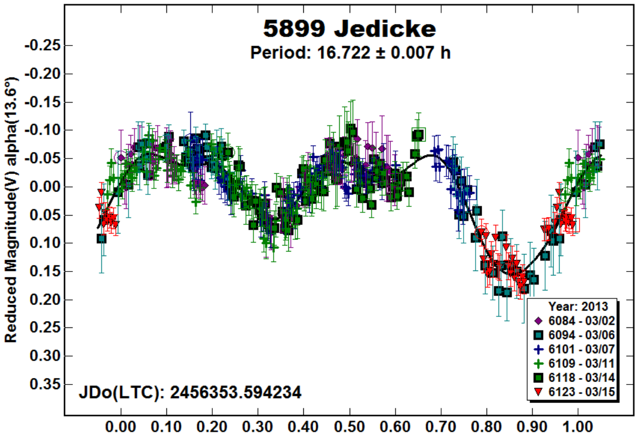
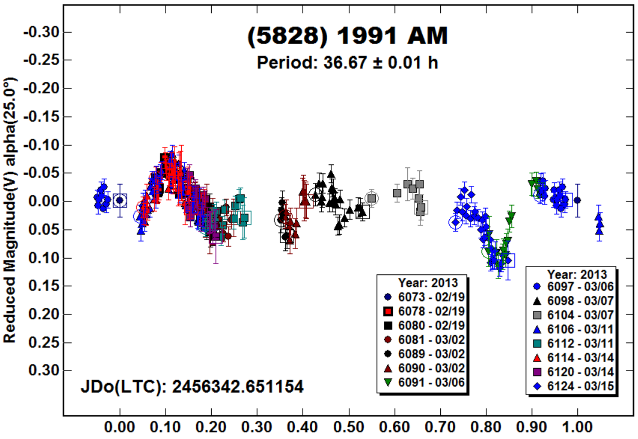
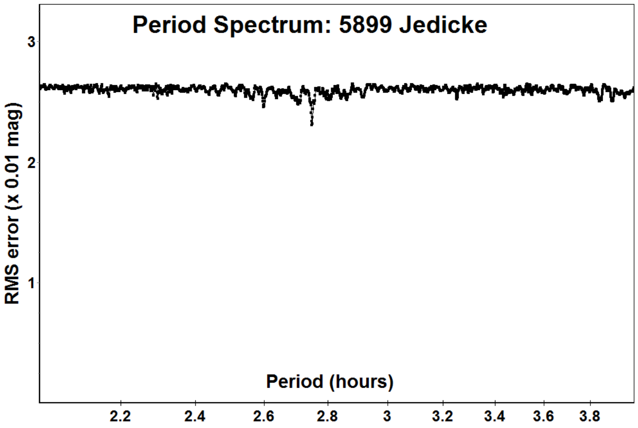
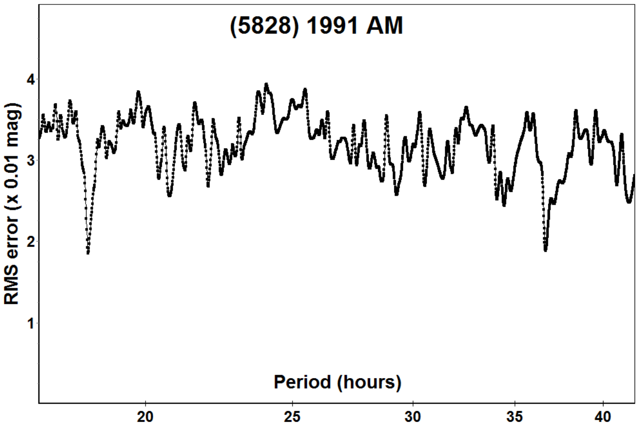

5899 Jedicke
Period: 16.722 ± 0.007 h
Reduced Magnitude(V) alpha(13.6°)
JDo(LTC): 2456353.594234
Year: 2013
6084 - 03/02
6094 - 03/06
6101 - 03/07
6109 - 03/11
6118 - 03/14
6123 - 03/15
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(5828) 1991 AM
Period: 36.67 ± 0.01 h
Reduced Magnitude(V) alpha(25.0°)
JDo(LTC): 2456342.651154
Year: 2013
6073 - 02/19
6078 - 02/19
6080 - 02/19
6081 - 03/02
6089 - 03/02
6090 - 03/02
6091 - 03/06
Year: 2013
6097 - 03/06
6098 - 03/07
6104 - 03/07
6106 - 03/11
6112 - 03/11
6114 - 03/14
6120 - 03/14
6124 - 03/15
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


Period Spectrum: 5899 Jedicke
RMS error (x 0.01 mag)
Period (hours)
3
2
1
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8


(5828) 1991 AM
RMS error (x 0.01 mag)
Period (hours)
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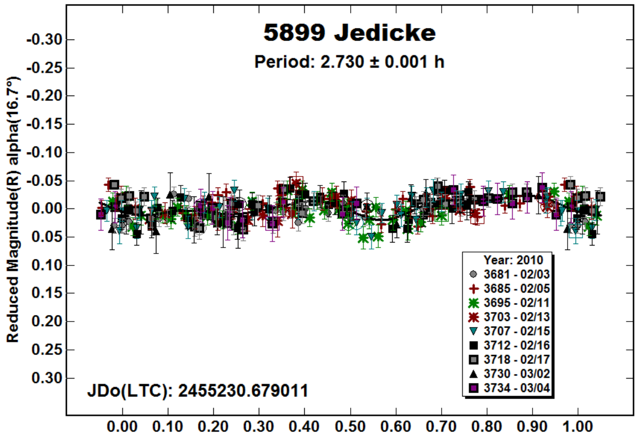
3
2
1
20
25
30
35
40


5899 Jedicke
Period: 2.730 ± 0.001 h
Reduced Magnitude(R) alpha(16.7°)
JDo(LTC): 2455230.679011
Year: 2010
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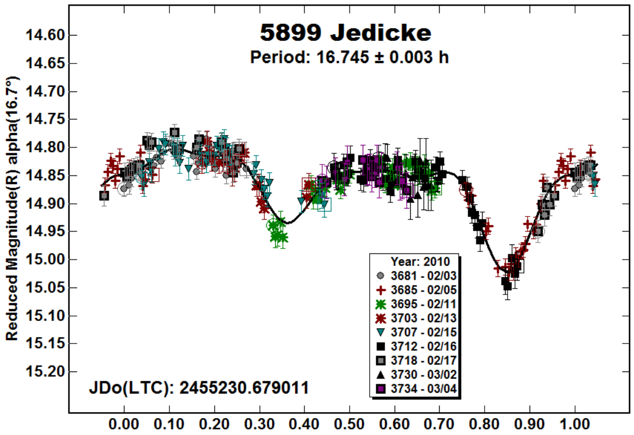
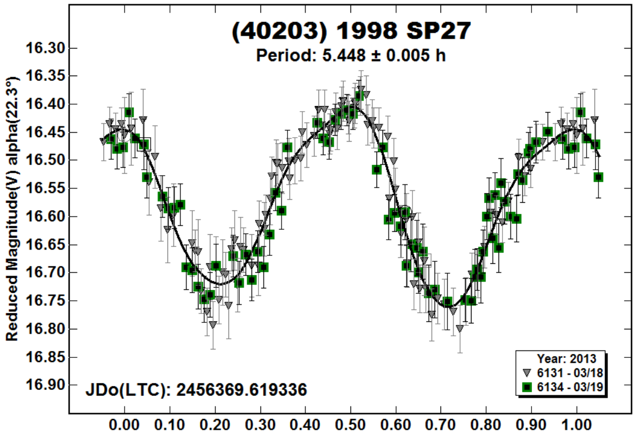
3685 - 02/05
3695 - 02/11
3703 - 02/13
3707 - 02/15
3712 - 02/16
3718 - 02/17
3730 - 03/02
3734 - 03/04
-0.30
-0.25
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


5899 Jedicke
Period: 16.745 ± 0.003 h
Reduced Magnitude(R) alpha(16.7°)
14.60
14.65
14.70
14.75
14.80
14.85
14.90
14.95
15.00
15.05
15.10
15.15
15.20
Year: 2010
3681 - 02/03
3685 - 02/05
3695 - 02/11
3703 - 02/13
3707 - 02/15
3712 - 02/16
3718 - 02/17
3730 - 03/02
3734 - 03/04
JDo(LTC): 2455230.679011
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(40203) 1998 SP27
Period: 5.448 ± 0.005 h
Reduced Magnitude(V) alpha(22.3°)
16.30
16.35
16.40
16.45
16.50
16.55
16.60
16.65
16.70
16.75
16.80
16.85
16.90
Year: 2013
6131 - 03/18
6134 - 03/19
JDo(LTC): 2456369.619336
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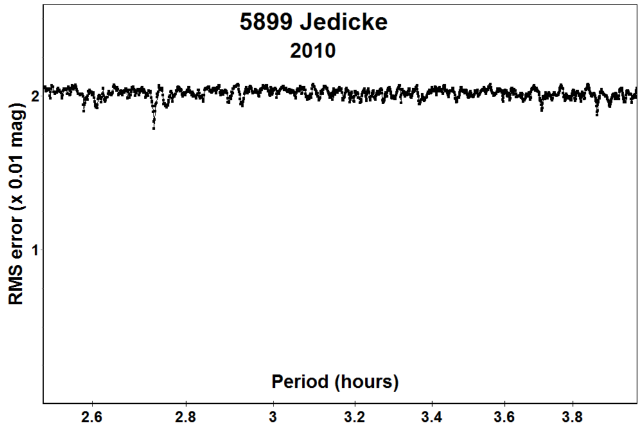
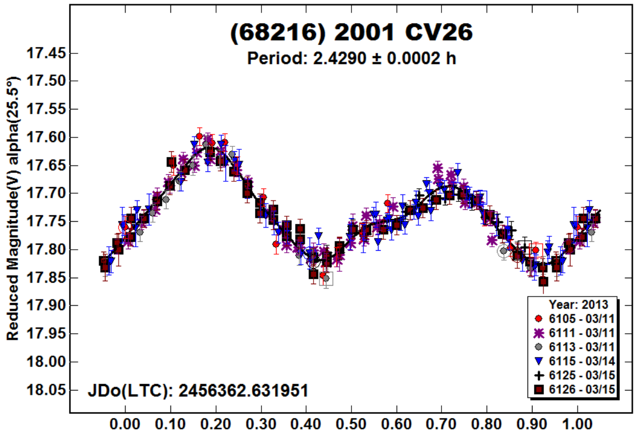
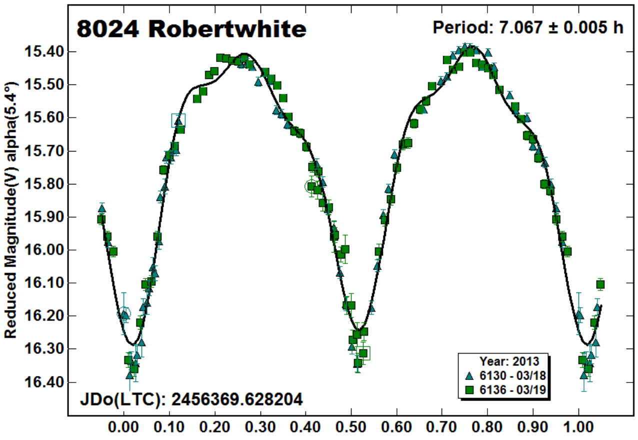
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


5899 Jedicke
2010
RMS error (x 0.01 mag)
2
1
Period (hours)
2.6
2.8
3
3.2
3.4
3.6
3.8


(68216) 2001 CV26
Period: 2.4290 ± 0.0002 h
Reduced Magnitude(V) alpha(25.5°)
17.45
17.50
17.55
17.60
17.65
17.70
17.75
17.80
17.85
17.90
17.95
18.00
18.05
Year: 2013
6105 - 03/11
6111 - 03/11
6113 - 03/11
6115 - 03/14
6125 - 03/15
6126 - 03/15
JDo(LTC): 2456362.631951
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


8024 Robertwhite
Period: 7.067 ± 0.005 h
Reduced Magnitude(V) alpha(5.4°)
15.40
15.50
15.60
15.70
15.80
15.90
16.00
16.10
16.20
16.30
16.40
Year: 2013
6130 - 03/18
6136 - 03/19
JDo(LTC): 2456369.628204
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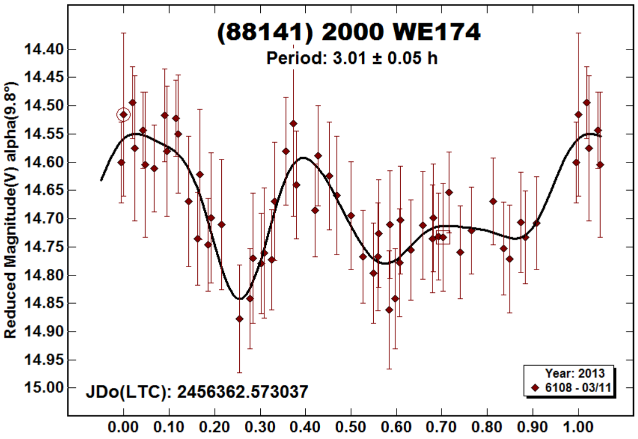
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(88141) 2000 WE174
Period: 3.01 ± 0.05 h
Reduced Magnitude(V) alpha(9.8°)
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14.45
14.50
14.55
14.60
14.65
14.70
14.75
14.80
14.85
14.90
14.95
15.00
Year: 2013
6108 - 03/11
JDo(LTC): 2456362.573037
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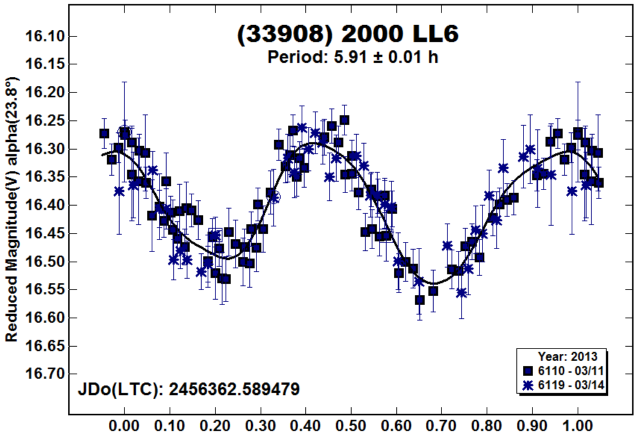
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(33908) 2000 LL6
Period: 5.91 ± 0.01 h
Reduced Magnitude(V) alpha(23.8°)
16.10
16.15
16.20
16.25
16.30
16.35
16.40
16.45
16.50
16.55
16.60
16.65
16.70
Year: 2013
6110 - 03/11
6119 - 03/14
JDo(LTC): 2456362.589479
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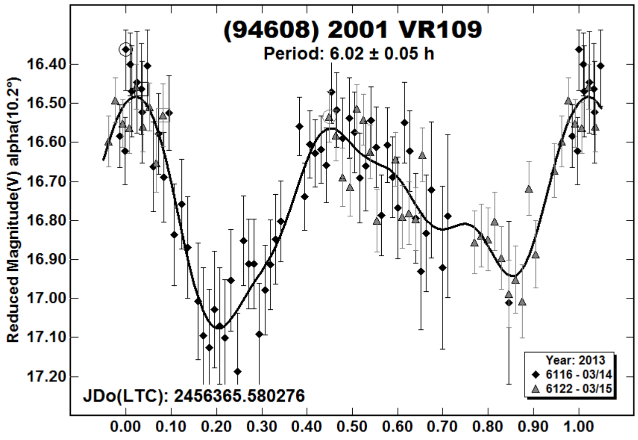
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00


(94608) 2001 VR109
Period: 6.02 ± 0.05 h
Reduced Magnitude(V) alpha(10.2°)
16.40
16.50
16.60
16.70
16.80
16.90
17.00
17.10
17.20
Year: 2013
6116 - 03/14
6122 - 03/15
JDo(LTC): 2456365.580276
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

ONE NEW AND ONE SUSPECTED HUNGARIA BINARY ASTEROID

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CCD photometry observations were made of two Hungaria asteroids in 2013 April and May. 4765 Wasserburg was found to be a previously undiscovered binary with a primary period of 3.6231 ± 0.0005 h and a satellite orbital period of 15.97 ± 0.02. What makes this a particularly interesting find is that the asteroid is one member of an *asteroid pair* (Vokrouhlický and Nesvorný 2008). The suspected Hungaria binary is (12390) 1994 WB1. Data from 2013 indicate the possibility of a satellite with an orbital period of 15.94 h and a primary rotation period of 2.462 h. However, analysis of data from 2008 does not show a satellite and found a period of 15.20 h. At best, 1994 WB1 is an "asteroid of interest."

CCD photometric observations of two Hungaria asteroids were made in 2013 April and May at the Center for Solar System Studies (CS3) located in Landers, CA. These were follow-up observations to provide additional data for spin axis modeling and to check for previously undetected satellites as part of a long-term study of these inner main-belt asteroids conducted by Warner (see Warner *et al*., 2009a).

Image processing and measurement as well as period analysis were done using *MPO Canopus* (Bdw Publishing). The period analysis is based on the FALC algorithm developed by Harris (Harris *et al.* 1989). Master flats and darks were applied to the science frames prior to measurements. The images were acquired almost exclusively by Stephens, who also did the initial image measurements that produced the data sets. Warner did the final analysis using the dual-period search feature of *MPO Canopus*. Conversion to an internal standard system with approximately ±0.05 mag zero point precision was accomplished using the Comp Star Selector in *MPO Canopus* and the MPOSC3 catalog provided with that software. The magnitudes in the MPOSC3 are based on the 2MASS catalog converted to the BVRcIc system using formulae developed by Warner (2007c).

In the plots presented below for the presumed primary of the binary system, the "Reduced Magnitude" is Johnson V corrected to unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. For plots showing the lightcurve due to the proposed satellite, differential magnitudes are used, with the zero point being the average magnitude of the lightcurve for the primary. The primary body magnitudes were normalized to the phase angle given in parentheses, e.g., alpha(6.5°), using $G = 0.15$, unless otherwise stated. The horizontal axis is the rotation phase, ranging from –0.05 to 1.05.

<u>4765 Wasserburg</u>. This Hungaria asteroid is one member of an *asteroid pair* (Vokrouhlický and Nesvorný 2008). The other member is (350716) 2001 XO105. For an in-depth discussion about the formation and characteristics of asteroid pairs, see Pravec and Nesvorný (2009) and Pravec *et al*. (2010).

Wasserburg had been observed several times before 2013, e.g., Warner (2007, 2010), Pravec *et al.* (2010). No satellite was reported as a result of those observations, analysis of all of which found a period of 3.625 h, in agreement with the results from our analysis. Observations made by Donald Pray and analysis by Pravec in 2013 consisted of one night in March and April and two in May, or within a few weeks prior to ours. They showed an interesting evolution of the primary lightcurve but no apparent deviations due to a satellite. Again the period was found close to 3.625 h.

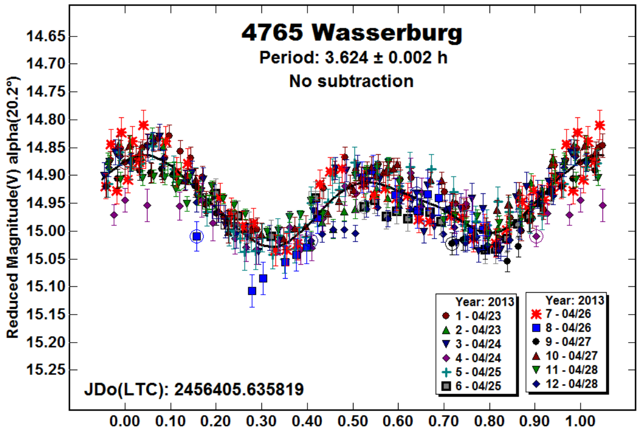

Figure 1. The lightcurve for 4765 Wasserburg without subtracting the effects of the proposed satellite.

Figure 1 shows the lightcurve the asteroid using a single-period analysis from our data set obtained by Stephens using a 0.35-meter Schmidt-Cassegrain (SCT) and SBIG STEL-1001E CCD camera.. In many cases, there would be good reason to suspect that the scatter about the mean curve (solid black line) was due to systematic or random noise. However, small satellites can produce deviations on the order of only 0.02-0.03 mag, about the limit for detection using only lightcurve photometry (Pravec *et al.* 2006). Therefore, to be certain, a dual period analysis was done. This amounts to finding a period, such as shown in Figure 1, and then subtracting the Fourier model lightcurve from the data and doing a second search. This can lead to finding something that may resemble *mutual events* (occultations and/or eclipses due to a satellite) or, if the viewing geometry is not right, a continuous lightcurve showing a symmetrical "upbowing." The latter is due to an elongated satellite that is tidally-locked to its orbital period. It's also possible that a second period, not integrally commensurate with the primary period can be found. This would be due to a satellite that is elongated but not tidally-locked to the orbital period.

If a second period is found, an iterative process is used by subtracting period 2 to find a new period 1 and the resulting model curve used to find a new model 2 curve. The process continues until the two periods and lightcurves stabilize. Figure 2 shows the result after this iterative process for period 1, or the lightcurve due only to the rotation of the proposed primary body. The amplitude is 0.17 ± 0.01 mag and the period 3.6231 ± 0.0005 h. Note the significant improvement in the fit to the Fourier model curve.

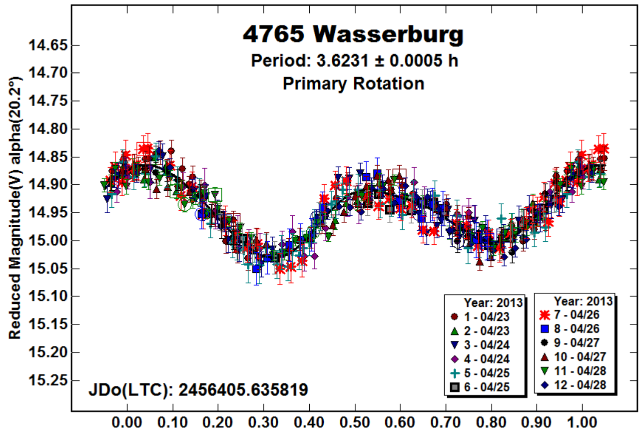

Figure 2. The lightcurve for 4765 Wasserburg after subtracting the effects due to the proposed satellite.

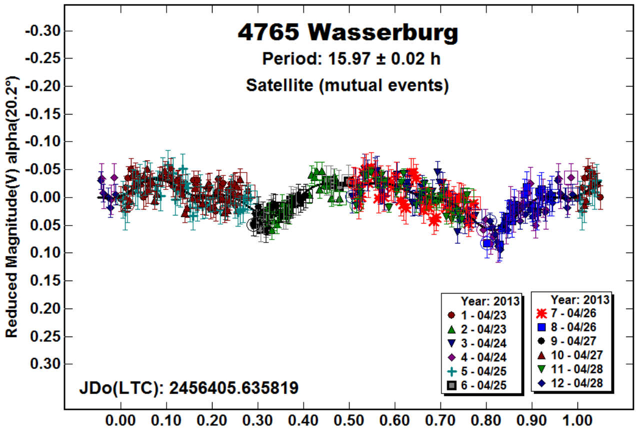

Figure 3. The lightcurve due to the proposed satellite of 4765 Wasserburg. The mutual events are seen at 0.3 and 0.8 rotation phase.

Figure 3 shows the result of subtracting the Fourier model curve for period 1 from the data set. The overall shape indicates the upbowing mentioned above but with two sharp drops separated by one-half the period. These are the result of the mutual events. Note that the depth of the drop at 0.3 rotation phase is slightly shallower than the one at 0.8. The amplitude of the shallower event can give an estimate on the size ratio of the two bodies. Since neither event is flat-bottomed, indicating a total event, then the ratio estimate is for a lower limit. Assuming the depth of the shallow event is 0.03 mag, this gives Ds/Dp ~ 0.16 ± 0.02.

The viewing aspect for an asteroid is often given by the phase angle bisector (PAB), which is the vector that is mid-way between the asteroid-Sun and asteroid-Earth vectors. When the PAB longitude (L_{PAB}) is nearly the same, or 180° removed, from a previous set of observations, the amplitude of an asteroid's lightcurve will be about the same as will be the viewing geometry regarding the orbital plane of a satellite. The observations prior to 2013 fit these criteria. The amplitude of the lightcurves were about 0.57 mag. In 2013, however, the L_{PAB} was about 90° from the line joining the previous data sets and, as might be expected, the amplitude of the lightcurve was considerably less, only 0.17 mag at the time of our observations. This may also account for why a satellite was not previously found. In 2013, L_{PAB} was ~205°. This gives a good indication of the orientation of the spin axis, i.e., it is near 205° (or 25°).

The large amplitude of the primary in years prior to 2013 gives an a/b ratio for a triaxial ellipsoid of about 1.7. This would make this among the more elongated primaries among the small (*D* < 10 km) binaries.

(12390) 1994 WB1. This Hungaria was observed by Warner (2008) in 2008 April. At that time, a period of 15.22 h and amplitude of 0.08 mag were reported (Figure 4). The unusual shape of the curve was noteworthy but there was no evidence of a second body.

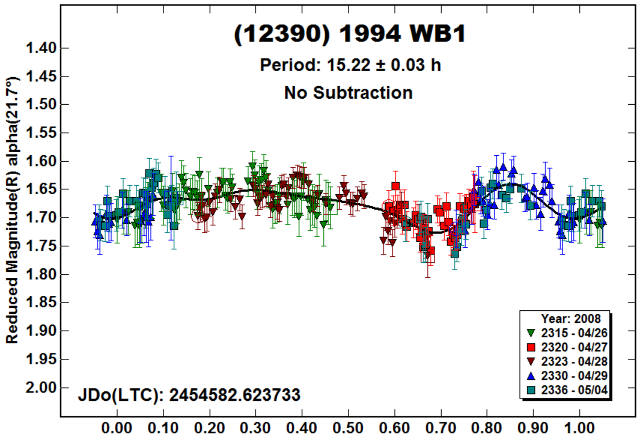

Figure 4. The original 2008 lightcurve for (12390) 1994 WB1.

Stephens observed 1994 WB1 on 16 nights between 2013 May 5 and June 3 using a 0.4-meter SCT and either an SBIG STL-1001E or Finger Lakes Instruments FLI-1001E CCD camera. Warner observed on June 4 using a 0.35-meter SCT and STL-1001E camera.

As more data became available, analysis found a period of 15.9 h and what appeared to be parts of mutual events due to a satellite. Being so close to a 3:2 ratio with an Earth day, observations every other night covered essentially the same part of the curve. Thus the effort to get full coverage of the lightcurve was slow.

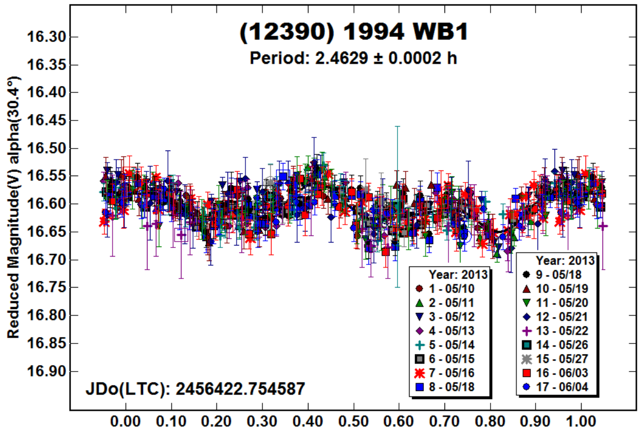

Figure 5. The lightcurve for the proposed primary of 1994 WB1.

Figure 5 shows the results of our analysis using 17 data sets. The proposed primary shows an unusually-shaped curve with three apparent maximums. The period of 2.4629 ± 0.0002 h fits well with the range expected for the primary of a small binary system, as does the amplitude of 0.09 mag, which indicates the primary is approximately spheroidal. However, as seen above for 4765 Wasserburg, it's possible, though not likely in this case because of the shape of the lightcurve, that the primary is more elongated than the amplitude implies.

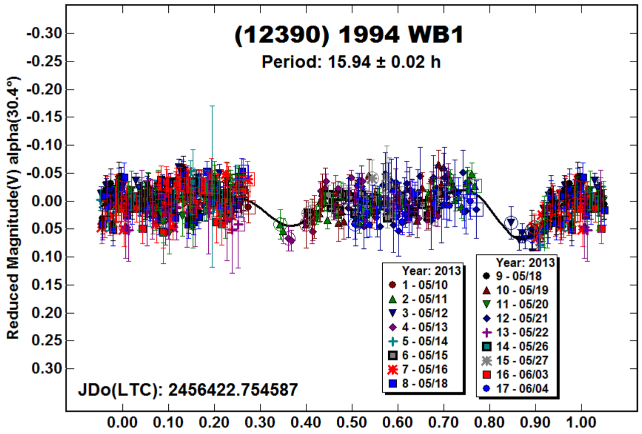

Figure 6. The lightcurve (2013 data) for 1994 WB1 after subtracting the Fourier model for period 1.

Figure 6 shows the results of subtracting the proposed primary lightcurve from the data set. The curve is essentially flat between the apparent drops at about 0.35 and 0.85 rotation phase. It is a concern that these "events" were seen towards the beginning or ends of runs and that there is incomplete coverage. We reached out to some observers in Europe but they were not able to help for various reasons. Therefore, we could not get pass the almost exact 3:2 commensurability to fill in the missing pieces of the puzzle.

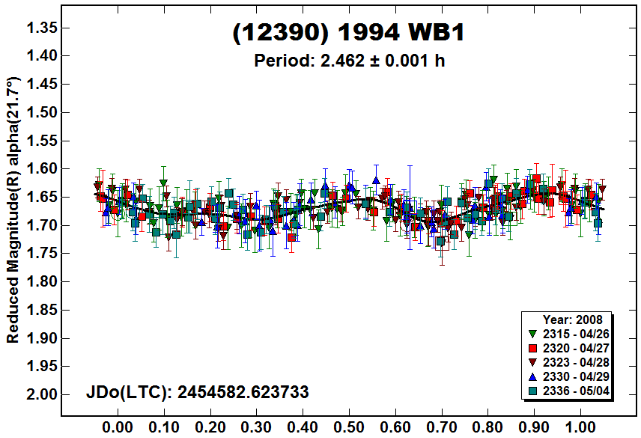

Figure 7. A proposed 2008 lightcurve for 1994 WB1.

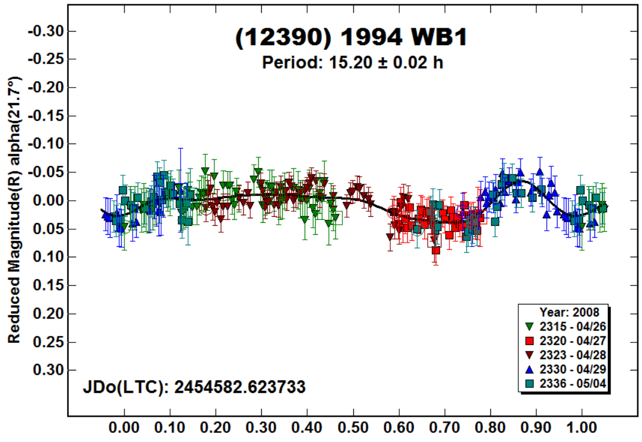

Figure 8. The 1994 WB1 lightcurve (2008) after subtracting P1.

More important, the period of 15.94 h is considerably different from that obtained in 2008. Using these results, we re-analyzed the data set from 2008 to see if the older data set could be matched to the 2013 results. A period of 2.462 h could be extracted, which is in good agreement with the 2013 result (Figure 7) but it has a very low amplitude. Furthermore, when subtracting that Fourier model curve from the data, we found a period of 15.20 h for a secondary period (Figure 8) with a shape very similar to the original lightcurve. If anything the period spectrum found a "worst case solution" for a period near 15.9 h. The two data sets just could not be reconciled with one another.

Since the data sets from 2008 and 2013 do not produce the same results, and because there is good cause for doubt about the 2013 results, we cannot say with certainty that this is a binary asteroid nor make a reasonable estimate of a size ratio. For now, it must remain an "asteroid of interest" for which observations at future apparitions are strongly encouraged.

Acknowledgements

The purchase of the FLI-1001E CCD camera used by Stephens at the CS3 site was made possible by a 2013 Gene Shoemaker NEO Grant from the Planetary Society. Funding for Warner was provided by NASA grant NNX10AL35G and National Science Foundation Grant AST-1032896.

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PHOTOMETRY OF MINOR PLANETS.
I. ROTATION PERIODS FROM LIGHTCURVE ANALYSIS FOR SEVEN MAIN-BELT ASTEROIDS

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(Received: 9 July)

CCD photometric measurements of the main-belt asteroids 417 Suevia, 453 Tea, 904 Rockefellia, 933 Susi, 1269 Rollandia, 1318 Nerina, and 1465 Autonoma were performed during the period 2010 August to 2012 March. The brightness amplitude and synodic rotation period of the composite lightcurves are presented and commented for each asteroid.

Introduction

A large part of our knowledge on asteroids is derived from their brightness variations. Indeed, shape and periodicities of lightcurves are mainly linked to the rotation rate and to the global morphology of the objects. The collections of lightcurves, built up over several decades, are a fundamental basis to perform statistical analysis, particularly the period distribution of asteroids. For example, and despite observational selection effects, a "spin rate barrier" was highlighted in a diagram of the rotation rate *versus* size (Harris and Pravec, 2005), indicating some clues on the internal structure of asteroids. Lightcurves can help to detect tumbling asteroids as well as binary and multiple asteroid systems. From many apparitions, it's also possible to determine if the Yarkovski and YORP thermal effects induce alterations of the asteroid's rotation rate and state.

Dense and/or sparse photometric observations (e.g., Ďurech *et al.*, 2009), combined with datasets from other techniques (e.g., radar, stellar occultations, thermal radiometry, spectroscopy, polarimetry, adaptative optics, interferometry) and analysed with powerful inversion methods, allow one to model and give a good approximation of the physical properties of the minor bodies, such as their spin state, 3-D morphology and scattering characteristics of the surface.

These characterization studies are bricks which contribute to built the knowledge on the composition and internal structure of the asteroids (e.g., Binzel *et al.*, 2003; Michel, 2009; Carry, 2012), as well as on their formation, collisional and rotational evolution, thermal evolution, dynamics, and interrelations with other solar systems bodies (see reviews edited by Bottke *et al.*, 2002, and also, e.g., Asphaug, 2009, and Nesvorný *et al.*, 2011).

Dense photometry is a time consuming technique – a constraint for professional astronomers. However, as small diameter telescopes remain useful, amateur astronomers – the "Masters of time"! – can play a role by their contribution to the observational effort (e.g. Fauvaud, 2009; Warner, 2009). It is in this context that we observe asteroids since several years. We were also encouraged to study this region of our Solar System by Isaac Asimov (1954) who wrote with a humoristic tone: "Space, you'd think a guy would know something about the asteroids, living out here."

We report the results of lightcurve analysis for seven main-belt asteroids: 417 Suevia, 453 Tea, 904 Rockefellia, 933 Susi, 1269 Rollandia, 1318 Nerina, and 1465 Autonoma. Table 1 summarizes some physical characteristics of these objects, in particular their semi-major axis in astronomical unit (AU), their taxonomic class, diameter, and albedo. In the following Sections, we present successively the observations, the data reduction, the lightcurve analysis and the results.

Observations

All data reported here were collected during the period 2010 August to 2012 March from Le Bois de Bardon Observatory (longitude: 0.407° E; latitude: 45.75° N; altitude: 105 m), a station located in Charente, in the Southwest of France.

Observations were carried out with a SBIG ST-402ME CCD camera attached to a 0.28 m diameter Schmidt-Cassegrain Celestron telescope. To obtain a large enough field of view (FOV) to be sure to have a sufficient sample of stars, a 0.33x telecompressor lens system designed by Optec, Inc. was chosen, giving a FOV of 17' x 26' and an image scale of 4.1 arcsec pixel^{-1} at an effective focal ratio f/3.2. In this configuration, the full-width at half-maximum (FWHM) was of ~2.5 pixels.

The CCD detector was a 16-bit Kodak KAF-0402ME microlensed device with an array of 756 x 510 pixel^2 and a pixel size of 9 x 9 μm^2. With our flat-field and bias frames, we applied the procedure described by Howell (2006) and measured a gain of 2.1 electrons ADU^{-1}, a read noise of 21.5 electrons pixel^{-1} read^{-1} and a dark current of 0.4 electron pixel^{-1} second^{-1} at a nominal temperature of about –15 °C.

The CCD camera was operated with *CCD Soft* (version 5) of Software Bisque, Inc. Images were taken at 2 x 2 binning. The telescope was unguided and tracked at the sideral rate. Typical integration times were 60, 120 or 180 s through a Bessel V or R filter, depending on the brightness of the objects and the weather conditions.

Scientific images were corrected for bias, dark and flat-field effects. For each observing run, master bias and dark frames were produced, and more than 100 twilight and/or daybreak flat-fields were obtained to perform a master flat-field frame.

During the runs, the R-exposures (respectively V-exposures) were complemented with some V-exposures (respectively R-exposures) at low airmasses (< ~1.3). This permitted, in the data reduction, to estimate the color indices of the field stars and so select and use only non-variable comparison stars that had a color similar to that of asteroids.

Data Reduction

All images were reduced with *Iris* (version 5.55), a software developed by Christian Buil (see *http://www.astrosurf.com/buil/iris/iris.htm*). Stellar and sky fluxes were measured by aperture photometry, by integrating the counts in a circular diaphragm with an aperture radius of ~2.5·FWHM pixels. A concentric annulus, with inner and outer radius of 12 and 25 pixels, respectively, centered on the asteroid and each selected stars, was used for estimating the median value of the sky background. Only differential magnitudes were computed. The methodology to reduce the image series is described below. This is based on the reduction procedure presented in Everett and Howell (2001) and adapted for our purpose.

(i) For each observational night, a set of $i = 1,\dots, N$ stars (generally, $N = 2$ or 3) was constituted to be compared to the asteroid. Each set of stars was selected for their brightness and color index similar to that of the asteroid, and to have any variability or trends exceeding a typical scatter of ~0.01-0.03 mag. We also carefully checked that the extinction effects were negligible, thus the lightcurves were not affected within a ~0.01 mag range by differential colors.

(ii) Using the "revised CCD equation" (Merline & Howell, 1995; Howell, 2006) for a point source, and taking also into account the contribution of the atmospheric scintillation noise (Dravins *et al.*, 1998), we computed the $(S/N)_a$ and $(S/N)_*$ signal-to-noise ratios, respectively for the asteroid and stars, and thus their expected σ_a and σ_* uncertainties (in magnitude) from the expressions (Howell, 1993, 2006):

$$\sigma_a = 1.0857\left(\frac{S}{N}\right)_a^{-1} \quad \text{and} \quad \sigma_* = 1.0857\left(\frac{S}{N}\right)_*^{-1} \qquad \text{(1 and 2)}$$

(iii) The asteroid magnitude m_a was then compared to the N star magnitudes m_*, weighted by their individual uncertainties σ_*, to obtain the asteroid differential magnitude:

$$\Delta m = m_a - \sum_{i=1}^{N}\left(\frac{m_{*i}}{\sigma_{*i}^2}\right) \qquad (3)$$

(iv) Assuming that σ_a and σ_* were uncorrelated, we computed for each data point Δm its uncertainty:

$$\sigma_{\Delta m} = \sqrt{\sigma_a^2 + \sigma_{set}^2} \qquad (4)$$

where:

$$\sigma_{set} = \left[\sum_{i=1}^{N}\left(\frac{1}{\sigma_{*i}^2}\right)\right]^{-1/2} \qquad (5)$$

(v) For each night, the comparison of the set stars each other was given a standard deviation (i.e., the root mean square rms of the deviations from the mean) smaller than 0.03 mag. This standard deviation was used to estimate the magnitude dispersion in the nightly asteroid lightcurves. Then, before searching for the period in the photometric time series, all times were corrected for the effect of the light travel-time to Earth (e.g., Francou, 1997), and nightly asteroid lightcurves were shifted to a common magnitude level.

Lightcurve analysis

The search for the periodicity in the asteroid lightcurves was carried out with *Peranso* (version 2.11; Vanmunster, 2006). Various time series analysis methods are implemented in this software, in particular the Fourier analysis procedure described by Harris *et al.* (1989) that we generally used. We were assumed that the assumption of a triaxial ellipsoid shape model (e.g., Burns & Tedesco, 1979) was consistent with our program targets. This assumption is generally true, at least (but not only) for asteroids which have an amplitude lightcurve greater than ~0.2 mag (e.g., Binzel, 1987). So, nightly asteroid lightcurves were shifted along the time axis to match similar features, and to construct a composite lightcurve with two maxima and two minima per synodic rotation. The uncertainty on the synodic rotation period was estimated by inspecting the dispersion in the composite lightcurve induced by a slight variation of the period around its most probable value. The magnitude dispersion in the composite lightcurve was measured by the residuals which remain after a polynomial least-squares fitting procedure, giving a typical scatter (rms) of ~0.02 mag or less.

The peak-to-peak brightness amplitude was evaluated by the difference between the means of the maximum and the minimum of the composite lightcurve. The brightness amplitude uncertainty was estimated from the scatter in the lightcurve and/or from the uncertainty of individual data points.

Results

Observational circumstances are given in Table 2. The UT mid-time of observations is given within 0.1 day, followed by the J2000.0 ecliptic longitude λ_{2000} and latitude β_{2000}, the solar phase angle α, the V magnitude and the filter used. Table 3 summarizes the synodic rotation period and the brightness amplitude of the composite lightcurves for the observed asteroids.

The composite lightcurves are presented in Figures 1 to 7. They show the relative (V or R) magnitude *versus* the rotational phase, calculated with the synodic rotation periods given in Table 3. The caption of figures indicates, for each night, the plot symbol used, the UT mid-time of observations, the standard deviation (rms, in magnitude) in the nightly lightcurve, and the observational station. The zero phase is corrected for the light travel-time effect. Uncertainty bars (± $\sigma_{\Delta m}$, see Eq. 4) are plotted for each individual data point.

Results for each asteroid are described and commented in the following Sections.

417 Suevia. Suevia was firstly observed in 1989 by Barucci *et al.* (1992), who founded a rotation period of 7.034 h and a lightcurve amplitude of 0.20 ± 0.01 mag. Marciniak *et al.* (2012) reported observations from six apparitions (2001, 2005, 2006, 2008, 2009, and 2010), with lightcurve amplitudes from 0.07 to 0.37 mag for a period of 7.019 h. These authors were also determined a 3-D shape model of the asteroid (Ďurech, 2013). We carried out observations of 417 Suevia during five nights in 2010 August-September. This asteroid was monitored over a large range of solar phase angles (from 15.4 to 3.7°), which explains – besides, of course, the uncertainty on measurements – the scatter in the composite lightcurve (Fig. 1). Our data yield to a small amplitude (0.06 ± 0.03 mag) and a rotation period of 7.020 ± 0.003 h, values consistent with those of Marciniak *et al.*

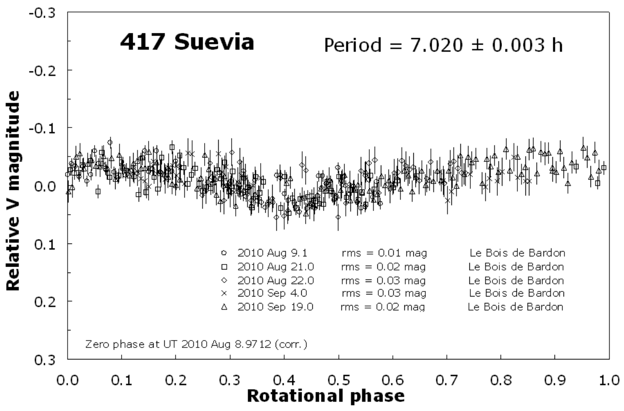

Figure 1. Composite lightcurve of 417 Suevia for 2010 August-September.

453 Tea. Wisniewski *et al.* (1997) were observed this Flora family member during one night in 1990 and reported a brightness amplitude of 0.4 mag and an indicating rotation period of ~6.4 h. Based on noisy datasets obtained by R. Roy in 2008 and M. Audejean in 2013, Behrend (2013) proposed a tentative period of 7.56 h and 7.35 h, respectively. In 2006, Licchelli (2006) found an amplitude of 0.30 ± 0.02 mag and a period of 6.812 ± 0.001 h. Observations of Kryszczyńska *et al.* (2012) were performed during five apparitions (2005, 2006, 2008, 2010, and 2011). Lightcurve amplitudes were varied from 0.45 to 0.1 mag, and the period was 6.811 ± 0.001 h, similar to the one derived by Licchelli (2006). Our observations of 453 Tea were carried out during two nights in 2011 October. The composite lightcurve (Fig. 2) is similar to the one of Kryszczyńska *et al.*, with a small brightness amplitude (~0.06 mag) and a rotation period of 6.831 ± 0.021 h. Slightly higher (~0.3 %) than the ones of Licchelli and Kryszczyńska *et al.*, our period is, however, in agreement with their results.

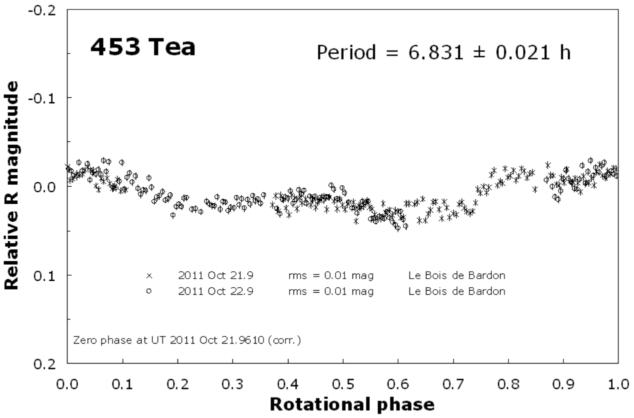

Figure 2. Composite lightcurve of 453 Tea for 2011 October.

904 Rockefellia. Ditteon and Hawkins (2007) observed 904 Rockefellia in 2006. They found a lightcurve amplitude of 0.10 ± 0.03 mag, but no period was derived from their data. A rotation period of 4.93 h and an amplitude of 0.18 mag were reported in CALL (2011; see Warner *et al.*, 2009). Behrend (2013) proposed a tentative period of 12.72 h from observations carried out by P. Antonini in 2009. Based on our observations of 904 Rockefellia performed during two nights in 2011 September and October, the best fit solution for our lightcurve (Fig. 3) is a rotation period of 5.823 ± 0.011 h and a brightness amplitude of 0.10 ± 0.02 mag.

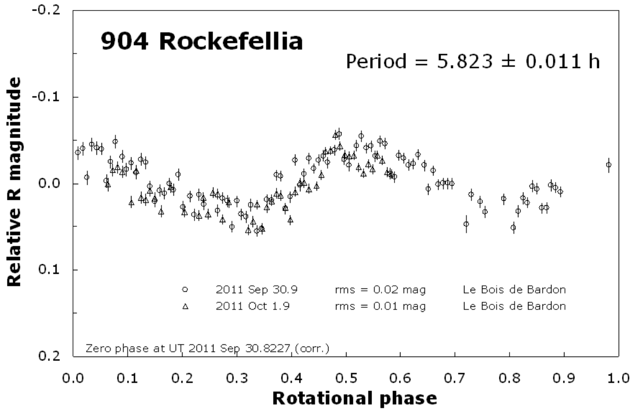

Figure 3. Composite lightcurve of 904 Rockefellia for 2011 September-October.

933 Susi. Behrend (2013) reported for this Erigone family member a period of 5.13 h from noisy data obtained by R. Roy and G. Casalnuovo in 2007 and 2011, respectively. Observed in 2011 by Bin et al. (2011), Higgins (2011), and Strabla et al. (2011), the brightness amplitude of Susi was in the range 0.30 to 0.35 mag, and the period of 4.622 h, a value also reported by Li and Zhao (2012). We performed observations of 933 Susi over ~4.9 h of a single night in 2011 April. The lightcurve amplitude is 0.32 ± 0.02 mag, and the search for the best period yields to 4.412 ± 0.034 h (Fig. 4), a value 4.5 % smaller than the previous published one.

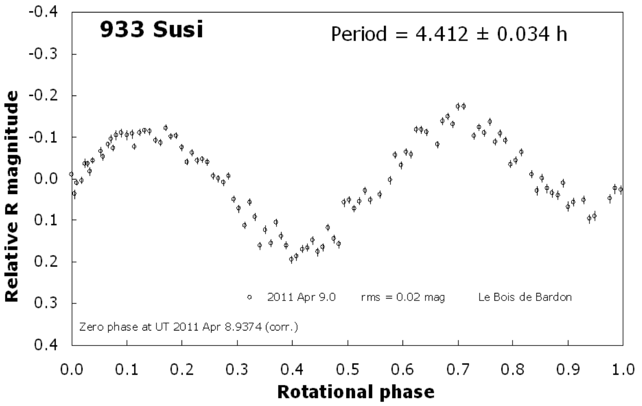

Figure 4. Composite lightcurve of 933 Susi for 2011 April.

1269 Rollandia. In 2008, Slyusarev *et al.* (2012) observed a very small lightcurve amplitude (0.02 mag) and a period of 30.98 h (see Warner *et al.*, 2009) for 1269 Rollandia. The amplitude and period from Franco's (2012) data, performed in 2012 March, were 0.08 mag and 15.4 ± 0.1 h, respectively. We also observed 1269 Rollandia in 2012 March, during three nights. Our composite lightcurve (Fig. 5) shows a lightcurve amplitude of 0.13 ± 0.02 mag, and a period of 15.315 ± 0.030 h, in agreement with Franco's results.

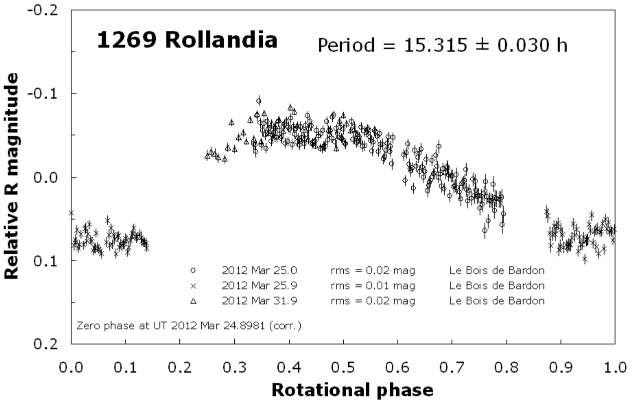

Figure 5. Composite lightcurve of 1269 Rollandia for 2012 March.

1318 Nerina. Behrend (2013) reported data obtained by R. Cripa *et al.* in 2007 and by G. Casalnuevo *et al.* in 2011, indicating a tentative period of 2.532 h for this Phocaea family member. Observed in 2004 and 2010 by Clark (2007, 2011), and in 2011 by Aymani (2011), Durkee (2011), Stephens (2011), and Strabla *et al.* (2011), the period of Nerina was found to be 2.525 h with a small lightcurve amplitude, from 0.16 mag (2004) to ~0.10 mag (2010-2011). Although noisy, our data on 1318 Nerina, obtained during two nights in 2011 April, are consistent with those of other authors, giving a rotation period of 2.529 ± 0.003 h and a lightcurve amplitude of 0.07 ± 0.02 mag (Fig. 6).

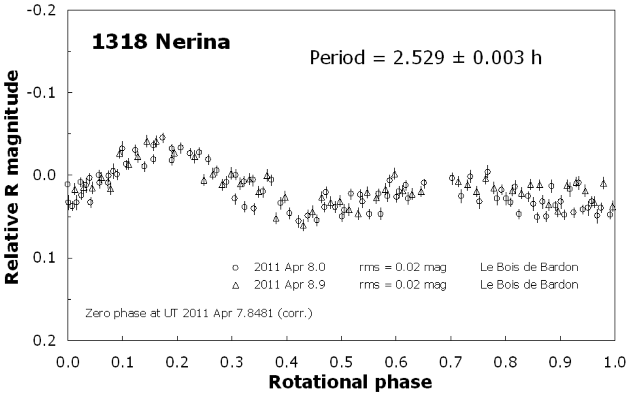

Figure 6. Composite lightcurve of 1318 Nerina for 2011 April.

1465 Autonoma. Only sparse measurements were obtained during our two runs on 1465 Autonoma in 2012 March, and any obvious common patterns were identified in the datasets. So, we used the phase dispersion minimization (PDM) method, developed by Stellingwerf (1978), to estimate the rotation period of the asteroid. Indeed, this method is well suited to search for periodicities if only a few data are available, and especially if the lightcurve is highly non-sinusoidal, which was the case for our time series. From this way, a rotation period of 4.886 ± 0.010 h and a 0.14 ± 0.02 mag lightcurve amplitude match the datasets (Fig. 7). If this period is correct, only 75 % of the rotation was covered by our data. This period is, however, similar to the one previously published by Brinsfield (2008) from observations carried out in 2007.

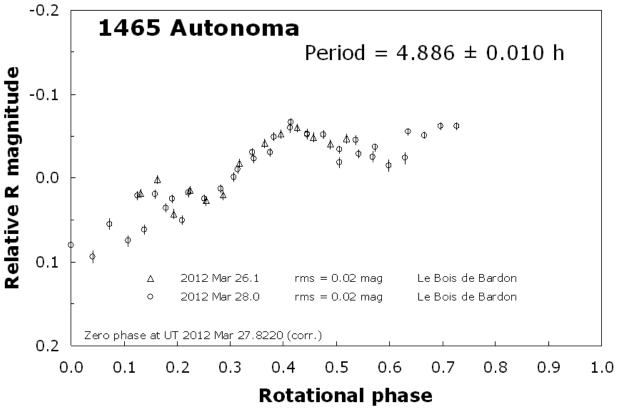

Figure 7. Composite lightcurve of 1465 Autonoma for 2012 March.

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Table 1. Selected physical parameters of the observed asteroids (from Warner *et al.*, 2009, and JPL Small-Body Database, available at *http://ssd.jpl.nasa.gov/sbdb.cgi*).

Asteroid	a (UA)	Taxonomic class	Diameter (km)	Albedo	Commentary
417 Suevia	2.799	X	40.7	0.1960	
453 Tea	2.183	S	20.9	0.1827	Flora family
904 Rockefellia	2.992	C	58.8	0.0561	
933 Susi	2.368	C	21.8	0.0707	Erigone family
1269 Rollandia	3.905	D	105.2	0.0473	
1318 Nerina	2.307	S	13.0	0.1811	Phocaea family
1465 Autonoma	3.027	C	~20	< ~0.12	

Table 2. Observational circumstances for the observed asteroids.

Asteroid	Date (UT)	λ_{2000} (°)	β_{2000} (°)	α (°)	V (mag)	Filter
417 Suevia	2010 Aug 9.1	12.6	+ 3.2	15.4	14.7	V
	2010 Aug 21.0	11.9	+ 3.1	12.8	14.5	V
	2010 Aug 22.0	11.8	+ 3.1	12.6	14.5	V
	2010 Sep 4.0	10.2	+ 2.9	8.9	14.2	V
	2010 Sep 19.0	7.4	+ 2.6	3.7	13.9	V
453 Tea	2011 Oct 21.9	21.6	+ 2.1	2.8	13.3	R
	2011 Oct 22.9	21.3	+ 2.1	3.3	13.3	R
904 Rockefellia	2011 Sep 30.9	20.4	+ 0.9	4.5	14.4	R
	2011 Oct 1.9	20.2	+ 0.9	4.2	14.4	R
933 Susi	2011 Apr 9.0	177.7	+ 7.7	10.8	14.8	R
1269 Rollandia	2012 Mar 25.0	180.6	+ 2.8	1.4	13.8	R
	2012 Mar 25.9	180.4	+ 2.8	1.6	13.8	R
	2012 Mar 31.9	179.4	+ 2.8	3.4	14.0	R
1318 Nerina	2011 Apr 8.0	163.4	– 2.6	17.8	14.3	R
	2011 Apr 8.9	163.3	– 2.9	18.3	14.3	R
1465 Autonoma	2012 Mar 26.1	187.4	+ 5.5	2.3	14.8	R
	2012 Mar 28.0	187.0	+ 5.7	2.2	14.8	R

Table 3. Synodic rotation period and brightness amplitude results for the observed asteroids.

Asteroid	Period (hour)	Amplitude (mag)
417 Suevia	7.020 ± 0.003	0.06 ± 0.03
453 Tea	6.831 ± 0.021	~0.06
904 Rockefellia	5.823 ± 0.011	0.10 ± 0.02
933 Susi	4.412 ± 0.034	0.32 ± 0.02
1269 Rollandia	15.315 ± 0.030	0.13 ± 0.02
1318 Nerina	2.529 ± 0.003	0.07 ± 0.02
1465 Autonoma	4.886 ± 0.010	0.14 ± 0.02

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LIGHTCURVE INVERSION FOR 38 LEDA

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We present shape and spin axis model for main-belt asteroid 38 Leda. The model was obtained with lightcurve inversion process, using combined dense photometric data from apparitions in 1979, 1995, 2000, 2008, 2009-10, 2011, 2012 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 12.836164 ± 0.000016 h and two possible pole solution at (λ = 160°, β = -17°) and (λ = 343°, β = -6°), with an error of ± 10 degrees. From sparse data from the USNO Flagstaff station we find H = 8.61 ± 0.04, G = 0.09 ± 0.04.

The main-belt asteroid 38 Leda has been observed in last four consecutive apparitions by Frederick Pilcher, with a variety of phase angles and phase angle bisectors. To improve the coverage at various aspect angles, we found in the literature further observations, whose lightcurves were downloaded from the Asteroid Photometric Catalogue (APC) by Lagerkvist et al. (2001) at website: *http://asteroid.astro.helsinki.fi/apc*. The observational circumstances for the seven apparitions are reported in Table I.

The data from two of the three sessions of Wang and Shi (2002) were reconstructed by Frederick Pilcher, starting from the published lightcurves, following the failed attempt to contact via email the authors.

To improve the solution we have also used sparse data from USNO Flagstaff Station, as has been shown by Kaasalainen (2004), Ďurech et al. (2009). Sparse data were taken from the AstDys website (*http://hamilton.dm.unipi.it/astdys/index.php/*) for a total of 211 data points. Figures 1, 2 and 3 shows respectively PAB Longitude/Latitude distribution for dense/sparse data and phase curve for the sparse data.

Lightcurve inversion process ware performed using MPO LCInvert v.11.0.0.2. Software (Bdw Publishing), which implement algorithms and code provided by Mikko Kaasalainen and Josef Ďurech. For guidelines and a description of the modeling process see LCInvert Operating Instructions manual and Warner et al. (2008).

Data Analysis

All data from thirty dense lightcurves and one sparse dataset were imported in *LCInvert* for analysis, assigning them a different weighting factor, from 1.0 for best data to 0.3 for sparse data.

In the inversion process the first step is to find an accurate sidereal rotational period. We have started the period search centered on the average of the synodic periods found in the previously published works. The search process found a isolated sidereal period of 12.83611412 h with lower chi-square value (Figure 4).

For pole search we have started using the “Medium” search option (312 fixed pole position with 15° longitude-latitude steps) and the previously found sidereal period set to “float”. The “dark facet” weighting factor was increased from 0.1 (default) to 0.5 to keep the dark facet area below 1% of total area. The number of iterations of processing was increased from 50 (default) to 75 for best convergence.

Data analysis shows two lower chi-square solutions differing by 180°, centered at (λ = 165°, β = -15°) and (λ = 345°, β = -15°), see Figure 5 for log(chi-square) values distribution. These values were then refined by running again the pole search using the “Fine” option with the previous period/longitude/latitude set to “float” (49 fixed pole steps with 10° longitude-latitude pairs). The two best solutions are reported in Table II with an averaged sidereal period obtained from the two values found in the pole search process. Typical errors in the pole solution are ± 10 degrees and the uncertainty in period has been evaluated as a rotational error of 10° over the total time-span of the observations.

We prefer the first solution as it has a stronger convergence, small chi-square and RMS values. We have a better lightcurve fit removing the sparse data from the generation of the shape model. The sparse data instead have been much useful to constrain the period and spin axis search. Figure 6 shows the shape model with first solution and Figure 7 shows the good agreement between the model (black line) and observed lightcurves (red points). The second shape solution is very similar to the first and has not been reported.

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

Acknowledgement

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

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Year	#LCs	Data Points	PA°	PABL°	PABB°	Ref.
1979	2	13	5/4	188	-9	(1)
1995	3	109	10	27/28	9	(2)
2000	2	47	17/14	89/90	5	(3)
2008	8	1551	9/14	329	4/5	(4)
2009-10	3	971	11/14	78/80	6/4	(5)
2011	5	1205	14/4	211	-9	(6)
2012	7	1206	12/5	290	-2/-1	(7)

Table I. Observational circumstances for 38 Leda over seven apparitions, a total of 30 lightcurves were used for lightcurve inversion analysis. Where: PA, PABL and PABB are respectively the phase angle, phase angle bisector longitude and latitude. References: (1) Harris and Young (1989), (2) Denchev, Magnusson and Donchev (1998), (3) Wang and Shi (2002), (4) Pilcher (2009), (5) Pilcher (2010), (6) Pilcher (2011), (7) Pilcher (2013).

λ°	β°	Sidereal Period(h)	ChiSq	RMS
160	-17	12.836164 ± 0.000016	1.5420	0.0170
343	-6		1.5668	0.0172

Table II. The two best spin axis solutions for 38 Leda. The sidereal period was the average of the two solutions found in the pole search process.

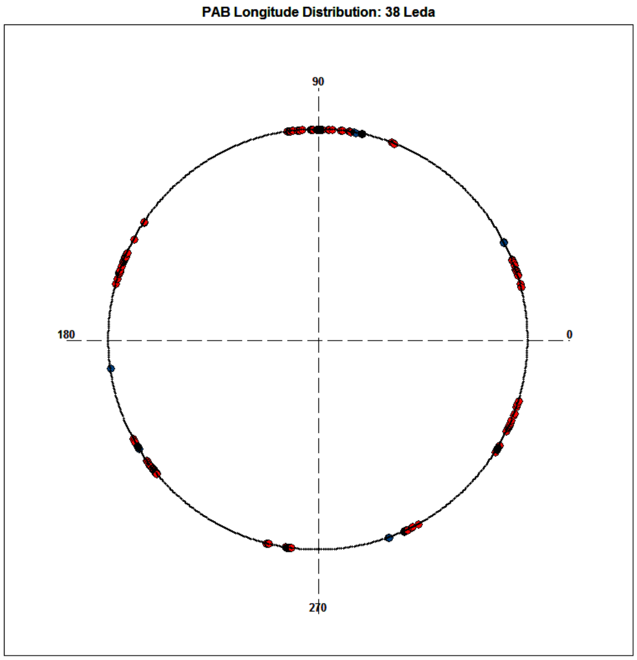

Figure 1. PAB Longitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

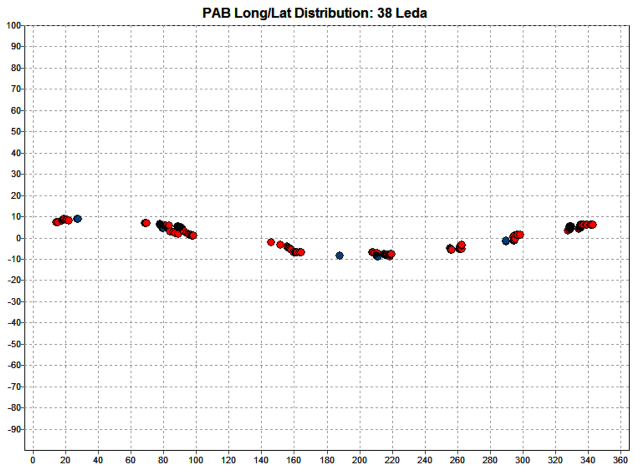

Figure 2. PAB Latitude distribution of the data used for lightcurve inversion model. Dense data in blue and sparse data in red.

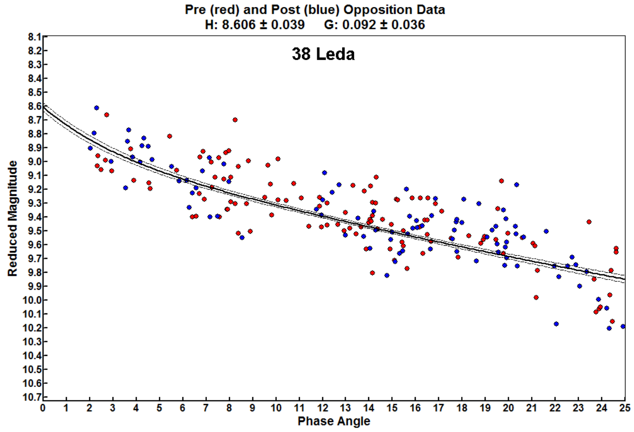

Figure 3. Visual reduced magnitude vs phase angle for sparse data from USNO Flagstaff Station.

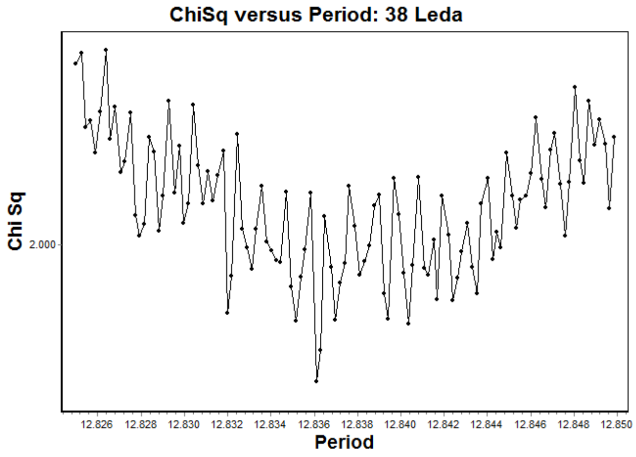

Figure 4. The period search plot from LCInvert shows an isolated minimum at 12.83611412 h.

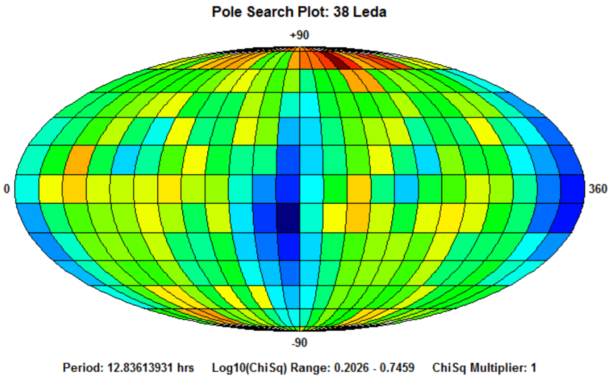

Figure 5. Pole Search Plot of log(ChiSq) values, where dark blue identify lower ChiSq values and Dark red underlying the worst solutions.

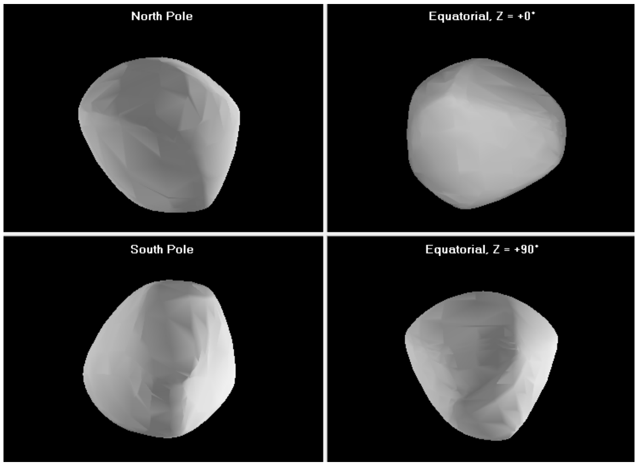

Figure 6. The shape model for 38 Leda (λ = 160°, β = - 17°).

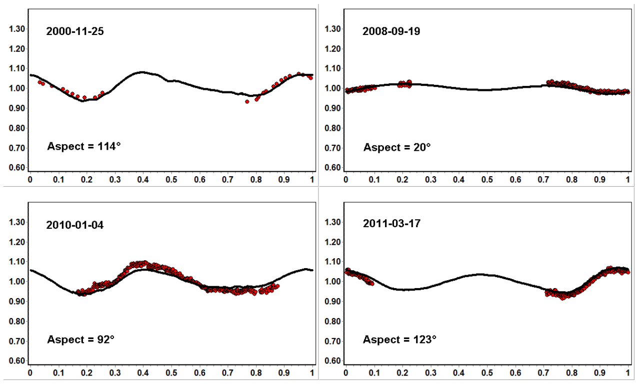

Figure 7. Comparison of model lightcurve (black line) versus a sample of four observed lightcurves (red points).

3 ASTEROIDS' LIGHTCURVE ANALYSIS FROM BASSANO BRESCIANO OBSERVATORY

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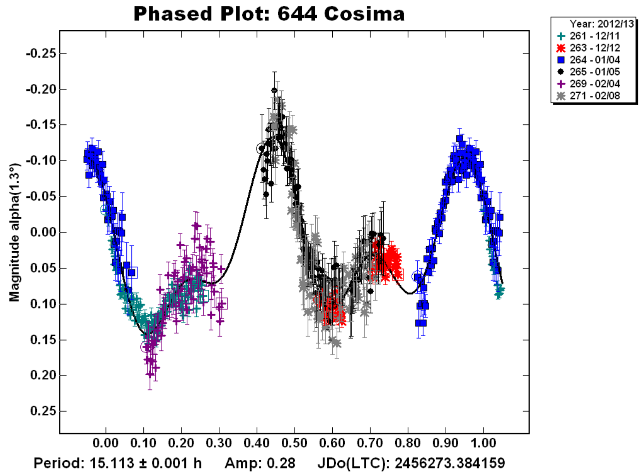
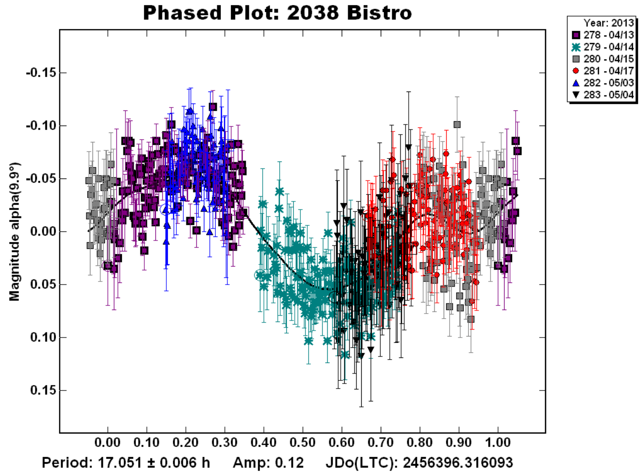
Lightcurves for 3 minor planets were obtained at Bassano Bresciano Observatory from December 2012 to May 2012: 644 Cosima, 2038 Bistro, 2448 Sholokhlov.

Usually winter and spring are the best seasons for astronomical activities at Bassano Bresciano Observatory (565). This year we have had the worse weather since years. In this paper there are the products of the only ones available nights. Photometric measurements of three minor planets were obtained with the 0.32-m *f*/3.1 Schmidt and Starlight HX-516 CCD camera. *Polypus* software release 1.9 (Bassano Bresciano Observatory, 2013) was used to control the robotic observations. Exposures were taken when the target's altitude was more than 30°, unfiltered, unguided with 120 s exposure times. Raw images were processed with flat field and dark frames. *MPO Canopus* ver.10.4.0.20 (Bdw Publishing, 2010) was used to perform differential photometry on the reduced images. Solar-coloured comparison stars were used in order to minimize colour difference errors by using the Comp Star Selector in *MPO Canopus*. Data were light-time corrected but not reduced to standard magnitudes. The periods reported here were based on those having the lowest RMS error. Night-to-night calibration was done by adjusting the DeltaComp value in MPO *Canopus.* Data have been sent to the ALCDEF database.

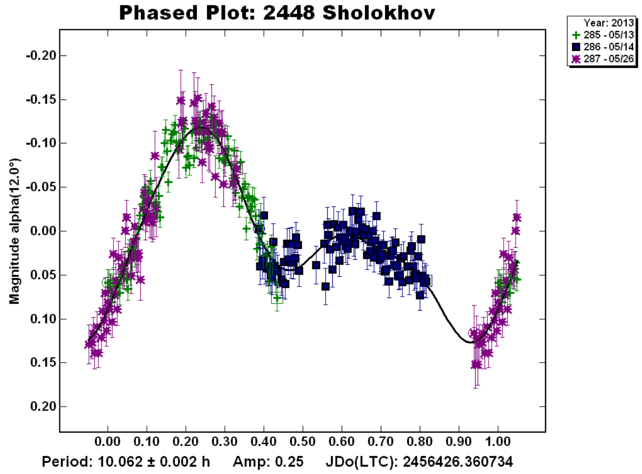
644 Cosima. It was selected from "Lightcurve Photometry opportunities: 2012 October December " *Minor Planet Bulletin* **39**. With period = 15.13 hours, amplitude 0.16 Mag. and quality code 1, (Binzel 1987). It was been observed for 6 nights covering 59 days. Weather was not very good in that time so we weren't able to have complete lightcurve coverage. Period spectrum analysis doesn't show other possible period than the previous with a little difference. P = 15.113 ± 0.001 hours with amplitude *A* = 0.28 ± 0.03 mag.



2038 Bistro. It was selected from "Lightcurve Photometry opportunities: 2013 April-June " *Minor Planet Bulletin* **40**. With period = 7.88 hours, amplitude 0.24 Mag. and quality code 1 (DeGraff 1998). It was been observed for 6 nights covering 21 days span. It shows very low amplitude comparable with the measurement noise. Fortunately all sessions have very low dispersion in the measurements of the known catalogue stars. A good correlation was be found on period P =17.071 hours with amplitude A = 0.12 ± 0.02 mag.



2448 Sholokhlov. It was selected from "Lightcurve Photometry opportunities: 2013 April-June " *Minor Planet Bulletin* **40**. With period = 10.065 hours, amplitude 0.63 Mag. and quality code 2+. (Warner 2005). It was observed for 3 nights covering 13 days span. Amplitude was lower than Warner observation but our observation seems to confirm period P =10.062 hours with amplitude A = 0.252 ± 0.03 mag.



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Asteroid	Date	Phase Angle	Time h.	Num. Obs
644 Cosima	2012-12-11	1.3	5.7	102
644 Cosima	2012-12-12	1.8	3.2	53
644 Cosima	2013-01-04	12.6	3.7	86
644 Cosima	2013-01-05	13.0	6.0	107
644 Cosima	2013-02-04	21.3	3.0	74
644 Cosima	2013-02-08	21.9	4.0	80
2038 Bistro	2013-04-13	9.9	5.0	146
2038 Bistro	2013-04-14	10.0	5.0	157
2038 Bistro	2013-04-15	10.3	4.0	106
2038 Bistro	2013-04-17	10.8	4.8	118
2038 Bistro	2013-05-03	15.7	3.7	70
2038 Bistro	2013-05-04	16.0	3.4	76
2448 Sholokhlov	2013-05-13	12.0	4.4	117
2448 Sholokhlov	2013-05-14	12.1	4.3	99
2448 Sholokhlov	2013-05-23	14.4	4.4	79

TARGET ASTEROIDS! OBSERVING TARGETS FOR OCTOBER THROUGH DECEMBER 2013

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Asteroids to be observed by the Target Asteroids! program during the period of July to September 2013 are presented. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and, hence, easier to observe for small telescope users and 2) analogous to (101955) Bennu, the target asteroid of the OSIRIS-REx sample return mission.

Introduction

The *Target Asteroids!* program strives to engage telescope users of all skill levels and telescope apertures to observe asteroids that are viable targets for robotic sample return. The program also focuses on the study of asteroids that are analogous to (101955) Bennu (formerly 1999 RQ36), the target asteroid of the NASA OSIRIS-REx sample return mission.

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

An introduction to the program can be found at Hergenrother and Hill (2013).

Quarterly Targets

There are many list asteroids that are observable in very large telescopes. For this observing plan only objects that become brighter than V = 20.0 are listed. A short summary of our knowledge about each asteroid and 10-day (shorter intervals for objects that warrant it) ephemerides are presented. The ephemerides include rough RA and Dec positions, distance from the Sun in AU (r), distance from Earth in AU (Δ), V magnitude, phase angle in degrees (PH) and elongation from the Sun in degrees (Elong).

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

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

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

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

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

Carbonaceous *Target Asteroids!* List Objects

None this quarter.

Target Asteroids! Objects of unknown type

(163249) 2002 GT (a=1.34 AU, e=0.33, i=7.0°, H = 18.5)
Unlike the other objects on the *Target Asteroids!* List which are only potential spacecraft targets, 2002 GT is an actual mission target. The Deep Impact/EPOXI spacecraft is scheduled to fly-by this asteroid in 2020. As a result, an international observing campaign has been conducting observations for much of 2013. In June of 2013, the asteroid peaked in brightness at V = 16.3 which is the brightest it gets before the 2020 fly-by. *Target Asteroids!* observations have identified a ~3.76 h rotation period *Target Asteroids!* members are especially encouraged to obtain photometry over a range of phase angles this quarter which will be important for determining its phase function.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	07 23.6	+18 44	0.46	1.01	19.4	76	78
10/11	07 39.2	+15 29	0.47	1.06	19.4	70	84
10/21	07 51.3	+12 27	0.48	1.11	19.3	64	90
10/31	07 59.2	+09 37	0.48	1.16	19.2	58	98
11/10	08 01.7	+07 03	0.48	1.21	19.1	52	106
11/20	07 58.2	+04 50	0.47	1.26	19.0	45	116
11/30	07 47.9	+03 06	0.46	1.32	18.8	37	127
12/10	07 31.1	+02 04	0.46	1.37	18.6	28	139
12/20	07 09.6	+01 53	0.47	1.41	18.5	20	151
12/30	06 46.9	+02 33	0.50	1.46	18.5	14	159

2002 NV16 (a=1.24 AU, e=0.22, i=3.5°, H = 21.3)
2002 NV16 is a low delta-V target that has been identified as a possible target for both robotic sample return missions and human explorations. Observations obtained during the Spring of 2013 found a rapid rotation period of ~0.91 h. Though it only peaks at a magnitude of V ~ 18.6 this October/November, photometry this quarter will be vital for determining its phase function and refining the rotation period.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	11 43.2	-06 34	0.04	0.97	29.0	168	12
10/11	09 28.6	-08 21	0.04	0.97	19.7	124	54
10/21	08 19.0	-08 14	0.06	0.99	18.8	97	80
10/31	07 43.1	-07 57	0.08	1.01	18.6	79	97
11/10	07 17.7	-07 28	0.10	1.03	18.6	63	112
11/20	06 54.2	-06 27	0.11	1.06	18.6	49	126
11/30	06 30.5	-04 41	0.13	1.09	18.7	36	139
12/10	06 07.6	-02 05	0.16	1.12	18.8	25	151
12/20	05 48.6	+01 03	0.19	1.16	19.0	19	158
12/30	05 35.6	+04 22	0.22	1.19	19.4	19	156

2007 CN26 (a=1.29 AU, e=0.27, i=7.6°, H = 20.8)
2007 CN26 is yet another potential spacecraft target with little known about it. It peaked at V=16.5 in early September 2013. The close approach presented a good opportunity to observe it over a wide range of phase angles from 26° to ~130°. This quarter the asteroid is slowly fading from view. Phase function photometry in October is requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	02 04.9	-21 51	0.14	1.12	18.1	30	145
10/11	01 47.5	-22 23	0.18	1.16	18.6	26	149
10/21	01 35.4	-21 22	0.24	1.20	19.2	26	148
10/31	01 28.4	-19 23	0.30	1.24	19.9	28	144
11/10	01 26.1	-16 50	0.36	1.29	20.5	30	139
11/20	01 28.0	-13 58	0.44	1.33	21.0	33	133
11/30	01 33.4	-10 58	0.52	1.37	21.5	35	127
12/10	01 41.7	-07 56	0.61	1.40	22.0	37	121

Non-carbonaceous *Target Asteroids!* List objects

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

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	01 51.4	+10 45	0.30	1.28	17.8	17	158
10/11	01 39.6	+07 48	0.24	1.23	16.9	7	171
10/21	01 18.7	+03 04	0.19	1.18	16.3	8	171
10/31	00 48.6	-03 41	0.15	1.13	16.4	25	151
11/10	00 10.2	-12 10	0.13	1.08	16.5	46	129
11/20	23 24.1	-21 40	0.11	1.02	16.8	69	105
11/30	22 24.9	-31 29	0.11	0.97	17.5	95	79
12/10	21 01.2	-39 57	0.10	0.92	19.0	123	52
12/20	19 16.3	-42 59	0.12	0.88	22.6	151	26

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

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	22 08.8	+21 32	0.26	1.21	18.8	31	141
10/11	21 52.1	+18 26	0.26	1.19	19.0	39	132
10/21	21 44.5	+15 08	0.27	1.16	19.2	47	122
10/31	21 45.2	+12 06	0.28	1.13	19.4	54	113
11/10	21 53.1	+09 32	0.28	1.10	19.6	60	105
11/20	22 06.6	+07 27	0.29	1.07	19.8	66	98
11/30	22 24.4	+05 45	0.29	1.04	19.9	72	92
12/10	22 45.9	+04 18	0.28	1.01	19.9	77	87
12/20	23 10.1	+02 53	0.27	0.98	20.0	83	82
12/30	23 36.6	+01 16	0.25	0.96	20.0	88	77

Other Asteroids Analogous to the OSIRIS-REx Target Bennu

(447) Valentine (a=2.98 AU, e=0.04, i=4.8°, H = 9.0)
One of two large Main Belt asteroids being targeted this quarter, Valentine is an 80 km diameter dark (albedo = 0.07) carbonaceous X-type asteroid. It rotates once every 9.65h with a lightcurve amplitude of 0.18 magnitudes. Minimum phase angle is reached on December 2 at 0.2° and V = 12.7.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	05 01.1	+21 15	2.35	2.87	14.1	19	112
10/11	05 03.1	+21 26	2.23	2.87	13.9	17	121
10/21	05 02.5	+21 35	2.12	2.88	13.8	15	131
10/31	04 59.1	+21 41	2.03	2.88	13.6	12	142
11/10	04 53.3	+21 45	1.96	2.88	13.4	9	153
11/20	04 45.5	+21 46	1.92	2.88	13.1	5	165
11/30	04 36.4	+21 44	1.90	2.88	12.8	1	177
12/10	04 27.1	+21 41	1.91	2.89	13.0	3	171
12/20	04 18.7	+21 37	1.95	2.89	13.3	7	159
12/30	04 11.9	+21 34	2.02	2.89	13.5	11	147

(535) Montague (a=2.57 AU, e=0.03, i=6.8°, H = 9.3)
The other large Main Belt asteroid is Montague. It is slightly smaller than Valentine (~74 km), slightly darker (0.05 albedo) and

a C-type. It rotates once every 10.25 h with a 0.25 magnitude lightcurve amplitude. Minimum phase angle is reached on December 14 at 0.3° and V = 12.4.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	05 47.3	+20 36	2.18	2.56	14.1	23	101
10/11	05 53.4	+20 48	2.05	2.56	14.0	22	109
10/21	05 56.9	+21 00	1.93	2.56	13.8	20	118
10/31	05 57.6	+21 15	1.82	2.56	13.6	18	128
11/10	05 55.2	+21 32	1.73	2.55	13.3	15	139
11/20	05 49.7	+21 52	1.65	2.55	13.1	11	150
11/30	05 41.5	+22 14	1.59	2.55	12.9	7	162
12/10	05 31.4	+22 35	1.56	2.55	12.5	2	174
12/20	05 20.7	+22 54	1.56	2.54	12.6	3	173
12/30	05 10.7	+23 11	1.59	2.54	12.9	7	160

(3200) Phaethon (a=1.27 AU, e=0.89, i=22.2°, H = 14.6)

Phaethon is well known as a possible comet due to its association with the Geminid meteor shower of December. Whether the shower was produced by cometary activity or a series of splitting events, the Geminids are now one of the strongest annual showers. Recently Phaethon has been observed to display comet-like activity around perihelion (Jewitt et al. 2013, Li and Jewitt 2013). It is a B-type asteroid similar to Bennu, the OSIRIS-REx target. Though carbonaceous, it is not as dark as many other carbonaceous asteroids (albedo 0.11). A rotation period of 3.60 h and amplitude of up to 0.34 magnitudes have been measured for this 5 km near-Earth asteroid.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/21	15 28.9	-04 41	0.75	0.47	16.4	107	27
10/31	17 12.6	+01 21	0.65	0.71	16.3	94	45
11/10	18 53.6	+06 31	0.68	0.90	16.2	76	62
11/20	20 13.4	+09 35	0.79	1.07	16.5	62	73
11/30	21 11.1	+11 11	0.96	1.22	16.9	52	78
12/10	21 53.6	+12 10	1.15	1.36	17.3	45	78
12/20	22 26.6	+12 56	1.36	1.48	17.7	40	76
12/30	22 53.9	+13 41	1.56	1.59	18.1	36	73

(52760) 1998 ML14 (a=2.41 AU, e=0.62, i=2.4°, H = 17.5)

Much is already known about 1998 ML14. Radar observations made in 1998 found a diameter of 1 km, albedo of 0.27 and a nearly spherical shape. Additional spectroscopic and photometric observations identified it as either an S, Sq or V type and a rotation period of 14.98 h. The near-spherical shape results in a very low lightcurve amplitude allowing a phase function to be measured with little interference from rotational variations. A large range of phase angles are observable during the last 4 months of 2013, from ~140° in early September when the 1998 ML14 will be V ~ 19.3 to a minimum of 3.5° in late December.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	08 07.9	+26 48	0.24	0.94	17.8	97	70
10/11	08 08.3	+27 06	0.29	0.99	17.7	84	80
10/21	08 09.3	+27 17	0.34	1.05	17.8	72	89
10/31	08 07.4	+27 33	0.37	1.11	17.8	62	99
11/10	08 00.3	+28 00	0.40	1.19	17.8	51	111
11/20	07 46.9	+28 35	0.42	1.27	17.7	40	124
11/30	07 27.3	+29 08	0.46	1.36	17.7	29	138
12/10	07 03.9	+29 24	0.50	1.45	17.7	18	153
12/20	06 40.6	+29 16	0.56	1.53	17.7	8	168
12/30	06 20.7	+28 48	0.64	1.62	17.9	4	173

(251346) 2007 SJ (a=2.01 AU, e=0.53, i=8.2°, H = 16.8)

Little is known about this upcoming radar target. It peaks around magnitude V = 15.3 in early January. Astrometry, phase function photometry and lightcurve observations are requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	02 11.3	+33 03	0.69	1.60	18.1	23	142
10/11	02 05.3	+35 45	0.58	1.52	17.5	20	148
10/21	01 53.1	+38 20	0.49	1.44	17.0	19	152
10/31	01 33.9	+40 32	0.41	1.37	16.5	20	152
11/10	01 08.7	+41 59	0.35	1.29	16.2	26	146
11/20	00 40.5	+42 26	0.30	1.22	16.0	35	136
11/30	00 13.1	+41 53	0.25	1.15	15.8	45	124
12/10	23 49.0	+40 37	0.21	1.08	15.7	57	112
12/20	23 26.8	+38 52	0.17	1.03	15.5	71	100
12/30	22 59.5	+36 05	0.13	0.98	15.3	87	86

2010 CL19 (a=1.54 AU, e=0.65, i=7.3°, H = 17.6)

Yet another object that little is known about. This year's close flyby results in 2010 CL19 brightening to V ~ 15 at the end of November and provides an opportunity to obtain photometry over a large range of phase angles for a relatively bright object.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/10	17 09.0	-12 30	0.24	0.80	20.8	140	31
11/15	17 50.0	-12 15	0.18	0.85	19.9	137	36
11/20	19 04.9	-11 03	0.12	0.91	18.1	125	50
11/25	21 19.6	-06 18	0.10	0.97	15.9	97	78
11/30	23 44.7	+01 10	0.11	1.03	15.2	65	109
12/05	01 10.0	+05 37	0.16	1.09	15.6	47	125
12/10	01 55.3	+07 46	0.22	1.14	16.2	40	132
12/20	02 40.9	+09 52	0.35	1.25	17.3	35	133
12/30	03 05.9	+11 09	0.50	1.35	18.2	35	129

2013 NJ (a=1.28 AU, e=0.28, i=4.2°, H = 21.8)

A very recent discovery, nothing is known about 2013 NJ's physical characteristics. With H of 21.8, rapid rotation (< 2 h period) is very possible. It is a possible radar target in late November, early December.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/26	15 47.6	-60 22	0.01	0.98	18.3	140	40
11/27	11 29.6	-72 33	0.01	0.98	15.8	116	64
11/28	07 52.3	-56 25	0.01	0.99	14.6	90	90
11/29	07 00.4	-39 45	0.01	0.99	14.5	71	108
11/30	06 40.2	-29 03	0.01	0.99	14.7	60	120
12/01	06 29.5	-22 14	0.02	1.00	14.9	52	127
12/02	06 22.9	-17 39	0.02	1.00	15.2	47	132
12/03	06 18.4	-14 23	0.03	1.00	15.5	43	136
12/04	06 15.1	-11 57	0.03	1.01	15.7	40	139
12/05	06 12.5	-10 03	0.03	1.01	15.9	38	141
12/10	06 05.1	-04 37	0.05	1.03	16.7	29	149
12/20	05 58.9	+00 02	0.09	1.07	17.9	22	157
12/30	05 56.3	+02 52	0.14	1.11	18.7	20	158

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2013 OCTOBER-DECEMBER

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

We present lists of “targets of opportunity” for the period 2013 October-December. For background on the program details for each of the opportunity lists, refer to previous issues, e.g., *Minor Planet Bulletin* **36**, 188. In the first three sets of tables, “Dec” is the declination and “U” is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

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

Objects with U = 1 should be given higher priority over those rated U = 2 or 2+ but not necessarily over those with no period. On the other hand, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even high quality ratings have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what’s given. Use the listing only as a guide.

The first list is an *abbreviated list* of those asteroids reaching V < 15.0 at brightest during the period and have either no or poorly-constrained lightcurve parameters.

The goal for these asteroids is to find a well-determined rotation rate. The target list generator on the CALL web site allows you to create custom lists for objects reaching V ≤ 18.0 during any month in the current year, e.g., limiting the results by magnitude and declination.

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

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

The Low Phase Angle list includes asteroids that reach very low phase angles. The “α” column is the minimum solar phase angle for the asteroid. Getting accurate, calibrated measurements (usually V band) at or very near the day of opposition can provide important information for those studying the “opposition effect.” You will have the best chance of success working objects with low amplitude and periods that allow covering, e.g., a maximum, every night. Objects with large amplitudes and/or long periods are much more difficult for phase angle studies since, for proper analysis, the data have to be reduced to the average magnitude of the asteroid for each night. Without knowing the period and/or the amplitude at the time, that reduction becomes highly uncertain. As an aside, some use the maximum light to find the phase slope parameter (*G*). However, this can produce a significantly different value for both *H* and *G* versus using average light, which is the method used for values listed by the Minor Planet Center.

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

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

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

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

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

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

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

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

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

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

Lightcurve Opportunities

Objects in bold italics are near-Earth asteroids (NEA), defined as $q < 1.3$ AU. An asterisk (*) follows the name if the asteroid is reaching a particularly favorable apparition.

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
2771	Polzunov*	10 02.2	14.7	+11	11.66	0.15	2
4517	Ralpharvey	10 02.9	14.4	+1			
1180	Rita	10 03.3	14.4	-5	9.605	0.05-0.30	2
2212	***Hephaistos***	***10 05.2***	***14.0***	***-44***	***> 20.***	***0.08-0.11***	***1***
9199	1993 FO1*	10 06.3	15.0	-3	5.322	0.47	2+
2286	Fesenkov*	10 06.6	14.5	+3			
828	Lindemannia	10 07.9	14.5	+6		0.08	
6634	1987 KB	10 07.9	14.4	+21	4.492	0.22	2
1653	Yakhontovia*	10 08.3	12.7	+14	15.41	0.03	2
2259	Sofievka	10 08.3	14.8	+14	31.6	0.10	2
1070	Tunica	10 08.4	14.8	-6			
2443	Tomeileen	10 10.0	14.7	-8	3.974	0.10-0.13	2
712	Boliviana	10 11.0	10.9	+18	11.732	0.10-0.11	2
1428	Mombasa	10 11.8	13.7	-19	16.67	0.15-0.25	2+
2660	Wasserman	10 13.0	14.9	+9		0.07	
1246	Chaka*	10 13.6	13.0	+40	> 20.	0.2	2
3330	Gantrisch	10 15.7	14.8	+12			
1557	Roehla	10 16.9	15.0	+17			
7288	1991 FE1*	10 16.9	14.8	+15			
641	Agnes*	10 17.2	13.9	+8	8.9	0.18	1
2112	Ulyanov*	10 17.3	13.9	+13	3.	0.33	2
4905	Hiromi*	10 17.8	14.2	+7			
3250	Martebo*	10 18.0	14.5	+9			
1359	Prieska	10 18.1	14.4	-1		0.04	
1384	Kniertje	10 18.2	14.4	-6	9.807	0.11-0.33	2
3062	Wren*	10 21.2	14.5	-6	7.097	0.17-0.22	2
1639	Bower	10 23.5	13.7	+24	12.5	0.15-0.38	2
16009	1999 CM8*	10 23.5	14.0	+7			
2281	Biela	10 23.8	15.0	+11			
5110	Belgirate*	10 23.8	15.0	+18	11.04	0.08	1
983	Gunila	10 25.7	14.5	+25	D	0.05-0.25	
3500	Kobayashi	10 25.7	14.5	+21			
7167	Laupheim*	10 26.0	15.0	+17			
691	Lehigh	10 26.4	12.9	-4	12.891	0.12-0.16	2+
1457	Ankara	10 26.9	15.0	+21	31.8	0.21	2
1305	Pongola	10 27.0	15.0	+11	8.03	0.14-0.18	2
2254	Requiem	10 27.3	14.3	+21			
1167	Dubiago	11 01.0	14.5	+15	14.3	0.23	2
1447	Utra*	11 01.0	14.5	+15	257.	0.63	2
5256	Farquhar	11 01.2	14.5	+15		0.04	
2305	King*	11 02.3	14.9	+18			
445	Edna	11 03.9	13.2	+45	19.97	0.21	2
425	Cornelia	11 05.2	13.6	+14	17.56	0.19	2
1079	Mimosa	11 05.6	14.5	+17	64.6	0.07-0.13	2
941	Murray*	11 05.8	13.9	+14			

Lightcurve Opportunities (cont'd)

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
8648	Salix*	11 09.0	14.5	+14			
431	Nephele	11 09.2	12.6	+14	18.821	0.03-0.30	2
2325	Chernykh*	11 09.3	15.0	+14			
3905	Doppler*	11 09.4	14.6	+41			
583	Klotilde	11 10.3	13.5	+23	9.2116	0.18-0.41	2
3248	Farinella	11 12.5	15.0	+28	6.676	0.20	2
2280	Kunikov	11 14.3	14.7	+13			
1603	Neva	11 14.4	14.1	+5	6.4249	0.22	2
2077	Kiangsu*	11 14.4	14.8	-14			
1033	Simona	11 14.6	14.7	+7	10.07	0.04	1+
1233	Kobresia	11 14.7	14.9	+26	27.83	0.32-0.34	2
2086	Newell*	11 14.7	14.7	+7	78.2	1.0	2
7355	Bottke*	11 16.0	14.8	+17			
507	Laodica	11 16.2	13.2	+31	6.737	0.22-0.29	2
4135	Svetlanov	11 17.6	14.9	+11	10.559	0.15	2
4067	Mikhel'son*	11 17.9	15.0	+30			
2053	Nuki*	11 19.3	14.7	+10			
3702	Trubetskaya	11 19.4	14.1	-5			
1055	Tynka	11 20.0	14.2	+11	11.893	0.06-0.33	2
2675	Tolkien	11 21.2	14.0	+24	1060.	0.75	2+
1911	Schubart	11 21.4	14.9	+22			
946	Poesia	11 22.0	13.9	+20	108.5	0.24-0.32	2+
1027	Aesculapia	11 22.7	15.0	+21	6.83	0.15	1
2271	Kiso	11 23.0	14.6	+15		0.12	
4649	Sumoto*	11 24.8	14.3	+12	26.31	0.15-0.30	2
2239	Paracelsus	11 25.0	15.0	+32			
6246	Komurotoru*	11 25.2	14.4	+31			
1887	Virton	11 26.8	14.7	+35			
920	Rogeria*	11 27.1	14.3	+6	8.09	0.16-0.21	2-
341	California	11 27.3	13.0	+27	8.74	0.02-0.07	1
2043	Ortutay	11 27.3	14.5	+26			
2413	van de Hulst	11 27.5	15.0	+5			
3437	Kapitsa*	11 27.5	15.0	+25			
1326	Losaka*	11 29.4	13.6	+5	6.9	0.03	2
1112	Polonia	12 01.0	13.8	+33	82.5	0.20	2
786	Bredichina	12 02.3	13.7	+15	18.61	0.05-0.60	2+
1365	Henyey	12 02.3	14.8	+23	18.986	0.23	2+
279	Thule	12 03.1	14.3	+22	15.962	0.04-0.10	2+
1085	Amaryllis	12 04.1	14.4	+14	18.2	0.20	2
1539	Borrelly	12 04.1	14.4	+20			
1194	Aletta	12 04.3	14.7	+33	20.39	0.28-0.32	2+
2531	Cambridge	12 04.6	14.9	+13	8.8	0.21	2-
2393	Suzuki	12 05.0	15.0	+15	9.31	0.40	2+
856	Backlunda	12 05.1	14.3	+4	12.08	0.24-0.33	2
2391	Tomita*	12 07.2	14.5	+17			
496	Gryphia*	12 10.1	13.5	+17	18.	0.05	1
1574	Meyer*	12 11.0	14.8	+18	12.64	0.12	2
2638	Gadolin*	12 12.5	14.5	+17			
560	Delila*	12 14.0	13.6	+17		0.1	
365	Corduba	12 15.9	12.5	+3	6.354	0.05-0.15	2
767	Bondia	12 17.7	14.2	+24			
666	Desdemona	12 17.8	13.0	+13	15.45	0.07-0.16	2
2536	Kozyrev	12 18.3	14.3	+25	7.188	0.52	2+
707	Steina	12 19.0	14.0	+25	414.	0.1- 1.0	2+
6906	Johnmills*	12 19.2	15.0	+30			
1596	Itzigsohn*	12 20.8	13.9	+16	39.722	0.15-0.41	2
537	Pauly	12 21.3	13.7	+16	14.15	0.15-0.20	2+
437	Rhodia	12 23.5	13.7	+22	56.	0.06-0.38	1
318	Magdalena*	12 24.0	13.6	+8	59.5	0.11	1
1191	Alfaterna	12 24.9	14.9	+4	3.664	0.03-0.05	1
1678	Hveen	12 26.3	14.8	+39			
1888	Zu Chong-Zhi*	12 27.4	13.8	+18	15.9	0.50	2
703	Noemi	12 27.6	14.2	+19			
1826	Miller*	12 28.7	14.5	+23	30.049	0.08	2
1264	Letaba	12 29.3	14.5	-1	32.16	0.11-0.13	1

Low Phase Angle Opportunities

#	Name	Date	α	V	Dec	Period	Amp	U
149	Medusa	10 01.9	0.43	12.6	+03	26.023	0.47-0.56	3
641	Agnes	10 17.1	0.52	13.9	+08	8.9	0.18	1
546	Herodias	10 21.1	0.97	13.0	+13	10.77	0.07-0.18	3
1675	Simonida	10 26.9	0.38	13.5	+13	5.2885	0.16-0.65	3
168	Sibylla	10 27.7	0.30	12.2	+12	47.009	0.16	3
326	Tamara	10 28.3	0.79	12.4	+15	14.445	0.10-0.27	3
99	Dike	10 30.3	0.55	13.7	+12	18.127	0.08-0.22	3
798	Ruth	10 30.5	0.23	13.6	+13	8.550	0.19-0.36	3
1074	Beljawskya	10 31.8	0.10	13.3	+14	6.284	0.28-0.37	3
20	Massalia	11 01.0	0.12	8.7	+14	8.098	0.15-0.27	3
425	Cornelia	11 05.2	0.63	13.7	+14	17.56	0.19	2
941	Murray	11 05.8	0.83	14.0	+14			
126	Velleda	11 08.1	0.86	11.7	+18	5.3672	0.07-0.22	3
284	Amalia	11 08.5	0.76	13.0	+18	8.545	0.16	3
431	Nephele	11 09.4	0.88	12.6	+14	18.821	0.02-0.30	2

Low Phase Angle Opportunities (cont'd)

#	Name	Date	α	V	Dec	Period	Amp	U
1567	Alikoski	11 12.6	0.23	13.9	+17	16.405	0.16	3
946	Poesia	11 22.0	0.14	14.0	+20	108.5	0.32	2+
76	Freia	11 23.3	0.64	11.8	+19	9.969	0.06-0.33	3
447	Valentine	12 02.3	0.15	12.7	+22	9.651	0.18	3
567	Eleutheria	12 03.0	0.87	13.7	+25	7.72	0.26-0.50	3
138	Tolosa	12 04.2	0.59	11.9	+24	10.101	0.18-0.45	3
64	Angelina	12 06.0	0.72	10.5	+24	8.752	0.04-0.42	3
899	Jokaste	12 07.0	0.33	13.1	+22	6.245	0.25-0.31	3
977	Philippa	12 09.4	0.22	13.8	+23	15.405	0.49	3
405	Thia	12 10.1	0.32	12.1	+22	10.08	0.15-0.23	3
222	Lucia	12 12.7	0.10	14.0	+23	7.80	0.25-0.38	3
535	Montague	12 14.3	0.24	12.4	+23	10.2482	0.18-0.25	3
437	Rhodia	12 23.7	0.65	13.7	+22	56.	0.06-0.38	1
277	Elvira	12 26.8	0.42	13.6	+22	29.69	0.34-0.59	3
3169	Ostro	12 27.3	0.63	13.6	+22	6.483	0.42-1.2	3

Shape/Spin Modeling Opportunities

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

Occultation Profiles Available

		Brightest			LCDB DATA		
#	Name	Date	Mag	De	Period	Amp	U
568	Cheruskia	10 02.1	13.2	+26	13.209	0.10-0.44	3
828	Lindemannia	10 07.9	14.5	+06		0.08	
404	Arsinoe	10 13.2	13.5	-10	8.887	0.27-0.38	3
99	Dike	10 30.3	13.6	+12	18.127	0.08-0.22	3
566	Stereoskopia	11 06.2	12.1	+12	12.103	0.05-0.25	3
431	Nephele	11 09.2	12.6	+14	18.821	0.02-0.30	2
76	Freia	11 23.3	11.8	+19	9.969	0.06-0.33	3
134	Sophrosyne	11 26.2	11.6	+40	17.196	0.19	3
638	Moira	12 01.4	14.3	+16	9.875	0.31	3
350	Ornamenta	12 07.6	11.9	+11	9.178	0.10-0.23	3
522	Helga	12 07.6	13.8	+19	8.129	0.13-0.30	3
366	Vincentina	12 09.8	13.3	+38	15.5	0.08	1
120	Lachesis	12 27.6	12.2	+32	46.551	0.14-0.22	3
381	Myrrha	12 28.8	13.2	+15	6.572	0.36	3
18	Melpomene	12 31.	9.8	+08	11.570	0.10-0.32	3
141	Lumen	12 31.	12.5	+23	19.87	0.12-0.2	3
51	Nemausa	12 31.	10.4	+06	7.783	0.10-0.25	3

Inversion Modeling Candidates

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
482	Petrina	10 01.2	12.9	+00	11.794	0.07-0.45	3-
6634	1987 KB	10 07.9	14.4	+21	4.492	0.22	2
718	Erida	10 25.9	14.6	+11	17.447	0.37	3
1426	Riviera	10 31.5	14.9	+26	4.404	0.30	3
20	Massalia	11 01.0	8.7	+14	8.098	0.15-0.27	3
1691	Oort	11 02.7	14.2	+14	10.2705	0.38	3
214	Aschera	11 06.8	12.4	+21	6.835	0.22	3
3737	Beckman	11 07.0	13.4	+60	3.124	0.16	3
1003	Lilofee	11 11.4	14.3	+15	8.255	0.52	3
1233	Kobresia	11 14.7	14.9	+26	27.83	0.34	2
2086	Newell	11 14.7	14.7	+07	78.2	1.0	2
734	Benda	11 20.7	13.7	+27	7.11	0.28	3
1125	China	11 22.4	14.8	+17	5.367	0.38	3
804	Hispania	11 23.9	11.9	+43	14.845	0.19-0.24	3
656	Beagle	11 24.8	14.1	+20	7.035	0.9 -1.2	3
228	Agathe	11 26.0	14.5	+25	6.484	0.27	3
1204	Renzia	11 29.8	14.3	+24	7.885	0.42	3
274	Philagoria	11 30.8	14.4	+20	17.96	0.43-0.51	3
638	Moira	12 01.4	14.3	+16	9.875	0.31	3
567	Eleutheria	12 03.1	13.6	+25	7.72	0.26-0.50	3
2393	Suzuki	12 05.0	15.0	+15	9.31	0.40	2+
856	Backlunda	12 05.1	14.3	+04	12.08	0.29	2
1797	Schaumasse	12 08.0	15.0	+27	6.105	0.75	3-
744	Aguntina	12 09.5	14.7	+13	17.47	0.50	3
3155	Lee	12 11.4	14.5	+33	8.310	0.22-0.35	3
707	Steina	12 19.0	14.0	+25	414.	0.1 -1.0	2+
537	Pauly	12 21.3	13.7	+16	14.15	0.15-0.20	2+

Inversion Modeling Candidates (cont'd)

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
5489	Oberkochen	12 21.8	14.5	+18	5.625	0.40	3
607	Jenny	12 22.7	13.9	+27	8.526	0.17-0.26	3-
1703	Barry	12 26.2	14.8	+21	107.1	0.5	3
1826	Miller	12 28.7	14.6	+23	30.049	0.08	2
1368	Numidia	12 29.9	14.8	+46	3.64	0.35	3
345	Tercidina	12 31.	11.7	+03	12.371	0.11-0.23	3
317	Roxane	12 31.	13.5	+17	8.169	0.61-0.75	3
1618	Dawn	12 31.	15.0	+23	43.19	0.38	2+
208	Lacrimosa	12 31.	13.7	+13	14.085	0.15-0.33	3
239	Adrastea	12 31.	14.1	+12	18.4707	0.34-0.51	3
271	Penthesilea	12 31.	14.0	+25	18.787	0.33	3
868	Lova	12 31.	14.2	+17	41.3	0.40	2
2381	Landi	12 31.	14.7	+05	3.91	0.75	2
1339	Desagneauxa	12 31.	14.5	+25	9.380	0.48	3
1021	Flammario	12 31.	11.5	+16	12.160	0.14-0.40	3-
1219	Britta	12 31.	13.7	+30	5.575	0.48-0.75	3
616	Elly	12 31.	14.9	+19	5.297	0.34-0.44	3
4299	WIYN	12 31.	14.9	+22	26.	0.06	2
502	Sigune	12 31.	15.0	+06	10.922	0.25-0.53	3
1494	Savo	12 31.	14.3	+18	5.35011	0.45-0.52	3
822	Lalage	12 31.	15.0	+11	3.345	0.47-0.58	3

Radar-Optical Opportunities

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

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

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

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

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	23 21.6	+22 22	1.14	2.09	9.2	11.8	155	137	-0.16	-36
10/08	23 15.3	+22 04	1.16	2.09	9.3	13.3	151	122	+0.11	-36
10/15	23 10.5	+21 37	1.19	2.09	9.4	15.4	146	32	+0.82	-35
10/22	23 07.3	+21 05	1.23	2.10	9.6	17.5	141	70	-0.91	-36
10/29	23 06.0	+20 32	1.28	2.10	9.7	19.6	135	147	-0.31	-36
11/05	23 06.5	+20 00	1.34	2.11	9.9	21.4	129	111	+0.03	-36
11/12	23 08.7	+19 33	1.40	2.11	10.0	23.0	123	23	+0.69	-37
11/19	23 12.5	+19 13	1.47	2.12	10.2	24.3	118	77	-0.98	-38

216 Kleopatra (Oct-Jan, H = 7.30)

This is the “dog bone” asteroid, so-called because of it shape. The period and even shape are well determined. It’s included here because it often helps to have supporting lightcurve observations to go with the latest radar data. It’s also an excellent teaching object of the high amplitude lightcurve, brightness, and ability to get a complete cycle (or more) in a single night’s run.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	03 52.0	+19 18	1.33	2.10	10.4	22.1	128	80	-0.16	-26
10/15	03 53.3	+17 17	1.23	2.10	10.1	17.1	142	88	+0.82	-27
10/29	03 48.2	+14 44	1.16	2.11	9.8	10.7	157	89	-0.31	-30
11/12	03 38.7	+11 58	1.14	2.12	9.5	4.3	171	74	+0.69	-34
11/26	03 28.0	+09 26	1.16	2.13	9.7	6.8	165	103	-0.48	-37
12/10	03 19.9	+07 35	1.24	2.15	10.1	13.3	150	58	+0.54	-40
12/24	03 16.9	+06 38	1.35	2.17	10.4	18.6	135	114	-0.65	-41
01/07	03 19.5	+06 30	1.50	2.19	10.8	22.4	122	49	+0.38	-41

324 Bamberga (Oct-Nov, H = 6.82)

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

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	22 56.0	+06 48	0.83	1.79	8.5	12.8	157	152	-0.16	-46
10/06	22 52.9	+07 05	0.84	1.79	8.6	15.4	152	141	+0.01	-45
10/11	22 50.8	+07 22	0.86	1.79	8.8	17.9	147	71	+0.39	-45
10/16	22 49.6	+07 38	0.89	1.78	8.9	20.2	142	10	+0.90	-44
10/21	22 49.5	+07 54	0.92	1.78	9.0	22.3	137	66	-0.96	-44
10/26	22 50.4	+08 11	0.95	1.78	9.2	24.1	133	125	-0.59	-44
10/31	22 52.3	+08 29	0.98	1.78	9.3	25.8	129	168	-0.14	-44
11/05	22 55.1	+08 50	1.02	1.78	9.4	27.2	125	105	+0.03	-44

1627 Ivar (Oct-Dec, H = 13.2)

This near-Earth asteroid (NEA) is well-placed for most of the quarter. It’s not quite as bright as earlier this year, but still be careful about overexposing it, at least in October. The period is well-known: 4.798 h. The amplitude has ranged from 0.25 to 1.4 mag.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	02 06.8	-12 46	0.44	1.40	12.7	20.4	151	111	-0.16	-67
10/11	01 54.0	-13 51	0.48	1.45	12.9	16.3	156	106	+0.39	-70
10/21	01 41.8	-13 57	0.54	1.51	13.2	15.9	155	39	-0.96	-72
10/31	01 32.4	-13 11	0.62	1.56	13.6	18.4	150	147	-0.14	-73
11/10	01 26.7	-11 46	0.71	1.61	14.1	21.7	143	65	+0.48	-73
11/20	01 25.0	-09 56	0.81	1.67	14.5	24.6	135	68	-0.95	-71
11/30	01 26.8	-07 51	0.93	1.72	14.9	27.0	128	160	-0.12	-69
12/10	01 31.7	-05 39	1.06	1.77	15.3	28.7	120	32	+0.54	-66

(85774) 1998 UT18 (Oct-Dec, H = 19.2)

Krugly *et al*. (2002; *Icarus* **158**, 294-304) reported a period of 34 hours for this NEA but the result is considered likely wrong (U = 1 in the LCDB). Skiff *et al*. (2008; *MPB* **39**, 111-130) reported only an amplitude of 0.34 mag. Don’t let past results influence your analysis. Given past results, it might be wise to collaborate with observers at widely-separated longitudes.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/20	05 55.3	+00 15	0.31	1.16	18.8	50.8	115	54	-0.99	-12
10/27	06 27.9	+02 37	0.26	1.13	18.5	53.5	114	30	-0.50	-4
11/03	07 08.7	+06 02	0.22	1.09	18.2	57.3	112	105	+0.00	+7
11/10	08 00.9	+10 38	0.19	1.06	18.0	62.8	107	165	+0.48	+20
11/17	09 06.1	+15 56	0.18	1.03	18.0	70.0	100	87	+1.00	+37
11/24	10 20.3	+20 33	0.17	1.01	18.1	77.9	92	23	-0.67	+55
12/01	11 32.7	+23 11	0.19	0.99	18.5	84.5	85	59	-0.06	+72
12/08	12 34.1	+23 46	0.21	0.97	18.8	88.6	79	136	+0.32	+85

(138095) 2000 DK79 (Oct-Dec, H = 15.8)

This NEA has no reported lightcurve parameters in the LCDB. Assuming $p_V = 0.2$, the estimated size if about 2 km. This asteroid makes the celestial rounds, going from far south to far north of the celestial equator during the last three months of the year.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	07 08.9	-53 44	0.73	1.15	17.5	59.7	82	70	-0.16	-19
10/15	06 48.4	-57 00	0.50	1.09	16.8	65.6	87	105	+0.82	-23
10/29	05 05.3	-62 55	0.26	1.06	15.4	68.9	97	89	-0.31	-36
11/12	22 57.4	-15 55	0.13	1.04	13.7	63.5	110	13	+0.69	-61
11/26	21 21.2	+31 13	0.32	1.05	15.9	70.5	92	141	-0.48	-13
12/10	20 58.3	+40 45	0.56	1.07	17.0	65.6	83	53	+0.54	-3
12/24	20 51.2	+45 15	0.78	1.12	17.6	59.2	78	125	-0.65	+1

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

There is no reported rotation period in the LCDB. 2007 CN26 is an NEA with an estimated diameter of 200 meters. This puts it on the edge of being a candidate for having a period of less than 2 hours. Statler *et al.* (2013; *Icarus* **225**, 141-155) report that 170 meters is about the upper limit with the number of faster rotators dropping rapidly at larger sizes. Until you know one way or the other, keep exposures to a minimum but long enough to avoid letting scintillation noise dominate (~10 sec for small telescopes).

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	02 04.9	-21 52	0.14	1.12	18.1	30.3	146	112	-0.16	-72
10/02	02 03.0	-22 01	0.14	1.12	18.1	29.7	146	122	-0.10	-73
10/03	02 01.0	-22 08	0.15	1.13	18.2	29.2	147	132	-0.05	-73
10/04	01 59.2	-22 14	0.15	1.13	18.2	28.7	147	140	-0.01	-74
10/05	01 57.3	-22 19	0.16	1.13	18.3	28.3	148	145	+0.00	-74
10/06	01 55.6	-22 22	0.16	1.14	18.3	27.8	148	146	+0.01	-75
10/07	01 53.9	-22 25	0.16	1.14	18.4	27.5	148	142	+0.05	-75
10/08	01 52.2	-22 26	0.17	1.15	18.5	27.2	148	135	+0.11	-75

(52760) 1998 ML14 (Nov-Jan, H = 17.6, PHA)

Hicks *et al.* (1998; *B.A.A.S.* **30**, 1029) reported a period of 14.98 hours for this NEA estimated to have an effective diameter of about 1 km (Ostro *et al.* 2001; *Meteoritics and Planetary Sci.* **36**, 1225-1236). It’s not exceptionally bright but it should be within reach of larger backyard telescopes. For northern observers at least, the high declination will mean long runs, which may help find a reliable solution sooner than later.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/10	08 00.3	+28 01	0.40	1.19	17.8	51.0	111	158	+0.48	+27
11/17	07 51.6	+28 25	0.42	1.25	17.8	43.4	120	67	+1.00	+25
11/24	07 39.7	+28 50	0.44	1.31	17.7	35.7	129	24	-0.67	+23
12/01	07 25.1	+29 11	0.46	1.37	17.7	27.9	140	113	-0.06	+20
12/08	07 08.8	+29 23	0.49	1.43	17.7	20.1	150	138	+0.32	+16
12/15	06 52.0	+29 24	0.53	1.49	17.7	12.7	161	46	+0.95	+13
12/22	06 36.2	+29 13	0.57	1.55	17.7	6.2	170	44	-0.82	+10
12/29	06 22.4	+28 52	0.63	1.61	17.9	3.6	174	134	-0.16	+7

1997 WQ23 (Nov-Dec, H = 20.3)

The estimated size of this NEA (assuming $p_V = 0.2$) is about 250 meters. As with 2007 CN26, this asteroid could have a rotation period under 2 hours. The LCDB does not have a reported period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/10	21 43.8	-20 51	0.08	1.00	17.7	81.7	94	14	+0.48	-47
11/13	22 47.2	-13 20	0.08	1.02	17.2	68.2	108	20	+0.79	-58
11/16	23 43.8	-05 19	0.08	1.03	17.0	55.4	121	41	+0.97	-63
11/19	00 29.6	+01 34	0.10	1.05	17.1	45.2	131	65	-0.98	-61
11/22	01 05.0	+06 50	0.11	1.07	17.2	38.0	138	91	-0.83	-56
11/25	01 32.3	+10 41	0.13	1.09	17.5	33.2	143	118	-0.58	-51
11/28	01 53.5	+13 29	0.15	1.11	17.7	30.2	145	150	-0.29	-47
12/01	02 10.4	+15 34	0.17	1.14	18.0	28.3	147	173	-0.06	-43

2006 CT (Dec-Jan, H = 22.3)
At only 100 meters diameter, this is the smallest object included this time, and reason that it is not very bright. Because of the wide range of phase angles, there is an excellent chance to get a series of lightcurves that show amplitude and/or shape evolution from late December into 2014 January. The LCDB has no period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/25	09 56.3	+19 07	0.07	1.03	18.5	48.5	128	33	-0.56	+49
12/30	09 15.3	+18 52	0.08	1.05	18.4	34.6	143	108	-0.09	+40
01/04	08 41.3	+18 23	0.09	1.07	18.4	22.4	155	167	+0.10	+32
01/09	08 13.9	+17 50	0.11	1.09	18.4	12.1	167	93	+0.59	+26
01/14	07 52.6	+17 20	0.12	1.11	18.4	4.3	175	27	+0.96	+21
01/19	07 36.5	+16 55	0.14	1.13	18.8	6.3	173	36	-0.93	+17
01/24	07 24.7	+16 37	0.16	1.14	19.4	12.3	166	101	-0.52	+15
01/29	07 16.5	+16 24	0.19	1.16	19.9	17.8	159	173	-0.06	+13

2009 WZ104 (Dec-Jan, H = 20.0)
Karashevich *et al*. (2012; *Solar System Research* **46**, 143-148) reported a period of 19.304 hours, but could not formally exclude the half-period of 9.652 hours. Be prepared for either possibility.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/25	11 07.0	-16 23	0.16	1.02	18.6	73.0	98	17	-0.56	+40
12/28	11 10.4	-20 53	0.15	1.02	18.5	73.3	98	44	-0.26	+36
12/31	11 14.0	-25 39	0.15	1.01	18.5	73.9	98	81	-0.03	+32
01/03	11 17.6	-30 40	0.14	1.01	18.4	74.8	97	118	+0.04	+28
01/06	11 21.6	-35 53	0.14	1.01	18.4	75.9	96	143	+0.28	+24
01/09	11 25.9	-41 15	0.14	1.00	18.4	77.3	95	137	+0.59	+19
01/12	11 30.8	-46 44	0.14	1.00	18.4	79.1	93	116	+0.85	+14
01/15	11 36.6	-52 14	0.14	1.00	18.5	81.0	91	94	+0.99	+9

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* * * * *

The deadline for the next issue (41-1) is October 15, 2013. The deadline for issue 41-2 is January 15, 2014.