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LIGHTCURVE ANALYSIS FOR 4167 RIEMANN

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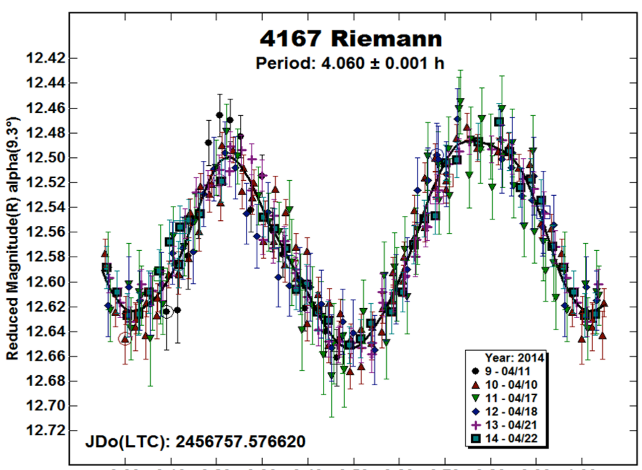
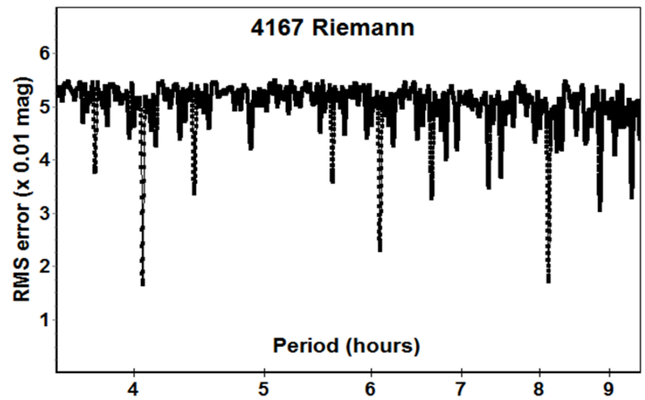
Photometric observations of 4167 Riemann were made over six nights in 2014 April. A synodic period of P = 4.060 ± 0.001 hours was derived from the data.

4167 Riemann is a main-belt asteroid discovered in 1978 by L. V. Zhuraveya. Observations of the asteroid were conducted at the Phillips Academy Observatory, which is equipped with a 0.4-m *f*/8 reflecting telescope by DFM Engineering. Images were taken with an SBIG 1301-E CCD camera that has a 1280x1024 array of 16-micron pixels. The resulting image scale was 1.0 arcsecond per pixel. Exposures were 300 seconds and taken primarily at –35°C. All images were guided, unbinned, and unfiltered. Images were dark and flat-field corrected with *Maxim DL*. Processed images were measured with *MPO Canopus* (BDW Publishing) using a differential photometry technique. Comparison stars in the image field were chosen to have near-solar color with the "comp star selector" feature of *MPO Canopus*.





Period analysis was carried out by the authors using *MPO Canopus* and its Fourier analysis feature developed by Harris (Harris *et al.*, 1989). The resulting lightcurve consists of 288 data points. The period spectrum strongly favors the bimodal solution. The resulting lightcurve has synodic period P = 4.060 ± 0.001 hours and amplitude 0.17 mag. Dips in the period spectrum were also noted at 8.1200 hours (2P) and at 6.0984 hours (3/2P). A search of the Asteroid Lightcurve Database (Warner *et al.*, 2009) and other sources did not reveal previously reported lightcurve results for this asteroid.

Acknowledgements

Research at the Phillips Academy Observatory is supported by the Israel Family Foundation.

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., Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Warner, B.D. (2010). *The MPO Users Guide: A Companion Guide to the MPO Canopus/PhotoRed Reference Manuals*. BDW Publishing, Colorado Springs, CO.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

ROTATION PERIOD DETERMINATION FOR 308 POLYXO

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Lightcurves of 308 Polyxo were obtained by a collaboration between Bassano Bresciano Observatory and Organ Mesa Observatory. For 308 Polyxo the period is 12.029 ± 0.001 hours, amplitude 0.15 ± 0.02 magnitudes with an irregular lightcurve.

Previous period determinations are by Debehogne and Zappala (1980), 12.032 hours; Harris and Young (1983), 12.02 hours; and Higgins (2011), 12.01 hours. Due to the very near commensurability with Earth's period all of their lightcurves were incomplete. To sample the complete lightcurve, observers Pilcher at Organ Mesa Observatory (G50) and Strabla at Bassano Bresciano Observatory (565) collaborated. Equipment at Organ Mesa Observatory consists of a 0.35 meter Meade LX200 GPS Schmidt-Cassegrain, SBIG STL-1001E CCD, with a clear filter, 60 second exposure time, unguided. At Bassano Bresciano Observatory a 0.32 meter Schmidt telescope operating at F/3.1 and Starlight CCD camera MX-916 applied at direct focus was used with 120 second exposure time, unfiltered, unguided. *MPO Canopus* (BDW Publishing, 2010) was used to measure the images photometrically. Comparison stars from the APASS catalog with near solar colors were selected with the Comparison Star Selector included in this software. A Fourier analysis algorithm developed by Harris et al. (1989) was utilized to obtain the period which satisfied the data with minimum residual. Even with the use of APASS magnitudes, it was necessary to adjust the instrumental magnitudes of the individual sessions by several x 0.01 magnitude for the minimum residual fit displayed in the lightcurve.

Photometric data from a total of 7 sessions 2014 Feb. 11 - Apr. 18 provide a good fit to a synodic rotation period 12.029 ± 0.001 hours, amplitude 0.15 ± 0.02 magnitudes, with a somewhat irregular lightcurve.

Observatory	Date	Phase Angle	Time h.	Num Obs
Organ Mesa	2014-02-11	13.0	7.5	288
Organ Mesa	2014-02-14	12.1	7.3	356
Organ Mesa	2014-02-21	9.7	7.3	349
Bassano Br.	2014-03-07	4.0	7.2	163
Organ Mesa	2014-03-20	1.4	7.7	390
Bassano Br.	2014-03-28	2.9	6.0	292
Organ Mesa	2014-04-18	12.7	5.0	236

References

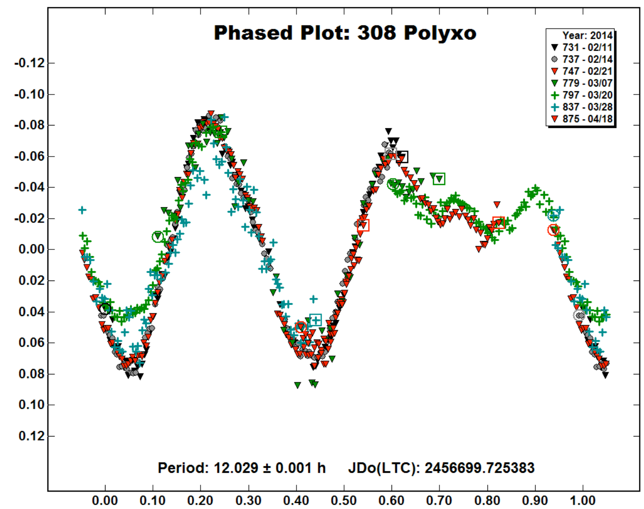
BDW Publishing (2010) MPO Canopus Software, version 10 *http://minorplanetobserver.com*

Debehogne, H., and Zappala, V. (1980). "Photoelectric Lightcurves and Rotation Period of 308 Polyxo, Obtained at ESO-La Silla in May 1978." *Astron. Astrophys. Suppl. Ser.* **39**, 163-165.

Harris, A.W., and Young, J.W. (1983). "Asteroid Rotation IV. 1979 Observations," *Icarus* **54**, 59-109.

Harris, A.W., Young, J.W., Bowell, E., Martin, J.L., 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.

Higgins, D. (2011). "Period Determination of Asteroid Targets Observed at Hunters Hill Observatory: May 2009 - September 2010." *Minor Planet Bull.* **38**, 41-46.



ANOTHER ASTEROID WITH A CHANGING LIGHTCURVE: 232 RUSSIA

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During its early 2014 apparition the lightcurve shape and inferred synodic rotation period for 232 Russia changed considerably. The best fit to data in the entire interval 2014 Mar. 25 - May 25 is with a lightcurve with a period 21.905 ± 0.001 hours, amplitude 0.14 ± 0.01 magnitudes.

Changes in asteroid lightcurves caused by changing phase angle and viewing aspect are frequently noted when the observations include a large range of phase angles. They provide information useful for spin/shape modeling. The photometric observations of 232 Russia in the interval 2014 Mar. 25 - May 25 constitute an example of an unusually large change in lightcurve appearance. Previously published rotation periods for 232 Russia are by Behrend (2005), 21.72 hours with only partial phase coverage; Torno et al. (2008), 21.8 hours from a very sparse data set; and Ruthroff (2009), 21.91 hours from a dense data set which looks convincing.

New observations of 232 Russia 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, clear filter. 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.

Observations on 8 nights 2014 March 25 - April 7 at phase angles 21.5 degrees to 17.0 degrees provide a good fit to a lightcurve with period 22.016 ± 0.004 hours, amplitude 0.15 ± 0.01 magnitudes, with full phase coverage. A second set of observations on 8 nights 2014 Apr 28 - May 25 at phase angles between 5.2 degrees and 9.6 degrees provides a good fit to a lightcurve with period 21.904 ± 0.002 hours, amplitude 0.14 ± 0.01 magnitudes, again with full phase coverage. When all 16 sessions are plotted on a single lightcurve a large misfit is shown between the March 25 - Apr 7 large phase angle observations and the April 28 - May 25 small phase angle observations. The synodic period which best represents all 16 sessions is 21.905 ± 0.001 hours. This value is consistent with all of the previous period determinations.

References

Behrend, R. (2005). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html*

Ruthroff, J. (2009). "Photometric Observations and Lightcurve Analysis of Asteroids 129 Antigone, 174 Phaedra, 232 Russia, 291 Alice, and 343 Ostara." *Minor Planet Bull.* **36**, 121-122.

Torno, S., Oliver, R. L., Ditteon, R. (2008). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory - October 2007." *Minor Planet Bull.* **35**, 54-55.

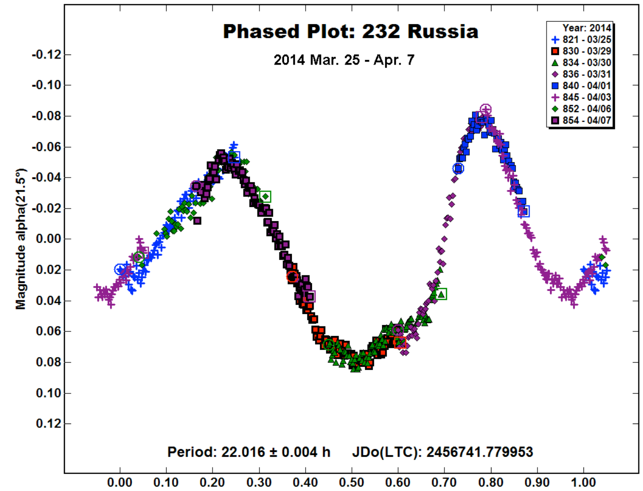

Figure 1. Lightcurve of 232 Russia in the interval 2014 Mar. 25 - Apr. 7

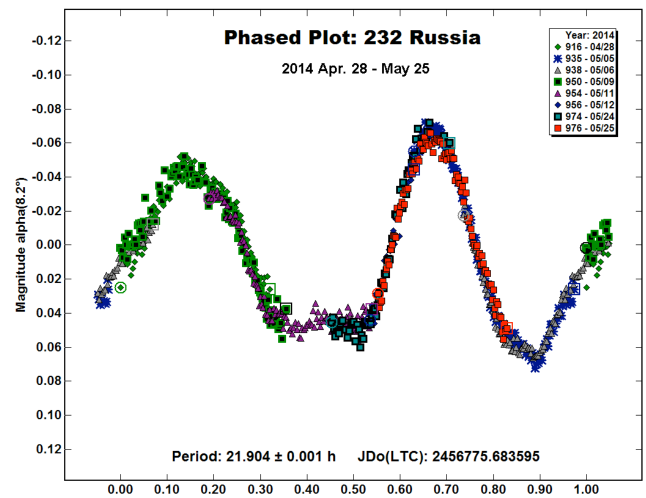

Figure 2. Lightcurve of 232 Russia in the interval 2014 Apr. 28 - May 25

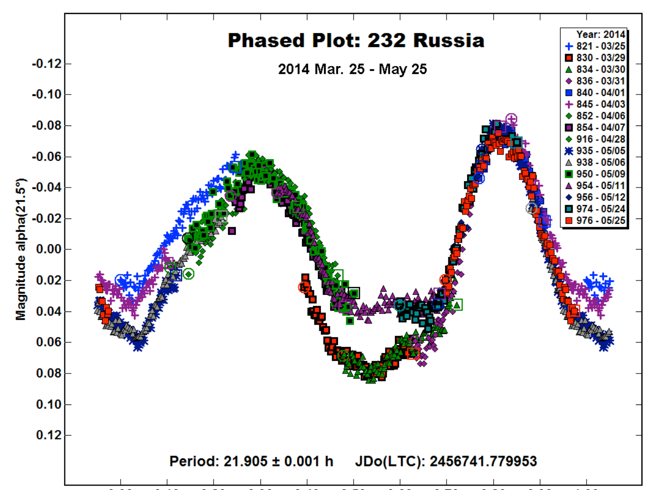

Figure 3. Lightcurve of 232 Russia in the interval 2014 Mar. 25 - May 25

LIGHTCURVES FOR INVERSION MODEL CANDIDATES

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We present lightcurves for four inversion model candidate asteroids that will benefit from additional data at another phase angle bisector phase angle. We obtained synodic periods for each asteroid that were within ±0.002 h. Most have lightcurves that differed from previously published lightcurves in both amplitude and shape.

Observations of asteroid lightcurves were obtained at the Etscorn Campus Observatory (ECO, 2014). We used three Celestron 0.35-m Schmidt-Cassegrain telescopes (SCT) on Software Bisque Paramount ME mounts (SB, 2014). Two of the telescopes use SBIG STL-1001E CCD cameras that have 1024x1024 24-micron pixels. These provide a scale of 1.25 arcsec/pix and a 22x22 arcminute field-of-view. The third telescope uses an SBIG ST-10XME with an Optec 0.5x focal reducer. The ST-10XME is binned 2x2, giving an array of 1092x736 13.6-micron pixels. The scale is 1.28 arcsec/pix and the field-of-view is 20x16 arcminutes.

All images were obtained through clear filters. Exposure times varied between 2 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 *TheSky 6* (SB, 2014) and the CCDs were controlled with *CCDsoft* v5 (SB, 2014). The images were flat-field corrected using image processing tools within *MPO Canopus* version 10.4.1.9 (Warner, 2014). The multi-night data sets for each asteroid were combined with the FALC routine (Harris *et. al*., 1989) within *MPO Canopus* to provide synodic periods for each asteroid.

Observed Asteroids

The four asteroids observed were taken from the list of possible inversion model candidates by Warner *et al.* (2014). All have periods less than 8 hours. This allowed us, in many cases, to obtain at least one complete cycle per observing night. The information about asteroid discovery dates and names comes from the JPL small bodies Database (JPLSBD, 2014). The list of observed asteroids is given Table I. This table contains the asteroid number, name, date range, solar phase angle, average solar bisector phase angles, period determination, period error, amplitude, and amplitude error. Table II summarizes the solar bisector phase angles of published lightcurves for these asteroids. The previously observed solar bisector phase angles were obtained from the lightcurve database (LCDB; Warner *et al.*, 2014).

446 Aeternitas is a main-belt asteroid discovered by M. Wolf and A. Schwassmann at Heidelberg on 1899 Oct 27. It is also known as 1899 ER. The original period determination was done by Florcak *et al*. (1997), who reported 15.85 h with an amplitude of 0.33 mag. Behrend (2006) published a period from P. Antonini of 15.7413 ± 0.00036 h. Fauerbach *et al*. (2008) reported a period of 15.7413 ± 0.001 h with an amplitude of 0.48 mag. Lucas *et al.* (2011) determined a period of 15.74 ± 0.003 h with an amplitude of ~0.40 mag. Lucus *et al*. (2012) presented a 3-D shape model using data from 3 apparitions (2006, 2008, and 2009). We observed 446 Aeternitas on 7 nights between 2014 May 9 and June 7. Our period of 15.745 ± 0.001 h is consistent with previous determinations. The lightcurve amplitude is 0.47 ± 0.05 mag.

502 Sigune is a main-belt asteroid discovered by M. Wolf at Heidelberg on 1903 Jan 19. It is also known as 1903 LC, 1925 AD, and 1929 EK. The first period determination was 10.5 h by Tedesco (1979). Stephens (2007) refined the period to 10.922 ± 0.002 h with an amplitude of 0.44 mag. Behrend (2001) reported the results from Rene Roy of 10.9656 h and Maurice Audejeam of 10.96416 ± 0.0002 h. We observed 502 Sigune on 8 nights between 2014 April 24 and May 16. Our period of 10.927 ± 0.001 h is consistent with previous determinations. Our amplitude of 0.59 ± 0.05 mag is slightly larger than the value reported by Behrend.

1146 Biarmia is a main-belt asteroid discovered by G. Neujmin at Simeis on 1929 May 07. It is also known as 1929 JF. The first period determination was by Warner (2000) of 11.514 ± 0.004 h with an amplitude of 0.32 mag. Durkee (2009) obtained a period of 5.4700 ± 0.0002 h with an amplitude of 0.20 mag. Warner (2011) revised his earlier determination to a period of 5.33 ± 0.01 h with an amplitude of 0.20 mag. We observed 1146 Biarmia on 7 nights between 2014 Apr 22 and May 15. Analysis found a period of 5.468 ± 0.004 h and an amplitude of 0.22 ± 0.10 mag. It is interesting to note that this light curve has 4 minima. It should also be noted that we used 8 orders in the FALC fit rather than the normal 4 orders, which allowed a closer fit to the extra minima.

1175 Margo is an outer main-belt asteroid discovered by K. Reinmuth at Heidelberg on 1930 Oct 17. It is also known as 1930 UD, 1953 VK, 1957 KU, and A907 VA. Behrend (2005) reported a period of 6.1038 ± 0.0002 h and an amplitude of 0.31 mag. Oliver (2008) determined a period of 11.99 ± 0.03 h with an amplitude of 0.22 mag. Brinsfield (2010) determined a period of 6.015 ± 0.001 h and an amplitude of 0.40 mag. Montgomery *et al.* (2013) determined a period of 6.01 ± 0.02 h and an amplitude of 0.32 mag. They pointed out that since the period was very close to an integer fraction of 24 hours, it was difficult to determine if the true period was 6.01h or 11.99 h. We observed 1175 Margo on 5 nights between 2014 Apr 11 and 2014 May 8. Our best fit period is 6.017 ± 0.001 h with an amplitude 0.28 ± 0.10 mag.

Acknowledgments

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References

Behrend, R. (2003, 2005, 2006, 2010, 2012). Observatoire de Geneve web site.
h*ttp://obswww.unige.ch/~behrend/page_cou.html*

Brinsfield, J.W. (2010). "Asteroid Lightcurve Analysis at the Via Capote Observatory: 2009 3rd Quarter." *Minor Planet Bul.* **37,** 19-20.

Durkee, R. I. (2009). "The lightcurves of 1146 Biarmia and 5598 CarlMurray." *Minor Planet Bul.* **36,** 170.

#	Name	2014 (mm/dd) UT	Phase	PABL	PABB	Period	P. E.	Amp.	A. E.
446	Aeternitas	05/09 - 06/07	5.4, 15.6	215.8	0.2	15.745	0.001	0.47	0.05
502	Sigune	04/24 - 06/16	19.1, 18.7, 22.6	221.1	32.6	10.972	0.001	0.59	0.05
1146	Biarnia	04/22 - 05/15	2.0, 11.9	208.1	-1.0	5.468	0.004	0.22	0.10
1175	Margo	04/11 - 05/08	5.7, 13.4	184.0	-14.6	6.017	0.001	0.28	0.10

Table I. Current results

#	Name	Reference	Date	PABL	PABB
446	Aeternitas	Behrend 2006	2006-Dec-06	22.0	-2.3
		Fauerbach 2008	2006-Nov-06	19.0	-4.2
		Lucus 2011	2009-Apr-26	186.5	6.6
		Lucas 2012	2006-Nov-07	19.1	-4.1
		Lucas 2012	2008-Feb-22	12.0	12.0
		this paper	2014-May-24	215.8	0.2
502	Sigune	Stephens 2007	2007-Jun-12	275.2	22.5
		Behrend 2010	2010-Apr-14	157.7	20.9
		Behrend 2011	2011-Jul-22	305.4	5.5
		this paper	2014-May-20	221.1	32.6
1146	Biarmia	Warner 2000	1999-Sep-27	357.9	13.0
		Behrend 2008	2008-Jan-27	153.0	-18.2
		Durkee 2009	2009-Jun-13	251.9	15.5
		this paper	2014-May-01	208.1	-1.0
1175	Margo	Behrend 2005	2005-Nov-21	26.3	8.5
		Oliver 2008	2008-Mar-02	169.8	-18.2
		Brinsfield 2010	2009-Jul-01	236.8	2.1
		Montgomery 2013	2011-Nov-30	44.5	3.0
		this paper	2014-Arp-29	184.0	-14.6

Table II. Previous Solar Bisector Phase Angles

ECO (2014). Etscorn Campus Observatory. *http://www.mro.nmt.edu/education-outreach/etscorn-campus-observatory*

Fauerbach, M., Marks, S.A., Lucas, M.P. (2008). "Lightcurve analysis of ten Main-Belt Asteroids." *Minor Planet Bul.* **35,** 44-46.

Florczak, M., Dotto, E., Barucci, M.A., Birlan, M., Erikson, A., Fulchignoni, M., Nathues, A., Perret, L., Thebault, P. (1997). "Rotational properties of main belt asteroids: photoelectric and CCD observations of 15 objects." *Planet. Space Sci.* **45**, 1423-1435.

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., Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

JPLSBD. Small Body Database Search Engine. *http://ssd.jpl.nasa.gov/sbdb_query.cgi*

Lucus, M.P., Ryan, J.G. Fauerbach, M. Grasso, S. (2011). "Lightcurve Analysis of five Taxonomic A-class asteroids." *Minor Planet Bul.* **39,** 218-220.

Lucus, M.P., Ryan, J.G. Fauerbach, M. (2012). "A shape model of the Taxonomic A-class asteroid 446 Aeternitas." *Minor Planet Bul.* **38,** 173-176.

Montgomery, K.A., Davis, C., Renshaw, T., Rolen, J. (2013). "Photometric Study of Four Asteroids at Texas A&M Commerce Observatory." *Minor Planet Bul.* **40**, 212-213.

Oliver, R.L., Shipley, H., Ditteon, R. (2008). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: March 2008." *Minor Planet Bul.* **35**, 149-150.

SB (2014). Software Bisque. *http://www.bisque.com/sc/*

Stephens, R.D. (2007). "Photometry from GMARS and Santana Observatories - April to June 2007." *Minor Planet Bul.* **34**, 102-103.

Tedesco, E.F. (1979). PhD Dissertation. New. Mex. State Univ. 280 pp.

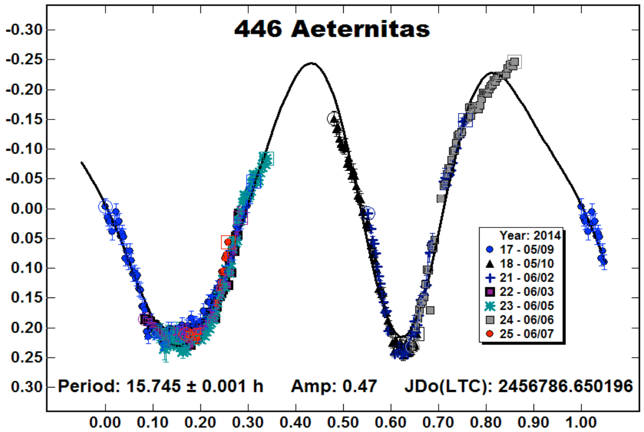
Warner, B.D. (2000). "Asteroid Photometry at the Palmer Divide Observatory." *Minor Planet Bul.* **27**, 4-6.

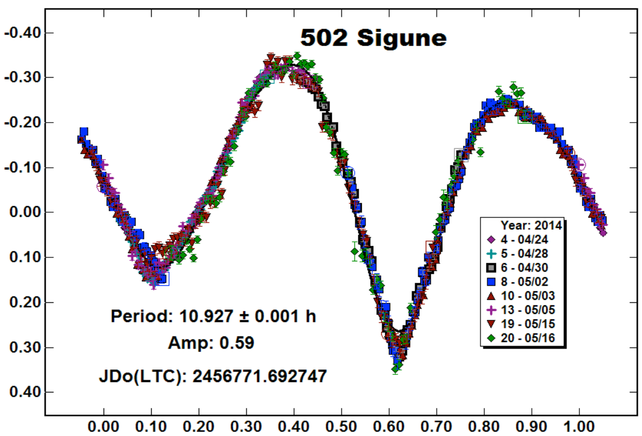
Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

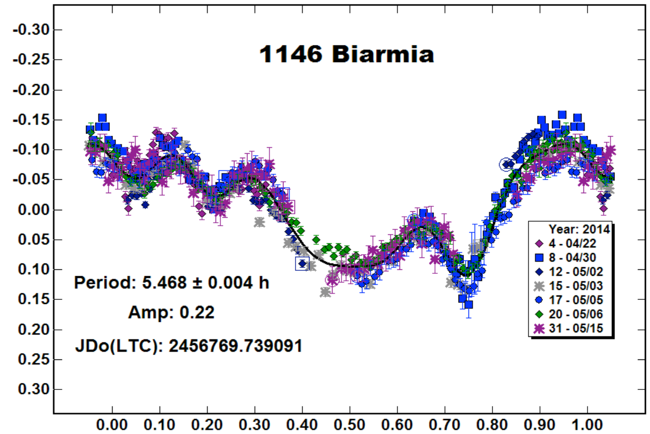
Warner, B.D. (2011). "Upon Further Review: III. An examination of Previous Lightcurve Analysis from the Palmer Divide Observatory." *Minor Planet Bul.* **38**, 21-23.

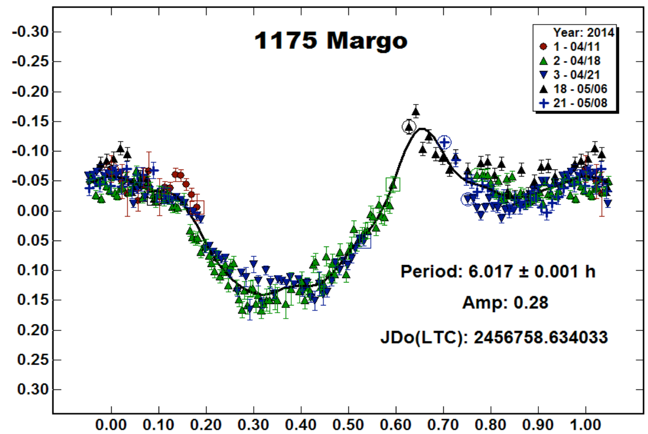
Warner. B.D. (2014). MPO Canopus software. *http://www.bdwpublishing.com*

Warner, B.D., Harris, A.W., Pravec, P., Durech, J., Benner, L.A.M. (2014). "Lightcurve photometry Opportunities: 2014 January-March." *Minor Planet Bul.* **40**, 61-65.









ROTATION PERIOD DETERMINATION FOR 299 THORA

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This is the first comprehensive photometric investigation ever made of 299 Thora. We find a synodic rotation period 273.6 ± 0.2 hours, amplitude 0.39 magnitudes. Inaccuracies in calibration star magnitudes and possible changes in the shape of the lightcurve through the two months of observation prevent finding any possible tumbling behavior.

Warner et al. (2014) state no previous photometric observations of 299 Thora. First author Pilcher on the first nights found very slow magnitude changes and invited second author Alvarez to collaborate. Author Pilcher used a 35 cm f/10 Meade LX200 GPS S-C, SBIG STL-1001E CCD, unguided, clear filter with infrared blocker. Author Alvarez used a 30 cm f/6.9 Meade LX200 ACF S-C, QSI 516 wsg NABG CCD, off axis guiding, clear filter with no infrared blocker. Both authors used *MPO Canopus v.10* software to measure the images photometrically and share data. Each night the instrumental magnitudes were calibrated with up to five comparison stars with near solar colors. The calibration star magnitudes were improved by finding their Sloan r' magnitudes on the Carlsbad Meridian Circle (CMC15) catalog on the VizieR web site (2014), and then subtracting 0.22 to convert to Johnson-Cousins R magnitudes where R = r' – 0.22.

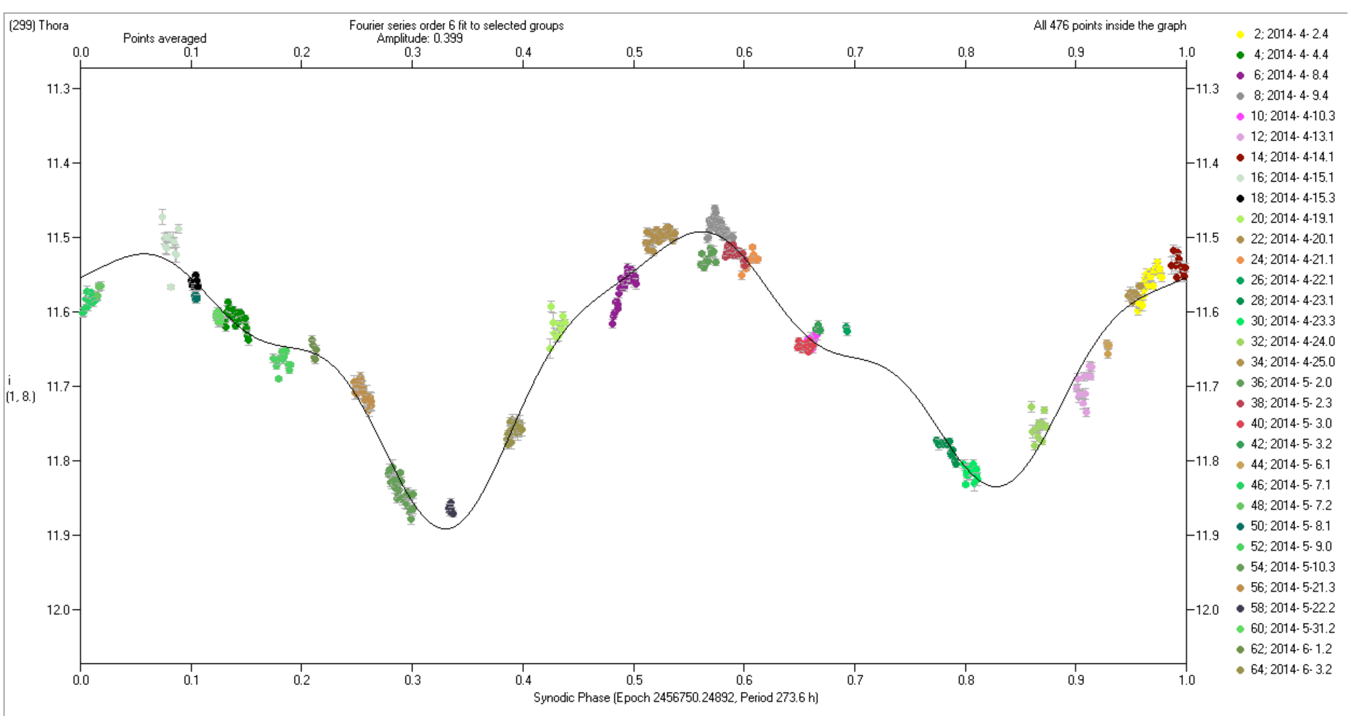
Observations obtained on 32 nights 2014 Apr. 2 – June 3 are summarized on table 1. On three of these nights observer Alvarez ended his session no more than three hours before observer Pilcher started his session and some or all of the same calibration stars could be used. These allowed a precise comparison of calibrated magnitudes by the two equipment sets. In each case Pilcher's data were 0.12 to 0.18 magnitudes brighter than the extrapolation of Alvarez's data. A systematic difference near 0.15 magnitude we attribute to different responses of the CCD sensors and to the clear filters being IR blocked and non IR blocked, respectively. An additional random difference of a few x 0.01 magnitudes also appears. These differences prevent precise calibration of comparison star magnitudes.

The period of 273.6 hours is well established by the data, with a formal error ± 0.2 hours, with amplitude 0.39 ± 0.04 magnitudes. A real uncertainly may be greater, perhaps on an order one hour, due to possible systematic errors in the calibrations and the assumption of principal axis rotation. A possible second frequency, which would be presumably due to tumbling, is not detectable with the given quality of data calibrations. The data fit reasonably well with the 273.6 hour period, there are a few small deviations apparent, but they could be due to calibration uncertainties and/or lightcurve evolution during the two month long observational interval. Thus, we cannot tell from the available data whether the asteroid is in principal axis rotation or if there may be some tumbling. In the composite lightcurve nearby points are averaged (taken over an interval not longer than 1% of the main period with averaging of more than 13 points was suppressed.)

References

VizieR (2014). *http://vizier.u-strasbg.fr/viz-bin/VizieR*

Warner, B. D., Harris, A. W., Pravec, P., "Asteroid Lightcurve Data Base, Revised 2014 March 1." *http://minorplanet.info.lightcurvedatabase.html*



Session	Observer	2014	UT	Data Pts
2	FP	Apr 2	06:09 – 12:11	273
4	FP	Apr 4	05:56 – 12:00	270
6	FP	Apr 8	05:35 – 11:45	267
8	FP	Apr 9	05:13 – 11:45	328
10	FP	Apr 10	05:40 – 08:34	115
12	EMA	Apr 13	00:23 – 04:31	114
14	EMA	Apr 13-14	23:46 – 03:45	87
16	EMA	Apr 14-15	23:54 – 04:02	109
18	FP	Apr 15	07:12 – 08:58	89
20	EMA	Apr 18-19	23:54 – 03:47	96
22	EMA	Apr 19-20	23:27 – 07:05	200
24	EMA	Apr 20-21	23:12 – 03:36	113
26	EMA	Apr 22	01:03 – 01:41	20
28	EMA	Apr 22-23	23:22 – 04:29	120
30	FP	Apr 23	06:12 – 10:02	139
32	EMA	Apr 23-24	22:54 – 02:55	113
34	EMA	Apr 24-25	22:58 – 02:04	91
36	EMA	May 1-2	22:42 – 02:43	106
38	FP	May 2	04:57 – 10:00	250
40	EMA	May 2-3	22:40 – 02:44	109
42	FP	May 3	03:20 – 04:28	49
44	FP	May 6	03:12 – 03:50	33
46	EMA	May 6-7	23:14 – 03:09	113
48	FP	May 7	03:10 – 04:05	46
50	FP	May 8	03:10 – 03:57	42
52	EMA	May 8-9	22:36 – 03:00	115
54	FP	May 10	03:11 – 09:26	296
56	FP	May 21	04:08 – 08:48	195
58	FP	May 22	03:36 – 04:45	60
60	FP	May 31	03:36 – 05:00	68
62	FP	June 1	03:27 – 04:41	46
64	FP	June 3	03:40 – 07:31	190

Table 1. Observing Circumstances. In the observer column EMA is Alvarez at OLASU and FP is Pilcher at Organ Mesa.

TROJAN ASTEROIDS OBSERVED FROM CS3: 2014 JANUARY - MAY

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(Received: 23 June)

Lightcurves for eight Jupiter Trojan asteroids were obtained from the Center for Solar System Studies from 2014 January to May.

The Jovian Trojan asteroids are found in orbits near the stable L4 and L5 Langrange points of Jupiter's orbit. They are thought to have formed further from the Sun and their composition and collisional history appears to be different from main-belt asteroids. The rotation properties of Trojan asteroids are poorly known compared to those of main-belt asteroids. The lower albedo and greater distance of the Trojans makes them more difficult to observe. Here we report lightcurve data for 8 Trojans. Most are in the 50 – 100 km diameter size range, many of which were observed to collect data for future pole solutions and shape models.

All images were made with a 0.4-m or two 0.35-m SCTs with a FLI-1001e, a SBIG STL-1001E or a SBIG ST-9E CCD camera. 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 V 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.

624 Hektor. As one of the brightest Trojans, Hektor has been observed a number of times. All reported results have a synodic rotational period of around 6.92 h. This year it was undertaken as a "Full Moon" project and the period found is consistent with those results. Marchis (2006) reports that Hektor is a binary and the primary is an ellipse with major and minor axes of approximately 350 km by 210 km. It has a satellite about 10 km in diameter orbiting about 600 km distant (Marchis 2014).

911 Agamemnon. The authors observed Agamemnon twice before (French 2012, Stephens 2009) and undertook observations this year in hope of getting sufficient data for a shape model in the future. This year's results are similar to those past results and that obtained by Mottola (2011).

1143 Odysseus. Also undertaken as a "Full Moon" project, Odysseus has been previously observed several times. Molnar

Number	Name	2014 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
624	Hektor	04/16-04/17	276	4.9,5.1	184	-8	6.928	0.003	0.29	0.02
911	Agamemnon	03/14-03/15	190	2.4,2.3	181	-10	6.59	0.01	0.21	0.03
1143	Odysseus	02/14-03/13	272	5.4,0.7	171	-3	10.029	0.001	0.15	0.02
2797	Teucer	03/15-03/20	637	2.5,5.4	176	20	10.157	0.003	0.20	0.02
9712	Nauplius	03/09-03/24	308	2.6,0.1,0.6	181	1	19.41	0.02	0.48	0.05
11429	Demodokus	02/04-02/24	518	3.9,2.4,2.7	150	12	50.16	0.06	0.18	0.03
15440	1998 WX4	03/07-03/08	131	4.4,4.5	159	21	-			
15539	2000 CN3	01/29-02/22	639	4.3,3.7,4.4	142	18	46.25	0.03	0.30	0.03

(2008), Mottola (2011) and Shevchenko (2012) all reported results near 10.11 h, in good agreement with this result.

2797 Teucer. The authors observed Teucer before (French 2011) finding a rotational period of 10.145 h. We followed it again this year to obtain data for a future shape model and pole solution. Our result of 10.157 h is in good agreement with our prior result.

9712 Nauplius. Nauplius does not have a previously reported rotational period in the Lightcurve Database (Warner 2014).

11429 Demodokus. Demodokus does not have a previously reported rotational period (Warner 2014).

(15440) 1998 WX4. We attempted to observe this asteroid in 2013 (French 2013) and found a flat lightcurve with no discernable features. That was our experience again this season.

(15539) 2000 CN3. This Trojan does not have a previously reported rotational period (Warner 2014).

References

French, L., Stephens, R., Lederer, S., Coley, D., Rohl, D. (2011). "Preliminary Results from a Study of Trojan Asteroids." *Minor Planet Bul.* **38**, 116-120.

French, L., Stephens, R., Coley, D., Megna, R., Wasserman, L. (2012). "Photometry of 17 Jovian Trojan Asteroids." *Minor Planet Bul.* **39**, 3.

French, L., Stephens, R., Coley, D., Wasserman, L., Vilas, F., La Rocca, D. (2013). "A Troop of Trojans: Photometry of 24 Jovian Trojan Asteroids." *Minor Planet Bul.* **40**, 198-203.

Harris, A., Young, J. (1989). "Asteroid lightcurve observations from 1979-1981." *Icarus* **81**, 314-364.

Marchis, F., Wong, M. H., Berthier, J., Descamps, P., Hestroffer, D., Vachier, F., Le Mignant, D., de Pater, I. (2006) "S/2006 (624) 1." *IAU Circ.*, 8732, 1.

Marchis, F., Durech, J., Castillo-Rogezn J., Vachier, F., Cuk, M., , Berthier, J., Wong, M., Kalas, P., Duchene, G., van Dam, M., Hamanowa, H., Viikinkoski, M. (2014) "The Puzzling Mutual Orbit of the Binary Trojan Asteroid (624) Hektor" *ApJ.*, **783**, 2.

Molnar, L., Haegert, M., Hoogeboom, K. (2008). "Lightcurve Analysis of an Unbiased Sample of Trojan Asteroids." *Minor Planet Bul.* **35**, 82-84.

Mottola, S., Di Martino, M., Erikson, A., Gonano-Beurer, M., Carbognani, A., Carsenty, U., Hahn, G., Schober, H., Lahulla, F., Delbò, M., Lagerkvist, C. (2011). "Rotational Properties of Jupiter Trojans. I. Light Curves of 80 Objects." *ApJ.* **141**, 5, 170.

Shevchenko, V., Belskaya, I., Slyusarev, I., Krugly, Y., Chiorny, V., Gaftonyuk, N., Donchev, Z., Ivanova, V., Ibrahimov, M., Ehgamberdiev, S., Molotov, I. (1989). "Opposition effect of Trojan asteroids." *Icarus* **217**, 202-208.

Stephens, R. (2010). "Asteroids Observed from GMARS and Santana Observatories." *Minor Planet Bul*. **36**, 59-62.

Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul*. **34**, 113-119.

Warner, B.D. (2014). The Asteroid Lightcurve Database (LCDB) website. *http://www.minorplanet.info/lightcurvedatabase.html.*

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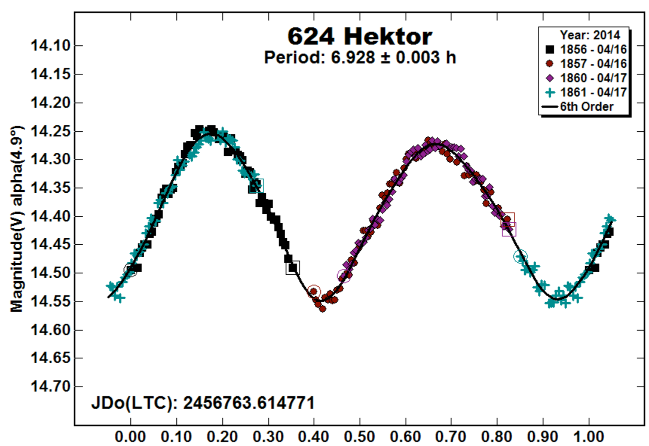

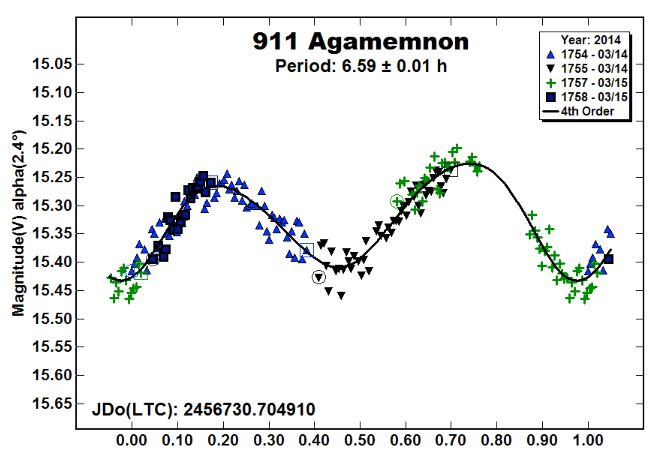

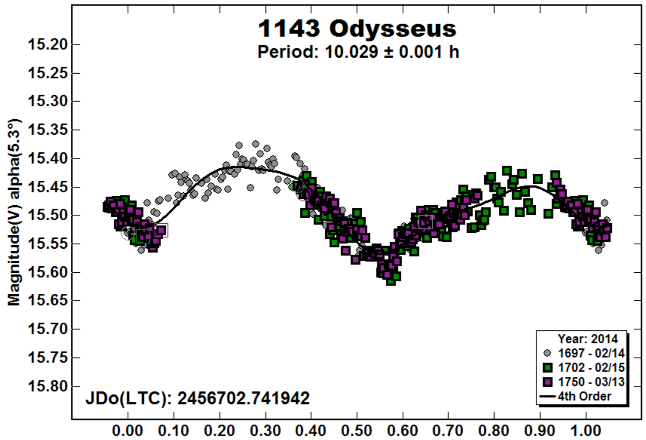
1143 Odysseus
Period: 10.029 ± 0.001 h
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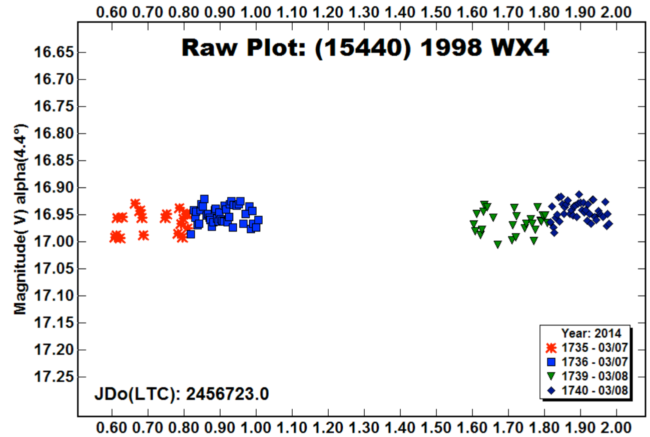
1702 - 02/15
1750 - 03/13
4th Order
JDo(LTC): 2456702.741942


Raw Plot: (15440) 1998 WX4
Magnitude(V) alpha(4.4°)
Year: 2014
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1736 - 03/07
1739 - 03/08
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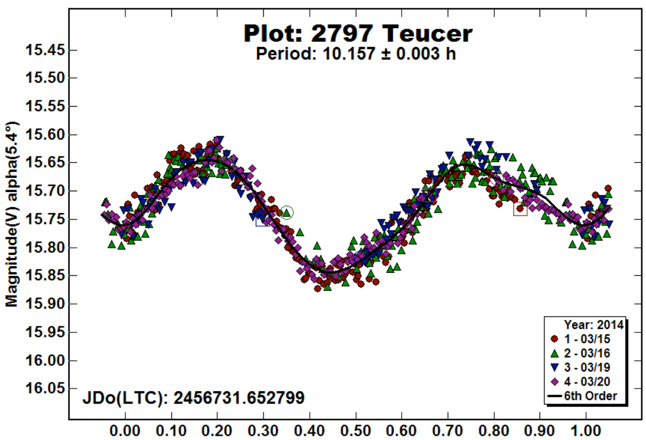
JDo(LTC): 2456723.0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Period: 10.157 ± 0.003 h
Magnitude(V) alpha(5.4°)
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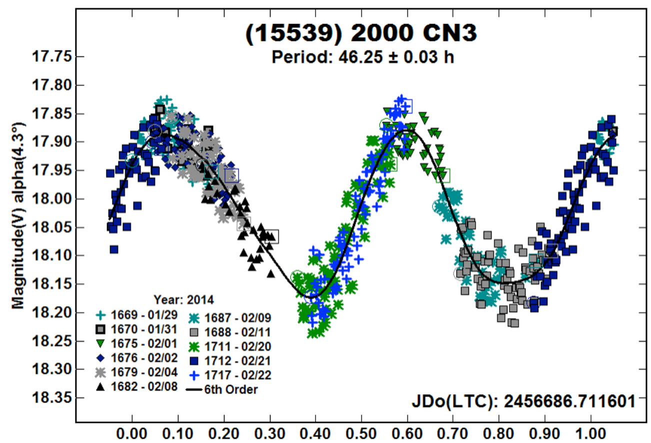
1 - 03/15
2 - 03/16
3 - 03/19
4 - 03/20
6th Order
JDo(LTC): 2456731.652799


(15539) 2000 CN3
Period: 46.25 ± 0.03 h
Magnitude(V) alpha(4.3°)
Year: 2014
1669 - 01/29
1670 - 01/31
1675 - 02/01
1676 - 02/02
1679 - 02/04
1682 - 02/08
1687 - 02/09
1688 - 02/11
1711 - 02/20
1712 - 02/21
1717 - 02/22
6th Order
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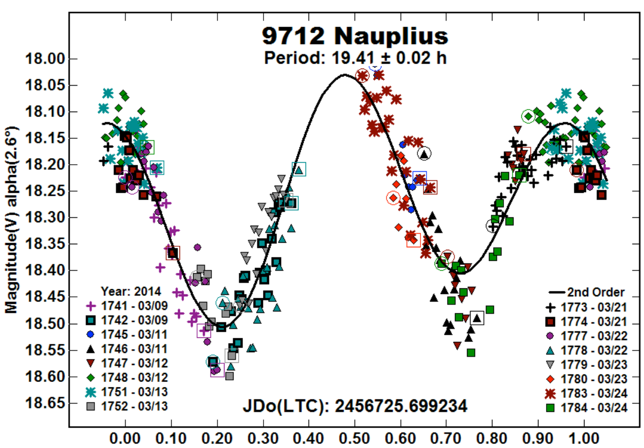
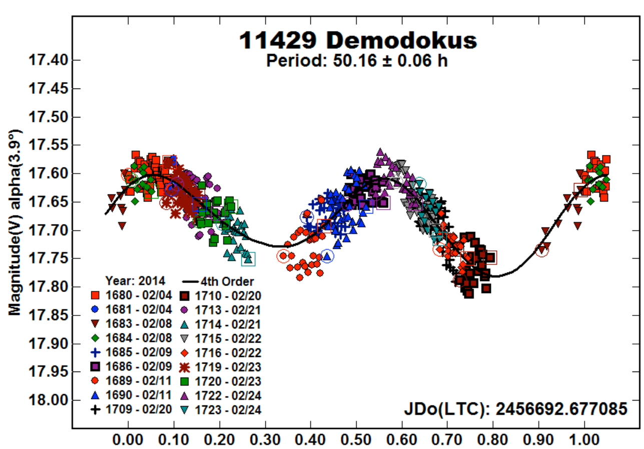

9712 Nauplius
Period: 19.41 ± 0.02 h
Magnitude(V) alpha(2.6°)
Year: 2014
1741 - 03/09
1742 - 03/09
1745 - 03/11
1746 - 03/11
1747 - 03/12
1748 - 03/12
1751 - 03/13
1752 - 03/13
2nd Order
1773 - 03/21
1774 - 03/21
1777 - 03/22
1778 - 03/22
1779 - 03/23
1780 - 03/23
1783 - 03/24
1784 - 03/24
JDo(LTC): 2456725.699234


11429 Demodokus
Period: 50.16 ± 0.06 h
Magnitude(V) alpha(3.9°)
Year: 2014
1680 - 02/04
1681 - 02/04
1683 - 02/08
1684 - 02/08
1685 - 02/09
1686 - 02/09
1689 - 02/11
1690 - 02/11
1709 - 02/20
4th Order
1710 - 02/20
1713 - 02/21
1714 - 02/21
1715 - 02/22
1716 - 02/22
1719 - 02/23
1720 - 02/23
1722 - 02/24
1723 - 02/24
JDo(LTC): 2456692.677085

NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2014 MARCH-JUNE

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Lightcurves for 38 near-Earth asteroids (NEAs) were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2014 March through June.

CCD photometric observations of 38 near-Earth asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2014 March through June. Table I gives a listing of the telescope/CCD camera combinations used for the observations. All the cameras use the same CCD chip from the Kodak KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. Guiding was done on a field star, which sometimes resulted in a trailed image for the asteroid. The exposure duration varied depending on the asteroid's brightness and sky motion.

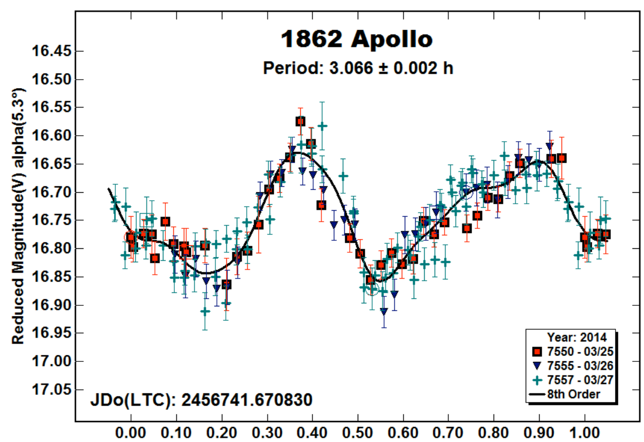
Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes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

In the plots below, the "Reduced Magnitude" is Johnson V (or Cousins R) as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) 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 and ranges from –0.05 to 1.05.

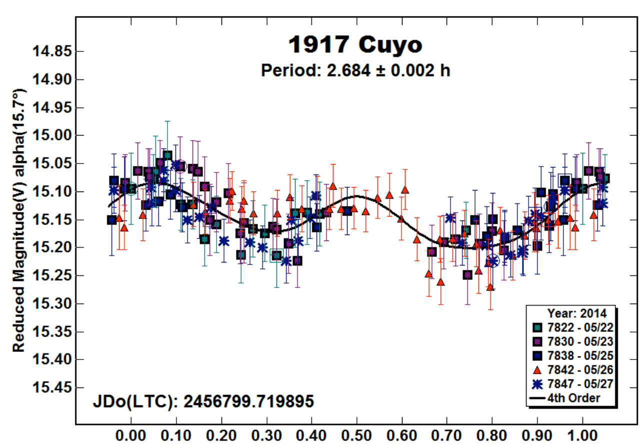
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

Individual Results

1862 Apollo. This is the namesake for the group of near-Earth asteroids that have semi-major axes greater than 1 AU but perihelion distances < 1.017 AU (the aphelion distance of the Earth). The author worked the asteroid in 2006 November (Warner, 2006) when the amplitude went from 1.15 mag to 0.26 over the course about two weeks. The 2014 apparition showed a more stable magnitude range, though the observations covered only three consecutive nights. Numerous other results have been reported, including a shape model by Kaasalainen *et al.* (2007). That paper demonstrated the slow acceleration of the asteroid's spin rate induced on the asteroid by the YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) effect.



1912 Cuyo. The period of 2.684 h found at CS3-PDS is in good agreement with previous results, e.g., Wisniewski (1997; 2.6905 h) and Behrend (2008; 2.6890 h).

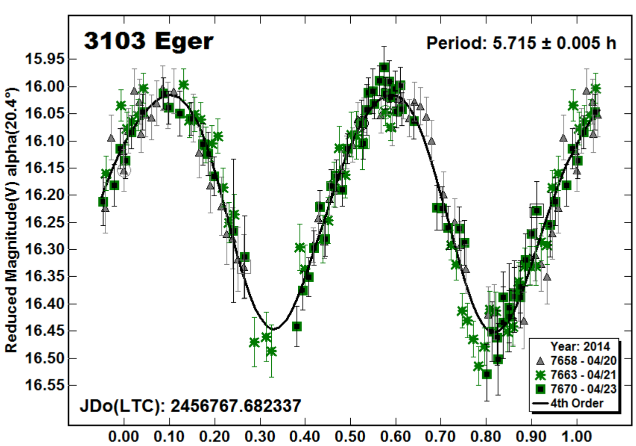


Number	Name	2014 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
1862	Apollo	03/25-03/27	150	5.3,6.5	181	6	3.066	0.002	0.22	0.02
1917	Cuyo	05/22-05/26	133	15.7,15.5	255	29	2.684	0.002	0.12	0.02
3103	Eger	04/20-04/23	168	20.4,20.6	210	31	5.715	0.005	0.49	0.03
21374	1997 WS22	04/08-04/17	183	54.6,53.2	232	31	3.405	0.005	0.07	0.01
24445	2000 PM8	04/24-04/29	129	24.7,25.3	169	-12	6.76	0.02	0.19	0.02
25916	2001 CP44	03/16-03/20	67	37.3,37.9	246	14	4.208[A]	0.003	0.37	0.03
85628	1998 KV2	04/24-04/30	193	16.6,11.9	228	10	2.819	0.002	0.16	0.02
85989	1999 JD6	05/20-05/22	109	36.0,34.8	260	30	7.667	0.006	1.12	0.03
86039	1999 NC43	03/15-03/22	93	65.0,57.4	128	-7	34.1	0.5	0.75	0.1
86829	2000 GR146	05/31-06/04	97	56.9,54.3	193	15	2.917	0.002	0.14	0.02
86878	2000 HD24	05/05-05/15	123	31.7,33.0	200	-5	23.1	0.5	0.35	0.05
143649	2003 QQ47	03/31-04/03	184	84.6,81.3	141	-9	3.679	0.005	0.19	0.02
153002	2000 JG5	04/25-04/28	178	39.7,32.9	238	18	6.051	0.005	0.91	0.03
153957	2002 AB29	06/04-06/05	49	45.9,42.9	283	18	2.545	0.005	0.24	0.03
162181	1999 LF6	05/22-05/28	203	22.2,26.4	236	22	14.77	0.04	0.17	0.03
188174	2002 JC	05/12-05/15	89	89.8,94.5	280	37	2.746[A]	0.002	0.26	0.03
222869	2002 FB6	03/22-03/24	109	30.9,31.7	205	14	8.98	0.04	0.28	0.03
267337	2001 VK5	04/24-05/02	379	47.4,0.0,58.3	158	21	39.05	0.04	0.92	0.05
274138	2008 FU6	03/29-04/04	233	6.0,12.7	182	-3	2.852	0.005	0.07	0.01
303174	2004 FH11	04/29-05/01	153	13.1,0.0,14.8	136	3	2.523	0.003	0.18	0.02
363599	2004 FG11	04/07-04/08	427	47.5,54.5	214	24	22.0[C]	0.5	0.37	0.03
387733	2003 GS	04/12-04/13	226	14.9,16.6	203	9	2.467	0.002	0.14	0.01
388468	2007 DB83	03/27-03/29	125	35.0,34.5	209	18	5.411	0.003	0.69	0.03
388838	2008 EZ5	03/27-04/03	103	18.2,17.8,18.2	202	1	8.4	0.02	0.29	0.03
392211	2009 TG10	05/06-05/14	294	58.8,59.1	248	48	13.87	0.02	1.34	0.05
395289	2011 BJ2	05/04-05/06	216	55.7,54.7	184	9	7.03	0.02	0.48	0.03
	2005 GP128	05/31-06/04	63	51.3,52.9	289	14	3.266	0.005	0.7	0.05
	2010 NG3	05/22-05/26	85	52.4,54.1	193	22	4.229	0.005	0.33	0.03
	2010 LJ14	03/27-04/15	404	23.9,12.7	208	10	113	2	0.82	0.05
	2011 JR13	05/19-05/22	674	54.0,96.8	258	36	3.77[A]	0.02	0.05	0.38
	2013 WF108	05/28-05/30	556	72.5,64.8	239	37	7.37	0.02	0.21	0.03
	2014 HM2	05/03-05/12	229	8.0,15.9	227	7	13.96	0.02	0.37	0.03
	2014 EQ12	03/23-03/31	914	8.5,43.0	187	11	8.49[A]	0.01	0.11	0.02
	2014 FH33	04/23-04/25	130	19.6,21.8	198	14	6.73	0.02	0.35	0.03
	2014 EZ48	03/21-03/23	131	1.7,4.3	179	2	5.96	0.02	0.53	0.03
	2014 GY48	04/28-05/02	347	85.6,0.0,93.8	129	17	6.82[A]	0.01	0.24	0.02
	2014 HO132	05/03-05/03	472	15.3,15.3	215	3	4.08	0.05	0.23	0.03
	2014 HS184	05/29-06/02	390	20.9,24.3	252	12	1.9557[B]	0.0004	0.89	0.05

Table II. Observing circumstances. [A] Favored period in ambiguous solution. [B] Dominant period of a tumbler. [C] Orbital period of satellite.

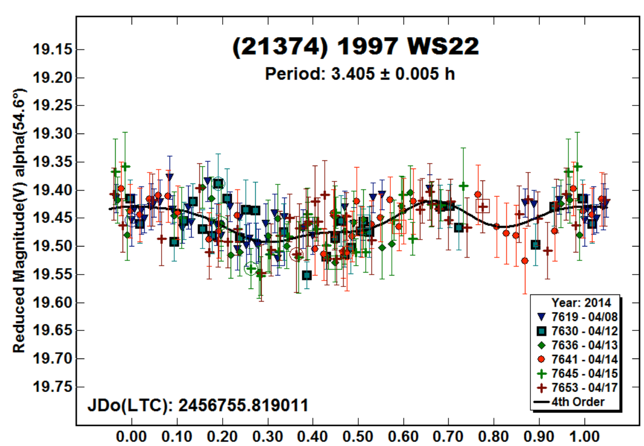
The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector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

3103 Eger. This asteroid shows a considerable amplitude range over different viewing aspects (see references in the LCDB). The 2014 observations showed the lowest amplitude recorded to date, only 0.49 mag.

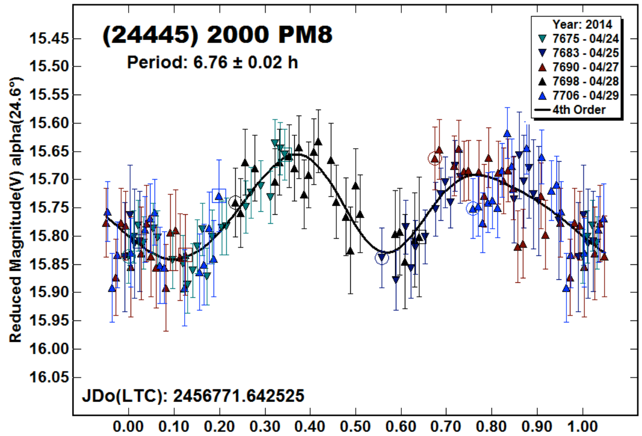


The phase angle bisector longitude (L_{PAB}; see Harris *et al.*, 1984) in 2014 was about 210°. Combined with the unusually low amplitude, this would favor the spin axis pole being near 210° (or 30°). This agrees with the pole of (226°, 70°) found by Durech *et al.* (2012).

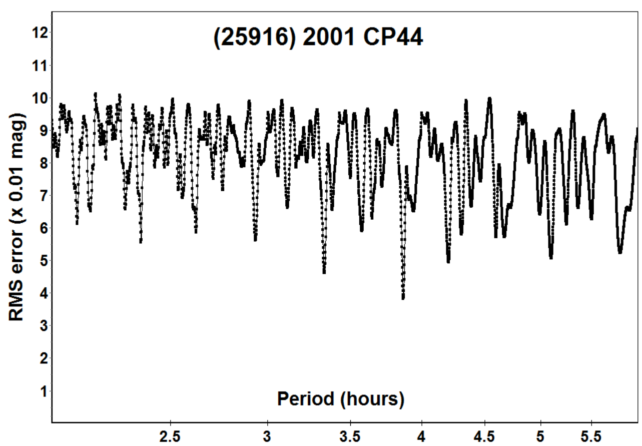
(21374) 1997 WS22. No previous period result was found in the literature for this asteroid. The low amplitude reduces the certainty of the result.

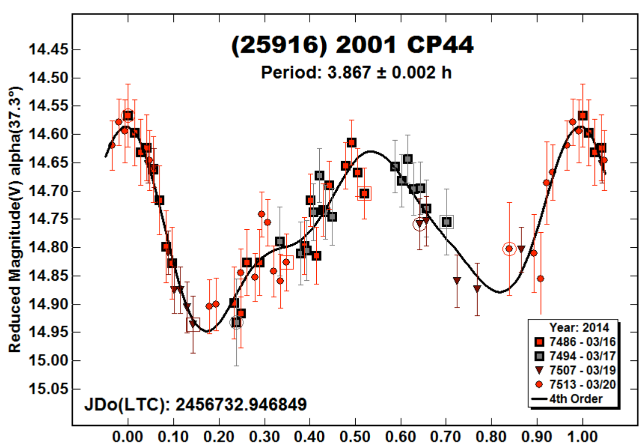


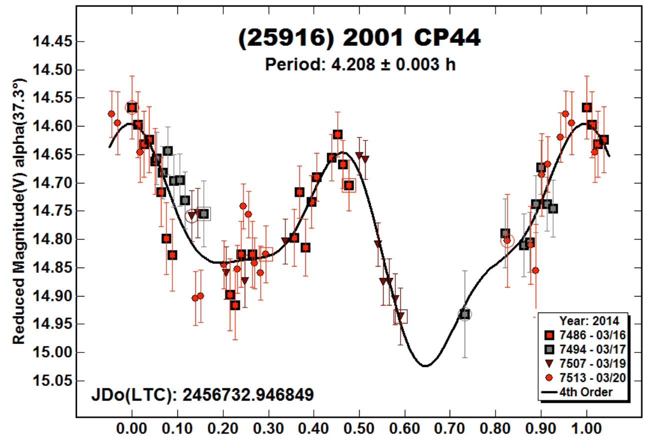
(24445) 2000 PM8. Warner (2014) found a period of 6.811 h based on data obtained in 2013 August. The amplitude was 0.25 mag at L_{PAB} ~ 5°. Jahn *et al*. (2014) found a similar period a month later, but an amplitude ranging from 0.65 to 0.95 mag near L_{PAB} 47°. The most recent observations from CS3-PDS were at L_{PAB} 169°, or close to 180° from the earlier observations. As might be expected, the amplitude was also relatively low, 0.19 mag. This leads to the conclusion that the spin axis longitude is near 0° (or 180°) and that the latitude is somewhat away from the ecliptic pole.



(25916) 2001 CP44. Elenin *et al*. (2012) found a period of 4.19 h based on an extensive data set covering three consecutive nights in 2010. The PDS 2014 data set did not favor that solution, but one of 3.867 hours. However, it was not as dense, although it did cover a range of four nights in two sets of two consecutive nights.



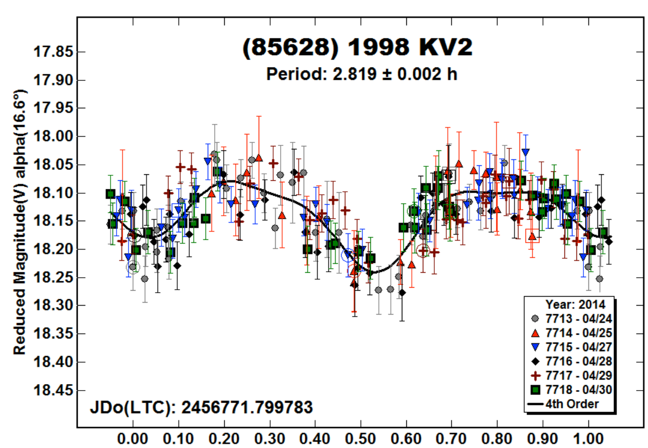




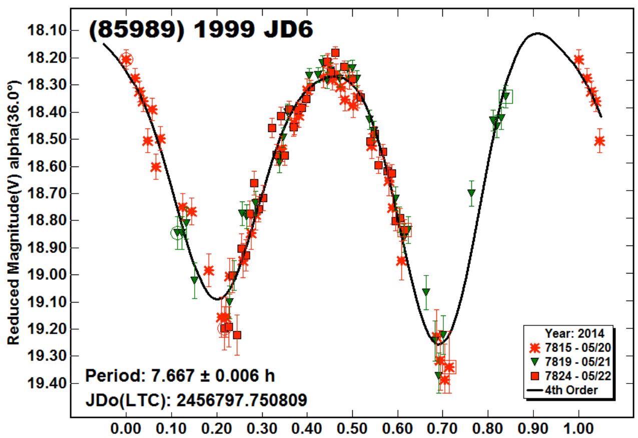
The period spectrum shows the Elenin *et al*. solution, but it is not even the second best fit in terms of RMS. The two lightcurves show the PDS data phased to the favored period and to one near the Elenin *et al*. value. Visually, the curve of the shorter period is more symmetrical and the fit to the model curve noticeably better. The data could not be manipulated, i.e., zero point adjustments, so that the longer period was favored.

The difference between the two periods is almost exactly one-half rotation over 24 hours. This could lead to a *rotational alias*, where – in this case – the halves of a symmetrical curve are not properly matched. The PDS lightcurves are not very symmetrical; however, the Elenin *et al* curve was highly symmetrical, which raised some doubts. Elenin (private communications) made his data available for additional analysis. They can be made to fit to the shorter period, but only by ignoring about ten data points in one night's run, for which there is no sound justification, and a noticeably poorer overall fit. In the end, the longer period is probably the correct one but follow-up work is encouraged.

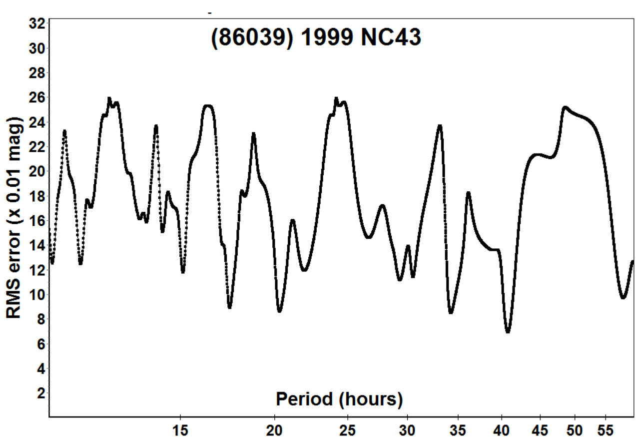
(85628) 1998 KV2. There were no previous results found in the literature for 1998 KV2. The period and shape are consistent with the primaries of small binary asteroids. However, there was no evidence of a satellite, i.e., occultations and/or eclipses. Observations at future apparitions are encouraged. For those who can wait, the asteroid will be as bright as 13.7 in 2037 November. Otherwise, the magnitude near opposition is only 17.2 in 2016 and gradually increases towards the 2037 culmination.

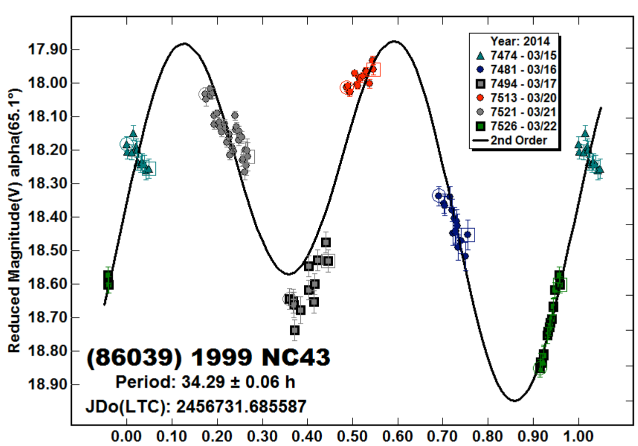


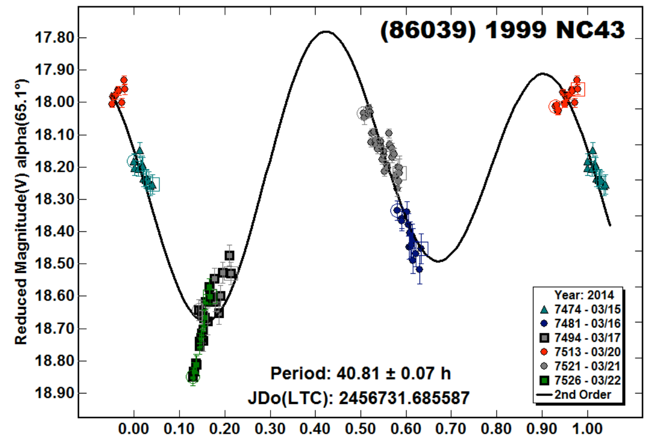
(85989) 1999 JD6. Polishook (2005, 2008) found a period of about 7.66 h for 1999 JD6, a result also supported by Pravec *et al*. (1999, 2000) and by the PDS observations in 2014. All the lightcurves obtained so far were at similar phase angle bisector longitudes and so the amplitudes have not varied much. The lack of observations at different longitudes makes modeling from dense lightcurves alone more difficult. Since the average amplitude is somewhat large, sparse data from the surveys may be useful in spin axis modeling.



(86039) 1999 NC43. Pravec *et al.* (2000) found a period of 34.49 h and amplitude of 1.1 mag based on observations in 2000 March. They also reported a possible alternative period of 122 h. The PDS data from almost exactly 14 years later roughly confirmed the shorter period but the result is ambiguous. Part of the problem was that the asteroid was located in rich star fields and so most data points had to be eliminated due to star contamination. This left a fairly sparse data set for analysis.

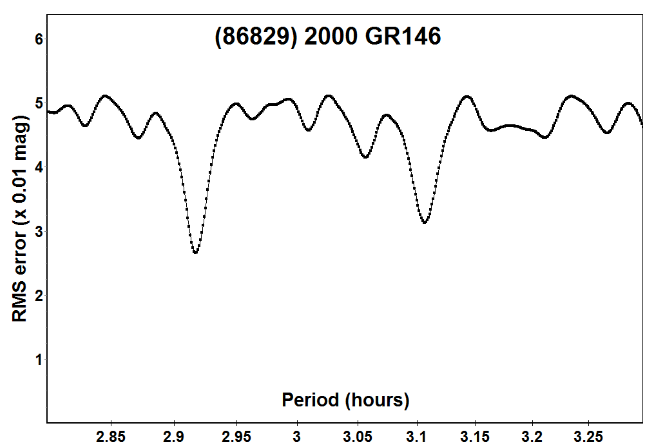


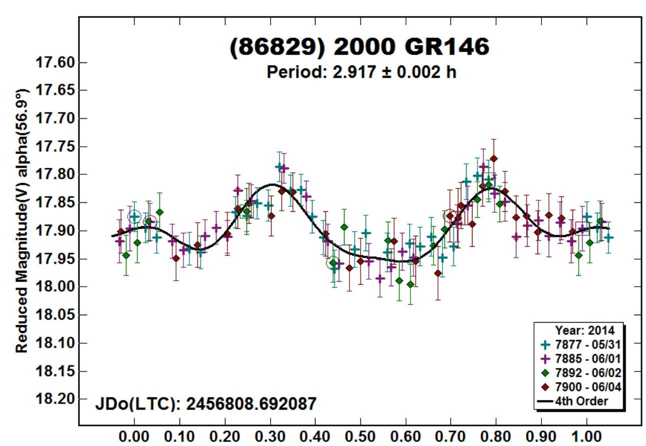




The period spectrum shows a number of possible solutions, with the one near 34 hours being a possibility, but not the most favored. A scan over a larger range of periods did not show a solution near 122 hours. However, given the sparse amount of data, this is not too surprising. The two lightcurves show the PDS data phased first to the shorter period of about 34.3 hours and then to the favored period in the spectrum of about 40 hours. In both cases, the data from at least one night has a slope that is contrary to the model lightcurve. This is often a sign that the asteroid might be in non-principal axis rotation (NPAR) or *tumbling* (see Pravec *et al.*, 2005, for a detailed study of tumbling asteroids).

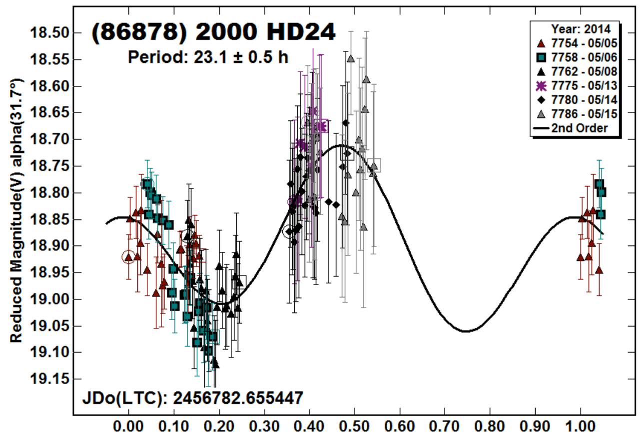
(86829) 2000 GR146. Previous results for this asteroid include Pravec *et al.* (2007; 3.0996 h) and Polishook (2012; 3.5 h). The PDS result of 2.917 h is outside the error bars of the Pravec *et al.* solution.



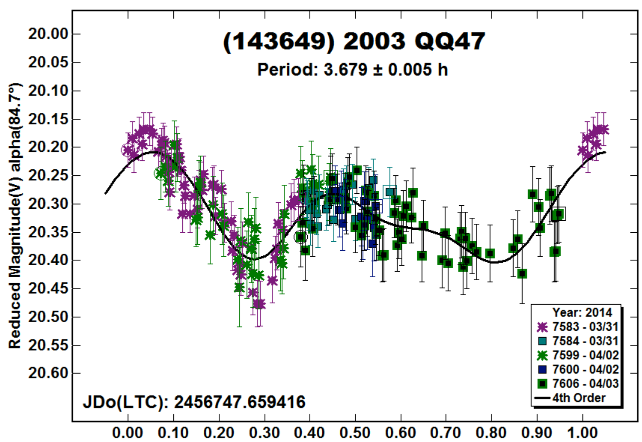


The period spectrum does show a solution near 3.1 hours. However, when the PDS data are forced to the longer period, the fit is not just noticeably worse, but cannot be made better by small zero point adjustments. Additional observations are encouraged.

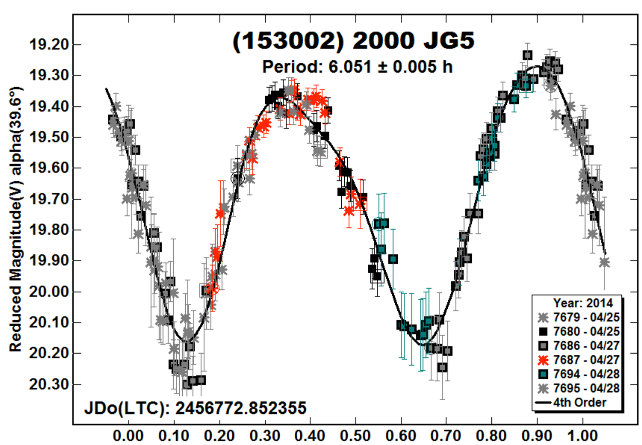
(86878) 2000 HD24. This was a case of working an asteroid too close to the sky background. The data were extremely noisy and, worse, what period could be found was nearly commensurate with an Earth day. Eventually the asteroid was abandoned.



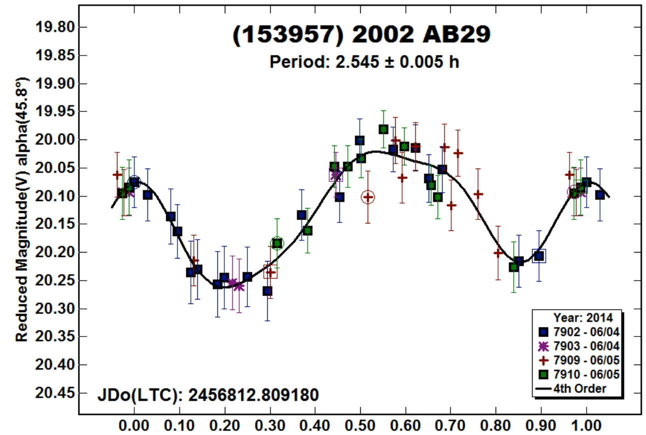
(143649) 2003 QQ47. No previous results were found in the literature for this asteroid. The solution should not be considered definitive and so needs confirmation.



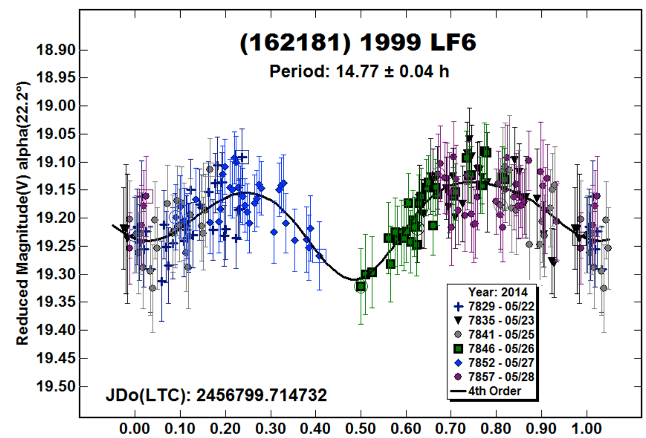
(153002) 2000 JG5. The PDS period agrees with that from Pravec *et al.* (2000).



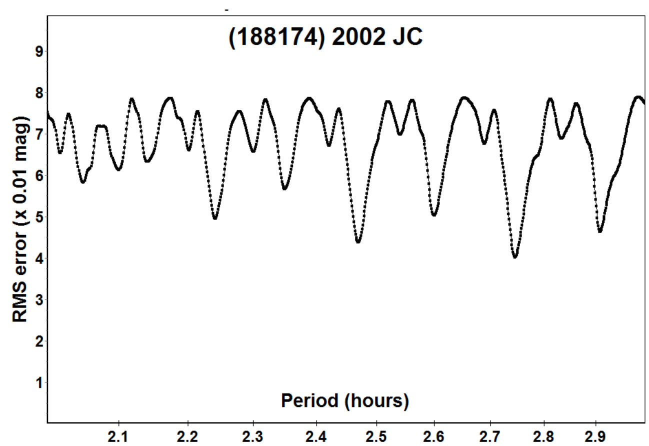
(153957) 2002 AB29. Despite the relatively few data points, the period seems well-determined.

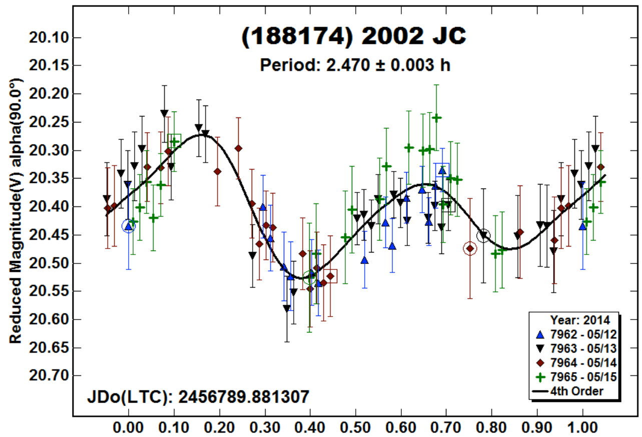


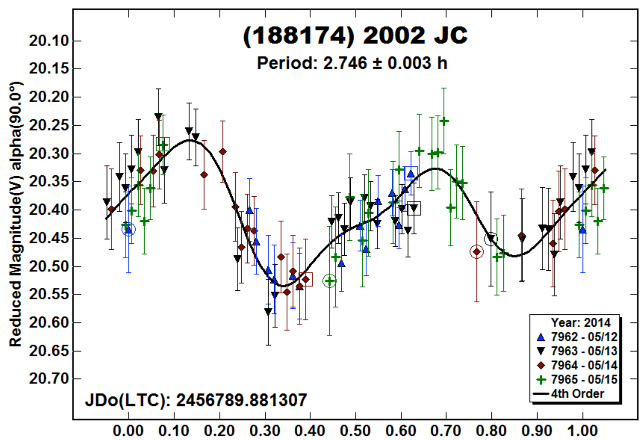
(162181) 1999 LF6. Pravec *et al.* (1999) found a period of 16.007 h. The period spectrum using the PDS data from 2014 shows a significantly weaker solution near 16 hours while a lightcurve forced to that period shows a very poor fit. The difference between the two solutions is unexplained.



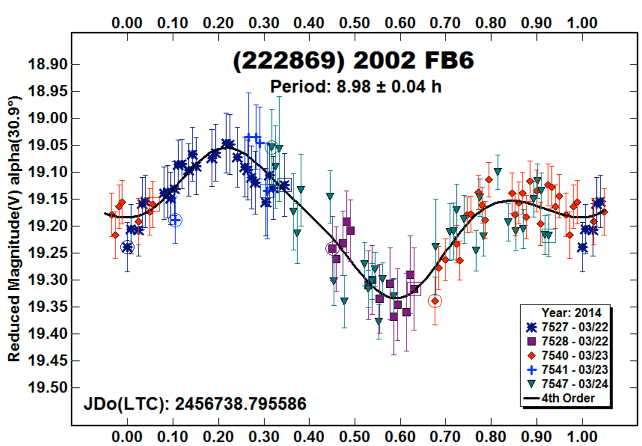
(188174) 2002 JC. Previous results for this asteroid by Polishook (2005, 2008), Skiff (2011), and Behrend (2011) are in the range of 2.47 to 2.49 hours. The period spectrum using the PDS data from 2014 shows that a period of 2.47 h is possible, but that one at 2.75 h is slightly favored. The difference between the two is almost exactly one rotation over 24 hours, presenting another possible case of *rotational aliasing*.



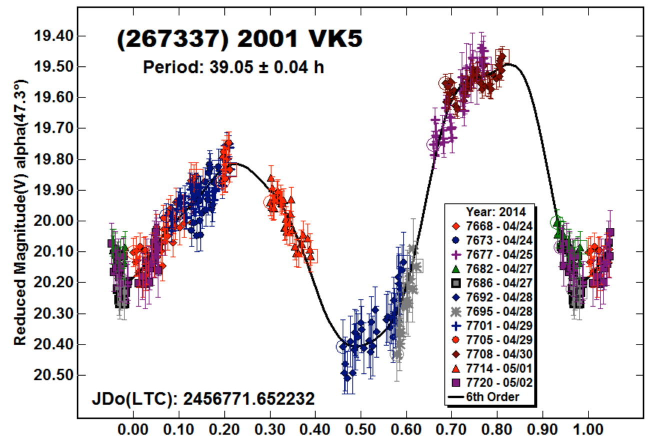




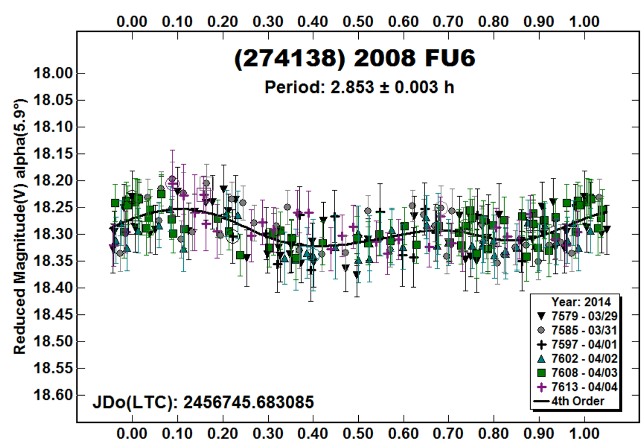
(222869) 2002 FB6. No previous results were found in the literature. The asymmetry of the curve raises at least some doubt about the certainty of the solution. However, the period spectrum showed only integral or half-integral multiples, e.g., 3P/2 and 2P.

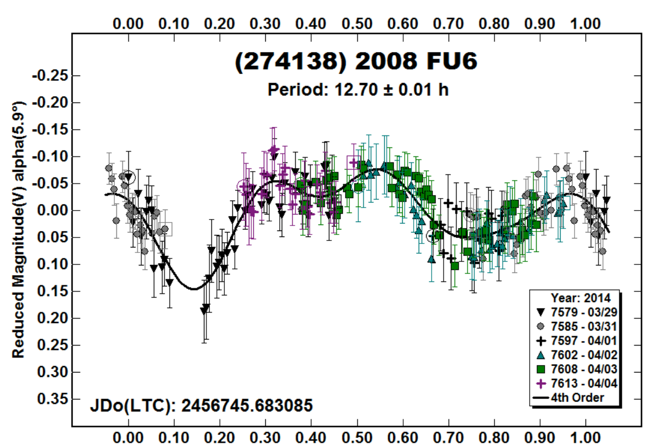


(267337) 2001 VK5. No previous results were found in the literature for 2001 VK5. The derived period of 39.05 hours makes the asteroid a candidate for being a tumbler (see Pravec *et al.*, 2014, and references therein). In fact, there were signs of a low-amplitude secondary period as seen by the unusual shape and how some of the overlapping sessions don't have the same general slope. It is very difficult, if not impossible for a single station to obtain sufficient data to resolve a slow rotator that may or may not be tumbling. Even with stations from different longitudes and an extended campaign of several weeks, a definitive solution may not always be found.

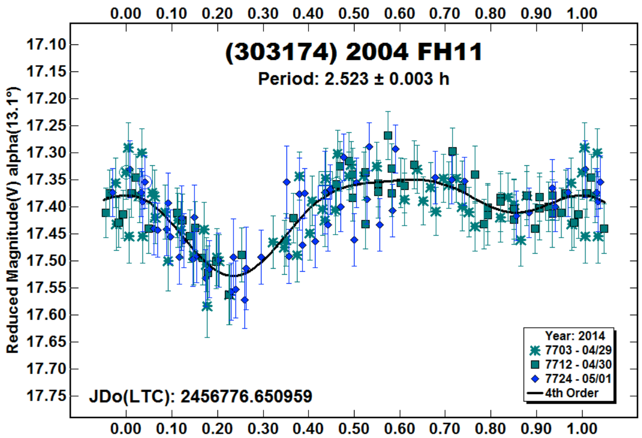


(274138) 2008 FU6. Skiff (2011) previously reported a period of 2.6 hours for this asteroid, but it was rated only U = 1 (probably wrong) in the LCDB. The PDS data did find a more reliable period of about the same duration, 2.852 h, but there were also signs of a second period of 12.70 hours. It is possible that this second lightcurve is the result of a satellite and that the two minimums represent occultation and/or eclipse events. The evidence is not sufficient to consider this a *probable* binary but does warrant a *possible* designation. Observations at future apparitions are strongly encouraged.

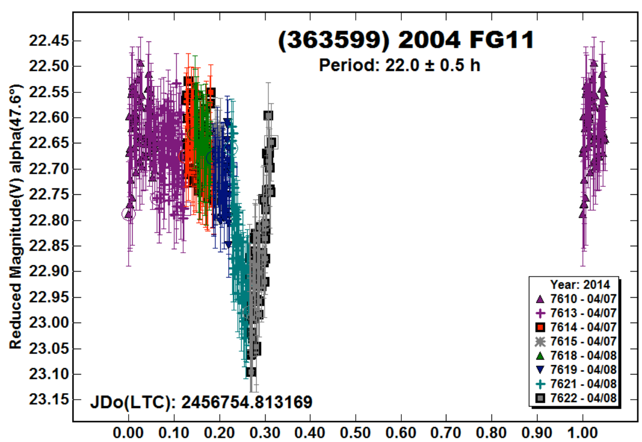




(303174) 2004 FH11. This appears to be the first reported lightcurve for 2004 FH11. This is another potential binary candidate by virtue of the short period, somewhat low amplitude, and general shape of the lightcurve. A check for signs of a satellite proved negative.

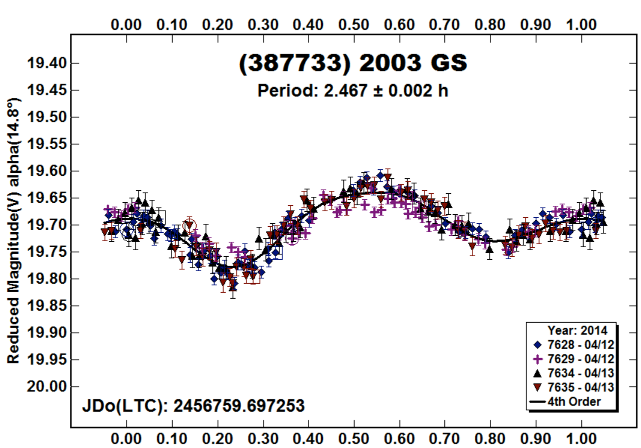


(363599) 2004 FG11. Radar observations by Taylor *et al.* (2012) showed this to be a binary asteroid. The primary's period was set as < 4 h and the orbital period of the satellite at approximately 20 h. Optical observations were not reported at the time to help confirm these results.

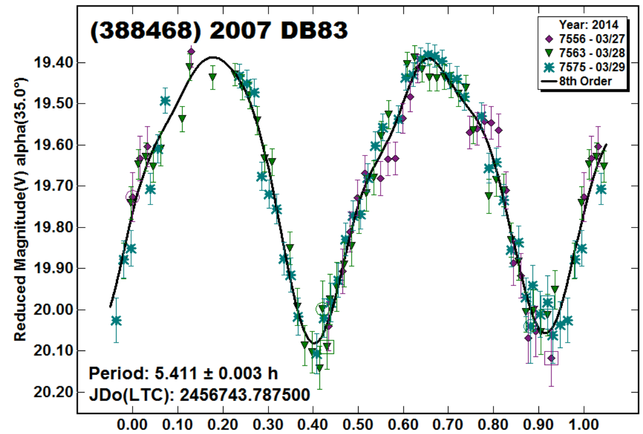


The asteroid was observable for only two days in 2014, April 7 and 8. Data on the second night appeared to have captured a mutual event involving the satellite. The lightcurve is the result of forcing the solution near the 20 h period from the radar observations. The primary rotation period could not be found in the limited data set, probably because of a combination of the noisy data and a low amplitude.

(387733) 2003 GS. Hicks *et al.* (2014) worked this NEA the same time as at PDS. Both efforts found essentially the same period.

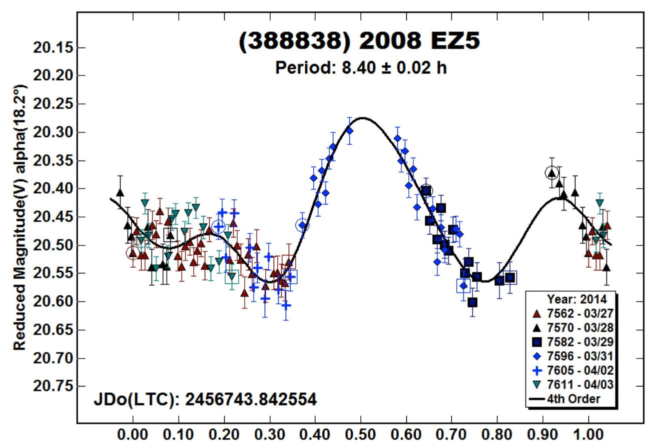


(388468) 2007 DB83. The initial analysis for this asteroid showed that a period of 6.05 h was favored, with another solution near 5.4 h. Pravec *et al.* (2014) subsequently reported a period of 5.414 h and so the PDS data were given a second look.

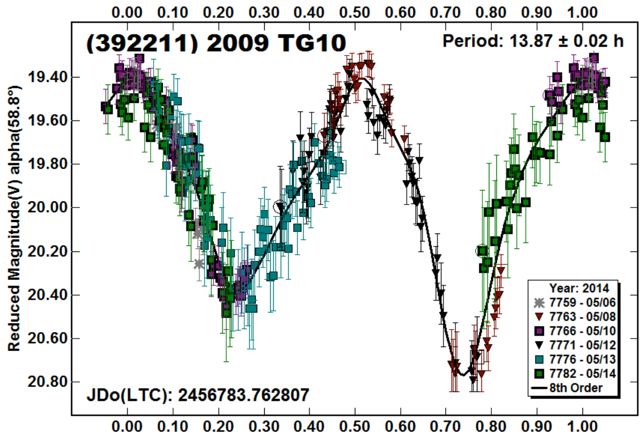


The longer period appears to have been a "fit by exclusion", meaning that the Fourier analysis incorrectly minimized the number of overlapping data points in order to achieve a lower RMS. Furthermore, the lightcurve for the longer period showed a flat, incomplete minimum near 0.9 rotation phase. This made the solution less likely given the large amplitude: it would have required a large flat spot or concavity on one end of the elongated asteroid. The revised lightcurve completed the second minimum with a smoother outline and matches the Pravec *et al*. result.

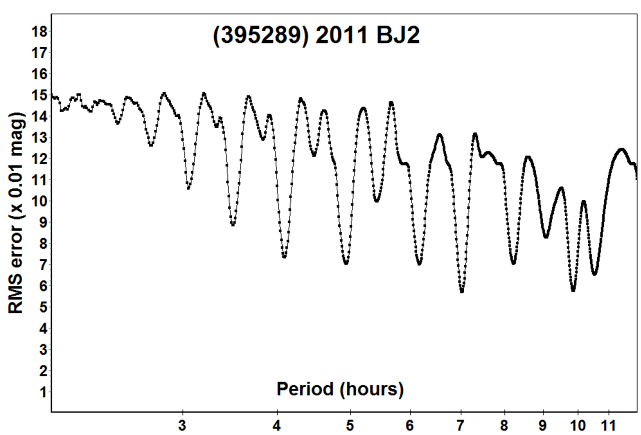
(388838) 2008 EZ5. The unusual shape of the lightcurve and data from only two sessions supporting the maximum near 0.5 rotation phase make the period of 8.4 hours somewhat suspicious. However, a scan of the period spectrum from 2 to 30 hours found no other solution save those with up to 6 minimum/maximum pairs per cycle.

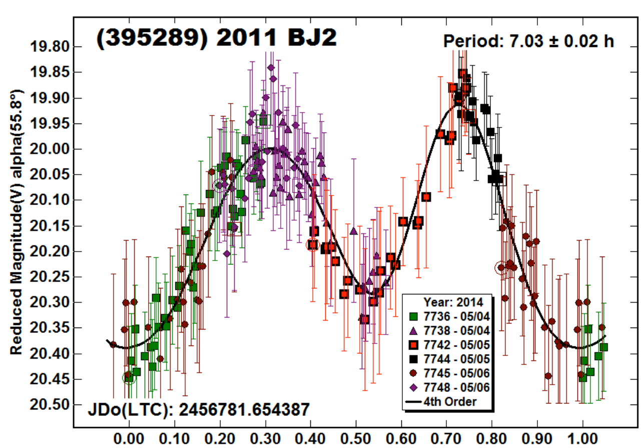


(392211) 2009 TG10. Despite the noisy data, the result of P = 13.87 h seems reasonably secure, mostly based on the large amplitude of 1.34 mag. At low phase angles, such an amplitude physically demands a bimodal lightcurve (see Harris *et al*., 2014). However, at high phase angles, such as nearly 60° in the case of the 2014 observations, lightcurves can take on "unexpected" shaped due to shadowing effects. For example, a nearly spherical object, which would have a low amplitude at small phase angles, can have a large amplitude at large phase angles because of a concavity causing deep shadows.

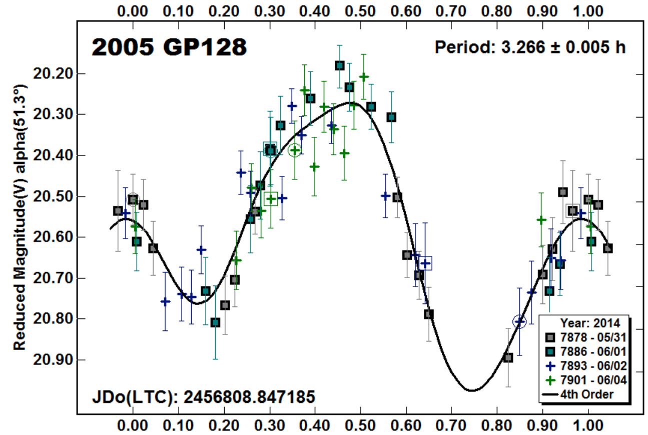


(395289) 2011 BJ2. The period spectrum for 2011 BJ2 favors a period of 7.03 h, which produces a typical bimodal lightcurve. However, as mentioned previously, lightcurves obtained at high phase angles don't always follow the basic rule of thumb tying amplitude and modality. There were no other results found in the literature.

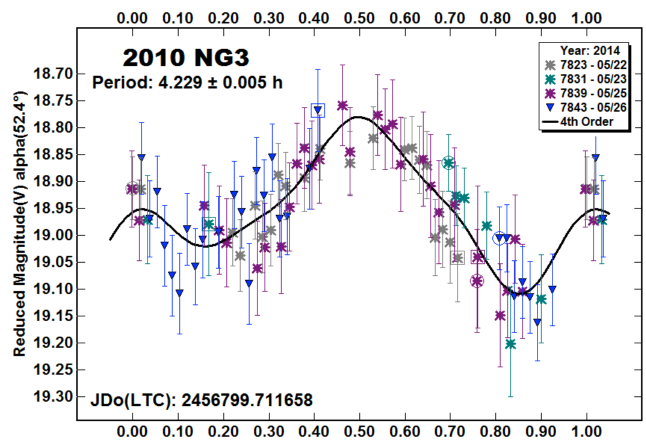




2005 GP128. Observations of this NEA were made in late May and early June 2014. The period of 3.266 h and 0.70 mag amplitude are reliable but, here again, because of the high phase angle observations and the potential for deep shadowing effects, it cannot be rated higher than U = 2+ on the reliability scale in the LCDB. These appear to be the first results reported for this asteroid.

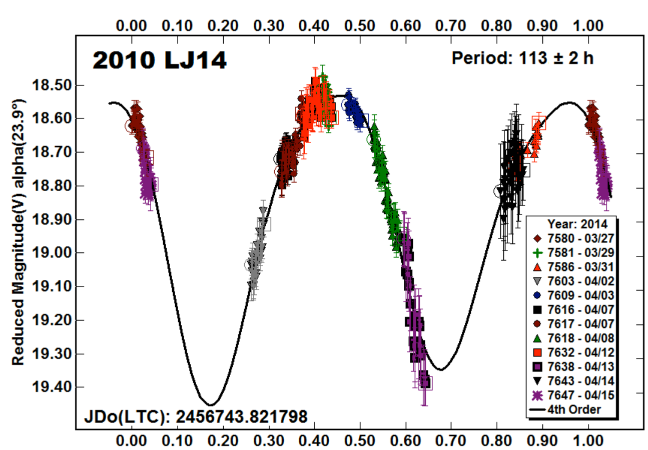


2010 NG3. There were no other results found in the literature for 2010 NG3. The asymmetrical lightcurve may be due to shadowing effects at high phase angles.



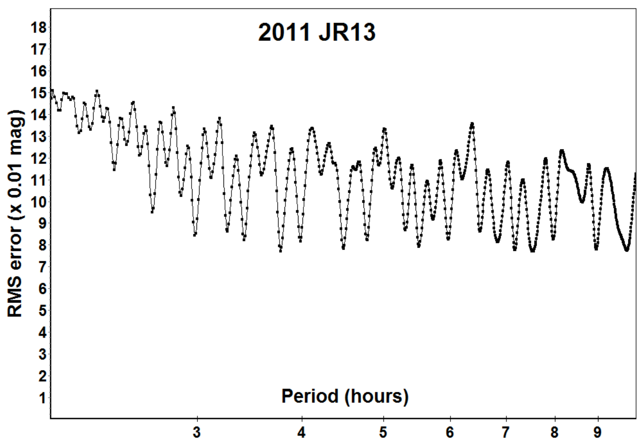
2010 LJ14. The long period of 113 hours makes this a good candidate for being a tumbler. There were no obvious signs of such, at least within the uncertainties of the zero point calibrations.

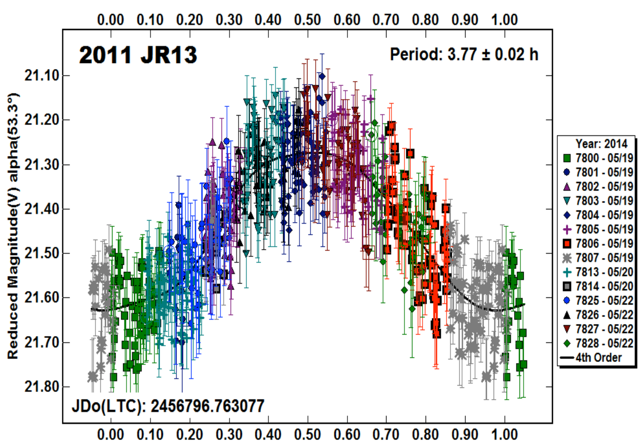
It should be noted that Pravec *et al.* (2014) adopted a different formulae for tumbling damping time, i.e., the time it takes for an asteroid to stabilize into single axis rotation after reaching its maximum tumbling state (see Pravec *et al.*, 2005). For a given damping time, e.g., the age of the Solar System, and diameter, the new formula reduces the expected rotation period by about half that under the old formula. In other words, tumbling asteroids "settle down" faster than previously expected.



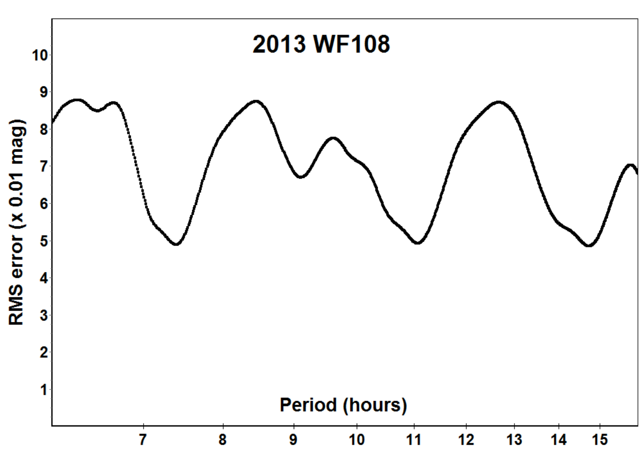
2011 JR13. Radar observations (Ellen Howell, private communications) showed that the rotation period of this asteroid was approximately 4 hours. The initial analysis of the optical data gave entirely different results, mostly because – as shown in the period spectrum – there were a number of potential solutions. The lightcurve shows the PDS photometry data forced to a solution of 3.77 hours, in agreement with the radar period.

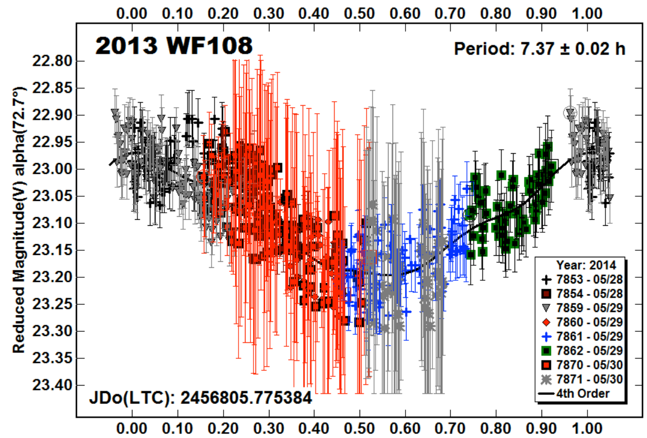
Furthermore, the radar observations indicated a nearly spheroidal shape. Given the high phase angle, where shadowing effects can alter the lightcurve significantly, the monomodal, high amplitude lightcurve is not overly surprising. This was a good example of how close coordination between optical and radar observers is highly beneficial and strongly encouraged.





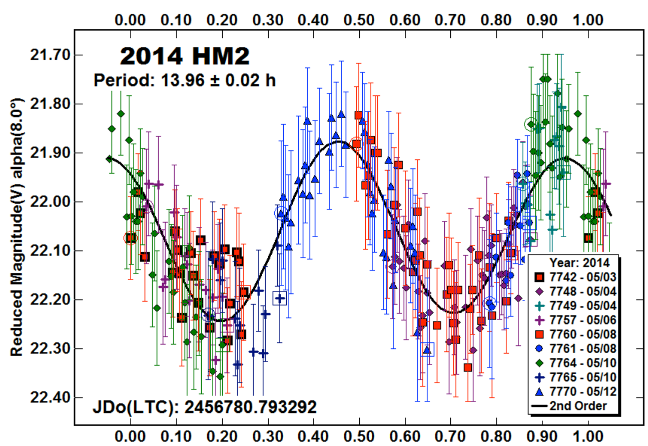
2013 WF108.



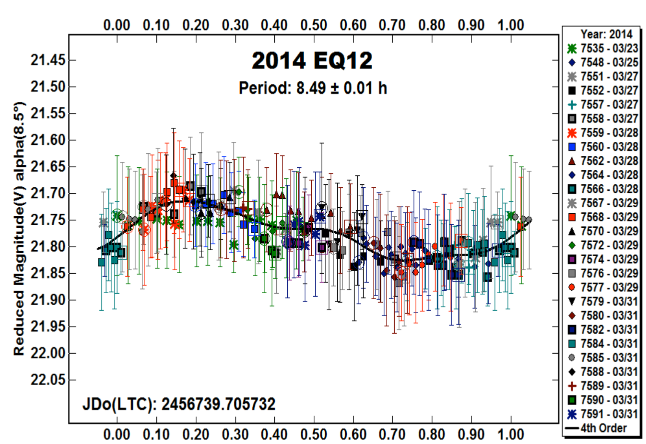


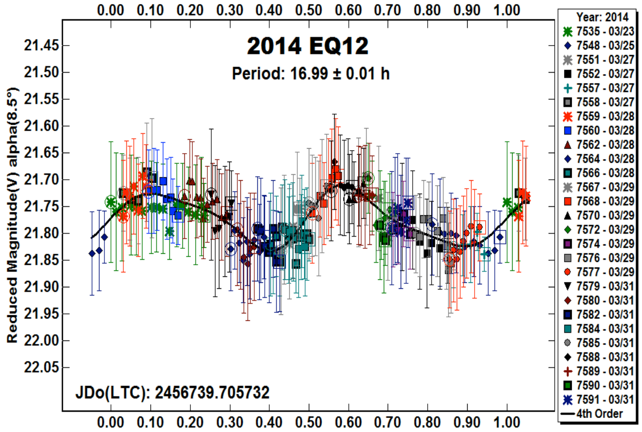
2013 WF108 was a fast moving, faint NEA observed at the end of May 2014. The period spectrum, as in many other cases, showed a number of potential solutions. Taking the results from 2011 JR13 as a guide, i.e., observations at very high phase angles and a monomodal solution, the preferred period is 7.37 h, although a bimodal solution at about 14.7 hours cannot be formally excluded.

2014 HM2. Given the low phase angle of 8°, this was a case where an amplitude of 0.40 would reasonably lead to a bimodal lightcurve (see Harris *et al.*, 2014). While the period spectrum showed a number of other possibilities, the bimodal solution is considered secure.



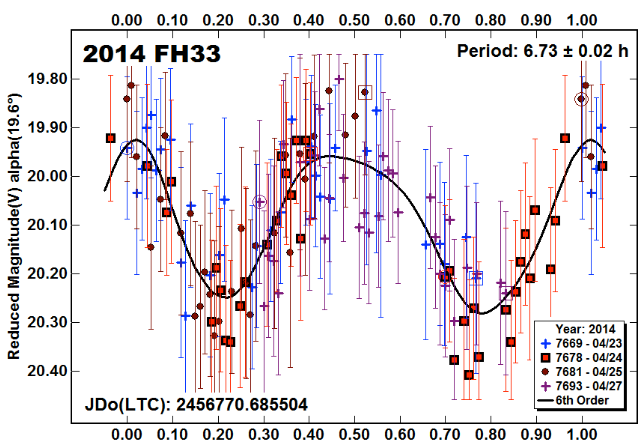
2014 EQ12. The lightcurves below use bins of 5 data points (*not* running average mode), but the analysis used all data points.



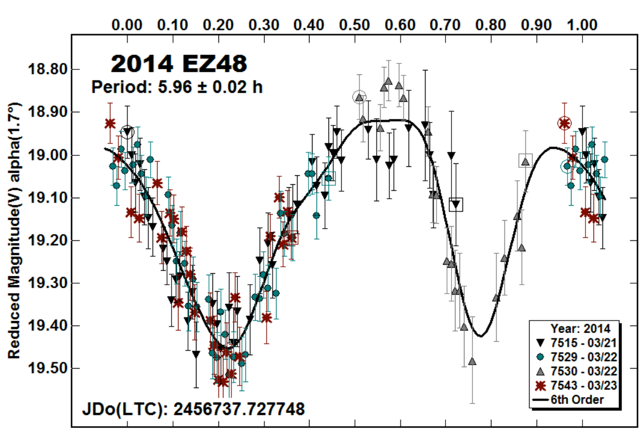


Because of the low amplitude and phase angle, no assumption could be made about the shape of the lightcurve (Harris *et al.*, 2014). The period spectrum, however, favored the two more common solutions, a monomodal lightcurve with a period of 8.49 h and a bimodal shape with a period of 16.99 h. Complicating matters was that radar observations (Ellen Howell, private communications) indicated a rotation period on the order of 4.4 hours. No amount of manipulation of zero points in the photometry data would lead to a period that short. Given the radar analysis, the shorter period, 8.49 h, is adopted for this paper but the solution should be considered ambiguous at best.

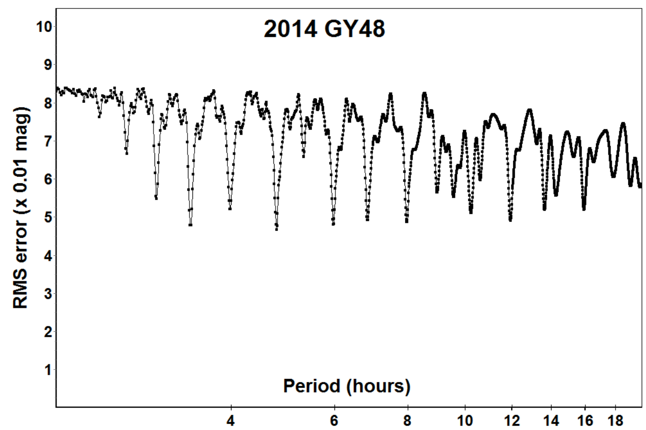
2014 FH33. No previous results for 2014 FH33 were found.

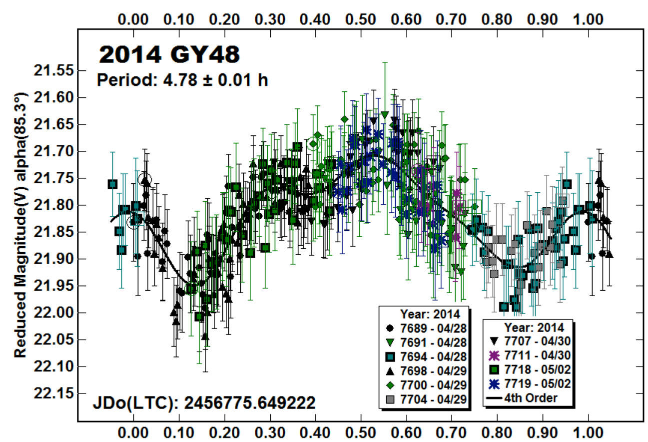


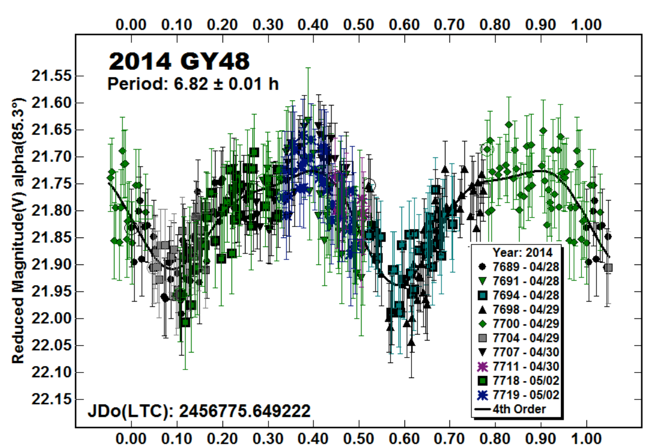
2014 EZ48. This appears to be the first reported lightcurve for 2014 EZ48. It was too far away and small for radar observations.



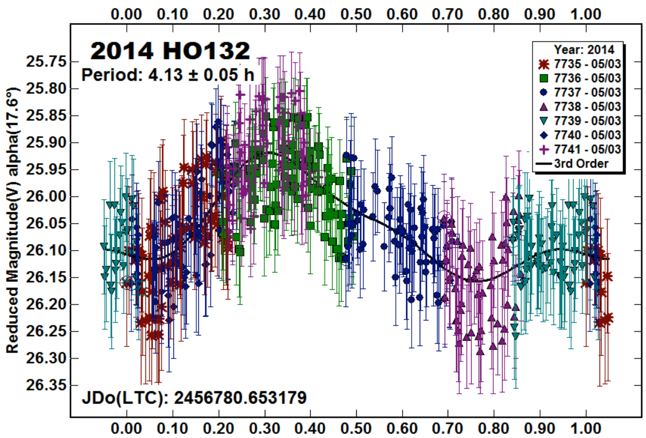
2014 GY48. The period spectrum for 2014 GY48 shows a number of equally possible solutions. The slightly favored result was for 4.78 hours and produced an asymmetrical bimodal lightcurve. On the other hand, the second most likely result produced a more symmetrical bimodal shape with a period 6.82 hours. Looking at the period spectrum RMS fits for the half-periods of the two possibilities, the one for the longer period, i.e., about 3.4 hours, is nearly equal to the fit for the full period solution while the half-period for 4.8 h (2.4 h) is considerably weaker. Because of this and the better symmetry in the lightcurve, the 6.82 h period is believed to be more likely correct, but the half-period cannot be formally excluded, especially in light of the high phase angle.

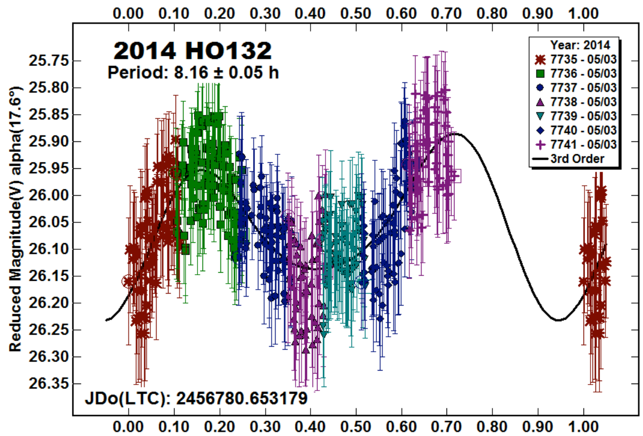




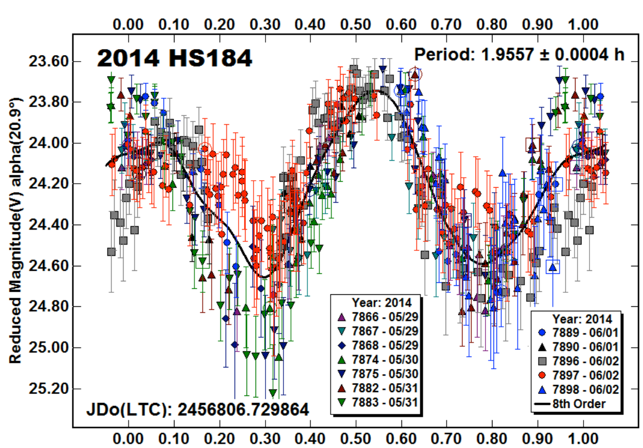


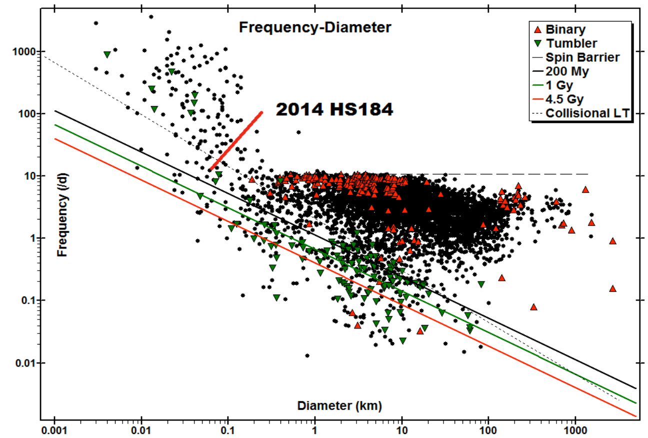
2014 HO132. Photometry analysis provided two possible solutions, a monomodal lightcurve at 4.13 h and a bimodal lightcurve at 8.16 h. Radar observations (Marina Brozovic, private communications) tend to support the shorter period and so it is the one adopted for this work.





<u>2014 HS184</u>. Analysis of photometric observations found a bimodal lightcurve with a period of 1.9557 h. This lies a little above the so-called *spin barrier* that divides objects with $D > \sim 0.2$ km between rubble piles and strength-bound bodies. At first, this made the solution a bit suspicious but, when noting that the estimated diameter is only 0.06 km, the solution was more plausible. The frequency-diameter plot from the LCDB shows the location of 2014 HS184, near the bottom-left of the *ascending branch* that is populated by small, super-fast rotators that are almost certainly strength-bound objects. It is also near the 0.2 Gy tumbling damping line (see Pravec *et al*., 2014) and close to two known tumblers. Analysis by Petr Pravec (private communications) indicated signs that the asteroid is a tumbler but the data set was insufficient to confirm this.





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References

Behrend, R. (2008, 2011). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Durech, J., Vokrouhlicky, D., Baransky, A.R., Breiter, S., Burkhonov, O.A., Cooney, W., Fuller, V., Gaftonyuk, N.M., Gross, J., Inasaridze, R. Ya., and 21 coauthors (2012). "Analysis of the rotation period of asteroids (1865) Cerberus, (2100) Ra-Shalom, and (3103) Eger - search for the YORP effect." *Astron. Astrophys.* **547**, A10.

Elenin, L., Molotov, I. (2012). "Asteroids Lightcurve Analysis at the Ison-NM Observatory: 3122 Florence, (25916) 2001 CP44, (47035) 1998 WS, (137170) 1999 HF1." *Minor Planet Bul*. **39**, 101-102.

Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

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., Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Harris, A.W., Pravec, P., Galad, A., Skiff, B.A., Warner, B.D., Vilagi, J., Gajdos, S., Carbognani, A., Hornoch, K., Kusnirak, P., Cooney, W.R., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Hicks, M., Frederick, J., Harley, I. (2014) Astronomer's Telegram 6090. *http://www.astronomerstelegram.org*

Jahn, J., Kretlow, M. (2014). "Photometric Observation and Lightcurve Analysis of (24445) 2000 PM8." *Minor Planet Bul*. **41**, 67.

Kaasalainen, M., Durech, J., Warner, B.D., Krugly, Y.N., Gaftonyuk, N.M. (2007). "Detecting YORP Effect with Photometry: (1862) Apollo." *Nature* **446**, 420-422.

Polishook, D., Brosch, N., Prianik, D. (2005). *Abstr. IAU Symp*. **229**, p. 60-61.

Polishook, D., Brosch, N. (2008). "Photometry of Aten asteroids – More than a handful of binaries." *Icarus* **194**, 111-124.

Polishook, D. (2012). "Lightcurves and Spin Periods of Near-Earth Asteroids, The Wise Observatory, 2005 – 2010." *Minor Planet Bul*. **39**, 187-192.

Pravec, P., Wolf, M., Sarounova, L. (1999, 2000, 2007, 2014). *http://www.asu.cas.cz/~ppravec/neo.htm*

Pravec, P., Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G., Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galád, A., Brown, P., Degraff, D.R., Lambert, J.V., Cooney, W.R., Foglia, S. (2005). "Tumbling asteroids." *Icarus* **173**, 108-131.

Pravec, P., Scheirich, P., Durech, J., Pollock, J., Kusnirak, P., Hornoch, K., Galad, A., Vokrouhlicky, D., Harris, A.W., Jehin, E., Manfroid, J., Opitom, C., Gillon, M., Colas, F., Oey, J., Vrastil, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Skiff, B.A. (2011). Posting on CALL web site. *http://www.minorplanet.info/call.html*

Taylor, P.A., Nolan, M.C., Howell, E.S. Benner, L.A.M., Brozovic, M., Giorgini, J.D., Margot, J.L., Busch, M.W., Naidu, S.P., Nugent, C., Magri, C., Shepard, M.K. (2012). "2004 FG11." CBET 3091.

Warner, B.D. (2006). "Analysis of 13 asteroid lightcurves obtained at the Palmer Divide Observatory." *Minor Planet Bul*. **33**, 39-41.

Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146.

Warner, B.D. (2014). "Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station: 2013 June-September." *Minor Planet Bul*. **41**, 41-47.

Wisniewski, W.Z., Michalowski, T.M., Harris, A.W., McMillan, R.S. (1997). "Photometric Observations of 125 Asteroids." *Icarus* **126**, 395-449.

LIGHTCURVE ANALYSIS OF THE NEA BINARY ASTEROID 5381 SEKHMET

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Radar observations in 2003 (Nolan *et al.*, 2003) showed that the near-Earth asteroid (NEA) 5381 Sekhmet was a binary. CCD photometry observations made from the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) during the 2014 apparition confirmed the discovery and found the first precise values for the primary rotation period, $P_1 = 2.8233 \pm 0.0001$ h, and the orbital period of the satellite, $P_{ORB} = 12.379 \pm 0.004$ h. The estimated effective size ratio of the two bodies is $Ds/Dp \geq 0.25 \pm 0.02$, which is good agreement with the sizes estimated by radar.

Using the Arecibo radar facility in 2003 May, Nolan *et al.* (2003) discovered that the near-Earth asteroid (NEA) 5381 Sekhmet was a binary object. Their analysis indicated sizes of 1 km and 0.3 km for the primary body and satellite, respectively. They also estimated the orbital period to be on the order of 12 hours, with 24 hours being less probable.

The NEA was favorably placed for optical observations in 2014 May and June, at which time CCD photometry was conducted at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS). A 0.3-m *f*/9.4 Schmidt-Cassegrain was used along with a Finger Lakes Instrumentations MicroLine-1001E operating at –30° C. The 1024x1024 array of 24-micron pixels provided a field of view of about 29.5x29.5 arcminutes and a plate scale of 1.7 arcsec/pixel. All images were guided and taken with no filter. Exposures were 120 seconds in late May and decreased to 90 seconds in June as the asteroid's sky motion increased. Dark frames and flat fields were applied in *MPO Canopus*.

Measurements were done using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* finds up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes were taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Period analysis was also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

In the lightcurve plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) 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 –0.05 to 1.05.

Photometry Analysis

The asteroid was observed from 2014 May 23 through June 6. A total of 724 data points were used in the analysis. Since this was a known binary, an initial period search used the entire data set to find an approximate period for the primary rotation, i.e., the apparent mutual events of the satellite were not subtracted beforehand.

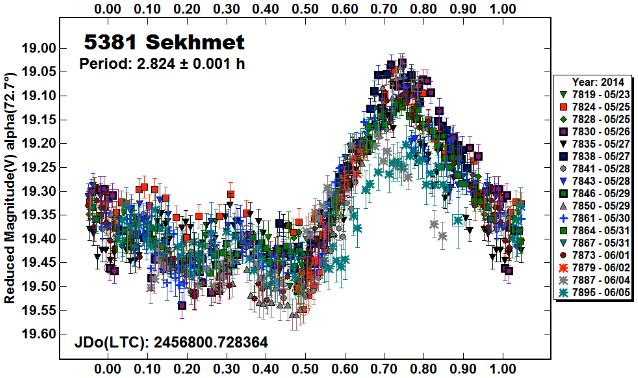

Figure 1. The lightcurve of 5381 before dual period analysis.

Figure 1 shows the lightcurve before using the dual period analysis tool in *MPO Canopus* and serves to demonstrate what would prompt the belief that the asteroid may be a binary, the fact that it was already known to be one notwithstanding. The most telling feature is that two sessions (7887 and 7895, June 4 and 5, respectively) showed distinct deviations, or attenuations, from the general curve near rotation phase 0.75. Note that satellite events *never* cause the lightcurve to be *brighter* than expected. In such a case, it's better to look for a faint field star, a variable comparison star, or some systematic cause.

Just one session with such a deviation is not enough. Two can be good cause for suspicion while three or more is better. In fact, session 7835 (May 27) does show a few data points that may also have been part of an attenuation. In addition, the general noisy nature of the lightcurve between 0.10 and 0.50 can also be a sign of a satellite event. However, this is not as strong an indicator and, in fact, noise is sometimes just noise.

Once a preliminary lightcurve, such as in Figure 1, was found, the corresponding Fourier curve was subtracted from the data and another period search in the range of 10 to 26 hours was run. This produced the initial lightcurve that included the mutual events (occultations and/or eclipses) caused by the satellite. This Fourier curve was then subtracted from the entire data set when a second search for the primary period was run. The process continued back and forth until the shape and periods of the two lightcurves stabilized.

Complicating the analysis somewhat was the very high phase angle of the asteroid during the observations (~ 73°). At such angles, even a nearly spheroidal body can have a large amplitude lightcurve due to shadowing effects. Furthermore, the primary's shadow projects well beyond the disc on the sky plane. This can create a very complex lightcurve for the satellite's mutual events.

Figure 2 shows the lightcurve for the primary body after subtracting the effects of the satellite. It is not the common nearly symmetrical monomodal or bimodal lightcurve seen for many binary primaries when observed at small phase angles.

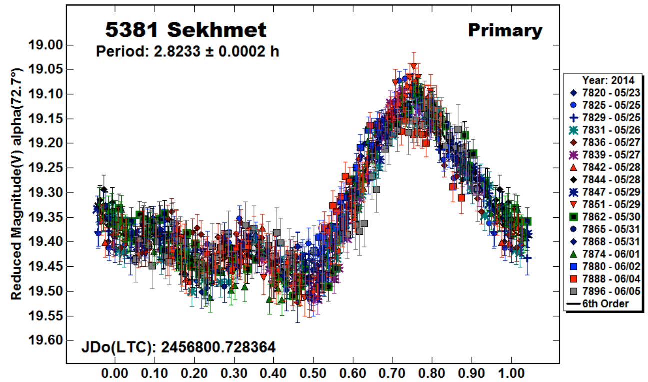

Figure 2. Primary lightcurve. The actual *sky magnitude* of the asteroid was V ~ 16.7 during the observing runs.

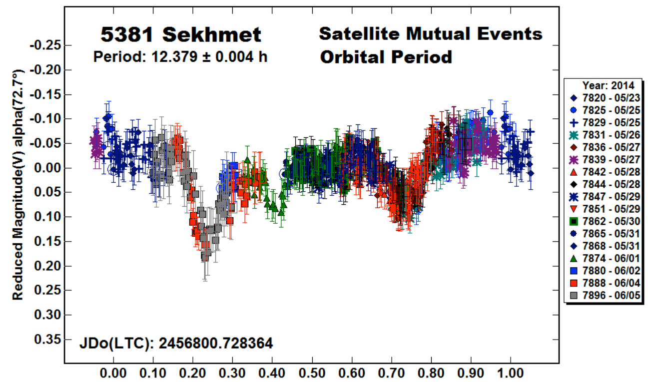

Figure 3. Lightcurve of the satellite showing the mutual events (occultations and/or eclipses). The period corresponds to the orbital period of the satellite. The magnitude zero level is the average magnitude of the primary.

Figure 3 shows the lightcurve after subtracting out the rotation of the primary, showing the mutual events and orbital period of 12.379 h. The depth of the shallower minimum can be used to estimate the ratio of the effective diameters of the two bodies. A drop of 0.07 magnitude gives $D_s/D_p \geq 0.25 \pm 0.02$. Had the event been flat-bottomed, meaning a total event, this value would have been a fixed value instead of a minimum. The derived ratio is in good agreement with the estimated diameters of the bodies from the radar observations.

The two events at 0.25 and 0.75 orbital phase (Figure 2) are likely *solar events*, eclipses involving shadows and the sun. There is a one-time event at about 0.40 phase that appears to be real and not an observing artifact. In this case, this is a *line-of-sight event*, i.e., the satellite going in front of or behind the primary as seen from the Earth.

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References

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.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Nolan, M.C., Howell, E.S., Rivkin, A.S., Neish, C.D. (2003). IAUC 8163 (5381).

Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

ASTEROIDS OBSERVED FROM CS3: 2014 APRIL - JUNE

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CCD photometric observations of 14 asteroids were obtained from the Center for Solar System Studies from 2014 April to June.

During most of this calendar quarter, the Center for Solar System Studies (CS3, MPC U81) was focusing on a study of Jovian Trojan asteroids. Many of the results described in this paper were 'Full Moon Projects,' when the moon is bright or close to the Trojan targets. Some of these targets were selected from the 'Shape/Spin Modeling Opportunities' list maintained by Josef Ďurech the back of each Minor Planet Bulletin. These are targets with at least one high quality lightcurve which are not in the Database of Asteroid Models from Inversion Techniques (DAMIT). In addition, bright NEOs or Mars Crossers away from the Moon were selected for study.

All images were made with a 0.4-m or a 0.35-m SCT with a FLI-1001E or a SBIG STL-1001E CCD camera. 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 V 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.

<u>113 Amalthea</u>. Harris and Young (1983) observed Amalthea on 10 nights in 1979 November – December determining a period of 9.935 h with a single maxima/minima and A = 0.19 mag. Tungalag (2002) found a period of 9.93768 h. The synodic rotational period found this year is consistent with those results. Like in 1979, a complex curve with a single extrema was found. A period spectrum shows a 2:1 alias exists at about 20 h. However, due to the complex and repeating features in the lightcurve, I prefer the 9.950 h period.

<u>232 Russia</u>. With a rotational period near 24 h, it is difficult for a single station to get sufficient observations covering a complete cycle on this Inner Main Belt asteroid. Behrend (2014) reported observations from 2005 February covering about half of the phased lightcurve with a 21.7 h period. Torno et al (2008) got two nights in October 2007 covering a portion of the lightcurve and reported a period exceeding 20 h. Ruthroff (2009) observed Russia for 11 nights in 2009 January – March reporting a period of 21.91 h. This result of 21.882 h covers the complete phased lightcurve and is an improvement on those results.

<u>402 Chloe</u>. Results for Chloe were reported by Behrend (2014) in 2002, 2005, and 2010. The results for 2002 and 2005 were updated to agree with the 2010 findings of 10.664 h. Warner (2009) observed Chloe over 4 nights in 2009 February reporting a period

Number	Name	2014 mm\dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
113	Amalthea	04/10-04/14	1035	4.6,4.2,4.3	203	7	9.950	0.004	0.22	0.02
232	Russia	05/11-05/28	1119	5.3,11.0	230	9	21.886	0.003	0.16	0.02
402	Chloe	05/15-05/17	803	8.6,9.0	227	15	10.665	0.003	0.37	0.02
472	Roma	05/30-06/01	1028	8.0,8.2	244	18	9.795	0.001	0.38	0.02
488	Kreusa	12/31-12/31	2539	8.0,0.0,8.2	0	0	32.666	0.003	0.09	0.02
491	Carina	04/10-05/10	971	3.6,9.6	202	11	15.153	0.002	0.08	0.02
660	Crescentia	04/16-05/29	1318	21.9,12.2	253	20	7.911	0.001	0.20	0.03
729	Watsonia	05/26-06/18	1435	16.9, 9.3	284	10	25.164	0.002	0.30	0.02
1658	Innes	05/25-05/27	428	13.9,14.7	220	9	3.191	0.001	0.25	0.02
2014	Vasilevskis	05/14-05/21	870	16.9,16.7,16.8	245	21	32.16	0.02	0.26	0.03
2035	Stearns	06/07-06/23	2829	26.9, 32.0	226	13	93.0	1.0	0.43	0.1
2077	Kiangsu	12/07-01/05	1547	24.9,33.3	50	-4	104.20	0.05	0.23	0.03
6447	Terrycole	06/02-06/06	186	6.6, 8.3	247	9	10.29	0.001	0.23	0.02
70410	1999 SE3	06/29-07/10	479	16.0,21.7	258	12	2.5895	0.0001	0.14	0.01

of 10.664 h. All of these results are similar to the one reported here.

472 Roma. Roma has had its rotational period measured many times over the years, all with similar results. Sheridan (2003) observed it over 5 nights in 2003 July reporting a period of 9.8007 h. Behrend (2014) reports lightcurves from 2001, 2005, 2010 and 2013 reporting periods of 9.8, 9.7965, 9.7964, and 9.7969 h respectively. The period found at this opposition is in good agreement with those previous results.

488 Kreusa. This Inner Main Belt asteroid has been a difficult case over the years. Harris and Young (1989) observed it on one night for about 7.5 h and reported a period exceeding 28 h. Robinson (2002) observed it over 6 nights in 2002 January – February and reported a period of 19.274 h with an alternate period of 29 h, the alternate being a 1.5 to 1 alias of his preferred period. The results obtained this year using 11 sessions spanning 17 nights definitively establishs the period as 32.666 h, close to Robinson's alternate period and consistent with the Harris – Young observations. With the small amplitude of 0.9 mag., Harris (2013) demonstrates the single or trimodal lightcurves are possible. However, unique repeating features in this year's lightcurve make this my preferred result.

491 Carina. Despite being a relatively low numbered asteroid, Carina has only had results reported twice over the years. Behrend (2014) reports single night lightcurve from 2005 covering about half the phased lightcurve and a period of 15 h. Florczak et al (1997) observed it over 9 nights in 1996 February and reported a period of 14.87 h. This year's results of 15.153 h were obtained over 8 nights spanning a month, and is similar to, but not in good agreement with the Florczak results. Harris (private communication) digitized their sparser data from the original paper and attempted to fit it to the 15.153 h result. The fit was not nearly as good resulting in a few outliers. Attempting to fit the 2014 data to the 14.87 h period resulted in a very poor fit with multiple sessions going against the trend of the overall phased curve. Therefore I prefer the 15.153 h result because it is based on a much denser dataset.

660 Crescentia. This Inner Main-Belt asteroid has had its rotational period determined three times before. Harris (1980) found a result of 7.92 h. Behrend (2014) reported results from 2005, 2006, 2009 and 2010. Originally reported as 9.1 h, these have now been corrected to 7.91 h. Warner (2009) reported a period of 7.910 h. Crescentia was observed this year as a "Full Moon" project to attempt to get sufficient data for a pole solution and shape model. The 7.911 h period determined for 2014 is similar to the prior results. With the rotational period being about one third of the Earth's makes it hard to get sufficient data in a few nights to cover the complete lightcurve. Six sessions spanning 6 weeks were obtained. The dates observed spanned a range of phase angels from 12 to 22, an evolution of the lightcurve is seen. Although this change in phase angle is useful for a shape model, we as yet do not have sufficient data to complete one. In the words made famous by Alan Harris – "More Data!"

729 Watsonia. Watsonia was observed in 2000 June by Malcom (2000) and again in 2013 January by the author (Stephens 2013). Malcom reported a period of 16.7 h which was a 3:2 alias of the result 25.230 h rotational period found in 2013. The result found this year is in good agreement with the 2013 findings.

1658 Innes. Despite the low number, this Inner Main Belt asteroid does not have a previously reported rotational period (Warner 2014).

2014 Vasilevskis. Holliday (1995) observed this Phocaea family asteroid over 5 nights in 1995 March – April obtaining sparse data with little nightly overlap and estimated the period to be 36.25 h. This much denser lightcurve differs from that result by only about 10% of a rotational phase.

2077 Kiangsu. No previous lightcurves for this Inner Main Belt asteroid have been reported in the Lightcurve Database (Warner 2014).

2035 Stearns. This Hungaria was previously observed by Shevchenko (2003) and Warner (2011). Shevchenko reported a period of 85 h while Warner found a period of 51.89 h over 10 nights. This year, after a few nights of observation, Stearns appeared to be tumbling. Many individual sessions required zero point adjustments far in excess of the typical Comp Star errors (~ 0.05 mag.). Petr Pravec (private communication) inspected the data and confirmed that Stearns was tumbling.

6447 Terrycole. Warner previously observed this Hungaria asteroid in 2009 and 2012 (Warner 2010, 2013) finding rotational periods of 10.278 h and 10.268 h respectively. It was observed at this opposition to get sufficient data for a future pole solution and possibly a shape model.

(70410) 1999 SE3. No previous lightcurves for this Inner Main Belt asteroid have been reported in the Lightcurve Database (Warner 2014). This Phocaea family asteroid has a primary rotational period close to the Spin Barrier. Minor deviations are suggestive of a secondary period of 22.89 h, but being so close to the Earth's rotational period, no single station can obtain good coverage.

References

Behrend, R. (2014). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html*.

Harris, A.W., Pravec, P., Galád, B. Skiff, B., Warner, B., Világi, J., Gajdoš, S., Carbognani, A., Hornoch, K., Kušnirák, P., Cooney, W., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B. (2014). "On the maximum amplitude of harmonics of an asteroid lightcurve." *Icarus*.**235**, 55-59.

Harris, A., Young, J. (1980). "Asteroid rotation. III." *Icarus* **43**, 20-32.

Harris, A., Young, J. (1983). "Asteroid rotation. IV." *Icarus* **54**, 59-109.

Harris, A., Young, J. (1989). "Asteroid lightcurve observations from 1979-1981." *Icarus* **81**, 314-364.

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., Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Holliday, B. (1995). "Lightcurve Observations of Minor Planets 1508 Kemi and 2014 Vasilevskis." *Minor Planet Bul.* **22**, 43.

Malcolm, G. (2000). "CCD Photometry of Minor Planet 729 Watsonia." *Minor Planet Bul.* **27**, 45.

Ruthroff, J. (2009). "Photometric Observations and Lightcurve Analysis of Asteroids 129 Antigone, 174 Phaedra, 232 Russia, 291 Alice, and 343 Ostara." *Minor Planet Bul.* **36**, 121-122.

Robinson, L. (2002). *http://btboar.tripod.com/lightcurves/id19.html*.

Sheridan, E. (2003). "Rotation periods and lightcurve photometry of 322 Phaeo and 472 Roma." *Minor Planet Bul.* **30**, 28.

Shevchenko, V.G, Yu, N., Chiorny, V.G., Bel'skaya, I.N., and Gaftonyuk, N.M. (2003). *Planet. Space Sci.* **51**, 525-532.

Stephens, R. (2013). "Lightcurve of 729 Watsonia." *Minor Planet Bul.* **40**, 178-179.

Tungalag, N., Shevchenko, V., Lupishko, D. (2002). "Rotation parameters and shapes of 15 asteroids." *Kinematika I Fizika Nebesnykh Tel*, **18**, 508-516.

Torno, S., Oliver, R., Ditteon, R. (2010). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory - October 2007." *Minor Planet Bul*. **35**, 54-55.

Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul*. **34**, 113-119.

Warner, B.D. (2009). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2008 December - 2009 March." *Minor Planet Bul*. **36**, 106-116.

Warner, B.D. (2010). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2009 June-September." *Minor Planet Bul*. **37**, 24-27.

Warner, B.D. (2011). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2010 December- 2011 March." *Minor Planet Bul*. **38**, 142-149.

Warner, B.D. (2014). The Asteroid Lightcurve Database (LCDB) website. *http://www.minorplanet.info/lightcurvedatabase.html.*

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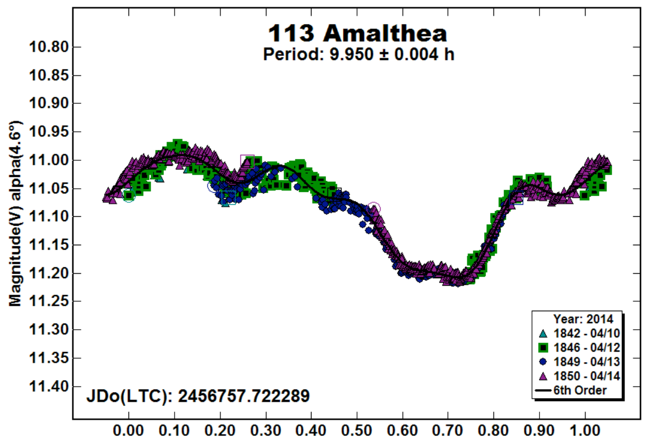
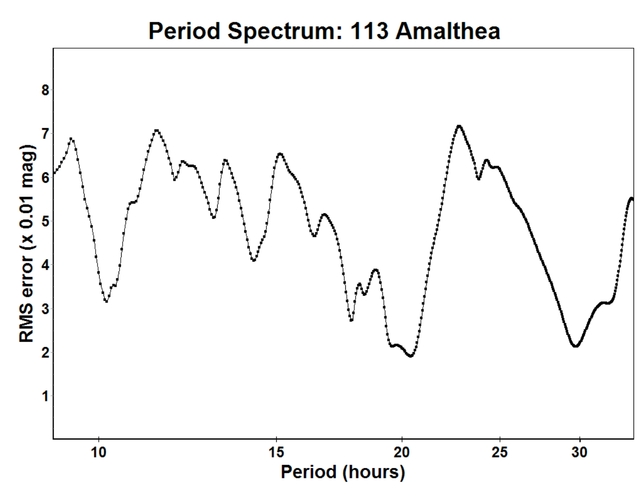
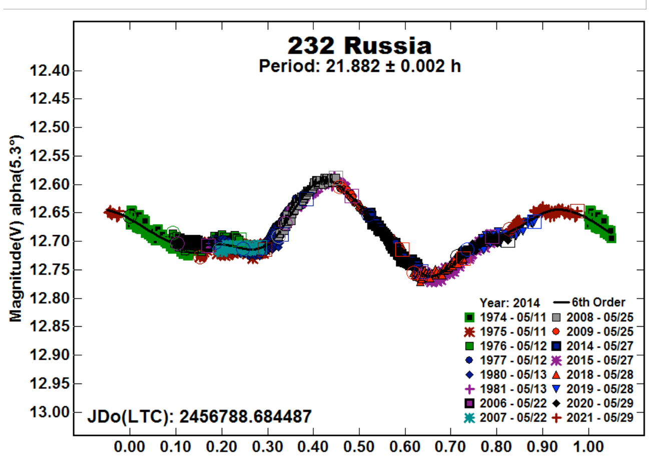
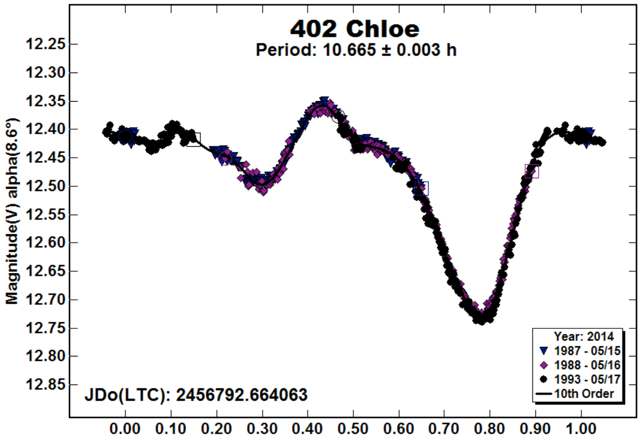
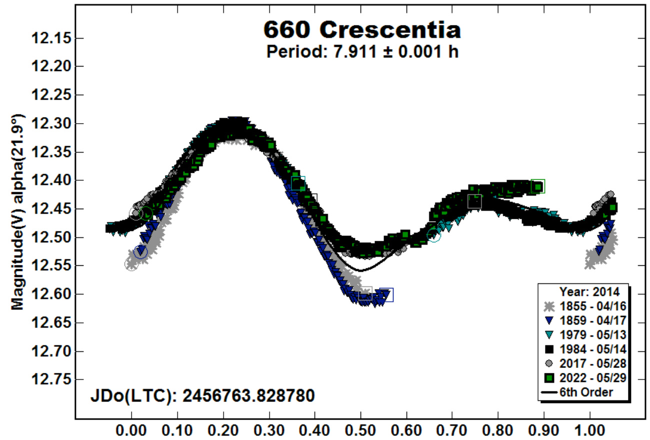
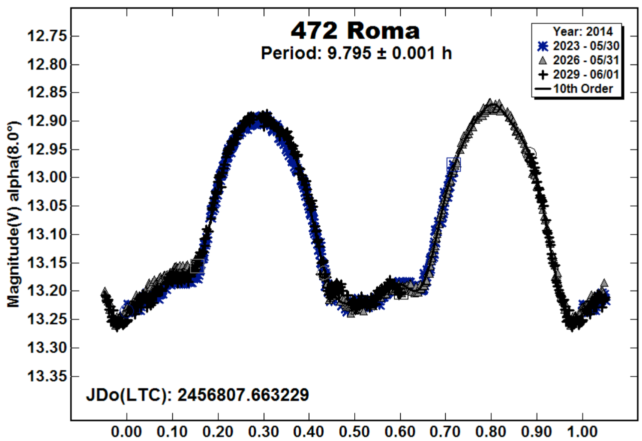


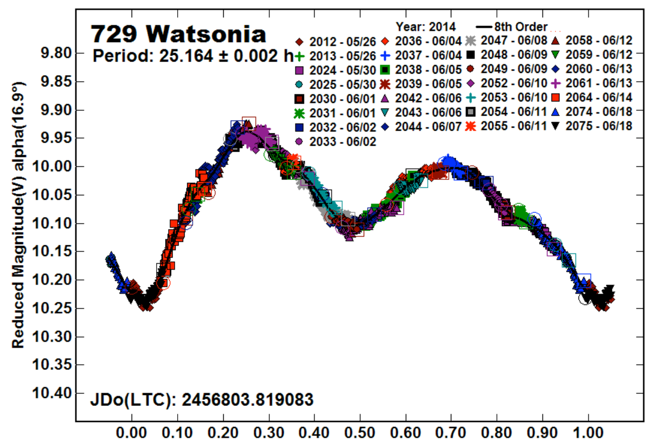





402 Chloe
Period: 10.665 ± 0.003 h
Magnitude(V) alpha(8.6°)
Year: 2014
1987 - 05/15
1988 - 05/16
1993 - 05/17
10th Order
JDo(LTC): 2456792.664063


660 Crescentia
Period: 7.911 ± 0.001 h
Magnitude(V) alpha(21.9°)
Year: 2014
1855 - 04/16
1859 - 04/17
1979 - 05/13
1984 - 05/14
2017 - 05/28
2022 - 05/29
6th Order
JDo(LTC): 2456763.828780


472 Roma
Period: 9.795 ± 0.001 h
Magnitude(V) alpha(8.0°)
Year: 2014
2023 - 05/30
2026 - 05/31
2029 - 06/01
10th Order
JDo(LTC): 2456807.663229


729 Watsonia
Period: 25.164 ± 0.002 h
Reduced Magnitude(V) alpha(16.9°)
Year: 2014
8th Order
2012 - 05/26
2013 - 05/26
2024 - 05/30
2025 - 05/30
2030 - 06/01
2031 - 06/01
2032 - 06/02
2033 - 06/02
2036 - 06/04
2037 - 06/04
2038 - 06/05
2039 - 06/05
2042 - 06/06
2043 - 06/06
2044 - 06/07
2047 - 06/08
2048 - 06/09
2049 - 06/09
2052 - 06/10
2053 - 06/10
2054 - 06/11
2055 - 06/11
2058 - 06/12
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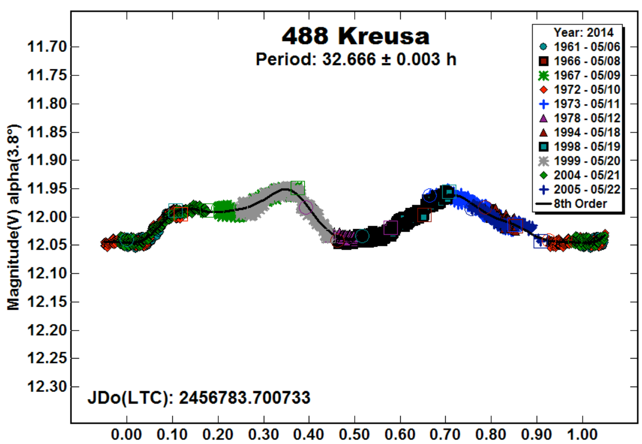
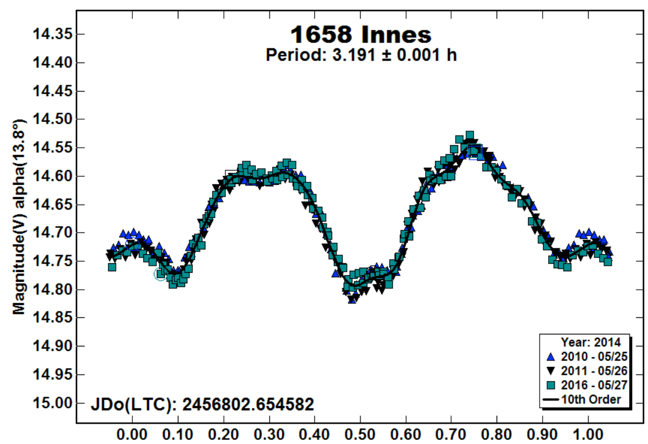
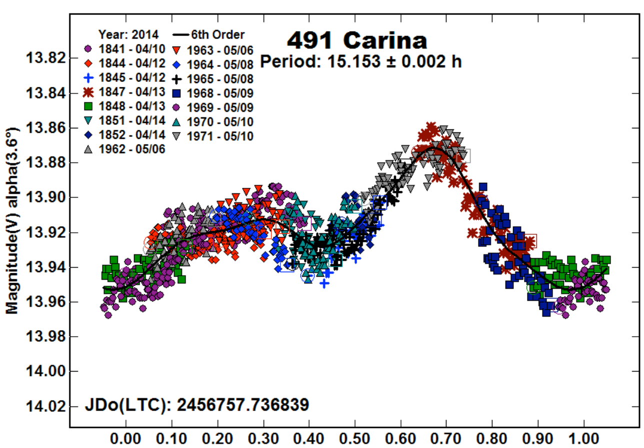
JDo(LTC): 2456803.819083


488 Kreusa
Period: 32.666 ± 0.003 h
Magnitude(V) alpha(3.8°)
Year: 2014
1961 - 05/06
1966 - 05/08
1967 - 05/09
1972 - 05/10
1973 - 05/11
1978 - 05/12
1994 - 05/18
1998 - 05/19
1999 - 05/20
2004 - 05/21
2005 - 05/22
8th Order
JDo(LTC): 2456783.700733


1658 Innes
Period: 3.191 ± 0.001 h
Magnitude(V) alpha(13.8°)
Year: 2014
2010 - 05/25
2011 - 05/26
2016 - 05/27
10th Order
JDo(LTC): 2456802.654582


491 Carina
Period: 15.153 ± 0.002 h
Magnitude(V) alpha(3.6°)
Year: 2014
6th Order
1841 - 04/10
1844 - 04/12
1845 - 04/12
1847 - 04/13
1848 - 04/13
1851 - 04/14
1852 - 04/14
1962 - 05/06
1963 - 05/06
1964 - 05/08
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1968 - 05/09
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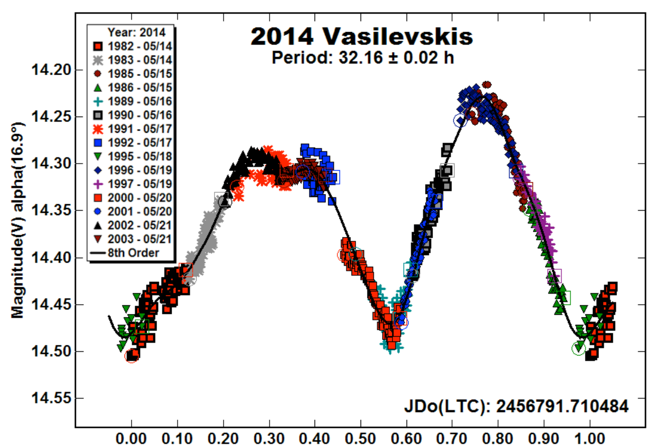
1970 - 05/10
1971 - 05/10
JDo(LTC): 2456757.736839


2014 Vasilevskis
Period: 32.16 ± 0.02 h
Magnitude(V) alpha(16.9°)
Year: 2014
1982 - 05/14
1983 - 05/14
1985 - 05/15
1986 - 05/15
1989 - 05/16
1990 - 05/16
1991 - 05/17
1992 - 05/17
1995 - 05/18
1996 - 05/19
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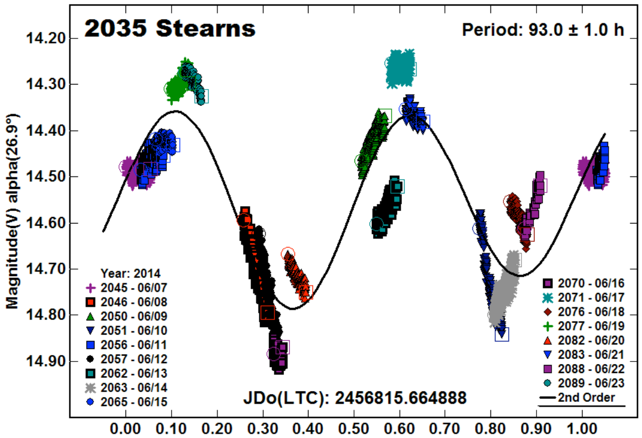
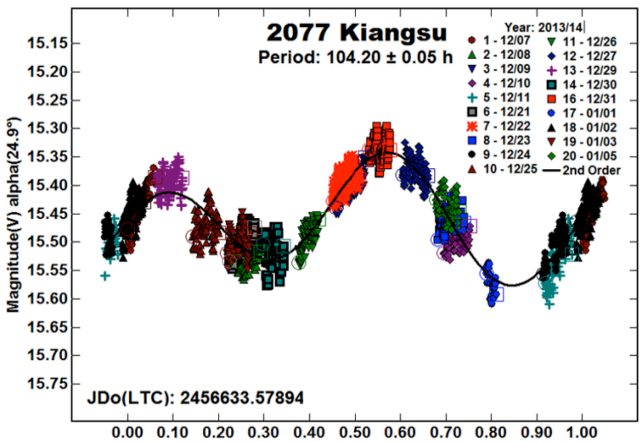
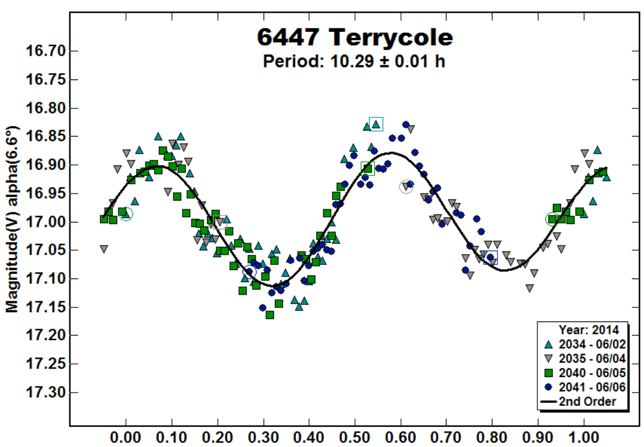
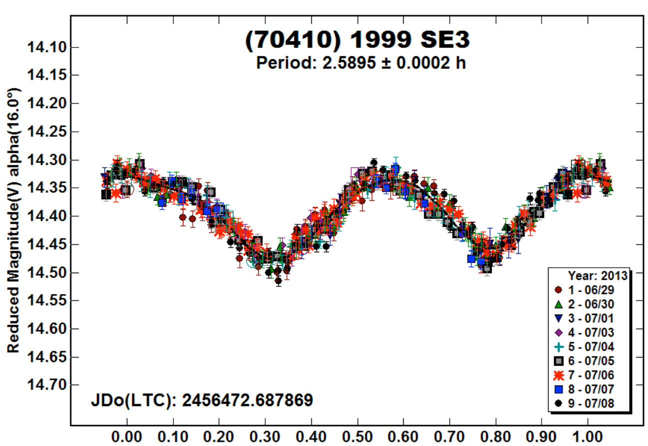
2000 - 05/20
2001 - 05/20
2002 - 05/21
2003 - 05/21
8th Order
JDo(LTC): 2456791.710484









ROTATION PERIOD, SPIN AXIS, AND SHAPE MODEL FOR MAIN-BELT ASTEROID 92 UNDINA

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(Received: 25 June)

CCD photometry observations of 92 Undina in 2014 April found a synodic rotation period of 15.933 ± 0.002 h and lightcurve amplitude of 0.16 ± 0.01 mag. An attempt was made to model the spin axis and shape for the asteroid using a combination of dense lightcurves from three apparitions and sparse data from two survey programs. The results were inconclusive other than to indicate that the pole latitude is not far removed from the ecliptic plane and rotation is probably retrograde.

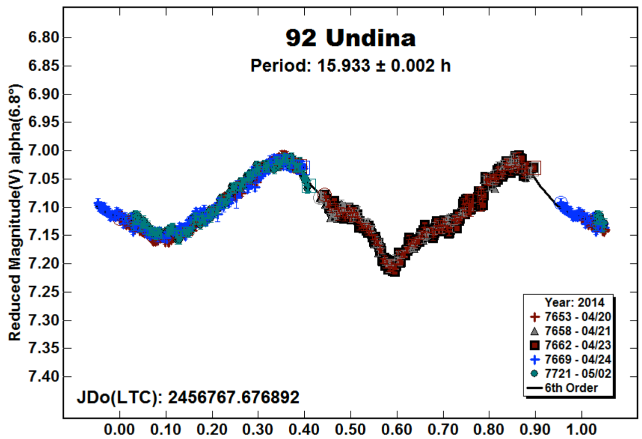
CCD photometry observations of the main-belt asteroid 92 Undina were made in 2014 April and May at the Center for Solar System Studies-Palmer Divide Station. A 0.3-m *f*/9.4 Schmidt-Cassegrain was used along with a Finger Lakes Instrumentations MicroLine-1001E operating at –30° C. The 1024x1024 array of 24-micron pixels provided a field of view of about 30x30 arcminutes and a plate scale of 1.7 arcsec/pixel. All images were guided and taken without a filter. Exposures were 60 seconds in early April and decreased to 45 seconds in late April and early May to avoid saturation. Dark frames and flat fields were applied in *MPO Canopus*.

Measurements were done using *MPO Canopus,* which was used to produce and apply the master dark and flat-field frames. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color to be used in differential photometry. Catalog magnitudes were taken from the APASS catalog (Henden *et al.,* 2009) since these are derived directly from reductions based on Landolt standard fields. Period analysis was also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

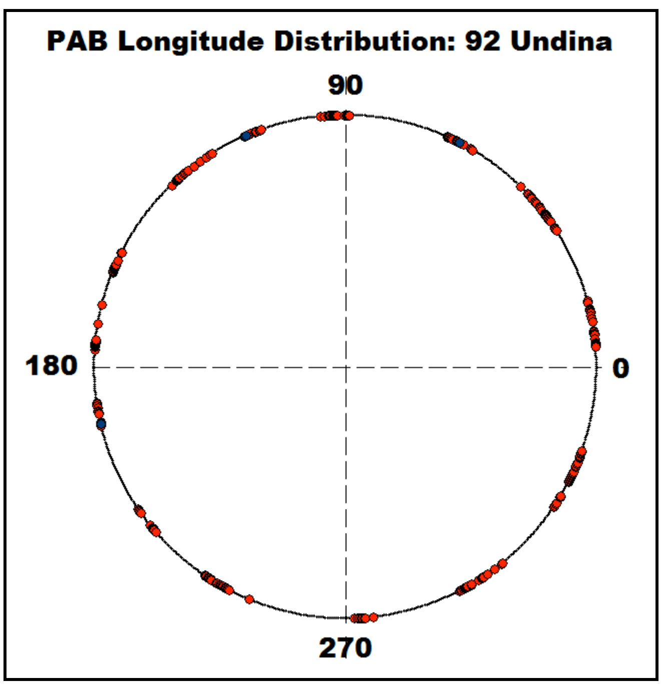
In the lightcurve plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid 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 –0.05 to 1.05.

Synodic Rotation Period (2014)

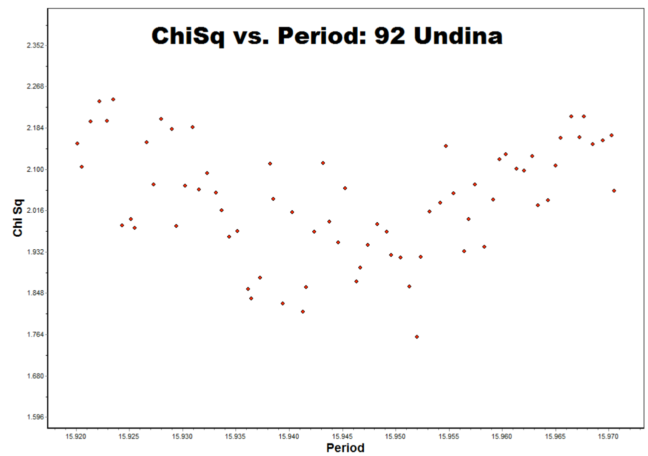
This was the third apparition at which this asteroid was worked by the author (Warner, 2007; 2012). The most recent period of *P* = 15.933 h is in good agreement with the earlier results as well as those from Schrober *et al.* (1979).



An earlier attempt to model the asteroid's spin axis (Warner, unpublished) found $P_{SIDEREAL}$ = 15.93612 h with a pole of (4°, 50°) or (190°, 73°) ecliptic coordinates. The addition of a third apparition, each with a different phase angle bisector longitude (see Harris *et al.*, 1984) from the others, prompted a new search that included sparse data from USNO-Flagstaff and the Catalina Sky Survey. The first figure below shows the distribution with red data points representing sparse data and blue points representing the dense lightcurves. The view is from the north ecliptic pole.

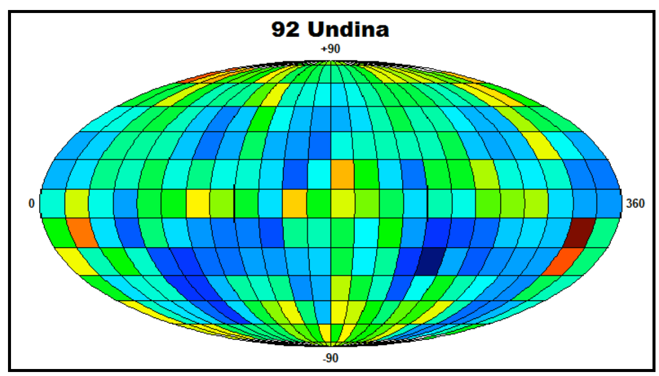


Generally, a search for the synodic period should cover at least ± 5% of the average synodic period *if all the lightcurves are rated U = 3 under the LCDB system* (see Warner *et al.*, 2009 and updated documentation on-line for the U rating system). Introducing lesser quality data, or when the synodic periods are significantly different, requires expanding the search range. With a large number of data points, this can result in a search that takes several *days* on a single PC. In this case, all the results covered a relatively small range and the data were of higher quality. To save time, the period search was limited to the range of 15.87-16.00 hours, or about centered on a 15.94 h average. Even so, the search required almost 24 hours of uninterrupted computing time.



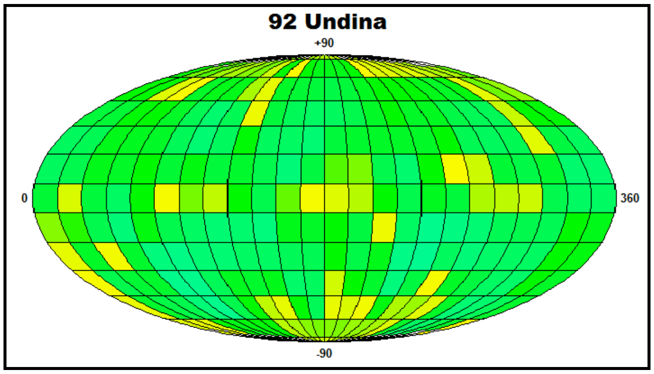
The plot showing the χ^2 value versus the period shows that the search did find a minimum, but it is poorly defined. The most likely cause is the generally low amplitude of the asteroid lightcurve and the noise in the sparse data at half (or more) the amplitude level. There was one period with a noticeably lower χ^2 value at 15.95198047 h. Generally, modeling will be more successful if the *second lowest* χ^2 value is at least 1.1x the lowest value. In this search, more than a dozen periods had χ^2 that met the *10-per cent rule*. Despite the less than ideal results, it was decided to continue with modeling by searching for the lowest χ^2 value among 312 discrete, fixed pole positions, but allowing the period to float.

In the two pole search plots below, scaling goes from dark blue for lowest χ^2 to red for higher values, the highest value being dark red.



The first plot uses a *relative scale*, i.e., the colors are scaled to fit the actual range of the χ^2 results. The scaling is based on $\log(\chi^2)$, which compresses the colors at the extremes and spreads them out in the mid-range values. Ideally, the hope is for a small "island of blue" in the middle of a sea of greens to reds. This was not the case here. Instead, there are two blue regions south of the ecliptic, indicating retrograde rotation, and some smaller groups of bluish areas north. From this, and a review of the χ^2 values, it seems likely that the asteroid is in retrograde rotation and that the spin axis favors the ecliptic plane more than the pole.

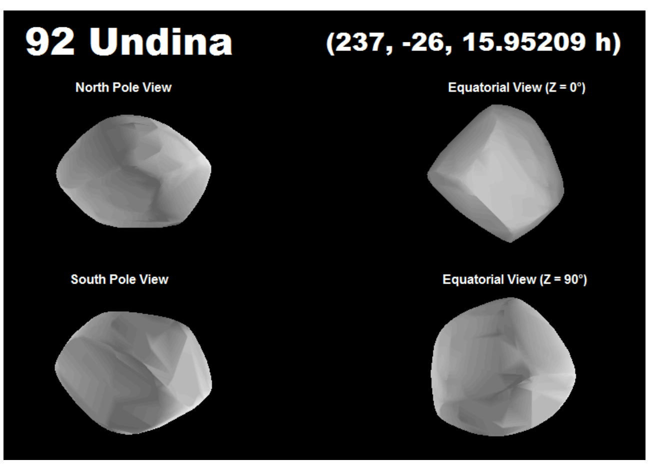
It should be noted that the lightcurve inversion process often results in at least two solutions, usually differing by 180° in longitude. Sometimes the longitudes are about the same but the latitudes are mirrored on either side of the ecliptic equator. A third possibility is a *double-mirroring*, where the longitudes *and* latitudes are reflected, thus creating four possible solutions.



A secondary check of the pole solution is on an *absolute scale*, where the colors range from blue to red using a fixed scale $0 < \chi^2 < 5$; all solutions $\chi^2 \geq 5$ are red. The choice of an upper cutoff of 5 is mostly arbitrary, based on experience when modeling with and without sparse data. The hope is still to see a small island of bluish colors on a sea of other colors well towards red. In the plot for 92 Undina, the plot shows little variation, an indication that the pole solution is not particularly strong.

With the results so far, the search for a shape model proceeded knowing that whatever came out would be, at best, a good guess. All the χ^2 values following the *10-per cent rule*, with two exceptions, had negative latitudes (retrograde rotation) and were generally grouped around 240° (lowest χ^2) and 60° longitude. Follow up searches that allowed the longitude, latitude, and period to float were centered on (240°, –30°) and (60°, –45°) ecliptic longitude and latitude. The initial period was the one found for the selected discrete pole.

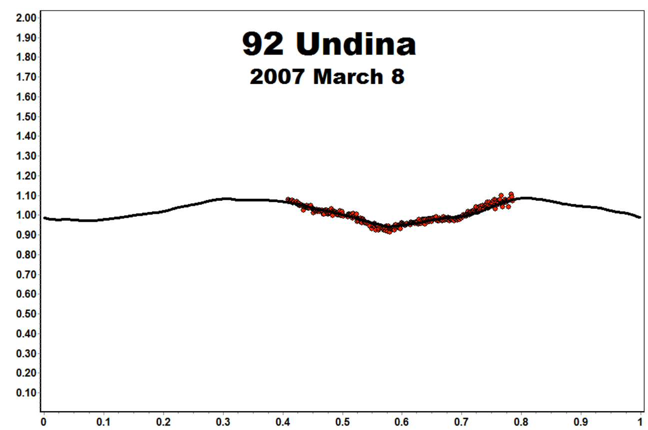
The final results were (237°, –26°, 15.95209 h) and (69°, –45, 15.95196 h). The first one is adopted for this work on the basis that it produced a more likely shape, but one that is still probably wrong.

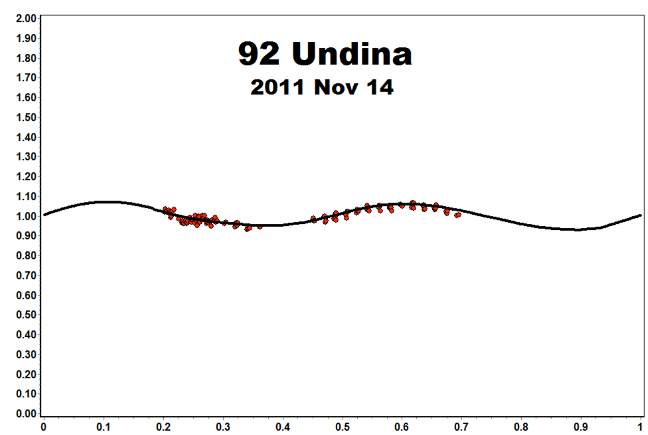


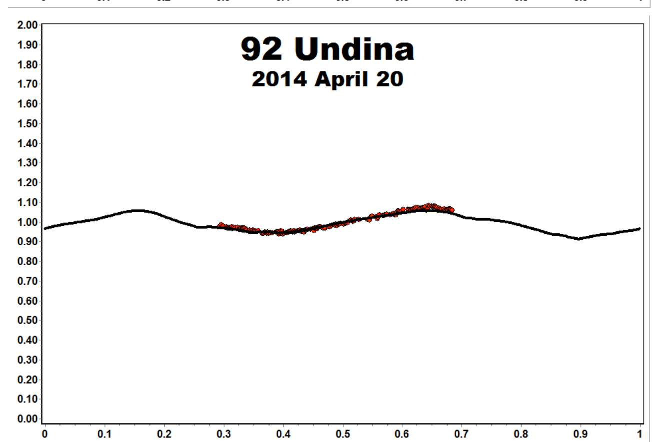
On the left are views of the asteroid model for the adopted solution from its north and south poles. The upper-right shows an equatorial view at 0° rotation. At lower right is an equatorial view at +90° rotation. The axis ratios are: a/b: 0.954, a/c: 0.880, and b/c: 0.923. Either a/c or b/c should be > 1.0. For the second candidate (69°, –45°, 15.95196 h), the ratios were even smaller.

Assuming the estimated size of the asteroid is correct, the adopted solution fits reasonably well with a pole found by Shepard *et al.* (2014) that indicated the subradar observations in 2011 were at a latitude of 45 ± 10°. The solution here would give about 54°.

Naturally, the model lightcurve for a given date should match data obtained on that date. This is another check of the results. Despite the abnormal shape, the model lightcurves matched the data very well at the three apparitions.







Conclusions

The spin axis and shape models presented here are a good start, but not definitive. Given the generally low amplitude of the asteroid, it may not be possible to do much better, i.e., the inversion process relies on the lightcurves from different viewing aspects and phase angles to have sufficient differences to build an unambiguous model.

One problem, the initial one, was that the sidereal period could not be well-defined. Slivan (2012, 2013) discussed the issues involved in finding a unique sidereal period using an analytical approach. Anyone attempting modeling should keep these two papers at hand. As mentioned before, sparse data are of best use when the noise (scatter) is not a significant fraction of the asteroid's lightcurve amplitude (see, e.g., Durech *et al.*, 2011; Hanus and Durech, 2012).

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References

Durech, J., Kaasalainen, M., Herald, D., Dunham, D., Timerson, B., Hanus, J., Frappa, E., Talbot, J., Hayamizu, T., Warner, B.D., Pilcher, F., Galád, A. (2011). *Icarus* **214**, 652-670.

Hanus, J., Durech, J. (2012). "The potential of sparse photometric data in asteroid shape modeling." *Plan. Space Sci.* **73**, 75-79.

Harris, A.W., Young, J.W., Scaltriti, F., Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

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.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Shepard, M.K., Taylor, P.A., Nolan, M.C., Howell, E.S., Springman, A., Giorgini, J.D., Warner, B.D., Harris, A.W., Stephens, R., Merline, W.J., Rivking, A., Benner, L.A.M., Coley, D., Clark, B.E., Ockert-Bell, M., Magri, C. (2014). "A Radar Survey of M- and X-class Asteroids. III. Insights into Their Composition, Hydration State, and Structure." *Icarus*, in press.

Slivan, S.M. (2012). "Epoch Data in Sidereal Period Determination. I. Initial Constraint from Closest Epochs." *Minor Planet Bul*. **39**, 204-206.

Slivan, S.M. (2013). "Epoch Data in Sidereal Period Determination. II. Combining Epochs from Different Apparitions." *Minor Planet Bul*. **40**, 45-48.

Warner, B.D. (2007). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: December 2006 - March 2007." *Minor Planet Bul.* **34**, 72-77.

Warner, B.D., Harris, A.W., Pravec, P. (2009a). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updates available: *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2012). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2011 September – December." *Minor Planet Bul.* **39**, 69-80.

ROTATION PERIOD OF 227 PHILOSOPHIA IS RE-EVALUATED

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We previously published a rotation period of 52.98 hours for 227 Philosophia (Pilcher and Alkema, 2014, *Minor Planet Bulletin* **41**, 188). By adjusting instrumental magnitudes of the observations reported there by 0.03 or less, we obtain equally good fits to 26.476 hours with a monomodal lightcurve and 52.955 hours with a bimodal lightcurve, amplitude 0.12 magnitudes. We prefer the shorter period because the two sides of the longer period lightcurve are nearly identical.

Earlier period determinations for 227 Philosophia are by Bembrick et al. (2006), 18.048 hours; Behrend (2006), 26.138 hours; Alkema (2013), 17.181 hours. In a lightcurve far more dense than any previously obtained, we (Pilcher and Alkema, 2014) reported a rotation period of 52.98 hours, with a slightly asymmetric bimodal lightcurve. By adjusting the instrumental magnitudes of the observations reported in this reference by 0.03 or less, we find equally good fits to 26.476 hours with a monomodal lightcurve (Figure 1) and 52.955 hours with a very symmetric bimodal lightcurve (Figure 2). A symmetric bimodal lightcurve can be produced only by an object whose shape is highly symmetric over a 180 degree rotation. This is unlikely for a real asteroid. We therefore prefer the 26.476 hour period, although the longer period cannot be ruled out. The formal error of ± 0.001 hours is unrealistic. We believe the real error is probably near ± 0.01 hours, or even larger.

The data obtained by Alkema (2013) provided a good fit to a nearly symmetric bimodal lightcurve of period 53.12 hours, although with incomplete phase coverage, and published by Pilcher and Alkema (2014). Following an instrumental magnitude adjustment, we are able to provide a good fit of these data to a monomodal lightcurve with period 26.560 hours (Figure 3), compatible with the 26.476 hours found in the more dense lightcurve.

Future work. It often occurs that an asteroid with a monomodal lightcurve at some oppositions has a bimodal lightcurve at a subsequent opposition at a different celestial longitude. We recommend that 227 Philosophia be observed at a future opposition. We can be fully confident that the period is near either 26.5 hours or 53 hours. The observer at the future opposition needs only to look for possible bimodal behavior in a 26.5 hour lightcurve. Its presence will definitively resolve the ambiguity in the current period determination, but if the bimodal behavior at 26.5 hours is absent, the period will still be ambiguous. Dates and declinations of future maximum elongations from the Sun are: 2015 Apr. 30, -28 degrees, southern hemisphere observers please take note; 2016 Aug. 23, -10 degrees; 2017 Oct. 25, +22 degrees; 2018 Dec. 26, +34 degrees.

References

Alkema, M. S. (2013). "Asteroid Lightcurve Analysis at Elephant Head Observatory 2012 November - 2013 April." *Minor Planet Bull.* **40**, 133-137.

Behrend, R. (2006). Observatoire de Geneve web site *http://obswww.unige.ch/~behrend/page_cou.html*.

Bembrick, C.S., Allen, B., Richards, T. (2006). "Lightcurves from Two Oppositions of 227 Philosophia and 2089 Cetacea." *Minor Planet Bull.* **33**, 42-43.

Pilcher, F., Alkema, M.S. (2014). "Rotation Period Determination for 227 Philosophia." *Minor Planet Bull.* **41**, 188.

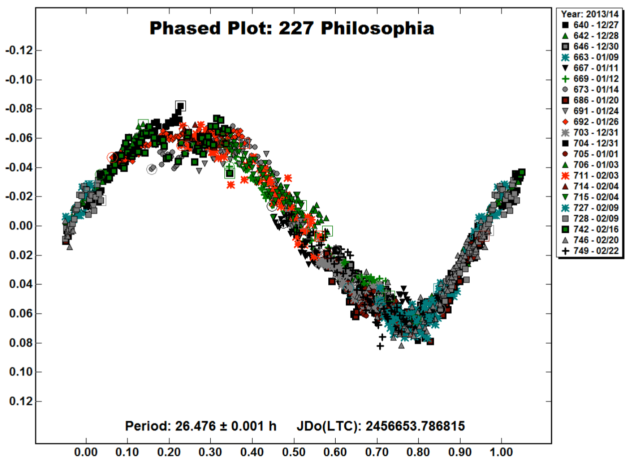

Figure 1. Observations of 227 Philosophia 2013 12 27 - 2014 02 22 phased to a period 26.476 hours with one maximum and minimum per cycle.

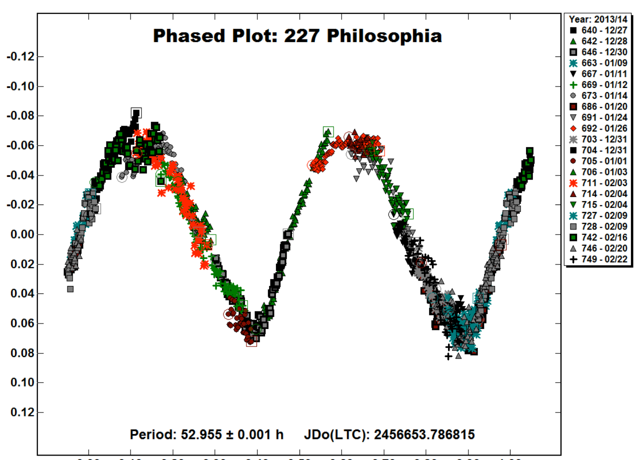

Figure 2. Observations of 227 Philosophia 2013 12 27 - 2014 02 22 phased to a period 52.955 hours with two nearly identical maxima and minima per cycle.

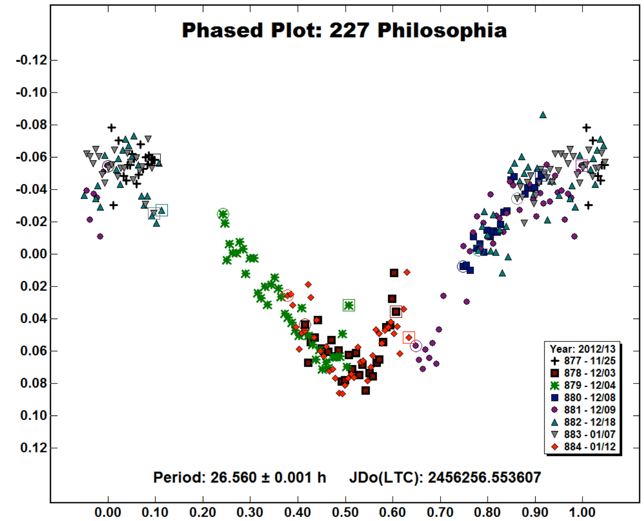

Figure 3. Observations of 227 Philosophia 2012 11 25 - 2013 01 12 phased to a period 26.560 hours with one maximum and minimum per cycle.

ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2014 MARCH-JUNE

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Lightcurves for 19 main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2014 March through June. Some of the objects were members of the Hungaria group/family, observed as follow-up to previous apparitions to check for the possibility of undiscovered satellites or to provide additional data for spin axis and shape modeling.

CCD photometric observations of 19 asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) in 2014 January through March. Table I gives a listing of the telescope/CCD camera combinations used for the observations. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales for the combinations range from 1.24-1.60 arcsec/pixel.

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

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

All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposure duration varied depending on the asteroid's brightness and sky motion. Guiding on a field star sometimes resulted in a trailed image for the asteroid.

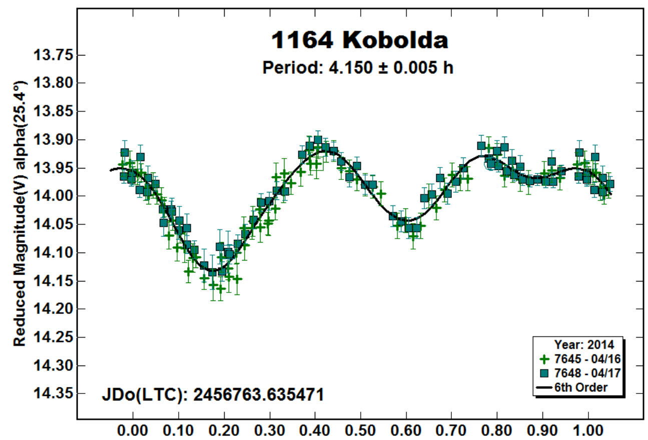
Measurements were done using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually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

In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) 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 –0.05 to 1.05.

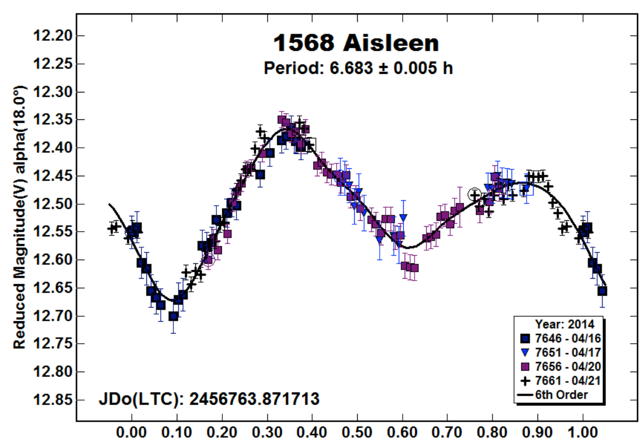
For the sake of brevity, only some of the previously reported results may be referenced in the discussions on specific asteroids. For a more complete listing, the reader is directed to the asteroid lightcurve database (LCDB; Warner *et al.,* 2009). The on-line version at *http://www.minorplanet.info/lightcurvedatabase.html*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

Individual Results

1164 Kobolda (Phocaea). Previously reported periods include Higgins and Oey (2007; 4.141 h), Sauppe *et al*. (2007; 4.154 h), and Higgins (2011; 4.142 h). The CS3-PDS period of 4.150 h is in good agreement.



1568 Aisleen (Phocaea). Malcolm (2001) reported a period of 6.68 h for this asteroid. Hanus *et al*. (2011) found a sidereal period of 6.67597 h as part of determining a spin axis and shape model. They reported a pole in ecliptic coordinates of (109°, –68°).

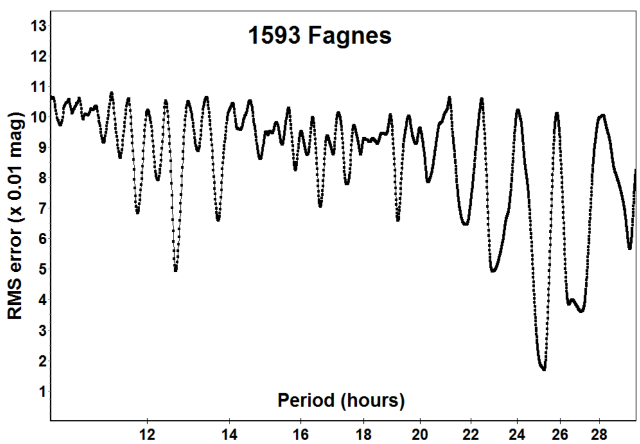


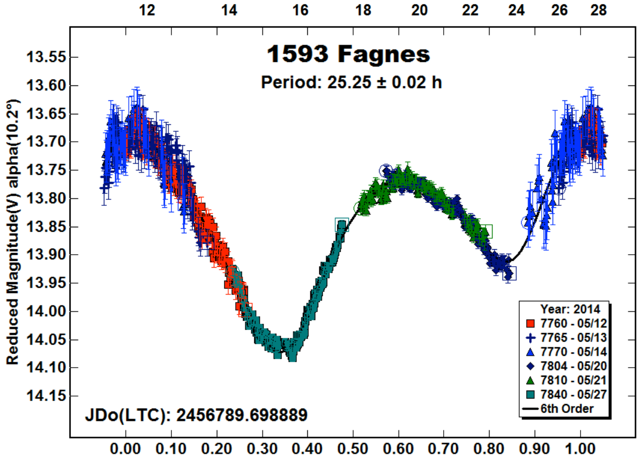
1593 Fagnes (Mars-crosser). Harris *et al.* (1992) reported a period of 16.45 h while Lagerkivst *et al.* (1992) reported 25.1 h. The period spectrum from the 2014 PDS data shows a weak solution near 16.5 h, but – by far – the preferred period is 25.25 hours.

Number	Name	2014 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.
1164	Kobolda	04/16-04/17	140	25.4,25.7	165	13	4.150	0.005	0.21	0.02
1568	Aisleen	04/16-04/21	130	18.0,17.4	245	30	6.683	0.005	0.31	0.02
1593	Fagnes	05/12-05/27	801	10.2,13.8	232	14	25.25	0.02	0.38	0.02
2048	Dwornik	06/05-06/08	112	31.6,31.3	313	20	3.730	0.005	0.05	0.01
3022	Dobermann	04/20-04/23	230	10.3,11.0	207	17	10.336	0.005	0.75	0.02
3893	DeLaeter	05/15-05/21	165	16.3,18.8	205	9	5.633	0.003	0.13	0.02
4132	Bartok	04/14-04/15	107	21.1,21.3	158	-2	3.297	0.005	0.41	0.03
5692	Shirao	06/10-06/11	181	10.9,11.2	249	16	2.8878	0.0004	0.16	0.02
6384	Kervin	04/02-04/07	220	19.4,18.8	204	31	3.619	0.002	0.10	0.01
7247	1991 TD1	[12]09/14-09/22	274	18.7,21.1	336	17	3.176	0.002	0.15	0.01
7247	1991 TD1	04/23-04/25	225	8.5,9.6	201	8	3.176	0.002	0.11	0.01
9356	Elineke	05/15-05/18	102	13.3,14.0	209	17	2.750	0.005	0.21	0.02
11279	1989 TC	04/16-04/21	165	17.3,19.8	179	-4	4.003	0.002	0.15	0.02
13186	1996 UM	05/02-05/04	100	22.3,23.0	181	1	4.293	0.003	0.37	0.02
13245	1998 MM19	05/01-05/04	140	12.8,12.6	228	17	4.667	0.002	0.47	0.02
17633	1996 JU	05/14-05/19	175	17.8,0.0,17.7	190	26	6.20[A]	0.02	0.21	0.02
26227	1998 HJ7	05/10-05/21	330	16.6,21.1	211	19	22.07[A]	0.05	0.15	0.03
48470	1991 TC2	04/12-04/17	186	6.5,8.8	195	6	10.19	0.05	0.19	0.02
52314	1991 XD	04/01-04/03	189	16.7,16.5	194	26	7.683	0.005	0.61	0.03
96155	1973 HA	04/12-04/15	271	16.9,16.9	196	21	15.59	0.02	0.59	0.03

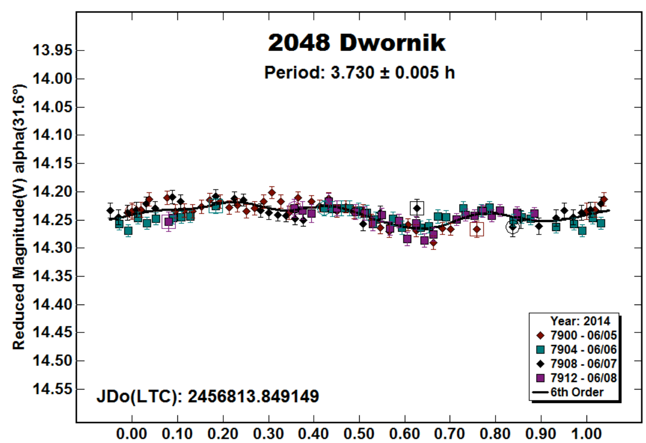
Table II. Observing circumstances. [12] Dates in 2012. [A] preferred period of ambiguous solution.

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).

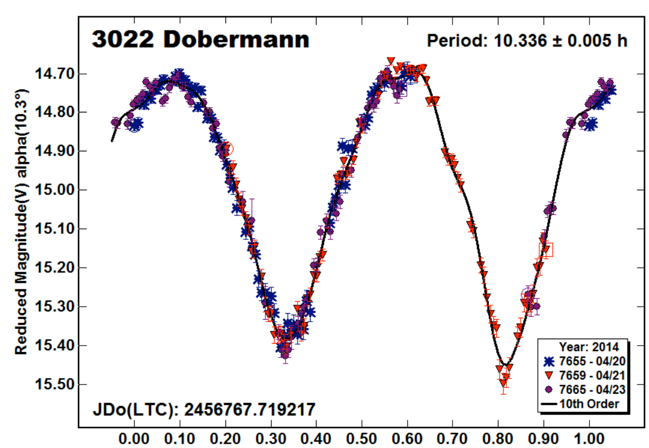




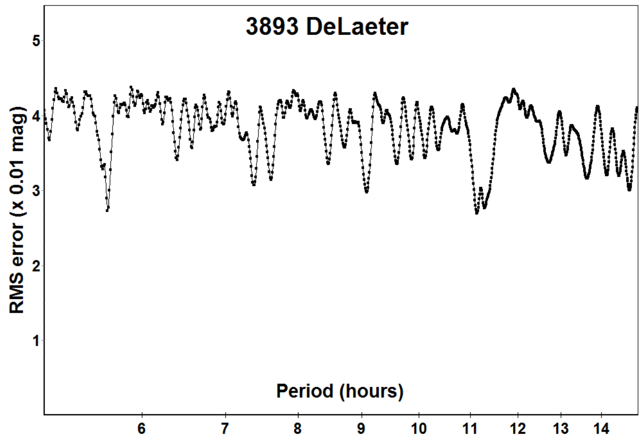
2048 Dwornik (Hungaria). Dwornik was observed in 2014 as part of an on-going program to obtain sufficient data for spin axis modeling for members of the Hungaria group/family. The 2014 apparition was the fourth one observed by the author (see the references in the LCDB).

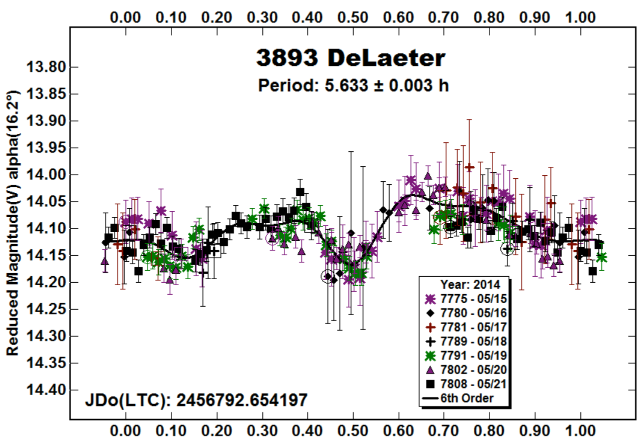


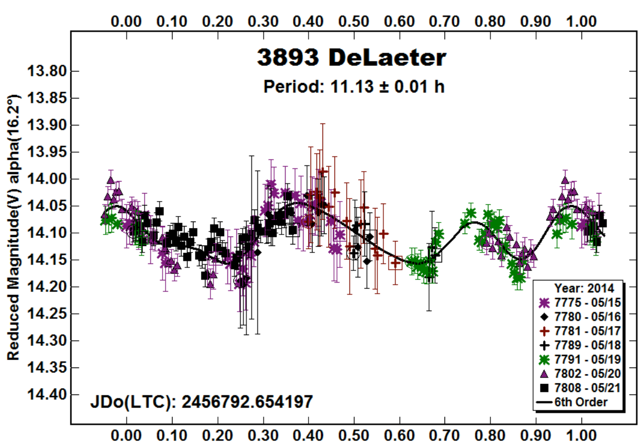
3022 Dobermann (Hungaria). This is also the fourth apparition that the author observed this particular Hungaria member. Initial modeling using those four data sets indicates a reliable pole solution and retrograde rotation. Details will be in a future paper.



3893 DeLaeter (Phocaea). The period spectrum using the 2014 PDS data indicates two possible solutions at around 5.5 and 11 hours. The lightcurve plots show the data phased to these solutions. Given the shape of the two, the shorter period is preferred, although the more complex shape of the longer period cannot be formally excluded (see Harris *et al.*, 2014).

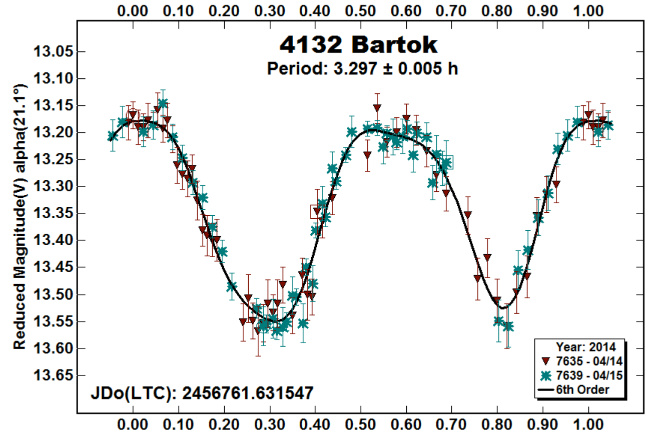




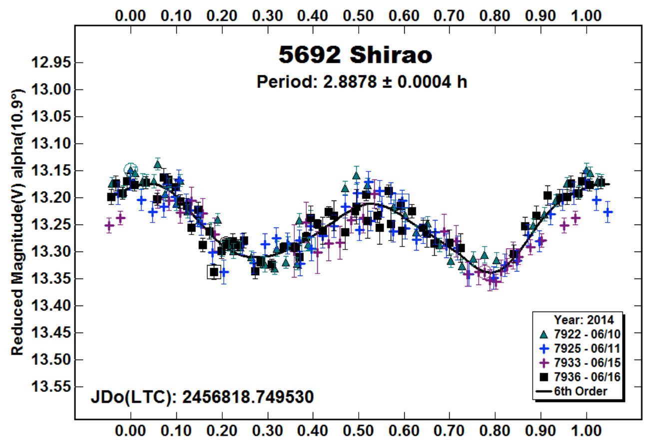


Stephens (2004) reported a period of 13.83 hours, which was not one of the likely solutions in the period spectrum above. His data were available on the MPC lightcurve database site (*www.minorplanetcenter.net/light_curve*). Even after adjusting zero points in his data, the period did not change substantially and could not be made to fit the periods reported here.

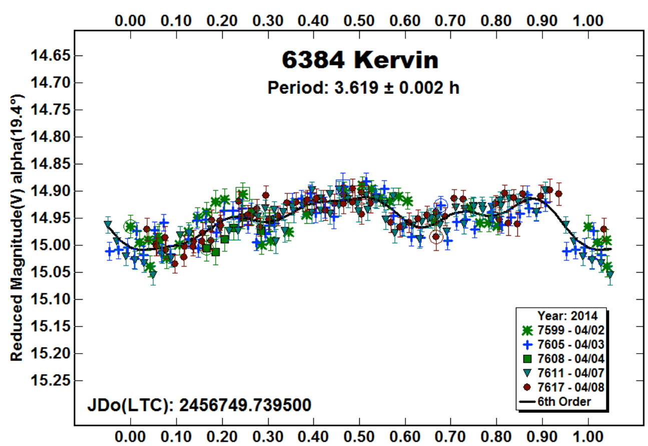
4132 Bartok (Phocaea). Skiff (2011) and Behrend (2014) both reported periods of about 3.297 h. The PDS period of 3.297 h matches those results.



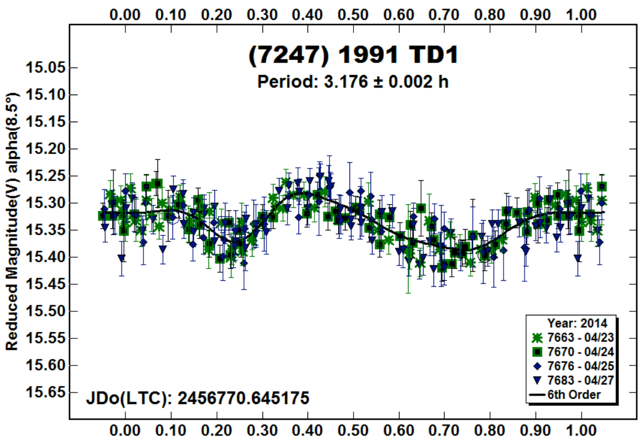
5692 Shirao (Main-belt, middle). Previous results include Behrend (2001; 2.90 h), Pray (2005; 2.886 h), and Behrend (2006; 2.90 h). The PDS result of 2.8878 h is in good agreement.

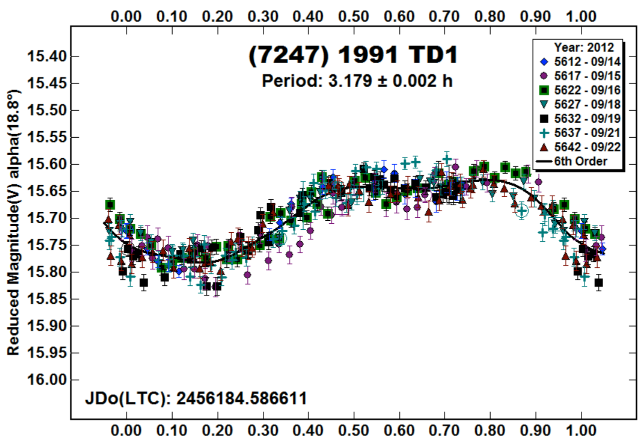


6384 Kervin (Hungaria). In addition to the 2014 apparition, the author worked this asteroid at three previous apparitions: Warner *et al.* (2006, 3.6203 h), Warner (2008, 3.647 h) and Warner (2011, 3.617 h). Analysis of the 2014 data set found *P* = 3.619 h.

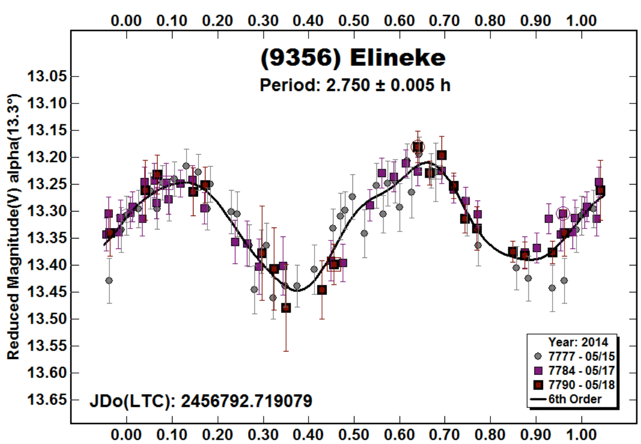


(7247) 1991 TD1 (Hungaria). The author first worked this asteroid in 2012, reporting a period of 6.3515 h (Warner, 2013b) based on a bimodal lightcurve. Analysis of the data obtained in 2014 found a period of 3.176 h. Forcing the data to the long period resulted in an unlikely quadramodal lightcurve, i.e., one with four minimum/maximum pairs per rotation. The 2012 data were re-examined and found to fit a period of 3.179 hours with a monomodal lightcurve. Given the low amplitude and relatively small phase angle, such a shape is not improbable (see Harris *et al.*, 2014).

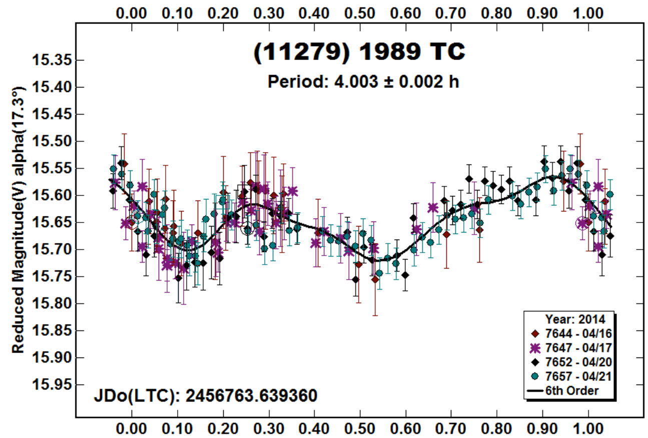




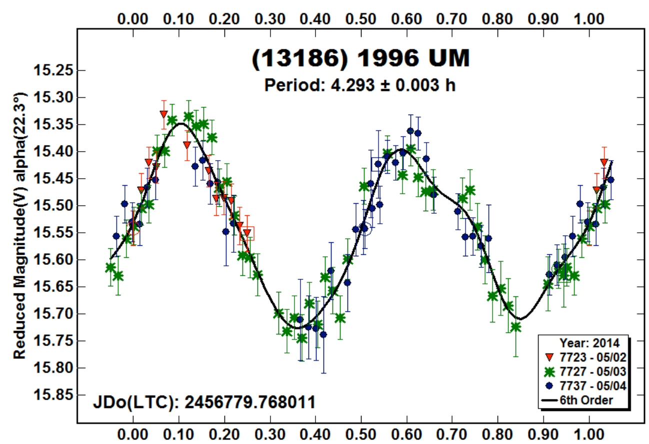
9356 Elineke (Main-belt, middle). This appears to be the first reported lightcurve for this asteroid.



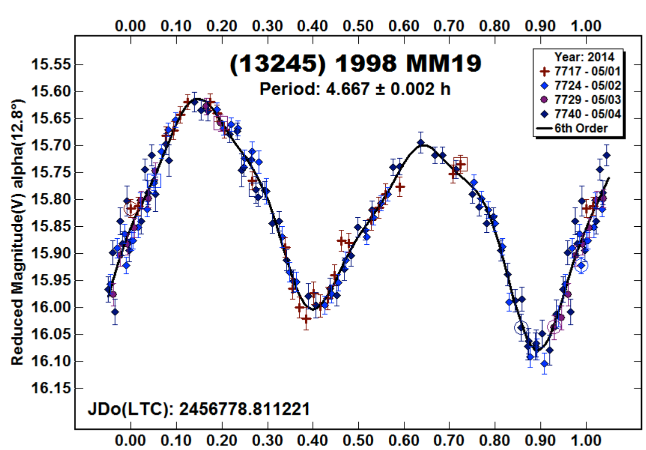
(11279) 1989 TC (Hungaria). The author first worked 1989 TC in 2010 (Warner, 2011) and reported a period of 4.020 h and amplitude A = 0.13 mag. Analysis of the data from 2014 produced a period of 4.003 h and amplitude of A = 0.15 mag. The two periods are statistically the same despite being more than 3-sigma apart. The phase angle bisector longitudes were about 90° apart so, given that the amplitude was about the same both times, it's probable that the spin axis pole favors one of the ecliptic poles.



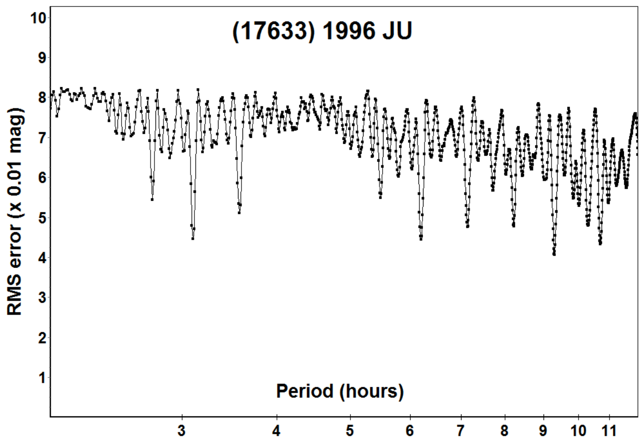
(13186) 1996 UM (Hungaria). A period of 4.304 h was reported by the author based on data obtained in 2013 (Warner, 2013a). The amplitude was 0.69 mag at L_{PAB} ~ 310°. The 2014 data, at L_{PAB} ~ 180°, produced P = 4.293 h and A = 0.37 mag. The diameters going through these two points are at an angle of 50°. Assuming that the viewing aspect in 2013 was nearly equatorial, it is likely that the amplitude would be even lower if L_{PAB} (and north pole of the spin axis) were in the vicinity of 40 ± 20° (or 220 ± 20°).

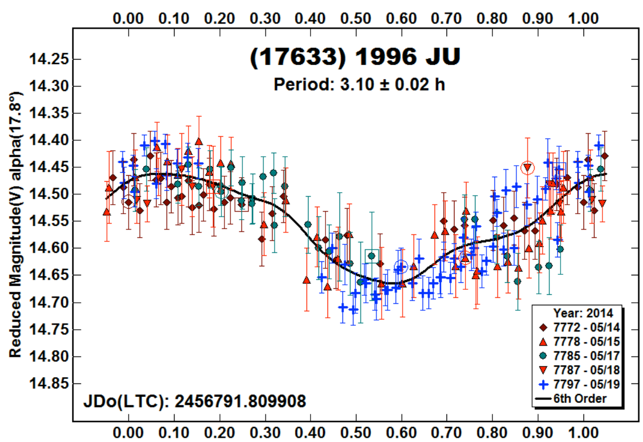


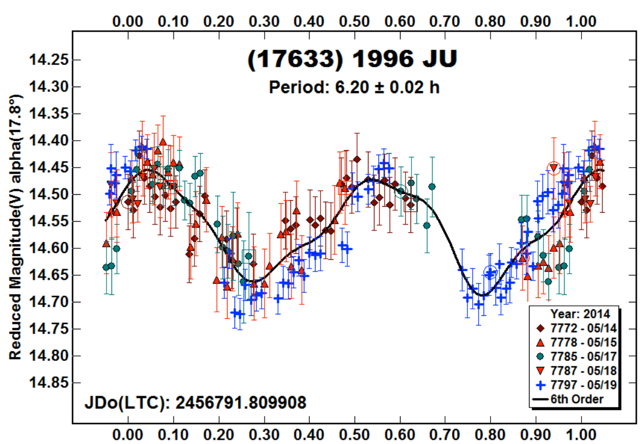
(13245) 1998 MM19 (Hungaria). Warner (2013c) found a period of 4.664 h. The period derived from the 2014 data is in close agreement. The amplitude at the two apparitions differed by nearly 0.2 mag, indicating that the spin axis is tilted somewhat away from the north or south ecliptic pole.



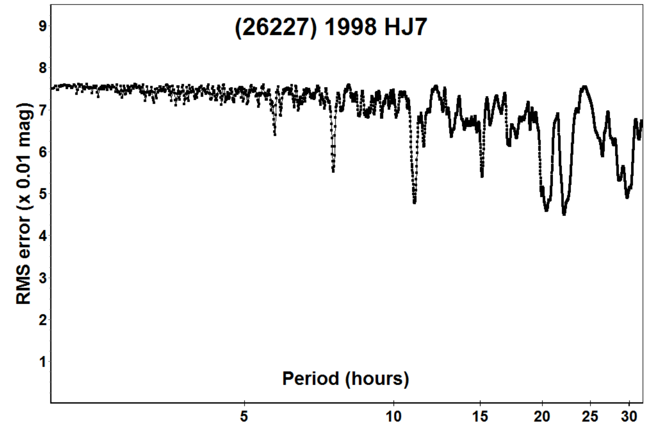
(17633) 1996 JU (Phocaea). Albers *et al.* (2010) first reported a period of 6.2098 h. The data from PDS in 2014 produced two periods, one close to Albers (6.20 h) with a bimodal lightcurve and one at the half-period (3.10 h) and a monomodal lightcurve. The amplitude in both cases is on the border for assuming a bimodal lightcurve (see Harris *et al.*, 2014). There is a significant asymmetry in the Albers lightcurve that supports the 6.20 h solution. The same cannot be said for the PDS data. However, since the period spectrum favors the longer period and it supported by earlier work, the 6.20 h solution is adopted for this work.

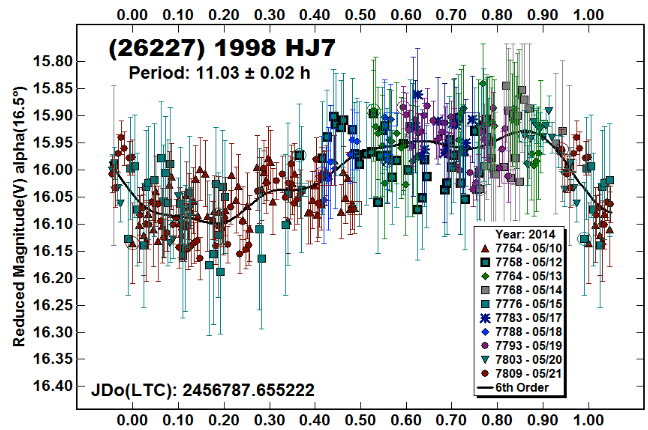


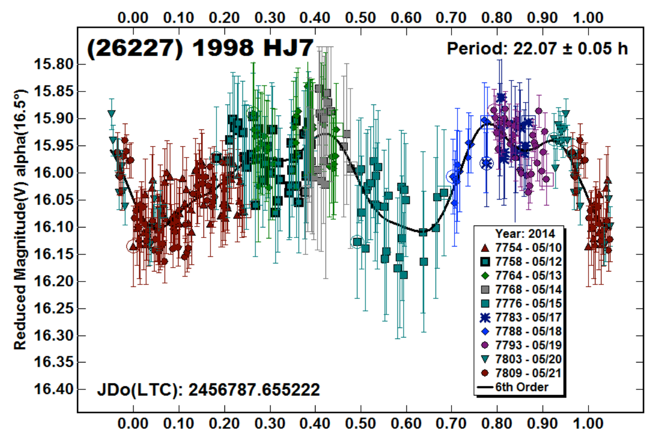




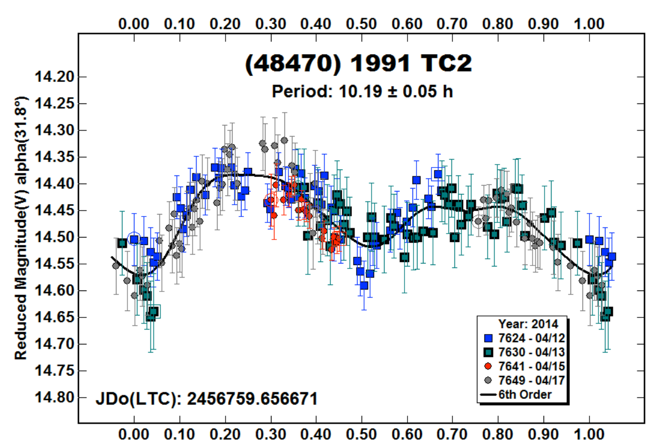
(26227) 1998 HJ7 (Hungaria). The period spectrum using the PDS 2014 data favors a period of 22 h. There is sufficient asymmetry in the two halves to support this, but the noisy data may be a contributing factor. The shorter period cannot be formally excluded. There were no other results found in the literature.





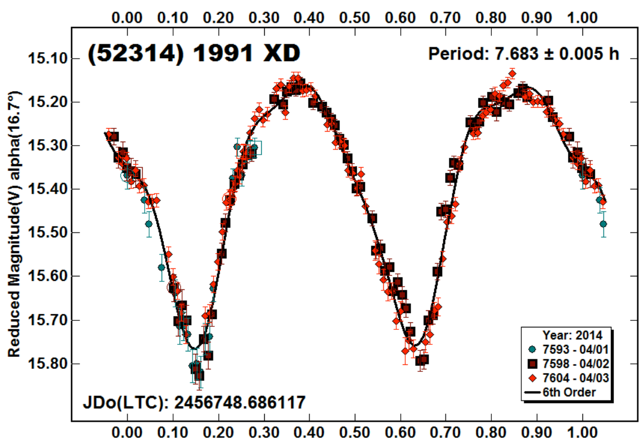


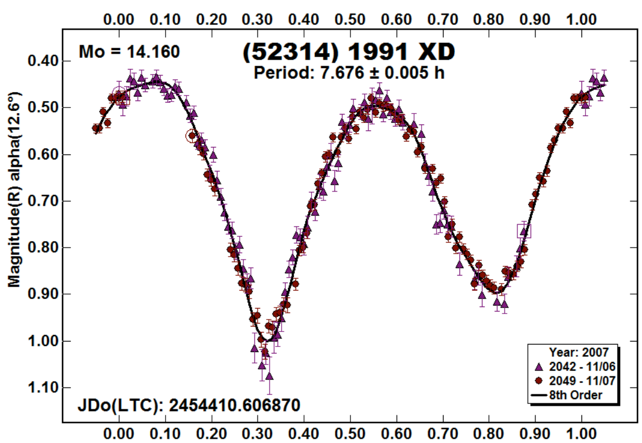
(48470) 1991 TC2 (Hungaria).



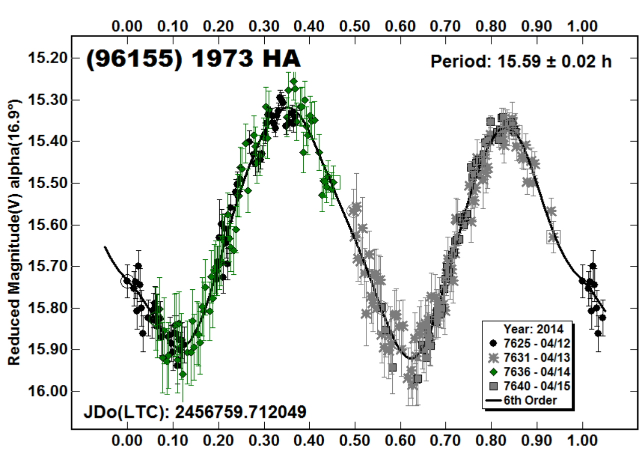
The author first worked 1991 TC2 in 2011 (Warner, 2011). The period was found to be 10.48 h. The data from the 2014 observations produced a period of 10.19 h. Neither data set could be manipulated so that it would fit the period of the other. The amplitude in both cases was 0.19 mag.

(52314) 1991 XD (Hungaria). The 2014 apparition was the second time the author had observed 1991 XD. The first time (Warner, 2008) a period of 7.663 h was found. Analysis of the 2014 data set found P = 7.683 h. A second look at the 2007 results found the data (consisting of two consecutive nights in November) better fit a period of 7.676 ± 0.005 h. This is more in line with the 2014 result.





(96155) 1973 HA (Mars-crosser). This appears to be the first reported lightcurve for 1973 HA.



Acknowledgements

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References

Albers, K., Kragh, K., Monnier, A., Pligge, Z., Stolze, K., West, J., Yim, A., Ditteon, R. (2010). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2009 October thru 2010 April." *Minor Planet Bul.* **37**, 152-158.

Behrend, R. (2001, 2014). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Hanus, J., Durech, J., Broz, M., Warner, B.D., Pilcher, F., Stephens, R., Oey, J., Bernasconi, L., Casulli, S., Behrend, R., Polishook, D., Henych, T., Lehký, M., Yoshida, F., Ito, T. (2011). "A study of asteroid pole-latitude distribution based on an extended set of shape models derived by the lightcurve inversion method." *Astron. Astrophys*. **530**, A134.

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., Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Harris, A.W. Young, J.W. Dockweiler, T., Gibson, J., Poutanen, M., Bowell, E. (1992). "Asteroid lightcurve observations from 1981." *Icarus* **95**, 115-147.

Harris, A.W., Pravec, P., Galad, A., Skiff, B.A., Warner, B.D., Vilagi, J., Gajdos, S., Carbognani, A., Hornoch, K., Kusnirak, P., Cooney, W.R., Gross, J., Terrell, D., Higgins, D., Bowell, E., Koehn, B.W. (2014). "On the maximum amplitude of harmonics on an asteroid lightcurve." *Icarus* **235**, 55-59.

Henden, A.A., Terrell, D., Levine, S.E., Templeton, M., Smith, T.C., Welch, D.L. (2009). *http://www.aavso.org/apass*

Higgins, D., Oey, J. (2007). "Asteroid Lightcurve Analysis at Hunters Hill Observatory and Collaborating Stations - December 2006 - April 2007." *Minor Planet Bul*. **34**, 79-80.

Higgins, D. (2011). "Period Determination of Asteroid Targets Observed at Hunters Hill Observatory: May 2009 - September 2010." *Minor Planet Bul*. **38**, 41-46.

Lagerkvist, C.-I., Magnusson, P., Debehogne, H., Hoffmann, M., Erikson, A., de Campos, A., Cutispoto, G. (1992). "Physical studies of asteroids. XXV - Photoelectric photometry of asteroids obtained at ESO and Hoher List Observatory." *Astron. Astrophys. Suppl. Ser.* **95**, 461-470.

Malcolm, G. (2001). "Rotational Periods and Lightcurves of 1166 Sakuntala and 1568 Aisleen." *Minor Planet Bul*. **28**, 64.

Pravec, P., Scheirich, P., Durech, J., Pollock, J., Kusnirak, P., Hornoch, K., Galad, A., Vokrouhlicky, D., Harris, A.W., Jehin, E., Manfroid, J., Opitom, C., Gillon, M., Colas, F., Oey, J., Vrastil, J., Reichart, D., Ivarsen, K., Haislip, J., LaCluyze, A. (2014). "The tumbling state of (99942) Apophis." *Icarus* **233**, 48-60.

Pray, D. (2005). "Lightcurve analysis of asteroids 106, 752, 847, 1057, 1630, 1670, 1927 1936, 2426, 2612, 2647, 4087, 5635, 5692, and 6235." *Minor Planet Bul.* **32**, 48-51.

Sauppe, J., Torno, S., Lemke-Oliver, R., Ditteon, R. (2007). "Asteroid Lightcurve Analysis at the Oakley Observatory - March/April 2007." *Minor Planet Bul.* **34**, 119-122.

Skiff, B.A. (2011). Posting on CALL web site. *http://www.minorplanet.info/call.html*

Stephens, R.D. (2004). "Photometry of 683 Lanzia, 1101 Clematis, 1499 Pori, 1507 Vaasa, and 3893 DeLaeter." *Minor Planet Bul.* **31**, 4-6.

Warner, B.D., Pray, D.P., Pravec, P. (2006). "The Lightcurve of Hungaria Asteroid 6384 Kervin." *Minor Planet Bul.* **33**, 99.

Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

Warner, B.D. (2008). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: September-December 2007." *Minor Planet Bul.* **35**, 67-71.

Warner, B.D. (2008). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: December 2007 - March 2008." *Minor Planet Bul*. **35**, 95-98.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updates available: *http://www.MinorPlanet.info/*

Warner, B.D. (2011). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2010 September-December." *Minor Planet Bul*. **38**, 82-86.

Warner, B.D. (2011). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2010 December- 2011 March." *Minor Planet Bul*. **38**, 142-149.

Warner, B.D. (2013a). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2012 June – September." *Minor Planet Bul*. **40**, 26-29.

Warner, B.D. (2013b). "Rounding Up the Unusual Suspects." *Minor Planet Bul*. **40**, 36-42.

Warner, B.D. (2013c). "Asteroid Lightcurve Analysis at the Palmer Divide Observatory: 2012 September - 2013 January." *Minor Planet Bul*. **40**, 71-80.

ASTEROID LIGHTCURVES FROM ALTIMIRA OBSERVATORY

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The following asteroid lightcurve synodic periods are reported: 502 Sigune (*P* = 10.929 ± 0.02 h); 781 Kartvelia (*P* = 19.04 ± 0.02 h); 828 Lindemannia (*P* = 20.52 ± 0.02 h); and 3322 Lidiya (*P* = 710 ± 10 h).

CCD differential photometry was performed on four asteroids at Altimira Observatory in southern California using a 28-cm *f*/6.3 Schmidt-Cassegrain telescope (SCT) and ST-8XE non-anti blooming gate (NABG) imager. Comparison stars were selected using the "solar-color" criterion in *MPO Canopus*, and their V-band magnitudes were extracted from the APASS DR7 catalog. No color transforms were applied to any of these targets; this is reasonable given that the comp stars were selected to have colors similar to a typical asteroid. All of the observations used for this report have been uploaded to the Minor Planet Center's ALCDEF web site (*http://www.minorplanetcenter.net/light_curve*).

502 Sigune. This object has a well-determined lightcurve period (*P* = 10.922 h) in the Lightcurve Database (LCDB; Warner *et al.*, 2009), and according to Warner *et al*. (2014) it is a candidate for shape/spin modeling if a few more lightcurves can be gathered. Three nights of differential photometry using a clear filter during the 2014 April apparition yielded the phased lightcurve shown in Figure 1. This figure is wrapped to the best-fit period, *P* = 10.929 ± 0.02 h, which is consistent with previous reports.

781 Kartvelia. A lightcurve period of *P* = 19.06 h has been reported by Behrend (2003) for this asteroid and Melton *et al*. (2012) reported *P* = 19.02 ± 0.02 h. This asteroid was observed on 7 nights during the 2014 April apparition using unfiltered differential photometry. The resulting lightcurve, phased to the best-fit period *P* = 19.04 h, is shown in Figure 2. Considering the formal accuracy of the period solutions (± 0.02 h), this is consistent with the previously-reported periods.

828 Lindemannia. No lightcurve period has been previously reported for this asteroid. Ditteon *et al.* (2012) observed a 0.08-mag variation but did not determine a period. Masiero *et al*. (2012) reported the diameter and albedo from WISE observations, but no lightcurve parameters. This asteroid was observed through 10 nights during its 2013 Oct–Nov apparition. The phased lightcurve is shown in Figure 3, wrapped to the best-fit period of *P* = 20.52 ± 0.02 h. The amplitude appears to be ≈ 0.15 mag (peak-to-peak) although this may be an underestimate since the maximum near phase ≈ 0.8 was not observed.

3322 Lidiya. There is no report in the lightcurve data base (Warner *et al.*, 2009), and no observations in ALCDEF for this asteroid. It was selected for study because it had a favorable apparition in late 2012, i.e., relatively bright and at a convenient northern declination. Observations were made in a mixture of V- and R-band as well as clear filter on nineteen nights. Each individual lightcurve was basically a flat line (within measurement noise), which suggested a long rotation period. The asteroid's V-magnitude was estimated from the R-band and unfiltered differential photometry using the APASS V-magnitudes of the comp stars, without applying any color transform; this is reasonable given that the comp stars were selected to have colors similar to a typical asteroid.

Figure 4 presents the time-history of the asteroid's reduced magnitude, based on the default slope parameter of G = 0.15. Several storms that passed through southern California caused sizeable gaps in coverage. The solar phase angle during this series of observations ranged from $\alpha \approx -5$ deg to +26 deg.

A search was made spanning a range of 16 to 1400 hours. The only plausible result was a bimodal lightcurve with period near 710 h (Figure 5). The 4th-order Fourier fit curve is provided only as a guide to the eye: no significance is claimed for it, particularly because the observations do not provide any information about the height of the brightness maximum that is presumed to be near rotational phase 0.25. Several iterations of the *MPO Canopus* lightcurve fitting procedure were run using subsets of the measured data (i.e., leaving out a randomly-selected night's data), changing the averaging of data points, and assuming 3rd or 4th order Fourier models. Different realizations of the fitting routine always converged to a best-fit period in the range 710 ± 10 h.

Acknowledgements

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References

Behrend, R. (2003). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page3cou.html#000781*

Ditteon, R., Horn, L., Kamperman, A., Vorjohan, B., Kirkpatrick, E. (2012). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2011 April – May." *Minor Planet Bulletin* **39**, 26-27.

Masiero, J.R., Mainzer, A.K., Grav, T., Bauer, J.M., Cutri, R.M., Nugent, C., Cabrera, M.S. (2012). "Preliminary Analysis of WISE/NEOWISE 3-Band Cryogenic and Post-Cryogenic Observations of Main Belt Asteroids." *Astrophysical Journal Letters* **759**, L8.

Melton, E., Carver, S., Harris, A., Karnemaat, R., Klaasse, M., Ditteon, R. (2012). "Asteroid Lightcurve Analysis at the Oakley Southern Sky Observatory: 2011 November – December." *Minor Planet Bulletin* **39**, 131-133.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D., Harris, A.W., Pravec, P., Durech, J., Benner, L.A.M. (2014), "Lightcurve Photometry Opportunities: 2014 April-June." *Minor Planet Bulletin* **41**, 134-136.

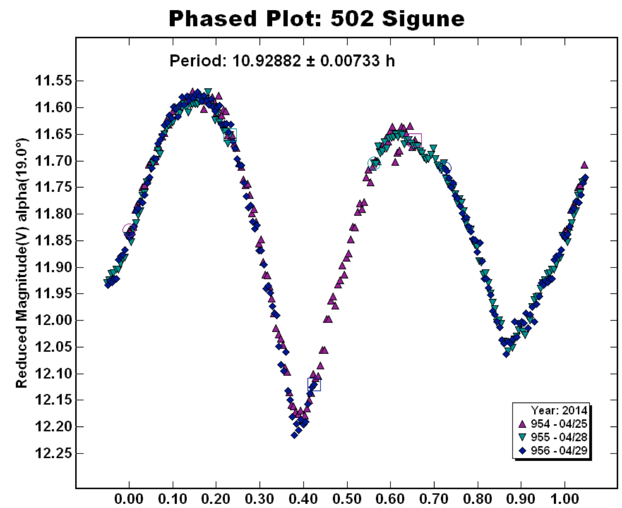

Figure 1: 502 Signune phased lightcurve, wrapped to best-fit period P= 10.929 h.

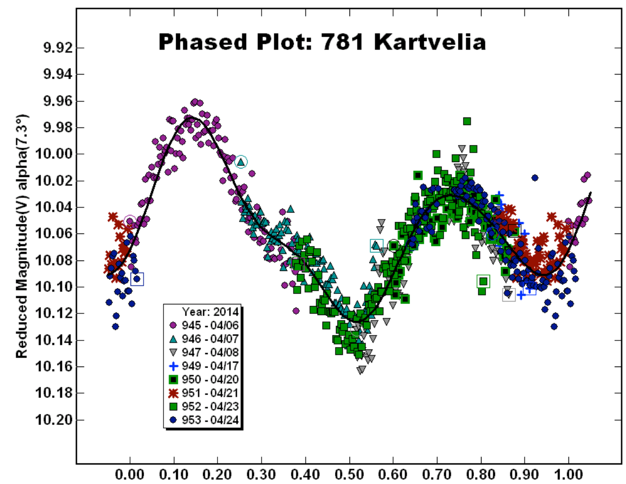

Figure 2: 781 Kartvelia phased lightcurve, wrapped to best-fit period P= 19.04 h.

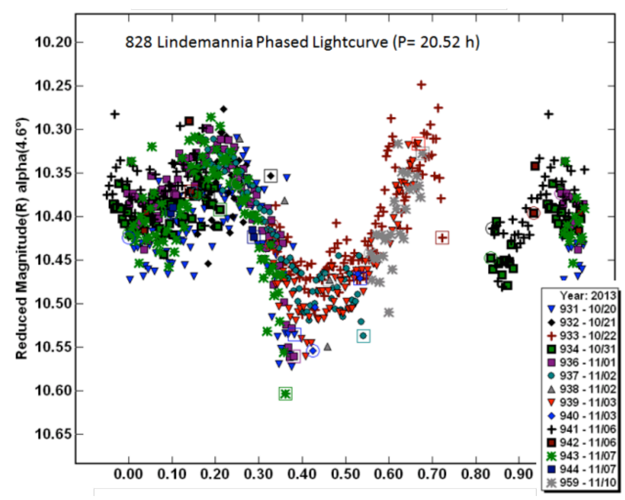

Figure 3: 828 Lindemannia phased lightcurve (P= 20.52 h)

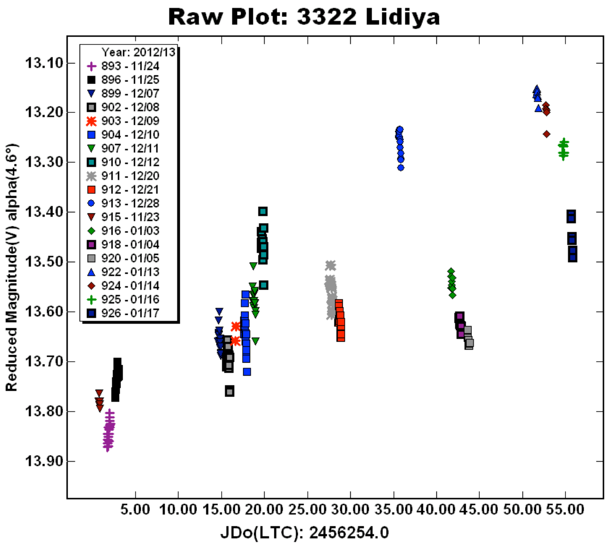

Figure 4: Reduced V-magnitude of 3322 Lidiya from Nov 2012 through Jan 2013.

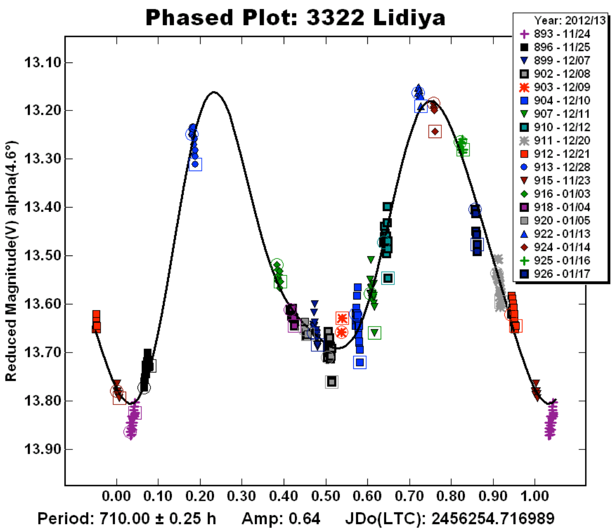

Figure 5: Lightcurve of 3322 Lidiya, phased to P= 710 h.

ROTATIONAL PERIOD FOR 1658 INNES, (10597) 1996 TR10, AND 30017 SHAUNDATTA

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Photometric observations of three main-belt asteroid were made over seven nights during 2014 April-June: 1658 Innes, (10597) 1996 TR10, and 30017 Shaundatta.

CCD photometric observations for three main-belt asteroids were collected from Balzaretto Observatory (A81) in Rome (Italy) on seven nights from 2014 April 9 to June 5. Images were obtained using a 0.20-m Schmidt-Cassegrain (SCT) reduced to *f*/5.5 equipped with an SBIG ST7-XME CCD camera. Observations at Carpione Observatory (K49) near Florence (Italy), were made using a 0.25-m *f*/10 SCT and SBIG ST9-XE CCD camera. Differential photometry and period analysis were done using *MPO Canopus* (Warner, 2013). All unfiltered images were calibrated with dark and flat-field frames. The asteroid magnitude was reduced to R-band using near-solar color index comparison stars that were selected using the Comp Star Selector feature in *MPO Canopus*.

1658 Innes. This main-belt asteroid was selected from the "Potential Lightcurve Targets" web site (Warner, 2014) and observed on three nights over a time span of 19 days. The derived synodic period was P = 3.191 ± 0.001 h with an amplitude of A = 0.22 ± 0.03 mag.

(10597) 1996 TR10. This main-belt asteroid was selected from the "Potential Lightcurve Targets" web site (Warner, 2014) and observed on three nights over a time span of 12 days. The derived synodic period was P = 6.60 ± 0.01 h with an amplitude of A = 0.32 ± 0.03 mag.

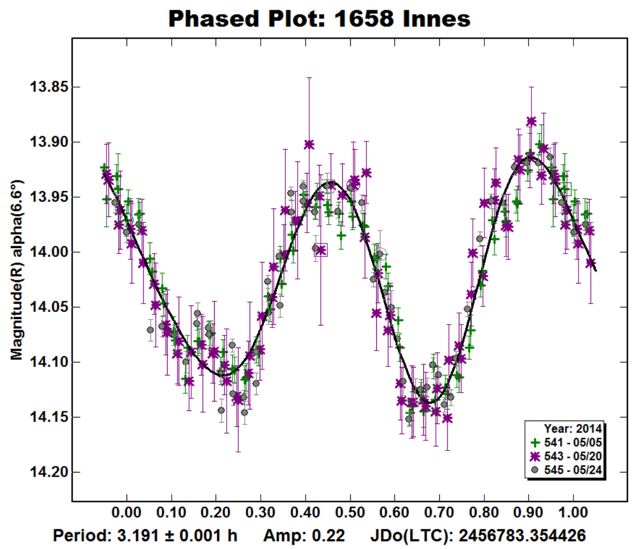
30017 Shaundatta. This main-belt asteroid was accidentally found in the field-of-view during a photometric session dedicated to another asteroid and was observed for only one night. However, enough data were obtained to cover the rotational period for more than two times. There are no entries in the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) for 30017 Shaundatta. The derived synodic period was P = 2.6 ± 0.1 h with an amplitude of A = 0.23 ± 0.03 mag.

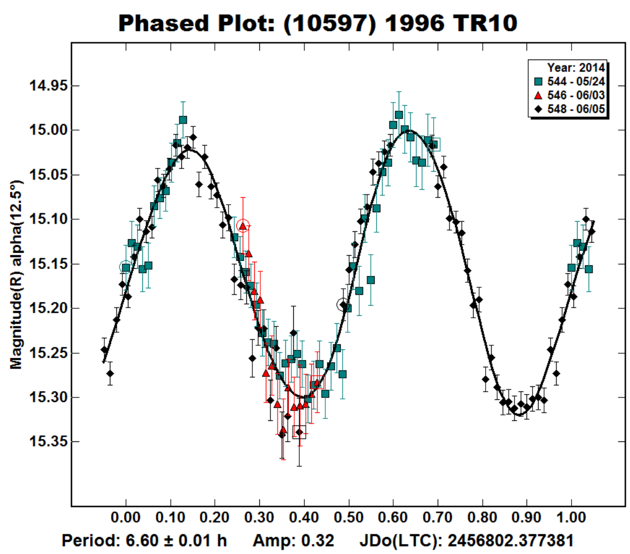
References

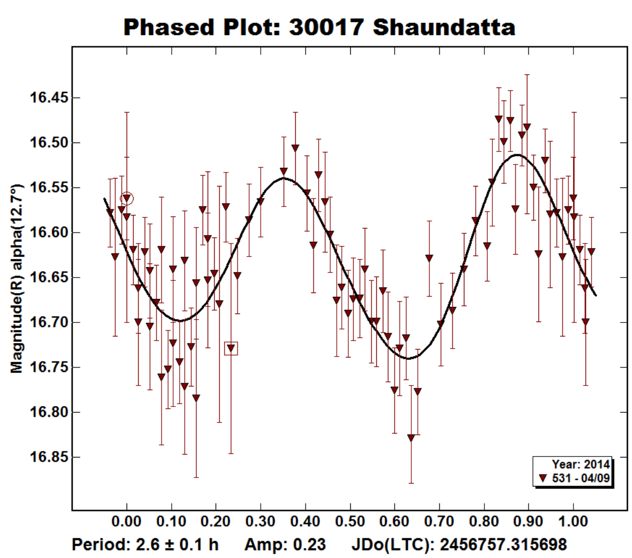
Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2013). MPO Software, *MPO Canopus* version 10.4.3.17. Bdw Publishing. *http://minorplanetobserver.com/*

Warner, B.D. (2014). "Potential Lightcurve Targets." *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*







A COMPREHENSIVE PHOTOMETRIC INVESTIGATION OF 185 EUNIKE

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We have reevaluated our previous photometric data sets of 185 Eunike for oppositions in the years 2010, 2011, and 2012, respectively, and have obtained new observations in 2014 Jan. - May. For each of these four years we draw period spectra which show deep minima only near 21.8 hours and the double period near 43.6 hours, and plot lightcurves phased to near 21.8 and 43.6 hours, respectively. For observation sets in each of the four years we find the available parts of the lightcurves phased to 43.6 hours and separated by 1/2 cycle to be identical within errors of observations, and conclude that the double period is ruled out. For the new observations in the year 2014 we find best fit to a lightcurve phased to 21.812 ± 0.001 hours with amplitude 0.08 ± 0.01 magnitudes. The absolute magnitude and the opposition parameter are H = 7.45 ± 0.01, G = 0.11 ± 0.02. The V-R color index was determined to be 0.36 ± 0.03. Both the color index and G value are compatible with a low albedo asteroid. The diameter is estimated to be D = 175 ± 33 km. The lightcurve inversion analysis shows a preliminary sidereal period/pole solution at Ps = 21.80634 ± 0.00012 h and (λ = 136°, β = 4°), (λ = 314°, β = -18°), with an error estimation of ± 30 degrees.

Debehogne et al. (1978) published a period of 10.83 hours based on rather sparse data. No further photometric observations were made for many years. In 2005 February – March two lightcurves were acquired by Behrend (2005) with no period estimation. In 2010 April - May dense data sets were by Ruthroff (2010), who suggested a period of 11.20 hours, and by Behrend (2010), who suggested a period of 21.807 hours. Ruthroff (2011) reevaluated his 2010 data and found them consistent also with 14.56 hours. Pilcher and Ruthroff (2012) examined these data again and found them consistent with a period of 21.80 hours. Another dense data set was obtained in 2011 June - August by Pilcher and Ruthroff (2012) who published a period of 21.797 hours. Still another data set was obtained in 2012 Nov. - Dec. by Hills (2013) who obtained a period of 21.777 hours. All of these investigations were with differential photometry only without comparison with catalog magnitudes. An examination of the lightcurve by Debehogne et al. (1978) suggests that their data are also compatible with twice their 10.83 hour period. It is noteworthy that the near 21.8 hour period found at all three oppositions, 2010, 2011, and 2012, features a somewhat wavy lightcurve with one maximum and minimum per cycle of approximately 21.8 hours. This suggests that the lightcurve form is dominated by hemispheric albedo variegation rather than the usual elongated shape.

In this paper the authors of all three of the data sets from the years 2010, 2011, and 2012, respectively, reevaluate their data. Additional observations were made 2014 Jan. 16 - May 4 by authors Pilcher, Franco, Hills, and Ruthroff. These new data used the Comparison Star Selector of *MPO Canopus* software and solar colored stars, which in addition to low noise lightcurves allowed a reliable H-G plot to be constructed and H and G parameters to be found. The first session 2014 Jan. 16 at phase angle 15.6 degrees showed an amplitude 0.10 magnitudes. Thirty additional sessions from 2014 Jan. 31 at phase angle 11.5 degrees pre-opposition to March 3 at minimum phase angle 2 degrees to May 4 at phase angle 18.0 degrees post-opposition all provide a good fit among sessions with full phase coverage for both a period of 21.812 ± 0.001 hours and the double period of 43.622 ± 0.001 hours. These data definitively ruled out all of the shorter periods. Unlike the lightcurves from the 2010, 2011, and 2012 oppositions, the usual bimodal behavior occurs, although with smaller amplitude only 0.08 ± 0.01 magnitudes and an unsymmetrical shape. We interpret the 0.10 magnitude amplitude 2014 Jan. 16 as due to the commonly occurring behavior among most asteroids of larger amplitudes at larger phase angles. Many of the sessions in 2014 April and May are of shorter time interval and do not cover a large enough section of the lightcurve to reveal any increase of amplitude which may have occurred with larger phase angle. They are valuable to extend the H-G plot to larger post-opposition phase angles but do not significantly improve the lightcurve.

Specifically for each year we present a separate period spectrum between 7 and 47 hours to cover all previously reported periods and also double the most likely period near 21.8 hours. Deep minima occur only near 21.8 hours and the double period of 43.6 hours, and all other reported periods are now ruled out. We also present for each of these three years new lightcurves based on a collection of all observations for each year and phased to both near 21.8 hours and 43.6 hours. To interpret the double period lightcurve we note the following. If 43.6 hours is twice the real period then segments of the lightcurve separated by phase 0.5 will be identical within errors of observation. This is noted for the available parts of all four 43.6 hour lightcurves. For the 2010 and 2011 lightcurves missing segments comprise less than 10% of the total lightcurve. For the 2012 lightcurve the sampling is less complete and the only available corresponding segments are those between phases 0.3-0.4 and 0.8-0.9, respectively. The 2014 lightcurve includes full phase coverage. All available evidence from all four years is therefore consistent with the hypothesis that 43.6 hours is the double period. An alternate interpretation that 43.6 hours is the real period requires a shape model highly symmetric over a 180 degree rotation which is extremely unlikely for a real asteroid.

The comparison stars for the sessions with clear and R band filter were calibrated to the R magnitude standard system, using the method described by Dymock and Miles (2009) and CMC-15 catalogue via VizieR Service (2014), while for the V band sessions the comparison stars were calibrated to the V magnitude standard system using the APASS catalogue. All the standardized clear and R band lightcurves were converted to the V band system adding the color index value V-R = 0.36 ± 0.03, obtained in the session of February 24, 2014 (Figure 14) and, for each lightcurve, the rotational effects, although small, was removed using Fourier fit model (Buchheim, 2010).

The absolute magnitude (H) and slope parameter (G) were found using the H-G calculator function of MPO Canopus. We have achieved H = 7.45 ± 0.01, G = 0.11 ± 0.02 (Figure 13). Both the color index and G value are compatible with a low albedo asteroid (Shevchenko and Lupishko, 1998). Note that our H value is quite different from H = 7.62, published on the JPL Small-Body Database Browser (JPL, 2014). The diameter is estimated to be D = 175 ± 33 km, assuming a geometric albedo pv = 0.06 ± 0.02 for C-type asteroid (Shevchenko and Lupishko, 1998) and using the formula by Pravec and Harris (2007). This value is consistent with other published values: 158 ± 3 km (IRAS), 168 ± 3 km (AKARI), 155 ± 5 km (WISE) and particularly close to 172 ± 7 km, obtained by occultations (Broughton, 2014).

The rotational lightcurve of 185 Eunike appears to be dominated by a hemispheric albedo dichotomy. This property is analogous to the hemispheric albedo dichotomy of 4 Vesta, as has been found from several independent investigations. Degewij et al. (1978) used polarimetry for the first verification that Vesta's monomodal 5.34 hour lightcurve is dominated by albedo. Drummond et al. (1988) used speckle interferometry to measure the hemispheric scale albedo variegations. Binzel et al. (1997) and Drummond et al. (1998) mapped these albedo variegations in greater detail with Hubble Space Telescope images and ground based adaptive optics images, respectively. The most detailed analysis of this 10% albedo variegation with global subkilometer scale Dawn spacecraft images has been published by Reddy et al. (2013).

Compared with the 570 x 570 x 460 kilometer triaxial dimensions of Vesta (Reddy et al. 2013), the diameter of 185 Eunike from WISE observations is only about 155 kilometers (Warner et al. 2014). This is, however, large enough that the Earth based techniques used for Vesta may be useful also for 185 Eunike. Polarimetry and speckle interferometry are hardly used nowadays, but adaptive optics imaging and narrow band spectroscopy extended over the full 21.8 hour rotational cycle should be highly productive. We recommend this procedure to all readers who may have access to the relevant equipment, especially at the 2016 September opposition. At this time Eunike will have geocentric distance 1.43 AU, nearly the minimum possible, and with a 155 kilometer diameter an angular size approximately 0.15 arcseconds.

Lightcurve Inversion

The not negligible number of lightcurves obtained so far at various phase angles and phase angle bisectors (table I), allow us to attempt the lightcurve inversion process. Figures 15, 16 show respectively PAB Longitude distribution and PAB Longitude/Latitude distribution for the entire dense data set used. The lightcurve inversion process was performed using MPO LCInvert v.11.1.0.2. Software (Bdw Publishing).

All data were imported in *LCInvert* for analysis, binning them at time interval of 15 minutes. The “dark facet” weighting factor was increased from 0.1 (default) to 0.8 to keep the dark facet area below 1% of total area, maybe due to the albedo variations. The number of iterations of processing was increased from 50 (default) to 100 for best convergence.

We have started the sidereal period search centered on the average of the synodic periods found in the years 2010, 2011, 2012 and 2014. The search process found a quite well isolated sidereal period of 21.80629277 h with lower chi-square value (Figure 17).

For pole search we have started using the "Medium" search option (312 fixed pole positions with 15° longitude-latitude steps) and the previously found sidereal period set to "float".

The data analysis does not show any isolated lowest chi-square values and additional sparse data from USNO Flagstaff does not bring any improvement, so we used only dense data. Therefore the found period/pole determination can not be considered very robust but only a preliminary solution.

The pole search found two cluster with similar lowest chi-square solution, centered around (λ = 135°, β = -30°) and (λ = 300°, β = 0°), within a radius of 30-40 degrees, see Figure 18 for log(chi-square) values distribution.

Refining the pole search again, using the "Fine" option (49 fixed pole steps with 10° longitude-latitude pairs) and the previous period/longitude/latitude set to "float", we found two best solutions at (λ = 136°, β = 4°), (λ = 314°, β = -18°) differing by 180° in longitude, with an averaged sidereal period Ps = 21.80634 ± 0.00012 h, obtained from the two previous solutions. The uncertainty in period has been evaluated as a rotational error of 30° over the total time-span of the observations.

Figures 19 and 20 show respectively the shape model (first solution) and the good fit agreement between the model (black line) and observed lightcurves (red points).

Acknowledgments

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Author	Year	#LCs	PA°	PABL°	PABB°
Debehogne	1977	2	12	97	-25
Behrend	2005	2	9/10	168/166	5/9
Behrend	2010	11	10/15	200	22
Ruthroff	2010	7	10/13	200	22
Pilcher	2011	5	12/9	292	22/20
Ruthroff	2011	5	11/13	292	19/18
Hills	2012	8	16/14	61/63	-30
Pilcher	2014	27	15/18	162/163	0/9

Table I. Observational circumstances for 186 Eunike over six apparitions, a total of 67 lightcurves were used for lightcurve inversion analysis. Where: PA, PABL and PABB are respectively the phase angle, phase angle bisector longitude and latitude.

References

Bdw Publishing (2013), *http://www.minorplanetobserver.com/MPOSoftware/MPOLCInvert.htm*

Behrend, R. (2005, 2010). Observatoire de Geneve web site *http://obswww.unige.ch/~behrend/page_cou.html*

Binzel, R.P., Gaffey, M.J., Thomas, P.T., Zellner, B.H., Storrs, A.D., Wells, E.N. (1997). "Geologic mapping of Vesta from 1994 Hubble Space Telescope images." *Icarus* **128**, 95-103.

Broughton J., (2014). *http://www.asteroidoccultation.com/observations/Asteroid_Dimensions_from_Occultations.html#Table1*

Dymock, R., Miles, R. (2009). "A method for determining the V magnitude of asteroids from CCD images." *J. Br. Astron. Assoc.* **119**, 149-156.

Debehogne, H., Surdej, J., Surdej, A. (1978). "Photoelectric lightcurves of the minor planets 29 Amphitrite, 121 Hermione, and 185 Eunike." *Astron. Astrophys. Suppl. Ser.* **32**, 127-133.

Degewij, J., Tedesco, E.F., Zellner, B.H. (1979). "Albedo and color contrasts on asteroid surfaces." *Icarus* **40**, 364-374.

Drummond, J., Eckart, A., Hege, E.K. (1988). "Speckle interferometry of asteroids." *Icarus* **73**, 1-4.

Drummond, J.D., Fugate, R.Q., Christou, J.C. (1998). "Full adaptive optics images of Asteroids Ceres and Vesta rotational poles and triaxial ellipsoid dimensions." *Icarus* **132**, 80-99.

Hills, K. (2013). "Asteroid Lightcurve Analysis at Riverland Dingo Observatory (RDO): 185 Eunike, (17252) 2000 GJ127, and (152858) 1999 XN35." *Minor Planet Bull.* **40**, 89-90.

JPL (2014). *http://ssd.jpl.nasa.gov/sbdb.cgi*

Pilcher, F., Ruthroff, J.C. (2012). "Rotation Period Determination for 185 Eunike." *Minor Planet Bull.* **39**, 13.

Pravec, P. Harris, A.W. (2007). "Binary Asteroid Population 1. Angular Momentum Content." Icarus **158**, 106-145.

Reddy, V., and 12 co-authors (2013). "Comparing Dawn, Hubble Space Telescope, and ground-based interpretations of (4) Vesta." *Icarus* **226**, 1103-1114.

Ruthroff, J.C. (2010). "Lightcurve Analysis of Main Belt Asteroids 185 Eunike, 567 Eleutheria, and 2500 Alascattalo." *Minor Planet Bull.* **37**, 158-159.

Ruthroff, J.C. (2011). "Lightcurve Analysis of Eight Main-Belt Asteroids and a Revised Period for 185 Eunike." *Minor Planet Bull.* **38**, 86-88.

Shevchenko V.G., Lupishko D.F. (1998). "Optical properties of Asteroids from Photometric Data", *Solar System Research* **32**, 220-232.

VizieR (2014). *http://vizier.u-strasbg.fr/viz-bin/VizieR*

Warner, B.D., Harris, A.W., Pravec, P. (2014). "Asteroid Lightcurve Data File, March 1, 2014." *http://www.minorplanet.info/lightcurvedatabase.html.*

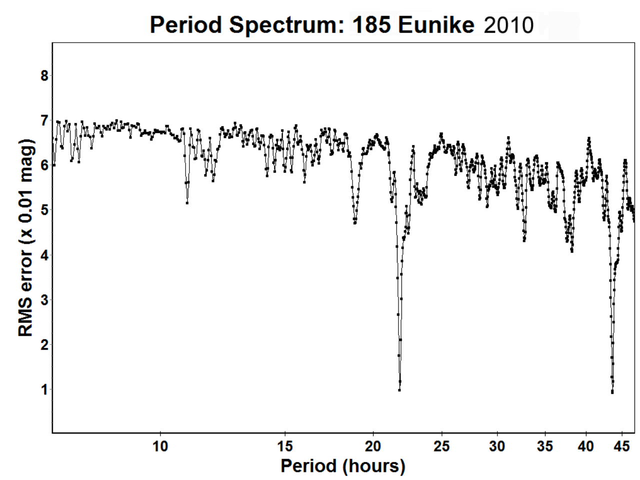

Figure 1. Period spectrum of year 2010 observations of 185 Eunike.

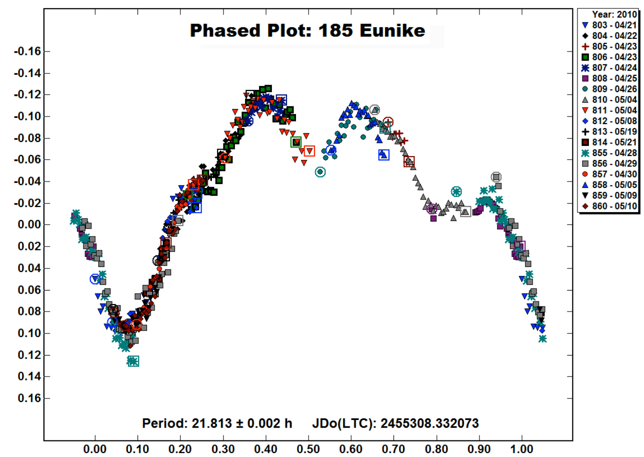

Figure 2. Year 2010 observations of 185 Eunike phased to a period 21.813 hours.

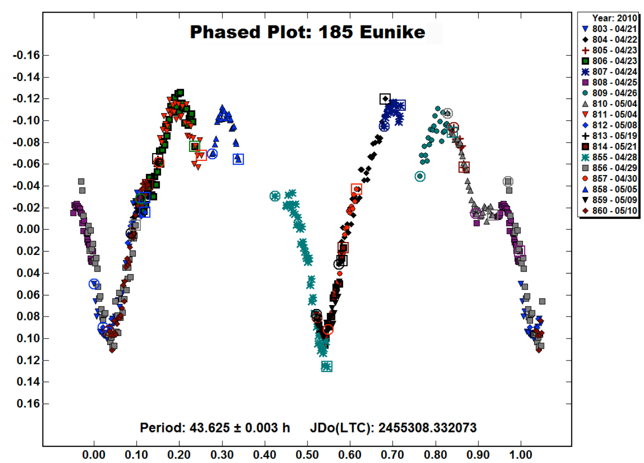

Figure 3. Year 2010 observations of 185 Eunike phased to the double period 43.625 hours.

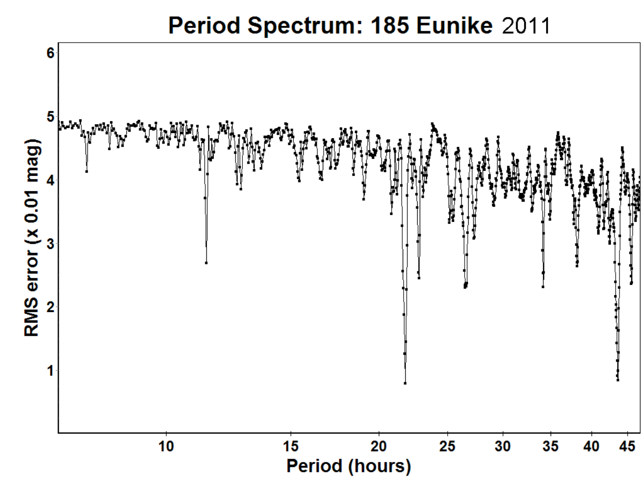

Figure 4. Period spectrum of year 2011 observations of 185 Eunike.

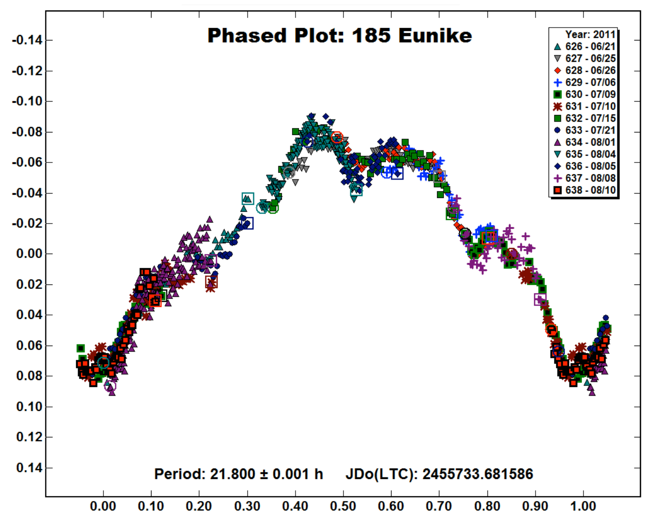

Figure 5. Year 2011 observations of 185 Eunike phased to a period 21.800 hours.

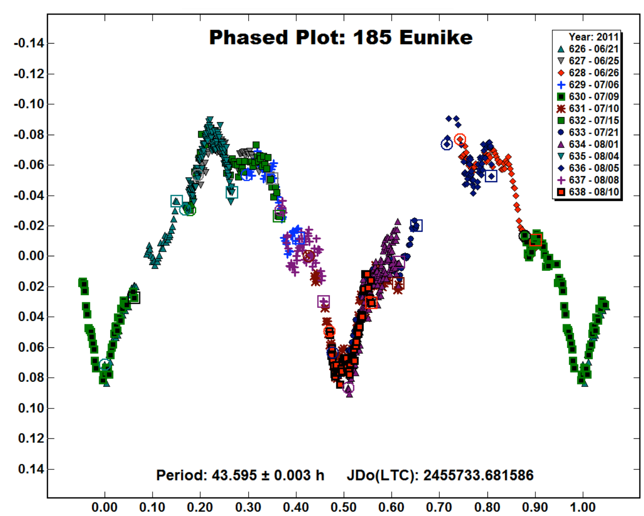

Figure 6. Year 2011 observations of 185 Eunike phased to the double period 43.595 hours.

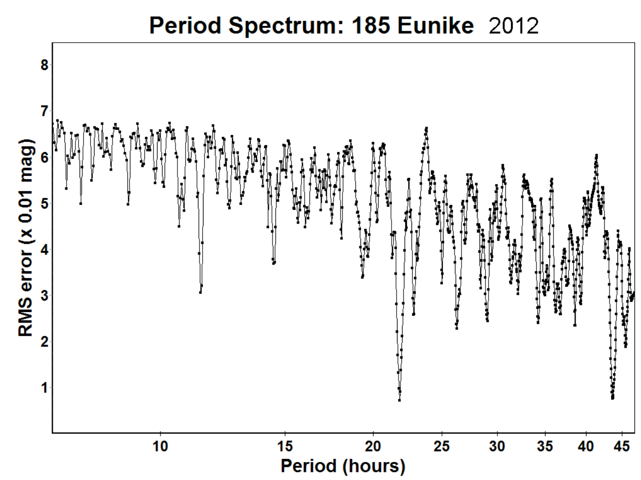

Figure 7. Period spectrum of year 2012 observations of 185 Eunike.

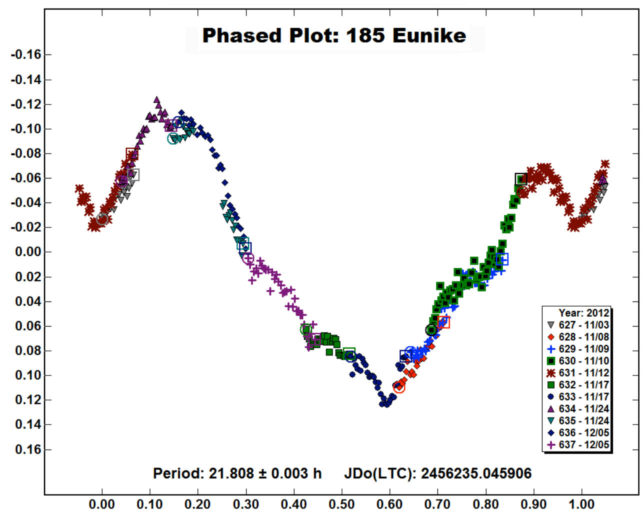

Figure 8. Year 2012 observations of 185 Eunike phased to a period 21.808 hours.

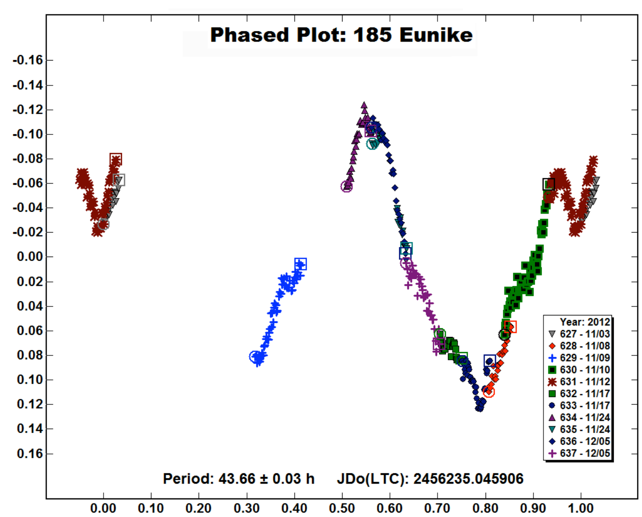

Figure 9. Year 2012 observations of 185 Eunike phased to the double period 43.66 hours.

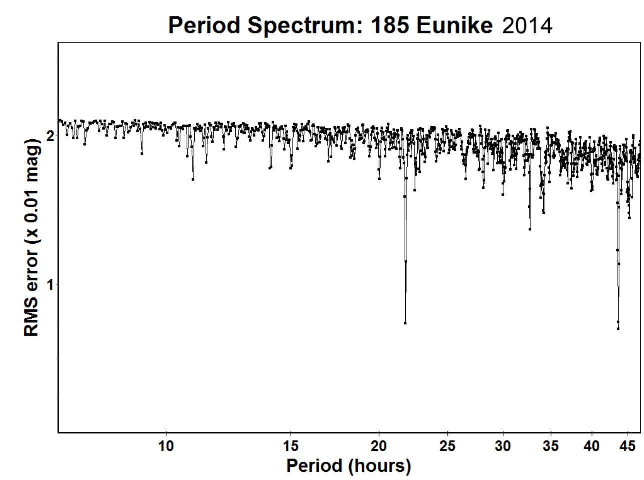

Figure 10. Period spectrum of year 2014 observations of 185 Eunike.

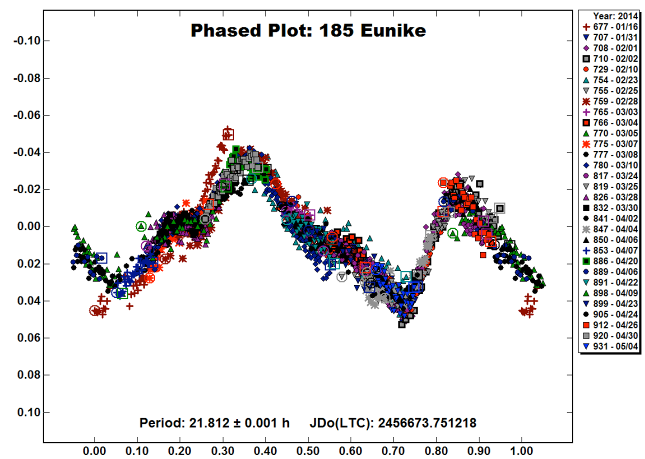

Figure 11. Year 2014 observations of 185 Eunike phased to a period 21.812 hours.

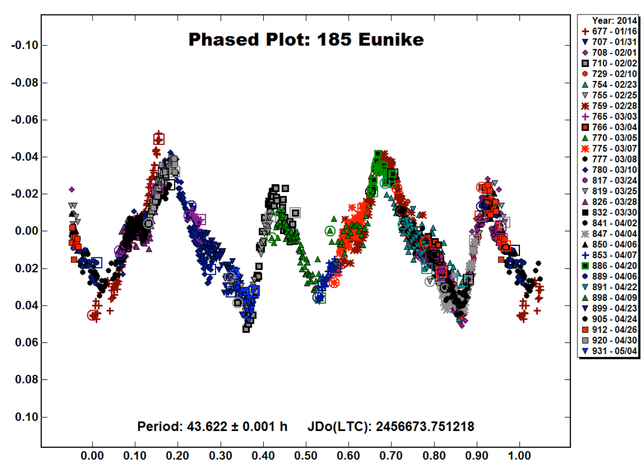

Figure 12. Year 2014 observations of 185 Eunike phased to the double period 43.622 hours.

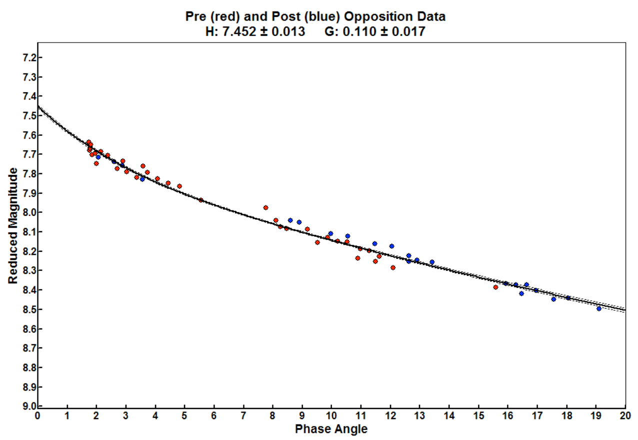

Figure 13. H-G plot of year 2014 observations of 185 Eunike converted to V magnitude system.

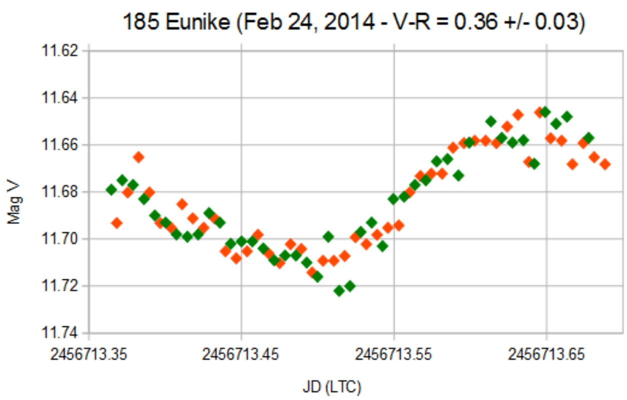

Figure 14. V and R lightcurve of 185 Eunike on 2014 Feb. 24.

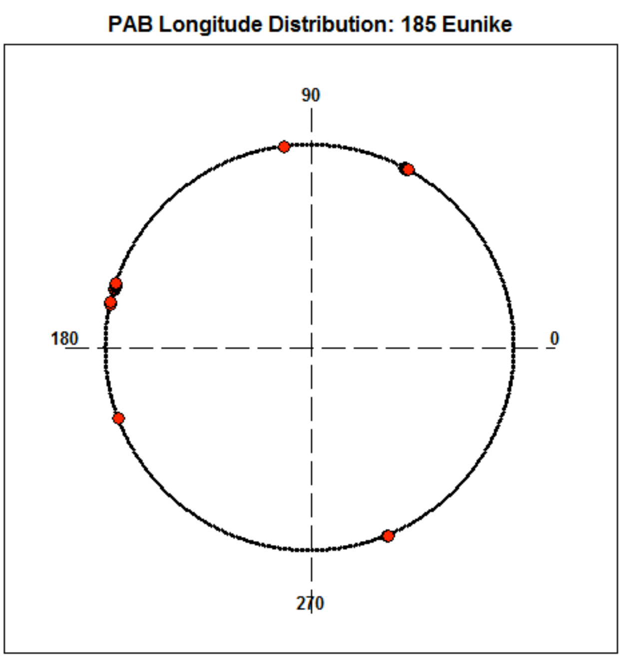

Figure 15. PAB Longitude distribution of the dense data used for lightcurve inversion model.

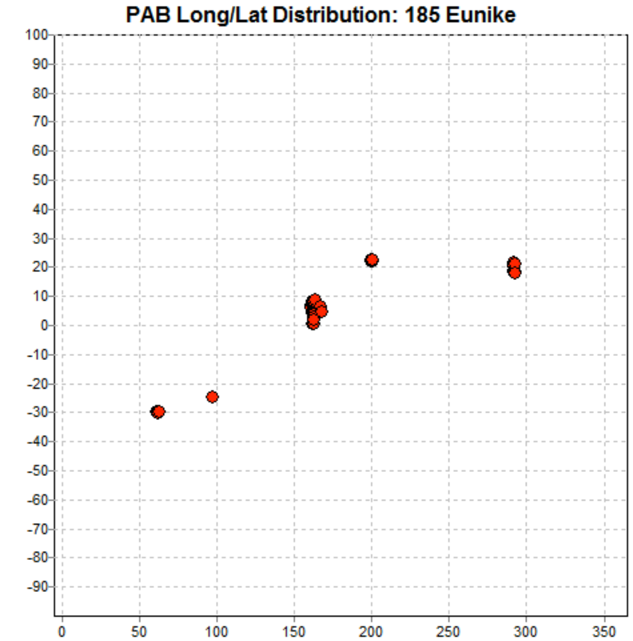

Figure 16. PAB Longitude and Latitude distribution of the dense data used for lightcurve inversion model.

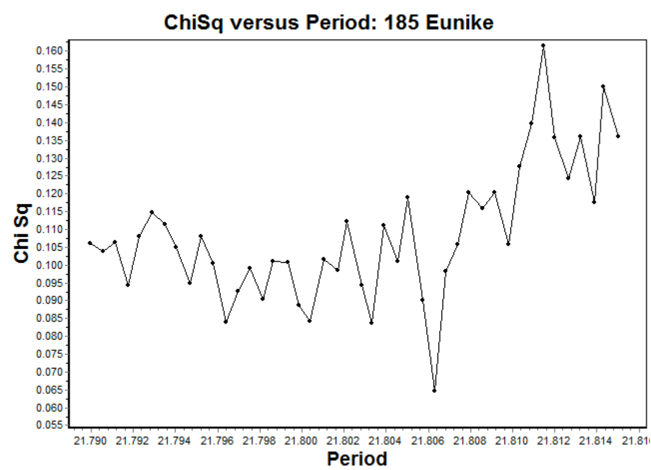

Figure 17. The period search plot from LCInvert shows a quite well isolated minimum at 21.80629277 h.

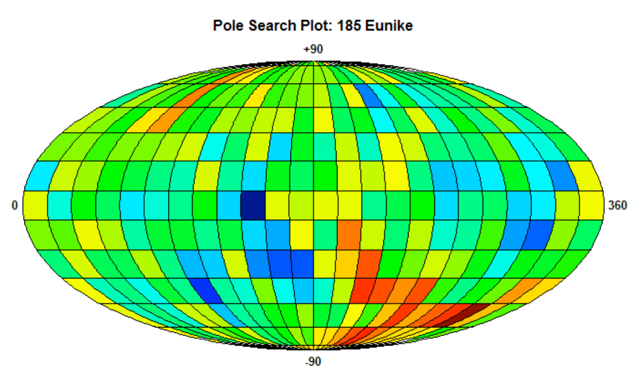

Figure 18. Pole Search Plot of log(ChiSq) values, where dark blue identify lower ChiSq values and Dark red underlying the worst solutions.

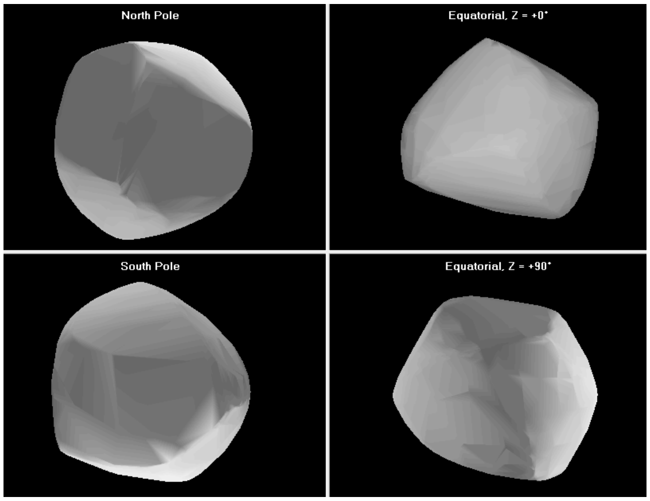

Figure 19. The shape model for 185 Eunike (λ = 136°, β = 4°).

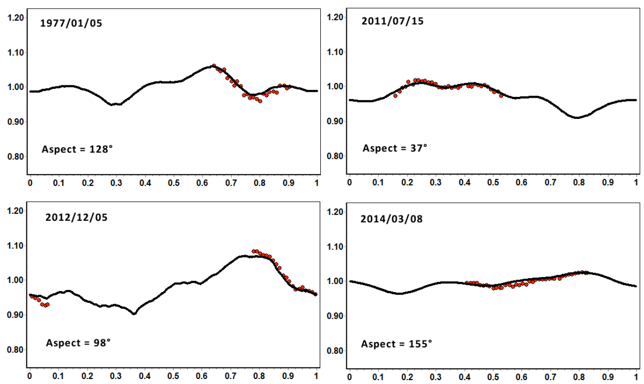

Figure 20. Comparison of model lightcurve (black line) versus a sample of four observed lightcurves (red points).

ROTATION PERIOD DETERMINATIONS FOR 24 THEMIS, 65 CYBELE, 108 HECUBA, 530 TURANDOT, AND 749 MALZOVIA

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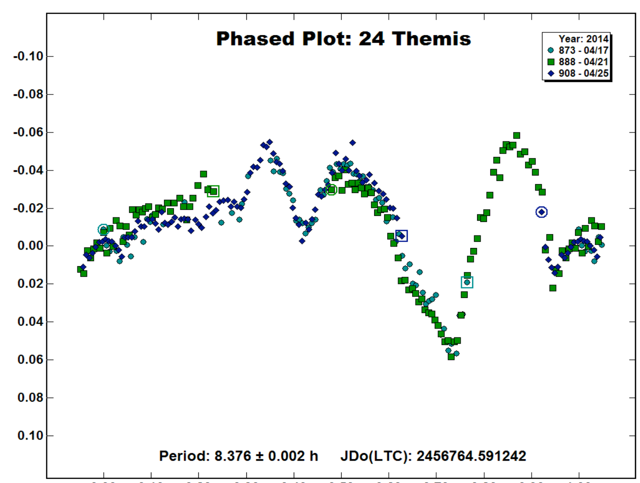
CCD photometric observations were made of five main-belt asteroids: 24 Themis, 65 Cybele, 108 Hecuba, 530 Turnadot, and 749 Malzovia. These were used to determine the synodic rotation period of the asteroids and their lightcurve amplitudes. In the cases of 108 Hecuba and 530 Turnadot, the results were able to exclude some periods previously reported by other authors.

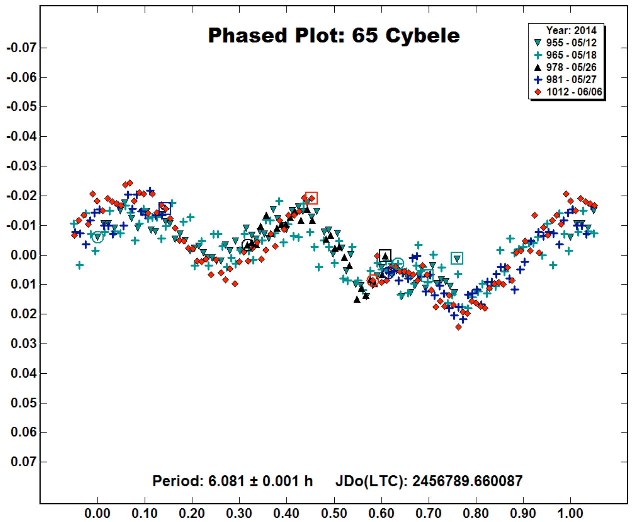
Reported here are CCD photometric observations of five main-belt asteroids that were made at the Organ Mesa Observatory with a 0.35-m Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001-E CCD. Photometric measurement and lightcurve construction were made with *MPO Canopus* software. All exposures were 60 sec, unguided, and used a clear filter. 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 of 5 minutes. In all cases, the lightcurve of the double period has been examined and shows complete or nearly complete phase coverage with the two halves almost the same, and may be safely rejected.

24 Themis. The asteroid lightcurve database (LCDB; Warner *et al.*, 2009) states a secure period of 8.374 hours based on several independent and consistent investigations. New data were obtained on 3 nights, 2014 Apr 17-25, to contribute toward a lightcurve inversion solution. They show a period of 8.376 ± 0.002 hours, amplitude 0.10 ± 0.01 magnitudes, which is consistent with previous studies.

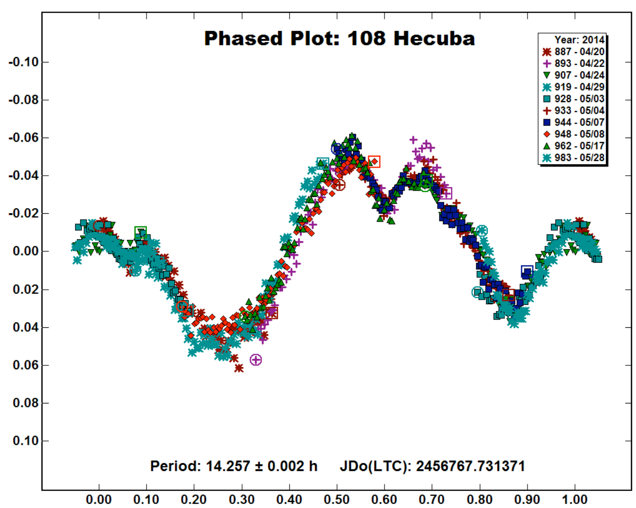


65 Cybele. The LCDB (Warner *et al*., 2009) states a secure period of 6.0814 hours based on several independent and consistent investigations. A period near 4.03 hours suggested by several other studies listed in this reference is now ruled out. New data were

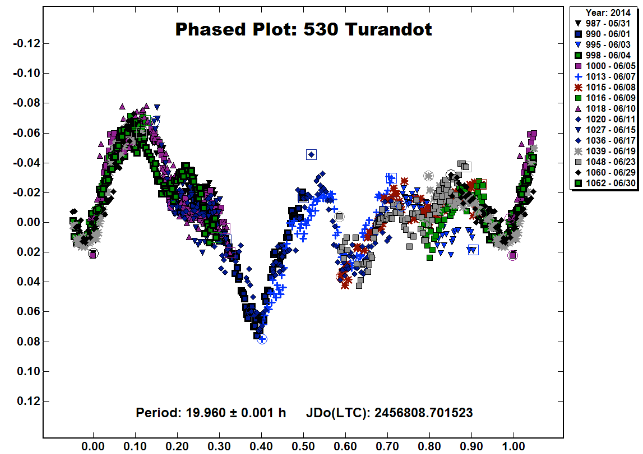
obtained on 5 nights, 2014 May 12 - June 6, to contribute toward a lightcurve inversion solution. They show a period of 6.081 ± 0.001 hours, amplitude 0.03 magnitudes, which is consistent with previous studies.



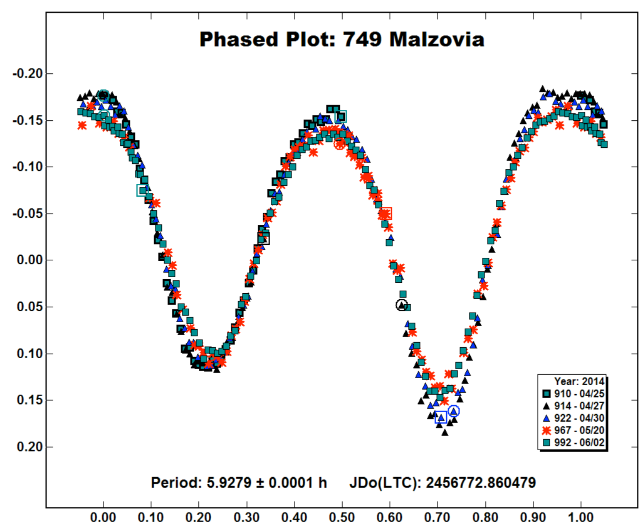
108 Hecuba. Previous period determinations are by Behrend (2005; 19.8 hours), Blanco *et al*. (1994; 14.46 hours), Warner (2007; 17.859 hours), and Pilcher (2013; 14.256 hours). New observations on 10 nights from 2014 Apr 20 - May 28 provide a good fit to a lightcurve with period 14.257 ± 0.001 hours and amplitude 0.09 ± 0.01 magnitudes. Among the previous period determinations, this is consistent with Blanco *et al*. (1994) and with Pilcher (2013).



530 Turandot. Previous period determinations are by Behrend (2002; 19.95 hours), Behrend (2005; 19.947 hours), and Di Martino *et al.* (1995; 10.77 hours). New observations on 16 nights from 2014 May 31 - June 30 provide a moderately good fit to an irregular lightcurve phased to 19.960 ± 0.001 hours, amplitude 0.13 ± 0.01 magnitudes. This is consistent with Behrend (2002) and Behrend (2005), but not with Di Martino *et al*. (1995). The lightcurve contains many small irregularities of amplitude near 0.02 magnitudes or smaller. The target was traveling through a dense Milky Way star field. Although star subtraction routines were used in the measurement process, these are often less than complete and some very faint stars may have been overlooked. Larger misfits are found in the descending part of the lightcurve between phases 0.2 and 0.3, which are probably caused by the usual changes in lightcurve shape with phase angle. Examination of other local minima in the period spectrum between 8 and 48 hours show that periods other than 19.960 hours and the double period can be ruled out. The same small misfits in the 19.960 hour lightcurve are also found in the double period lightcurve. Because the two sides of the double period lightcurve look almost the same, and the lightcurve is irregular, the double period may also be safely rejected. Therefore I claim that the 19.960 hour period is secure.



749 Malzovia. The LCDB (Warner *et al*., 2009) shows no previous observations. New observations on 5 nights from 2014 Apr 25 - June 2 provide a good fit to a lightcurve phased to 5.9279 ± 0.0001 hours and amplitude 0.30 ± 0.03 magnitudes.



References

Behrend, R. (2002, 2005). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Blanco, C., Di Martino, M., Lazzarin, M., Cellino, A., Riccioli, D. (1994). "A Physical Study of the Asteroid 108 Hecuba." in *Seventy-five (75) years of Hirayama asteroid families: The role of collisions in the solar system history."* (Kozai, Y, Binzel, R.P., and Hirayama, T., eds.). *ASP Conf. Ser.* **63**, pp 280-285.

Di Martino, M., Dotto, E., Celino, A., Barucci, M.A., Fulchignoni, M. (1995). “Intermediate size asteroids: Photoelectric photometry of 8 objects.” *Astron. Astrophys. Suppl. Ser.* **112**, 1-7.

Pilcher, F. (2013). “Rotation Period Determinations for 102 Miriam, 108 Hecuba, 221 Eos, 255 Oppavia, and 745 Mauritia, and a note on 871 Amneris.” *Minor Planet Bull.* **40**, 161-163.

Warner, B.D. (2007). “Asteroid Lightcurve Analysis at the Palmer Divide Observatory – December 2006 – March 2007.” *Minor Planet Bull.* **34**, 72-77.

Warner, B.D., Harris, A.W., Pravec, P. (2009). “The asteroid lightcurve database.” *Icarus* **202**, 134-146. Updated 2014 Mar 1. *http://www.minorplanet.info/lightcurvedatabase.html*

ROTATION PERIODS AND *R* MAGNITUDES OF THREE KORONIS FAMILY MEMBERS

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(Received: 8 July)

We report synodic rotation periods for three Koronis family asteroids: 1443 Ruppina, 5.880 ± 0.001 h; 1848 Delvaux, 3.639 ± 0.001 h; and 2144 Marietta, 5.489 ± 0.001 h.

Koronis family asteroids 1443 Ruppina, 1848 Delvaux, and 2144 Marietta were observed at Whitin Observatory in Wellesley, Massachusetts between 2014 February and April. The observations were made in order to determine the asteroids’ *R* magnitudes and rotation periods, specifically in support of future spin vector determinations.

Observations

Ruppina, Delvaux, and Marietta were observed for three nights over spans of 13, 18, and 40 nights, respectively, following the observing principles described by Slivan *et al*. (2008). Table I presents a summary of the observing circumstances. The images were taken on a 2048-pixel square back-illuminated CCD camera with a 2x2 binned e2v detector. The scale was 1.2 arc seconds per pixel using Whitin Observatory’s 0.61-m Sawyer telescope. Lightcurve image integrations of 240 s were collected using an *R* filter. The *IRAF* software package was used for bias level and dark signal subtraction and twilight field flattening as well as for measuring instrumental magnitudes using synthetic aperture photometry. The standard uncertainties of the lightcurves, with respect to the on-chip comparison stars, were estimated from the RMS dispersion of the differential brightness of non-variable on-chip field stars of comparable brightness to the asteroid.

To determine *R* magnitudes, we used the simplified method for standard star calibration described by Binzel (2005) and Neugent and Slivan (2008). On one night of each object’s lightcurve observations, we included a standard star from Landolt (1992). Prior to the observations, the “airmass plot calculator” application at the Web site *http://www.koronisfamily.com* was used to determine the times at which the asteroid and its comparison star were at the same airmass as the standard star.

Analysis

To determine the rotation periods from on-chip differential photometry, light-time corrections were applied and then features were matched by inspection as described by Slivan *et al.* (2008). Each object’s period estimate was then refined using a Fourier series model to the folded composite lightcurve shape including all data, while adjusting the nightly brightness zero points to best match the calibrated *R* lightcurves until the overall RMS residual was minimized. Our rotation period results are summarized in Table II, which lists the derived periods with their uncertainties. Amplitude ranges were calculated by using the brightness of the Fourier series model primary and secondary extrema.

Results

The observing program reached its goals of independently checking the periods for Ruppina, Delvaux and Marietta. It also improved the previously determined period for Marietta. All three rotation periods are well within the wide range of values, 3 - 60 h, known of other Koronis family members (Slivan *et al*., 2008; Fig. 71). Figures 1-3 show the composite lightcurves for 1443 Ruppina, 1848 Delvaux, and 2144 Marietta respectively. The error bars represent the estimated one-sigma uncertainty with respect to the local comparison star used. Each graph spans a vertical scale of one magnitude. Nights of relative lightcurve data have been shifted in brightness for best fit to the standard *R* calibrated lightcurves.

1443 Ruppina. During the 2014 apparition of Ruppina, lightcurves were obtained between phase angles 3°-13°. Observations from UT February 26 spanned 6 hours, which allowed us to determine a rotation period of 5.880 h. Analysis of all three nights of data gathered over the 13-night apparition span determined a rotation period of 5.880 ± 0.001 h. This agrees with the previously determined period obtained by Neugent and Slivan (2008).

1848 Delvaux. We observed Delvaux on three nights during its 2014 apparition between phase angles 1°-4°. Data from March 7 spanned 4 hours, leading to a straightforward initial period determination of 3.639 h. Analysis of data from three nights yields a rotation period of 3.639 ± 0.001 h, which is consistent with the previously determined period from Slivan *et al.* (2008) as well as the unpublished values reported by Behrend (2004, 2011).

(2144) Marietta. Three nights of observations yielded a rotation period of 5.489 ± 0.001 h. This is consistent with the less precise previous measurement of a 5.489 ± 0.006 h made by Slivan *et al*. (2008), and significantly shorter than the provisional result reported by Behrend (2010). Marietta was observed at phase angles 4°-16° during its 2014 apparition.

The data for all of these objects eventually will be used for spin vector and shape modeling. In order to obtain reliable spin vector results, observations from at least five to six different viewing aspects need to be collected. Our images provide data for the second apparition of 1443 Ruppina, the sixth apparition of 1848 Delvaux, and the fifth apparition of 2144 Marietta in Dr. Stephen Slivan's Koronis family spin vector solution program.

Acknowledgements

We thank Stephen M. Slivan for his advice and encouragement, as well as the corps of loyal observers who assisted with data collection: Kirsten Blancato, Michaela Fendrock, and Carolyn Thayer.

References

Behrend, R. "Courbes De Rotation D'astéroïdes Et De Comètes, CdR." *http://obswww.unige.ch/~behrend/page_cou.html*.

Binzel, R.P. (2005). "A simplified method for standard star calibration." *The Minor Planet Bulletin.* **32,** 93-95.

Binzel, R.P., Slivan, S.M., Magnusson, P., Wisniewski, W.Z., Drummond, J., Lumme, K., Barucci, M.A., Dotto, E., Angeli, C., Lazzaro, D., and 9 coauthors (1993). "Asteroid 243 Ida: Groundbased Photometry and a Pre-Galileo Physical Model." *Icarus* **105**, 310-325.

Lagerkvist, C.-I. (1978). "Photographic photometry of 110 main belt asteroids." *Astron. Astrophys. Suppl. Ser.* **31**, 361-381.

Neugent, K.F., Slivan, S.M. (2008). "Rotation Periods and *H* Magnitudes of Two Koronis Family Members." *The Minor Planet Bulletin.* **35**, 116-118.

Slivan, S.M. (2002). "Spin vector alignment of Koronis Family asteroids." *Nature* **419**, 49-51.

Slivan, S.M., Binzel, R.P., Boroumand, S.C., Pan, M.W., Simpson, C.M., Tanabe, J.T., Villastrigo, R.M., Yen, L.L., Ditteon, R.P., Pray, D.P., Stephens, R.D. (2008). "Rotation Rates in the Koronis Family, Complete to H ≈ 11.2." *Icarus* **195**, 226-276.

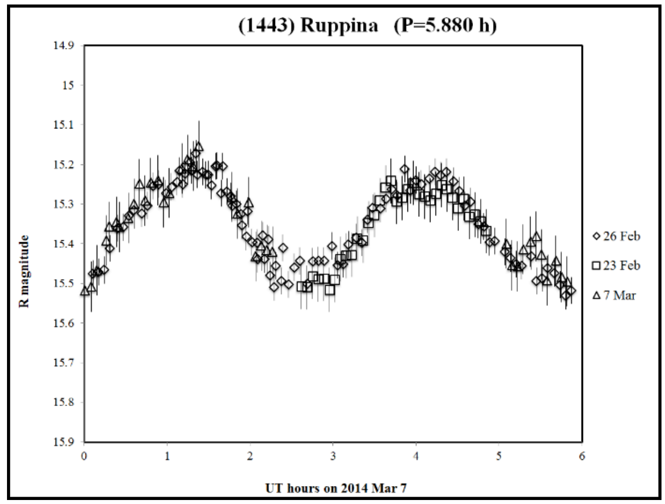

Figure 1. Composite lightcurve for (1443) Ruppina. The error in the photometric calibration to the standard R magnitude scale is ± 0.02.

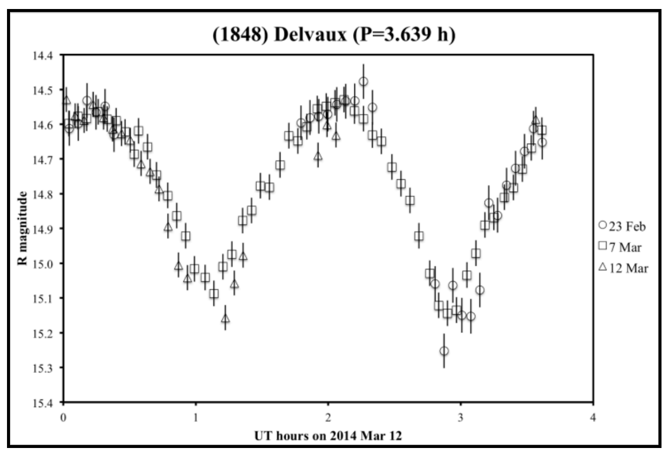

Figure 2. Composite lightcurve for (1848) Delvaux. The error in the photometric calibration to the standard R magnitude scale is ± 0.09.

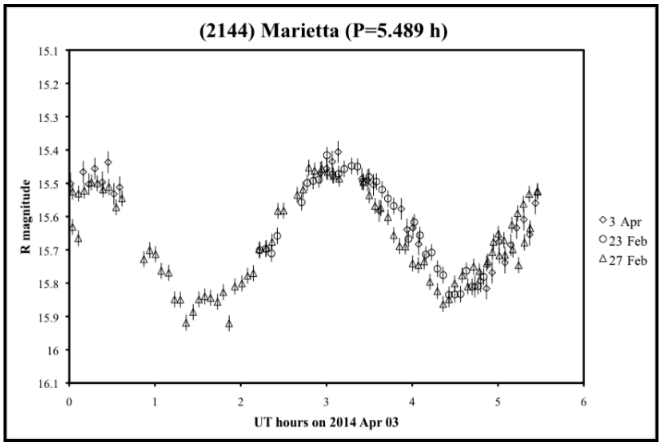

Figure 3. Composite lightcurve for (2144) Marietta. The error in the photometric calibration to the standard R magnitude scale is ±0.02.

Asteroid	UT Date	λ (PAB) (°)	β (PAB) (°)	α(°)	Observer(s)
(1443) Ruppina	23 Feb	146.8	-1.1	2.8	Slivan, Yazdi
(1443) Ruppina	26 Feb	146.8	-1.0	3.9	Slivan, Hartt
(1443) Ruppina	07 Mar	146.7	-1.0	7.1	Hartt, Thayer
(1848) Delvaux	23 Feb	163.1	-0.3	3.6	Slivan
(1848) Delvaux	07 Mar	163.0	-0.4	1.3	Arredondo, Fendrock
(1848) Delvaux	12 Mar	162.9	-0.4	3.3	Arredondo, Thayer
(2144) Marietta	23 Feb	146.7	0.4	3.9	Slivan, Yazdi
(2144) Marietta	27 Feb	147.5	0.4	5.5	Yazdi, Blancato
(2144) Marietta	03 Apr	154.5	0.8	16.4	Yazdi, Blancato

Table I. Observing Circumstances. UT dates are in year 2014. λ and β are J2000.0 ecliptic longitude and latitude of the phase angle bisector respectively, and α is the solar phase angle.

Asteroid	H	Synodic Period (h)	Amplitude (mag)
(1443) Ruppina	11.40	5.880 ± 0.001	0.27-0.34
(1848) Delvaux	11.24	3.639 ± 0.001	0.49-0.62
(2144) Marietta	11.37	5.489 ± 0.001	0.32-0.42

Table II. Lightcurve period and amplitude results. Values for H given by Slivan et al. (2008). The subjective confidence code Q as used by Lagerkvist et al. (1989) is 3 "no ambiguity" for all three periods.

PERIOD DETERMINATION FOR 398 ADMETE: THE LOWEST NUMBERED ASTEROID WITH NO PREVIOUSLY KNOWN PERIOD

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Lightcurve analysis for 398 Admete was performed using observations during its 2014 opposition. The synodic rotation period was found to be 11.208 ± 0.001 h and the lightcurve amplitude was 0.13 ± 0.02 mag.

398 Admete is a main-belt asteroid discovered in 1894 by Auguste Charlois in Nice (France). It appeared on the CALL web site as an asteroid photometry opportunity due to it reaching a favorable apparition in 2014 and having no defined lightcurve parameters.

Unfiltered CCD photometric images were taken at Observatorio Los Algarrobos, Salto, Uruguay (MPC Code I38) in 2014 from May 27 to July 7. The telescope was a 0.3-m Meade LX-200R reduced to *f*/6.9. The imager was a QSI 516wsg NABG (non-antiblooming gate) with a 1536x1024 array of 9-micron pixels and 23x16 arcminute field-of-view. The exposures increased from 120 to 210 seconds as the asteroid faded past-opposition (May 10). 2x2 binning was used, yielding an image scale of 1.77 arcseconds per pixel. The camera was set to –15° C and off-axis guided by means of an SX Lodestar camera and *PHD Guiding* (Stark Labs) software. Image acquisition was done with *MaxIm DL5* (Diffraction Limited). The computer was synchronized with atomic clock time via Internet NTP servers at the beginning of each session.

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

More than 85 hours of effective observation along 19 sessions and about 2,140 data points were required in order to solve the noisy and essentially flat lightcurve. Over the span of observations, the phase angle varied from 6.0º to 15.7º, the phase angle bisector ecliptic longitude from 231.0º to 230.8º to 231.9º, and the phase angle bisector ecliptic latitude from –8.4º to –6.9º. The rotation period for 398 Admete was determined to be 11.208 ± 0.001 h along with a peak-to-peak amplitude of 0.13 ± 0.02 mag. The period spectrum also showed another plausible solution at 22.4 h (twice the adopted period), although slightly mathematically worse than the chosen period. No clear evidence of tumbling or binary companion was seen in the lightcurve.

At the time of this study 398 Admete happened to be the lowest numbered asteroid for which no rotation parameters were found in the literature. For those numbered below 500, only one remains in such condition (457 Alleghenia), and from 501 to 1000, 22 still have no reported rotation period. This is a dramatic reduction from just two years ago (Alvarez, 2012). However, even in cases where low numbered asteroids do have reported lightcurve parameters, not all of these period determinations are secure (i.e., U < 3) and ongoing investigations to verify, refine, or revise their values remains an important and pending endeavor.

Acknowledgements

Given the shallow amplitude and noisy data, the author found trouble with the proper resolution of this challenging target. Thanks to Brian D. Warner for a fruitful exchange of emails and wise advices, from which it was finally possible to shed light on this subject.

References

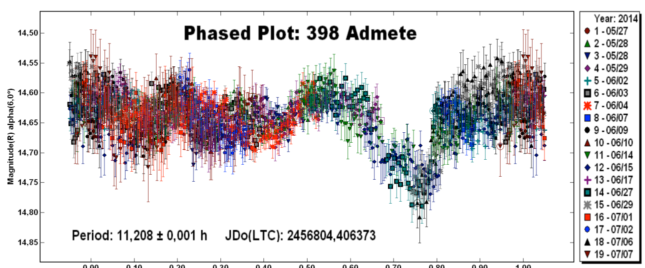
Alvarez, E. M. (2012). "Period Determination for 414 Liriope." *Minor Planet Bulletin* **39**, 21-22.

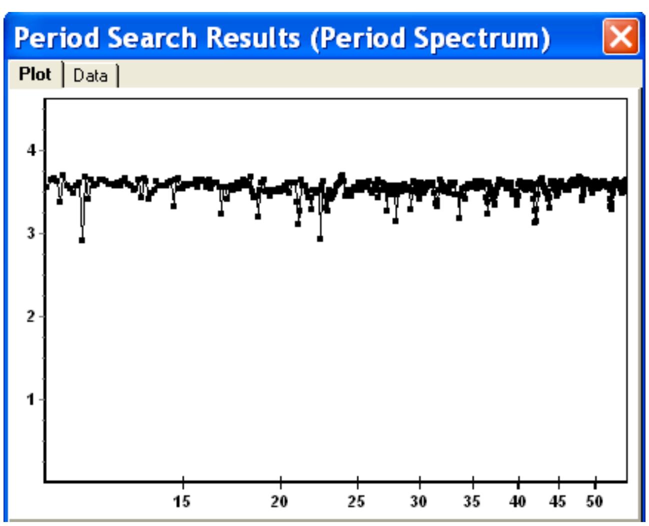
Collaborative Asteroid Lightcurve Link (CALL) Web Site at *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*

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, Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Stephens, R.D. (2008). "Long Period Asteroids Observed from GMARS and Santana Observatories." *Minor Planet Bul*. **35**, 21-22.

Warner, B.D. (2007). "Initial Results from a Dedicated H-G Project." *Minor Planet Bul*. **34**, 113-119.





ROTATIONAL PERIOD OF ASTEROID 12282 CROMBECQ

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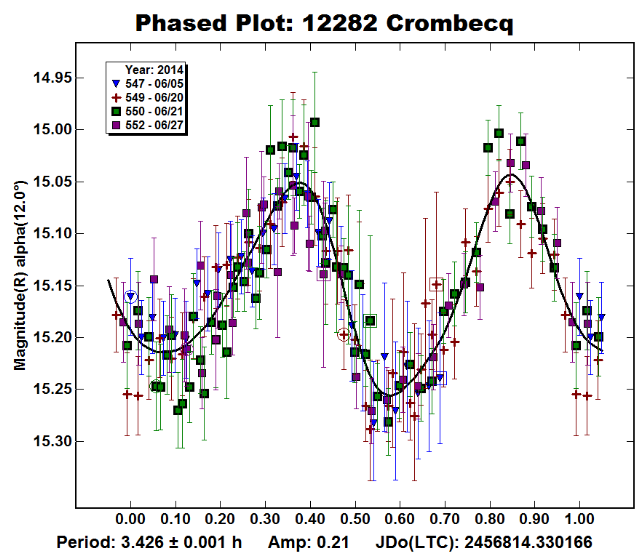
Photometric observations of main-belt asteroid 12282 Crombecq were made over four nights in 2014 June. Lightcurve analysis shows a synodic period of 3.426 ± 0.001 h with an amplitude of 0.21 ± 0.04 mag.

The main-belt asteroid 12282 Crombecq was selected from the "Potential Lightcurve Targets" web site (Warner, 2013a). Observations on four nights in 2014 June were carried out from Balzaretto Observatory (A81) in Rome, Italy, using a 0.20-m Schmidt-Cassegrain (SCT) reduced to *f*/5.5 and an SBIG ST7-XME CCD camera. All unfiltered images were calibrated with dark and flat-field frames. Differential photometry and period analysis was done using *MPO Canopus* (Warner, 2013b).

The derived synodic period was P = 3.426 ± 0.001 h with an amplitude of A = 0.21 ± 0.04 mag.



References

Warner, B.D. (2013a). "Potential Lightcurve Targets." *http://www.MinorPlanet.info/PHP/call_OppLCDBQuery.php*

Warner, B.D. (2013b). MPO Software. *MPO Canopus* version 10.4.3.17. Bdw Publishing. *http://minorplanetobserver.com/*

AN UPDATED PERIOD DETERMINATION FOR 772 TANETE

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CCD photometric observations of main-belt minor planet 772 Tanete were made during its favorable opposition from 2014 April-June. Analysis of the data found a synodic period of 17.258 ± 0.001 h.

772 Tanete is a main belt asteroid, discovered in 1913 by A. Massinger at Heidelberg and named after the city of Tanete on the southwest coast of Celebes, Indonesia (Schmadel, 2003). The asteroid was selected from Brian Warner's Collaborative Asteroid Lightcurve Link (CALL) site's Lightcurve Targets list (Warner, 2014).

CCD photometric observations of the asteroid were made at the Lenomiya Observatory using a Celestron CPC1100 0.28-m Schmidt-Cassegrain operating at *f*/6.3 using a focal reducer. The camera was an SBIG ST-8XME set to –17° C and binned 2x2. This resulted in an array of 765x510 18-micron pixels and a scale of 1.92 arcsec/pixel. All exposures were unfiltered and guided and ranged from 30 to 50 s based on atmospheric conditions brightness of the asteroid.

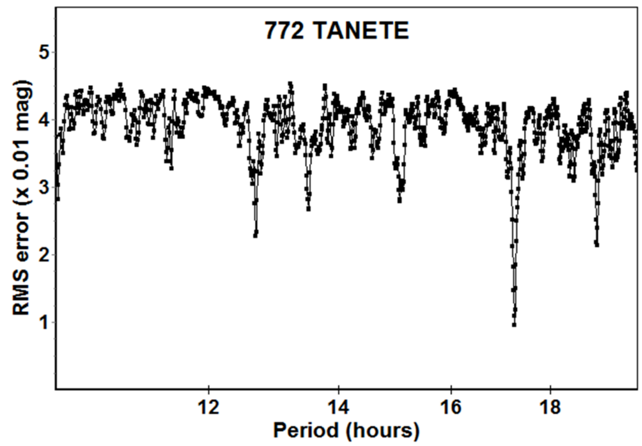
The 3,402 images were dark and flat-field corrected using *CCDSoft* version 5.00.205. Differential photometry using up to five comparison stars of near-solar color was used to obtain the magnitude of the asteroid on each image. The data were light-time corrected prior to period analysis, which was done with *MPO Canopus* version 10.4.4.0 (Warner, 2014), which incorporates the Fourier period analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989).

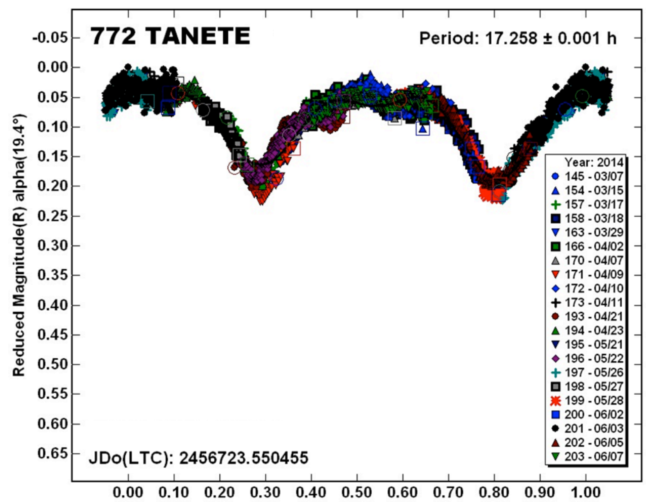
Tanete was independently observed at the Bigmuskie Observatory during 2014 March-April (Ferrero, 2014) where the equipment was a 0.30-m Ritchey-Chretien telescope coupled to an SBIG ST-9 CCD camera. The 512x512x 20-micron pixel array produced a field-of-view of about 15x15 arcmin and a scale of 1.7 arcsec/pixel. Photometric reductions and measurements were done with *MPO Canopus* version 10.4.3.17. The most probable period found after ten sessions was 8.629 ± 0.001 h with an amplitude of 0.18 mag.

Shortly before submitting his results for publication, Martinez was advised by Frederick Pilcher (private communications) that Ferrero had already submitted his results to the *Minor Planet Bulletin* with a different period. This prompted the authors to form a collaboration by merging the two data sets for additional analysis. It soon became evident that the period of 8.629 h was about the semi-period of the true period. Because the period was nearly commensurate with an Earth day, nearly the same part of the lightcurve was observed from a given station on succeeding nights. Merging all the sessions from the two observatories located in opposite hemispheres led to a final solution of 17.258 ± 0.001 h and an amplitude of 0.15 mag.

Observer	Sessions
Martinez	193,194,195,196,197,198,199,200,201, 202,203
Ferrero	145,154,157,158,163,166,170,171,172, 173

Table I. Observing sessions per observer (see lightcurve plot). Observations by Ferrero used an R filter while Martinez used a clear filter.





A search of the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009), the NASA Astrophysics Data System (ADS), and other sources revealed an earlier period determination by Behrend (2006) of 11.8 hours and a tentative estimation of 12 hours or longer by L. Bogan (1994). Bogan's estimate was based on only 6 hours of observations. The period spectrum, a plot of the RMS residual values versus the period, shows two possible solutions near 13 hours and 17 hours, with 17 hours being the best fit. Analysis of the data found a bimodal lightcurve with a period of 17.258 ± 0.001 h and amplitude of 0.15 ± 0.01 mag. Individual sessions spanned the complex section of the lightcurve, ruling out any trimodal or monomodal fit.

Acknowledgments

The author wishes to express gratitude to Frederick Pilcher for his support and helpful suggestions on the *MPO Canopus* software, and period determination for asteroid 772 Tanete.

References

Behrend, R. (2006). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page_cou.html*

Bogan, L., Robb, R., Balam, D.D. (1994). "The Lightcurves of the Asteroids 198 Ampella 481 Emita and 772 Tanete." *J. Royal Ast. Soc. Canada* **88**, 55.

Ferrero, A. (2014). "Photometric Determination of Six Main Belt Asteroids." *Minor Planet Bul.* **41**, 184-185.

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, Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Schmadel, L.D. (2003). *Dictionary of Minor Planets* (5th ed., p. 146). New York: Springer. *http://books.google.com/books*

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

Warner, B.D. (2014). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

Warner, B.D. (2014). MPO Software. *MPO Canopus* version 10.4.4.0. Bdw Publishing. *http://minorplanetobserver.com*

ROTATION PERIODS AND LIGHTCURVES FOR SIX NEAR-EARTH ASTEROIDS

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The lightcurves and synodic rotation periods for six near-Earth asteroids observed in the period 2013 October to 2014 June are presented.

Photometric observations of six near-Earth asteroids were carried out in the period 2013 October through 2014 June using an SBIG ST-8XME CCD camera mounted on a 0.35-m LX200 GPS Schmidt-Cassegrain (SCT) that operated at focal ratios of *f*/6.3 (2014 observations) and *f*/10 (2013 observations). The exposures were unguided. No filters were used in order to maximize signal-to-noise. To further increase the sensitivity, the camera was operated in a 2x2 binning mode, which produced an image scale of 1.66 arcsec/pixel at *f*/6.3 and 1.04 arcsec/pixel at *f*/10. The exposure times were customized depending on the brightness and apparent motions of the particular targets.

All photometric measurements, lightcurve constructions, and period analyses were performed in *MPO Canopus* software (2012). The Comparison Star Selector (CSS) utility in *MPO Canopus* was employed for differential photometry. This allowed using up to five comparison stars of near solar color. The V-band magnitudes were taken from the hybrid MPOSC3 catalog, where BVRI magnitudes were derived from J and K 2MASS catalog magnitudes by applying formulae developed by Warner (2007). As a result, the magnitude zero-points for individual data sets are generally consistent within a few hundredths of a magnitude. However, in some cases, more significant misfits between the individual data sets on the order of a few tenths of a magnitude have been noticed. Most likely such discrepancies could be a consequence of catalog magnitude errors.

Due to the very rapid movement of the observed targets in a relatively small field of view and consequent changes of surrounding stellar configurations, it was necessary to change comparison star selections for the observations made during a single night, which resulted in a number of individual data sets for that night. Elliptical apertures with the long axis oriented along an object's path were used in these rapid motion cases.

(154275) 2002 SR41. This asteroid was observed from 2014 June 9–11. The observations resulted in 16 individual photometric sessions with a total of 794 data points. Since the asteroid was fairly faint (V ~ 16.4–17.0), a quite noisy lightcurve was obtained, even with a relatively long exposure time of 240 seconds. Period analysis suggests many possible solutions (see the period spectrum). The most likely is the bimodal solution of 2.75 ± 0.01 hours that, while having the lowest RMS residual, only slightly stands out among other solutions. The Fourier fit amplitude of the corresponding lightcurve is 0.16 mag.

(275677) 2000 RS11. The target was observed from 2014 March 19–23. A bimodal period of *P* = 4.444 ± 0.001 h can be clearly distinguished among all other solutions in the period spectrum. A large amplitude lightcurve was obtained for this solution. The calculated amplitude for the 15th order Fourier fit is 1.15 ± 0.01

mag., but the real amplitude is even higher than this value. The recently published result of 4.444 ± 0.001 h by Warner (2014a) is fully consistent with the result presented here.

(387733) 2003 GS. The combined data set obtained from 2014 April 06-09 shows an unambiguous bimodal solution for period of P = 2.467 ± 0.001 h and amplitude A = 0.13 ± 0.02 mag. The period is consistent with the one of 2.469 ± 0.001 h reported by Hicks *et al*. (2014).

2011 JR13. Analysis of the photometric data gathered for this asteroid from 2014 May 18–21 indicates a bimodal solution with a period of P = 3.96 ± 0.01 h as the most favorable one. The lightcurve amplitude is 0.35 ± 0.02 mag.

2013 SU24. The target was observed for astrometric purposes on 2013 October 6 over a span of ~40 minutes. Subsequently, having noticed large multiple changes in the target's brightness during the short time interval, the author decided to try to perform photometric measurements using the available images. This resulted in 3 data sets and a total of 76 data points. The period analysis showed that it is indeed a fast rotator and produced two characteristic harmonically related solutions of 0.11 h (monomodal) and 0.22 h (bimodal). On the basis of the data gathered by Warner (2014a), Pravec conducted a more detailed analysis and found that this NEA is a non-principal axis rotator with two periods of 0.23335 h and 0.19894 h (Warner, 2014a). It is interesting to note that the rough bimodal solution obtained by the author of this paper (P = 0.22 ± 0.01 h) from the routine photometric measurements of the images obtained in a very short period of time lies between the two periods found by Pravec. The value found for amplitude of the bimodal lightcurve is extremely large: 1.67 mag.

2013 WT44. This NEA target was observed from 2014 March 29 until April 4. The observations resulted in 9 sessions with a total of 393 data points. The period analysis shows two almost equally dominant solutions in the period spectrum: 3.29 hours (monomodal) and 6.58 hours (bimodal). Taking into account radar observations that showed a nearly pole-on viewing aspect and revealed a nearly spherical shape of this asteroid as stated by Warner (2014b), the shorter period should be considered as the more likely solution. The value for period recently published by Warner (2014b) of 2.8849 h is significantly different from that presented in this paper (3.29 ± 0.01 h). It would be of importance to check why there is such a difference in the period values independently obtained by two authors. The value found for amplitude is 0.06 ± 0.02 mag.

References

Hicks, M., Frederick, J., Harley, I. (2014). *Astronomer's Telegram* **6090**. *http://www.astronomerstelegram.org*

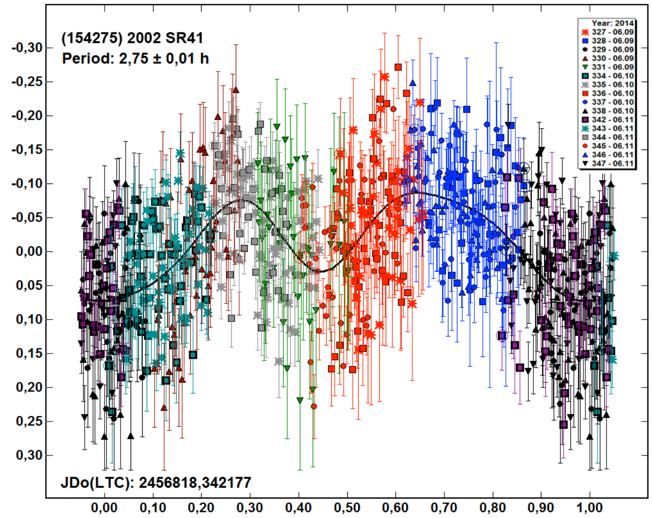
Warner, B.D. (2007). "Initial Results of a Dedicated H-G Program." *Minor Planet Bul.* **34**, 113-119.

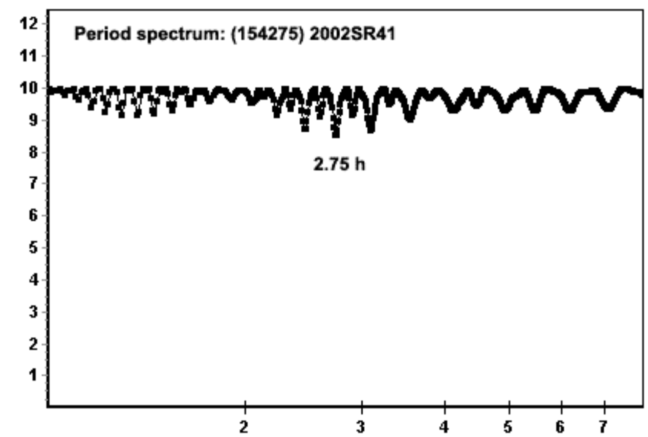
Warner, B.D. (2012). MPO Software, *MPO Canopus*, version 10.4.1.9. Bdw Publishing. *http://minorplanetobserver.com/*

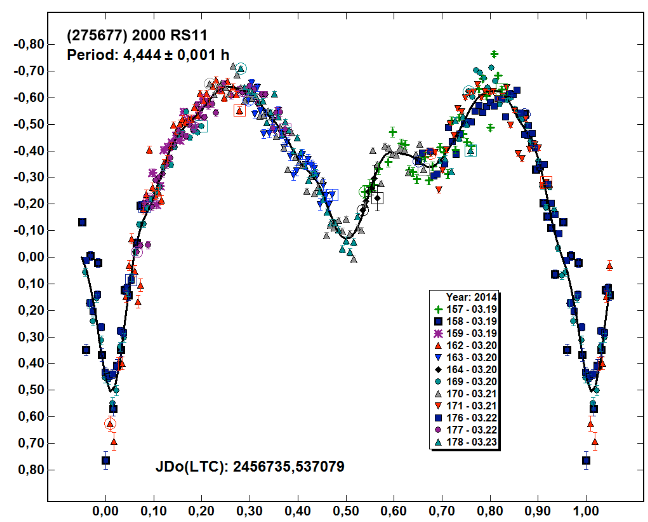
Warner, B.D. (2013). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

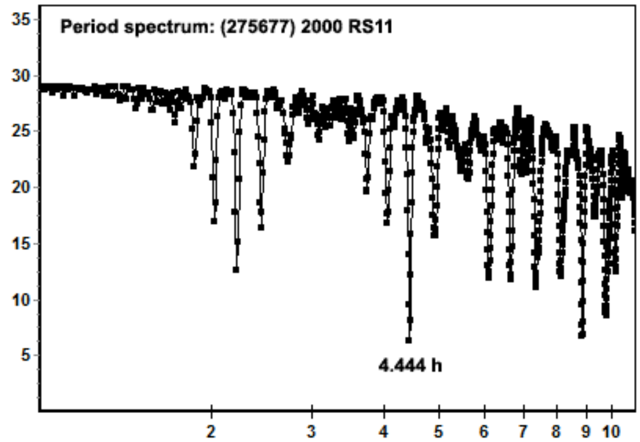
Warner, B.D. (2014a). "Near-Earth Asteroid Lightcurve Analyses at CS3-Palmer Divide Station: 2013 September – December." *Minor Planet Bul*. **41**, 113-124.

Warner, B.D. (2014b). "Near-Earth Asteroid Lightcurve Analyses at CS3-Palmer Divide Station: 2014 January – March." *Minor Planet Bul.* **41**, 157-168.





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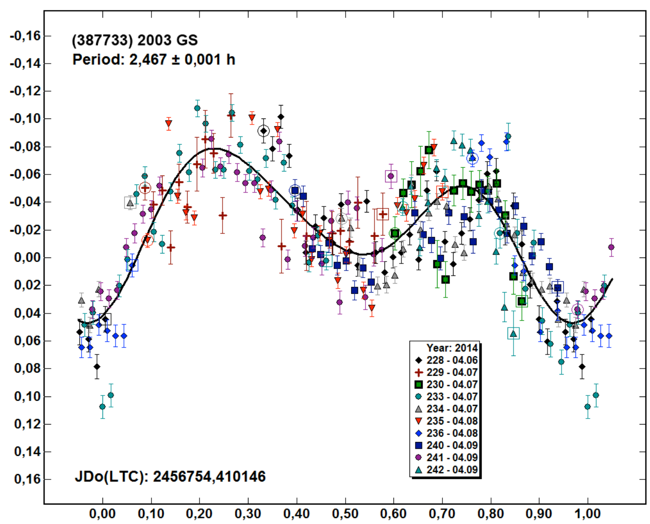
(387733) 2003 GS
Period: 2,467 ± 0,001 h
Year: 2014
228 - 04.06
229 - 04.07
230 - 04.07
233 - 04.07
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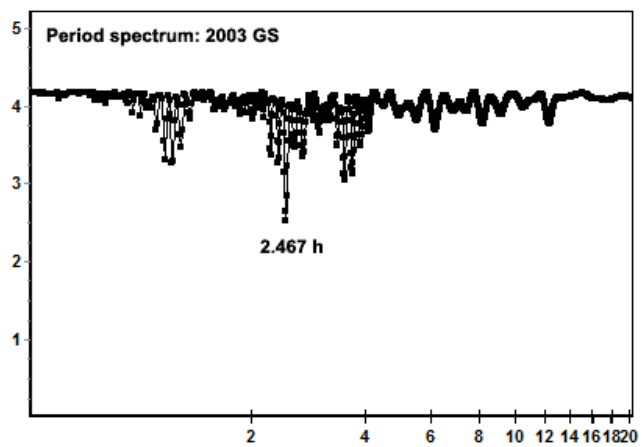
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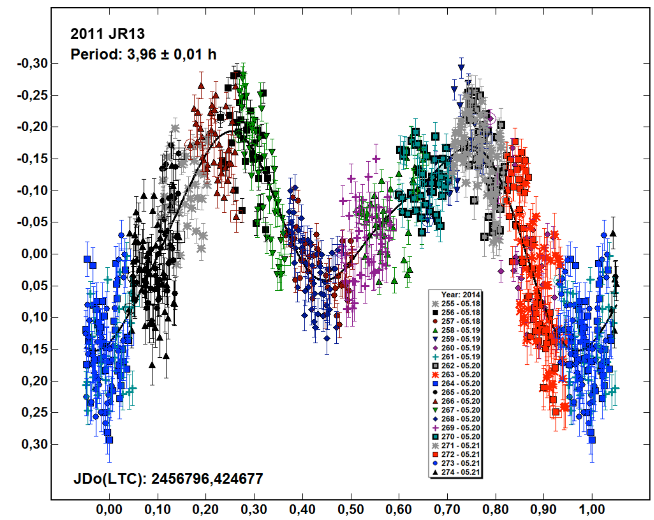
2.467 h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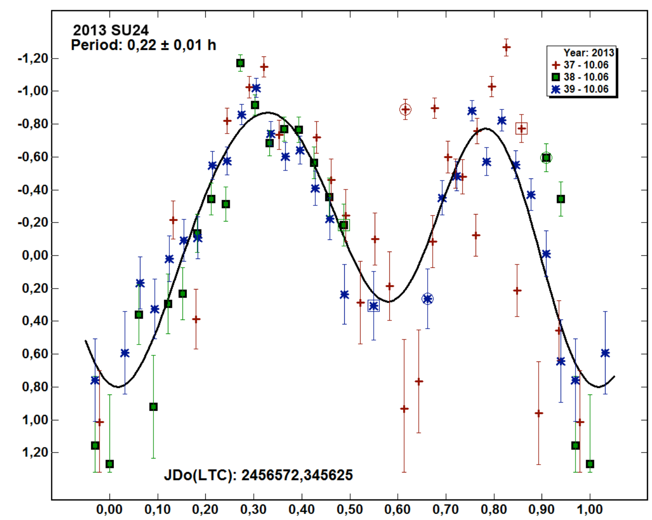
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38 - 10.06
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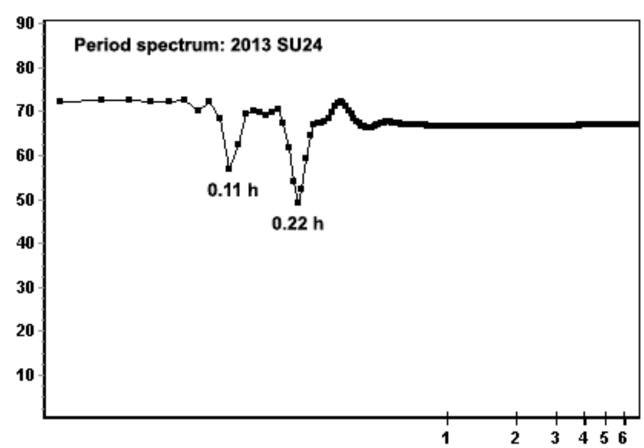
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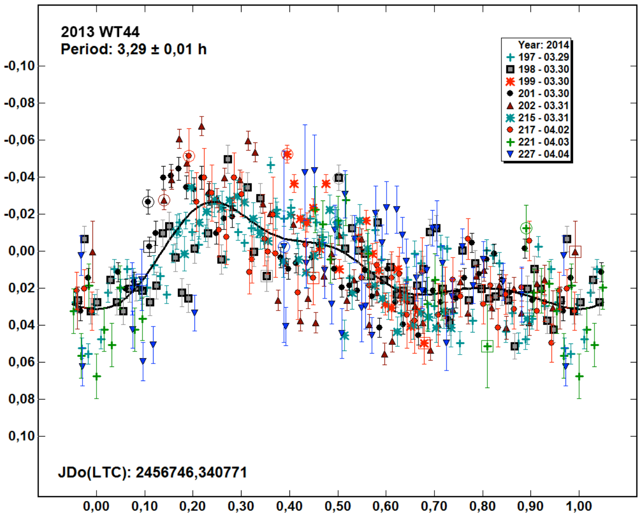

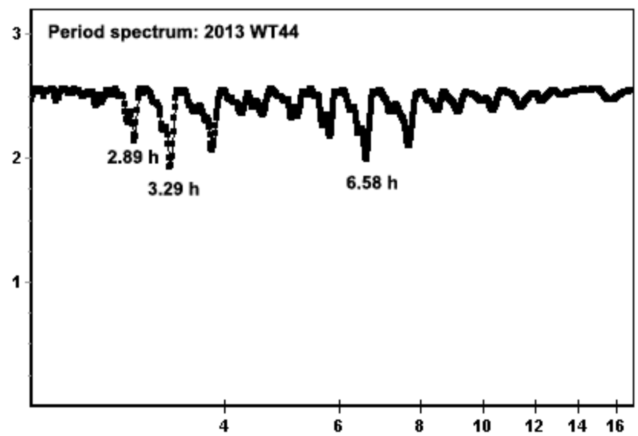

ROTATION PERIOD DETERMINATION FOR THE SLOW ROTATOR 3345 TARKOVSKIJ

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Photometric observations of the main-belt asteroid 3345 Tarkovskij conducted by the authors over more than three months from 2013 December to 2014 March revealed its slow rotation rate and a synodic rotation period of 187.0 ± 0.1 hours. The corresponding bimodal lightcurve has an amplitude of 0.59 ± 0.02 magnitudes.

The main-belt asteroid 3345 Tarkovskij was discovered on 1982 December 23 by L. G. Karachkina at the Crimean Astrophysical Observatory. The asteroid appeared on the list of potential lightcurve targets for 2013 December on the CALL website (Warner, 2013). It reached opposition on 2013 November 27.

Prior to this work there were no published results of the rotation period for this asteroid. Motivated by this fact, in order to determine a synodic rotation period, Benishek began unfiltered photometric observations of 3345 Tarkovskij on 2013 December 10 at the phase angle of 11.0 degrees using a 0.35-m *f*/6.3 Schmidt-Cassegrain (SCT) equipped with SBIG ST-8XME CCD camera. From the beginning it became clear that the asteroid was rotating very slowly and a collaboration with other observers was needed. An invitation for collaboration was extended and Coley kindly offered his participation in the observation campaign. Coley used a 0.35-m *f*/6.6 SCT and a SBIG ST-9XE CCD camera with a clear filter.

As of 2014 March 19, the collaborative observations resulted in 30 data sets, of which 13 were obtained by Coley and 17 were obtained by Benishek. The total interval of phase angles covered by the observations extended from 11.0 to 28.1 degrees. *MPO Canopus* software was used for photometric measurements, period analysis, and data sharing between the authors. Differential photometry with up to five comparison stars of near-solar color was carried out by both authors using the Comparison Star Selector (CSS) feature in *MPO Canopus* by selecting the V-band comparison star magnitudes derived from the hybrid MPOSC3 catalog provided with the program. The individual data sets containing magnitudes obtained using the CSS show a certain misalignment which sometimes can reach up to a few tenths of magnitude. Such discrepancies are most likely to be attributed to catalog magnitude errors. Gradual additional adjustments of the magnitude zero-points for particular data sets were necessary until the best fit in terms of the lowest RMS residual is reached.

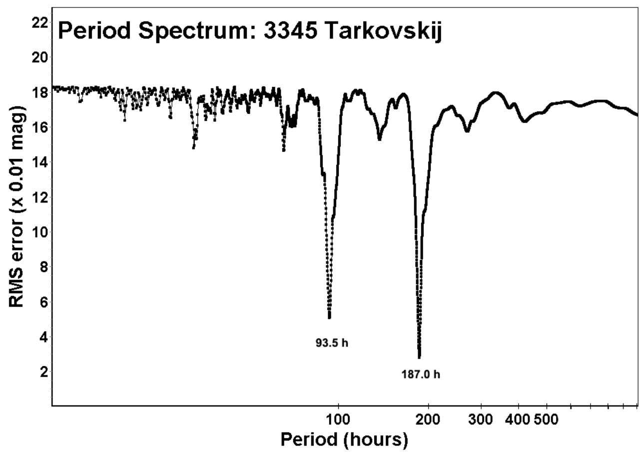
The combined data set of 3090 data points was used in the period analysis, which covered a range of 10 to 1000 hours. The synodic period of 187 hours related to a bimodal solution is clearly seen among all the other values in the period spectrum. The Fourier fit amplitude for the corresponding bimodal lightcurve is A = 0.59 ± 0.02 mag. This amplitude, combined with the range of relatively low phase angles, strongly favors a bimodal solution of 187 h over a monomodal of 93.5 h, which is also possible, although it has a significantly higher RMS residual. The relatively insufficient lightcurve coverage affected the period accuracy, which resulted in adopting the coarse result of 187.0 ± 0.1 hours. A more precise and accurate result would require denser lightcurve data coverage and better zero point linkage among the individual data sets.

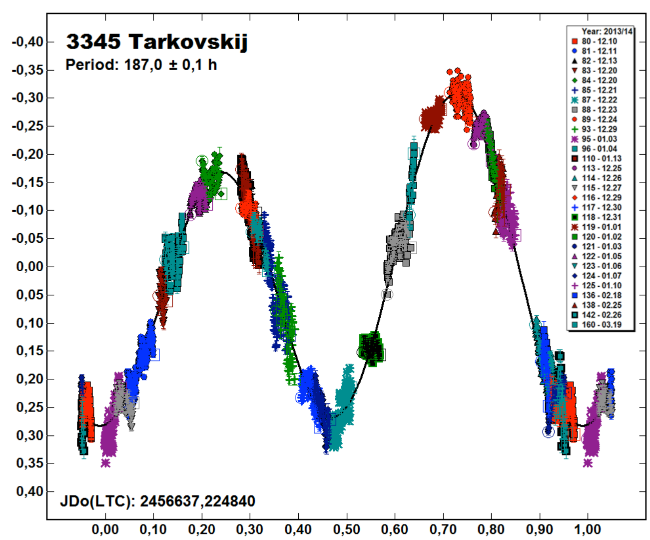
The asteroid 3345 Tarkovskij will have another favorable opposition in late 2017, which could be a great opportunity for a broader collaboration between observers in order to improve the rotation period.

References

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

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





ROTATION PERIOD DETERMINATION FOR 671 CARNEGIA

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Analysis of photometric observations of the main-belt asteroid 671 Carnegia from 2014 January-March revealed a bimodal lightcurve with a period of 8.332 ± 0.001 hours as the most likely solution. However, a trimodal solution of 12.50 hours still could not be formally ruled out.

The main-belt asteroid 671 Carnegia was discovered by Austrian astronomer Johann Palisa on 1908 September 21 in Vienna. The asteroid was listed as a potential lightcurve target in February 2014 on the CALL website (2014). No previous rotation period determination results have been published.

In order to determine its synodic rotation period, the initial photometric observations were started by Benishek on 2014 January 13, slightly more than a month before the opposition date on 2014 February 15. Benishek used a 0.35-m Meade LX200 GPS Schmidt-Cassegrain (SCT) operating at *f*/6.3 and SBIG ST-8XME CCD camera in 2x2 binning mode. With the exactly same goal, Papini independently began photometric observations on 2014 February 23 using a 0.25-m *f*/10 SCT and SBIG ST-9XE CCD camera. Soon afterwards, Papini kindly made his data available to Benishek and the collaboration between two authors was successfully established. The exposures were unfiltered for both authors, unguided (Benishek) and guided by employing a built-in TC-237H guiding CCD (Papini).

As of 2014 March 20 the collaborative observations resulted in 9 sessions with a total of 1061 data points, of which 6 were obtained by Benishek and 3 by Papini. Over the time interval of more than two months, the data covered a range of phase angles ranging from 11.6 degrees before to 12.7 degrees after the opposition.

Data sharing between the authors, as well as data processing and period analysis were performed using *MPO Canopus* software by BDW Publishing (2012). Differential photometry measurements were performed using the Comparison Star Selector (CSS) procedure in *MPO Canopus* that allows selecting of up to five comparison stars of near-solar color. Subsequently, the additional adjustments of the magnitude zero-points for the particular data sets were carried out in order to achieve the best alignment between them, i.e., to reach the minimum Fourier RMS residual.

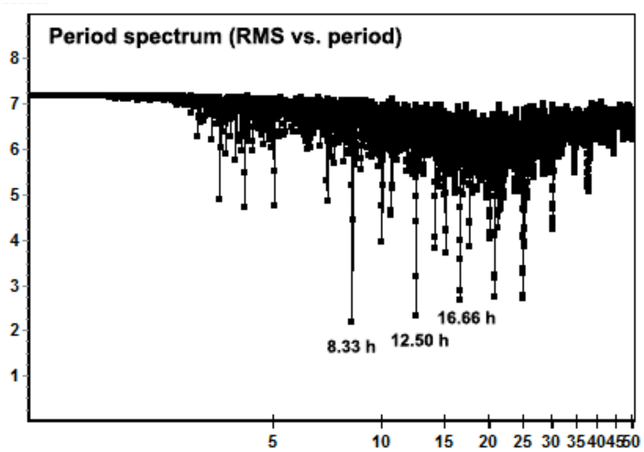
The period analysis yielded several possible solutions that clearly stand out in the period spectrum with nearly comparable RMS residuals, but only some have a valid physical justification. The complex lightcurve solutions with multiple minima and maxima phased to periods of over 20 hours were immediately ruled out as physically unreasonable and the three remaining solutions were taken into further consideration: the bimodal lightcurve phased to 8.332 hours, the double value of this period, i.e., a quadramodal solution of 16.664 hours, and a trimodal lightcurve phased to 12.50 hours. A closer examination of the Fourier series coefficients favors the period of 8.332 hours over its double value due to larger values for the even term coefficients with respect to the odd term coefficients in the longer period case. The bimodal solution shows significantly better uniformity between the even and odd term coefficients, which is an indication of its greater adequacy. The trimodal solution might not be formally rejected due to the considerable comparability of its RMS error value with that of the bimodal solution.

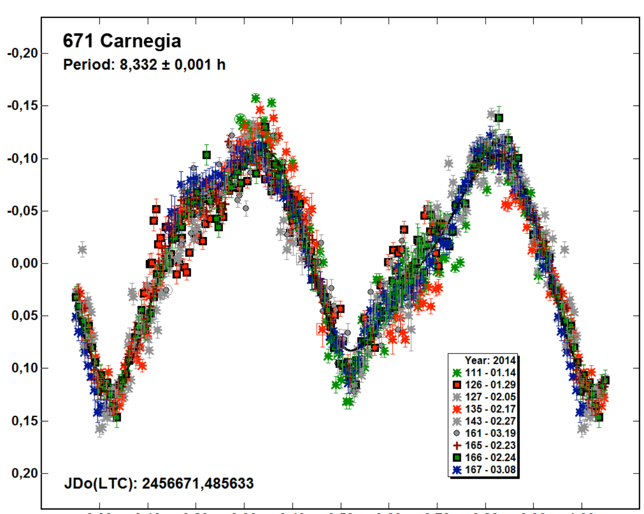
We conclude that the most likely value of the synodic period for 671 Carnegia is associated with the established bimodal lightcurve phased to 8.332 ± 0.001 hours with amplitude of 0.24 ± 0.01 mag. The possibility of trimodal lightcurve and period of 12.50 hours could be definitely confirmed or rejected by a more thorough analysis of additional data that would be collected at some future apparitions. Therefore, we strongly recommend further photometric monitoring of this asteroid in the future.

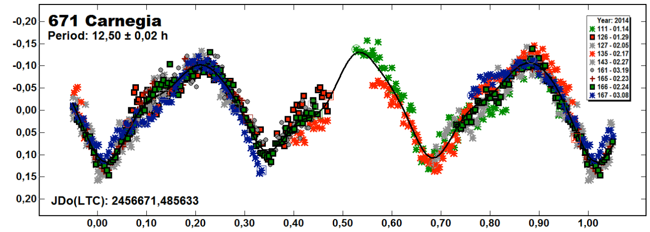
References

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

Warner, B.D. (2014). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*







ROTATION PERIOD DETERMINATION FOR THE MAIN-BELT ASTEROID 1517 BEOGRAD

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New photometric data on the main-belt asteroid 1517 Beograd were obtained during the period 2014 March-May, covering a relatively wide range of phase angles. Analysis of the data indicates a synodic rotation period solution of 6.9490 ± 0.0006 h.

The main-belt asteroid 1517 Beograd was discovered by Serbian astronomer Milorad B. Protitch at the Belgrade Astronomical Observatory on 1938 March 20. The only prior rotation period determination result was published by Behrend (2005), who reported a period of 6.943 h based on observations obtained by L. Bernasconi in 2005. This solution has been characterized with an uncertainty flag of U = 2 on the CALL website (2014), which indicates a fairly high degree of its unreliability.

Guided by this fact, Benishek began the initial observations 3 days before the opposition date on 2014 March 11 in order to test the previously determined rotation period. The observations were made using a 0.35-m Meade LX200GPS Schmidt-Cassegrain (SCT) operating at *f*/6.3 and SBIG ST-8XME CCD camera in 2x2 binning mode. The exposures were unfiltered and unguided. As of 2014 March 23, Benishek obtained a total of 5 data sets covering phase angles from 2.8-5.7 degrees. Another group of 7 photometric data sets were obtained at significantly higher phase angles (18.9-21.3 deg) from 2014 May 6-27. The last data set of May 27 was contributed by Frederick Pilcher using a 0.35-m *f*/10 Meade LX200 GPS SCT and an unguided SBIG STL-1001E CCD camera with clear filter.

Data sharing between the authors, photometric measurements, and period analysis were performed using *MPO Canopus* software (Warner, 2012). The unfiltered observations were reduced using the Comparison Star Selector feature in *MPO Canopus* and applying the V-band magnitudes derived from the MPOSC3 hybrid catalog (Benishek) and R-band magnitudes derived from the CMC-15 catalog (Pilcher). To achieve the best match between the different data sets based on a minimum Fourier RMS residual, additional zero-point adjustments were performed.

The resulting composite bimodal lightcurve consisting of 825 data points that represent all phase angles covered by our observations shows period of 6.9490 ± 0.0006 hours (Fig 1). The calculated Fourier fit amplitude is 0.24 ± 0.02 mag. In addition to this clearly distinguished solution, its double value of 13.898 hours (the quadramodal solution) almost equally stands out in the period spectrum (Fig 2). After simple inspection of the obtained quadramodal lightcurve, the longer solution was completely ruled out as the two halves of the lightcurve appear nearly the same (Fig 3).

There was a significant increase (~0.1 mag) in the amplitude of the lightcurve with increasing phase angle throughout the interval of nearly three months. For this reason, the authors considered it necessary to construct and analyze two separate lightcurves related to the groups of data sets obtained at low (March 2014) and high phase angles (May 2014). These particular lightcurves are shown in the Figures 4 and 5. The rotation period values obtained by analyzing both low (6.949 ± 0.004 h) and high (6.949 ± 0.002 h) phase angle data sets independently are consistent with each other. As in the case of the analysis that comprises all the sessions obtained in a wide range of phase angles, the analogous quadramodal solutions appear as the results of the separate analyses of both low and high phase angle data. These were rejected for the reasons stated above. The Fourier fit amplitudes found for the low and high phase angle lightcurves are 0.20 ± 0.02 mag. and 0.31 ± 0.02 mag., respectively.

Our synodic rotation period solution of 6.9490 hours determined from the new photometric data collected over an almost three-month interval is found to be consistent with the result previously found by Behrend and, therefore, should indicate a much higher degree of its reliability.

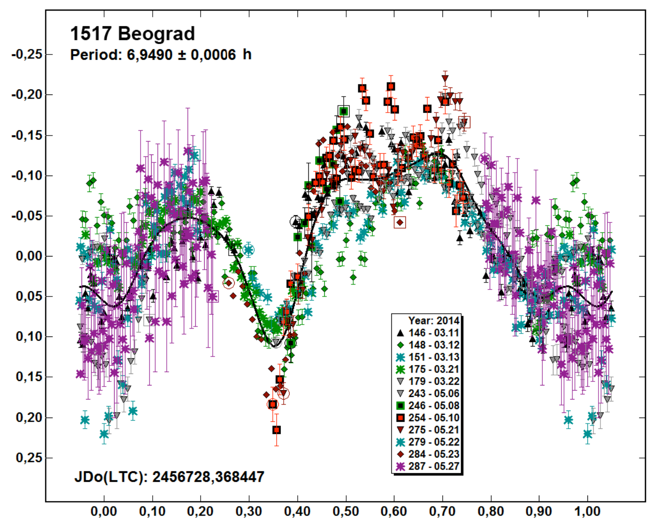

Figure. 1. The lightcurve for 1517 Beograd using all data.

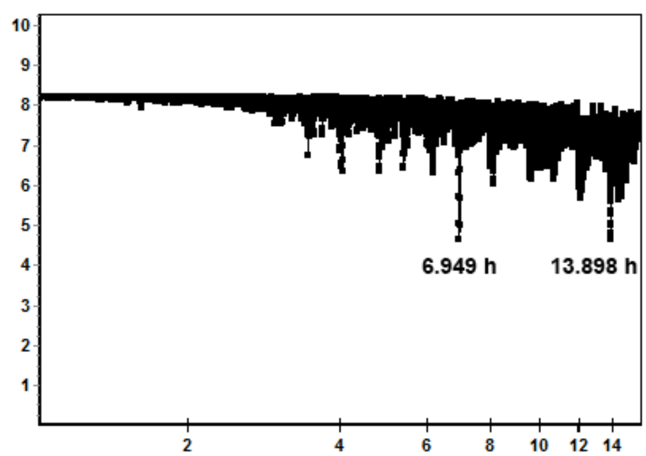

Figure 2. The period spectrum using all data.

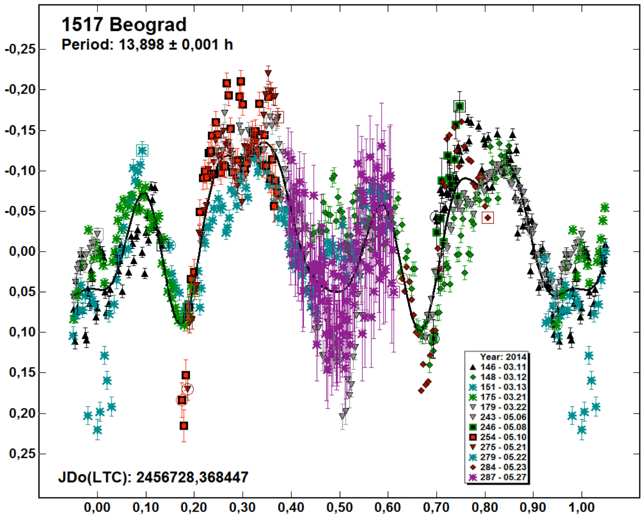

Figure 3. The lightcurve using all data assuming a period of 13.898 hours.

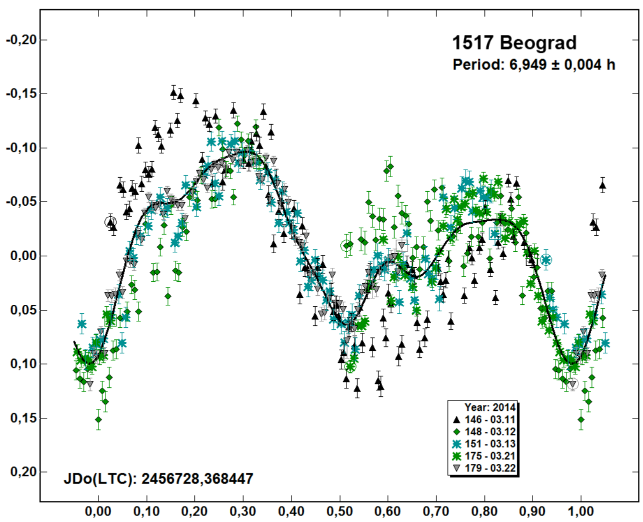

Figure 4. The lightcurve for 1517 using data from 2014 March.

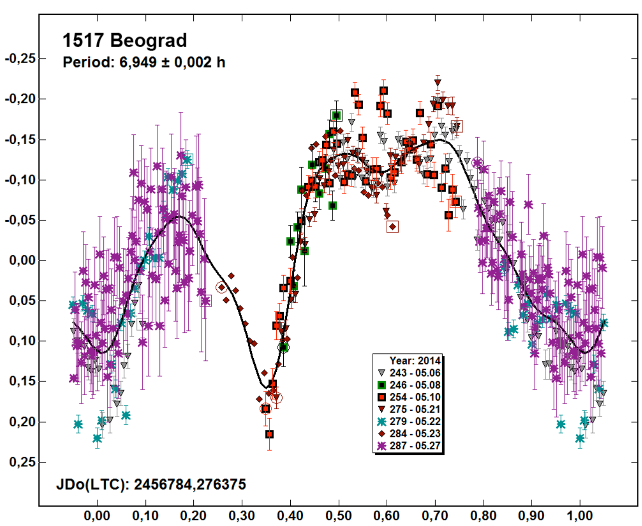

Figure 5. The lightcurve for 1571 using data from 2014 May.

References

Behrend, R. (2005). Observatoire de Geneve website, *http://obswww.unige.ch/~behrend/page_cou.html*

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

Warner, B.D. (2014). Collaborative Asteroid Lightcurve Link website. *http://www.minorplanet.info/call.html*

ASTEROIDS LIGHTCURVES AT OAVDA: 2013 DECEMBER – 2014 JUNE

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Twelve asteroids, main-belt (MBA) and near-Earth (NEA), were observed at OAVdA from 2013 December through 2014 June: 1678 Hveen, 2834 Christy Carol, 3744 Horn-d'Arturo, 7436 Kuroiwa, (21374) 1997 WS22, (53435) 1999 VM40, (143649) 2003 QQ47, (242708) 2005 UK1, (243566) 1995 SA, (251346) 2007 SJ, 2013 XY8, and 2014 CU13.

This paper features the results of photometric observations on asteroids, both main-belt (MBA) and near-Earth (NEA), made at OAVdA Observatory (Carbognani and Calcidese, 2007), from 2013 December through to 2014 June, and as outlined in Carbognani (2011). It was not possible to determine the amplitude and the rotation period for all the observed asteroids, but the data collected are nevertheless provided for all objects (see Table 1). At the end of June, 2014 MF6, an Apollo-PHA object, was also observed in collaboration with others; the results for that NEA will be presented in a separate paper.

The images, unless otherwise noted, were captured by means of a modified Ritchey-Chrétien 0.81-m *f*/7.9 telescope using an FLI 1001E CCD with an array of 1024×1024 pixels. The field-of-view was 13.1×13.1 arcmin and the plate scale was 0.77 arcsec per pixel in 1×1 binning mode.

We used *MPO Canopus* (Warner, 2009) version 10.4.1.0 for differential photometry and period analysis. When possible, the sessions were calibrated with the *MPO Canopus* "Comp Star Selector" (CSS), which chooses comparison stars that are similar in color to the target (in general solar-type stars), and the "DerivedMags" approach. The amplitude of the lightcurve was also obtained directly from *MPO Canopus* and not with a polynomial fit as in Carbognani (2011).

Known rotation periods were all drawn from the asteroid lightcurve database (LCDB; Warner *et al.*, 2009; 2014 February 28 update).

<u>1678 Hveen</u> is an MBA. A total of 290 images in V band were taken on three nights, for about 12 hours of observations: the first on 2013 December 10, the second on 2013 December 11 (with bad seeing), and the last on 2014 January 27. All sessions were calibrated with the CSS. A period value of 5.987 ± 0.002 h is the most probable for all the sessions, with an amplitude of about 0.07 mag (Figure 1). No period was known for this object before.

<u>2834 Christy Carol</u> is an MBA. A total of 269 images in V and R band was taken over 2 nights (2013 December 3-12), for a total of 11 hours of observation. Unlike all the other asteroids, Christy Carol was been observed with a Ritchey-Chrétien 0.40-m *f*/8 telescope using a Moravian G2-3200 CCD with an array of 2184×1472 pixels in 1×1 binning mode. The bimodal lightcurve appears almost completely covered (Figure 2). The best rotation period is 9.450 ± 0.004 h with amplitude of 0.50 mag. Other values close to this period are possible. No period was known for this object before.

<u>3744 Horn-d'Arturo</u> is an MBA. A total of 449 images in V band were taken over 5 nights, from 2013 December 3 to December 12, before the opposition date. All sessions were calibrated with CSS. Between the first two and the last three sessions, the lightcurve showed significant changes due to variation in lighting conditions. The period is 7.18 ± 0.01 h with amplitude of 0.45 mag for the first two sessions (Figure 3), and 7.09 ± 0.01 h with amplitude of 0.28 mag for the last three (Figure 4). The results appear coherent and the mean period is 7.13 ± 0.01. No period was known for this object before.

<u>7436 Kuroiwa</u> is an MBA. A total of 170 images using a clear filter during 8 hours of observation were taken in three sessions in the second half of 2014 March. The object was faint and the lightcurve in Figure 5 is a bit noisy; moreover, the amplitude is low. Despite these issues, the lightcurve shows a period of 5.61 ± 0.01 h with amplitude of 0.07 mag. This result is not compatible with the LCDB value of 1.8192 h with U = 1. Note how this first value was below the spin barrier of about 2.2 h despite the estimated size of about 3 km for Kuroiwa. The new value appears to be more reasonable for this asteroid.

<u>(21374) 1997 WS22</u> is an Amor object and a Mars-crosser. A total of 100 images using a C filter was taken in 8 hours spread over two nights on 2014 April 5/6, long before Earth flyby occurred on May 21 at 0.12 AU. The object was about 17.5 mag so the lightcurve, also with a 240 s exposure, is noisy. The best rotation period is 2.292 ± 0.004 h with an amplitude of 0.17 mag (Figure 6). The rotation period is just above the spin barrier, reasonable for an asteroid of about 1-2 km in diameter. No period was known for this object before, and for a check of this value it must be kept in mind that this asteroid will make its next closest approach in 2027, November 08.

<u>(53435) 1999 VM40</u> is an Amor object. A total of 177 images in V band were taken over 5.8 hours in a single nights (2014 January 27). Despite the single session, the lightcurve appears fully covered and the best period is 5.09 ± 0.02 h with an amplitude of 0.25 mag (Figure 7). The period value is in good agreement with that of the LCDB (5.189 h, with U = 3).

<u>(143649) 2003 QQ47</u> is an Apollo-PHA object. A total of 174 images with a clear filter (to maximize the signal-to-noise ratio), were taken over 8 hours distributed on two nights on 2014 March 8/9 (the minimum distance from Earth of 0.129 UA was reached on March 26). The differential photometry of this object was made difficult by the rather dense stellar fields through which it is passed. The images in which the asteroid was close too close to brighter stars were deleted. Because of the resulting poor data set, the rotation period is very difficult to determine. We can guess a value of about 4.1 ± 0.1 h with an amplitude of about 0.53 mag (Figure 8). No period was known before.

<u>(242708) 2005 UK1</u> is an Apollo-PHA object. A total of 556 images using clear filter were taken in 10 hours on four sessions between 2014 May 24 and June 7 (the flyby with Earth was on May 21 at 0.094 UA). The lightcurve was very noisy (Figure 9), the most probable period is about 4.3 ± 0.1 h, with an amplitude of 0.13 mag. No period was known before.

<u>(243566) 1995 SA</u> is an Apollo-PHA asteroid which made its Earth flyby on 2014 April 2 at 0.188 AU. A total of 214 images

with no filter were taken in 7 hours over 3 nights in 2014 January 28 and March 6/8. Photometry was made difficult by the low signal-to-noise of the asteroid, its angular velocity, and by the crowded star field. As before, images where the asteroid passed close to bright stars were deleted from data analysis. The better session is that in January with a resulting period of 2.23 ± 0.08 h and an amplitude of 1.12 mag, indicative of a very elongated object (Figure 10). The other sessions are more noisy, and so of little use, even if the resulting period is about the same but with an amplitude of the lightcurve of 0.14 mag. No period was known before.

(251346) 2007 SJ is an Apollo-PHA that made an Earth flyby on 2014 January 21 at 0.049 AU. A total of 138 images in R band were taken during 5 hours session in a single clear night (2013 December 12). The phased lightcurve and the comparison stars (solar type only) seemed normal but the peak of the maximum of the curve changed by 0.04 mag during the session (Figure 11 and 11a). The minimum changed as well. If this was due to background noise, one would expect greater scattering of the lightcurve. A search for possible background stars that may have altered the lightcurve was negative. These variations may be due to an asynchronously binary system without mutual phenomena. The result for a double period search with *MPO Canopus* is shown in the Figures 11b, 11c, and 11d. A monolithic satellite with about 1.65 h rotation period and amplitude of 0.08 mag would be able to justify the difference observed, but the data are not sufficient to be sure. The rotation period value for the primary is 2.78 ± 0.02 h with amplitude of 0.17 mag, in good agreement with that of the LCDB (2.718 h, with U = 3).

2013 XY8 is an Apollo object, with an estimated diameter of about 50 meters. This asteroid was observed for both photometry and astrometry in the night of 2013 December 9 following a request by the Goldstone radar team published on the minor planet Mailing List (MPML). The first photometric observations indicated a rotation period of 0.0605 h with a substantially symmetrically rather noisy bimodal lightcurve with an amplitude of 0.18 mag. Given the cloudy sky at times, a post was made on MPML so that other observers could help confirm the short rotation period. At OAVdA, a total of 737 images with a clear filter was taken on a session 4.5 hours long. The result are shown in the Figures 12, 13 and 14 (period spectrum). The period spectrum with a fourth order Fourier fit shows four possible periods: about 0.03 h (P/2, monomodal solution), 0.06 h (P, bimodal solution), 0.09 h (3P/2, trimodal solution) and 0.12 h (2P, quadramodal solution). The RMS value for these four solutions is almost identical, with a value slightly smaller for 0.09 h. The lightcurve is too noisy to decide among these different values. Considering that asteroids usually have an elongated shape, the value of 0.06056 h with amplitude 0.18 is the more physically plausible. This period value is in good agreement with that reported on the LCDB (0.06055 h, with U = 3-).

2014 CU13 is an Apollo-PHA. A total of 60 images with no filter was collected in a single night on 2014 March 3, while the flyby with Earth was on March 13 at 0.0048 AU. The session lasted for only 1 hour and the data are insufficient to derive a rotation period. From the raw lightcurve trend (Figure 15), and assuming that the curve is bimodal, it is reasonable to assume a period of 4-5 hours with a minimum amplitude of 0.3 mag. No period was known before.

Acknowledgements

This research has made use of the NASA's Astrophysics Data System and JPL Small-Body Database Browser. Thanks to Jon Giorgini (NASA/JPL) for the appreciation about the astrometric observations of 2013 XY8 (private communication). Thanks to the Planetary Society for the award of the 2013 Shoemaker NEO Grant to OAVdA which made it possible to upgrade the telescope used to observe the NEAs.

References

Carbognani, A. (2011). "Lightcurve and Periods of Eighteen NEAs and MBAs." *Minor Planet Bulletin* **38**, 57-63.

Carbognani, A., Calcidese, P. (2007). "Lightcurve and rotational period of asteroids 1456 Saldanha, 2294 Andronikov and 2006 NM." *Minor Planet Bulletin* **34**, 18-19.

Warner, B.D., Harris, A.W, Pravec, P. (2009). "The asteroid lightcurve database." *Icarus*, **202**, 134-146.

Warner, B.D. (2009). MPO Software, *MPO Canopus*. Bdw Publishing. *http://minorplanetobserver.com/*

Number	Dates yyyy mm dd	Phase [deg]	Period [h]	Amp [mag]
1678	2013 12 10 2013 12 11 2014 01 27	8.3- 13.1	5.987 ±0.002	0.07
2834	2013 12 03 2013 12 12	8.1- 4.7	9.450 ±0.004	0.50
3744	2013 12 03 2013 12 04 2013 12 05 2013 12 11 2013 12 12	8.2- 3.2	7.18±0.01 7.09±0.01	0.45 0.28
7436	2014 03 18 2014 03 20 2014 03 24	13.7- 16.6	5.61±0.01	0.07
21374	2014 04 05 2014 04 06	54.8- 54.8	2.292 ± 0.004	0.17
53435	2014 01 27	20.4	5.09 ± 0.02	0.25
143649	2014 03 08 2014 03 09	88.0- 88.6	4.1±0.1 (?)	0.53
242708	2014 05 24 2014 06 05 2014 06 06 2014 06 07	61.6- 29.3	4.3±0.1 (?)	0.13
243566	2014 01 28 2014 03 06 2014 03 08	22.4- 46.2	2.23 ± 0.08	1.12
251346	2013 12 12	59.8	2.78 ± 0.02 (binary?)	0.17
2013 XY8	2013 12 09	17.9	0.06056 ± 0.00002	0.18
2014 CU13	2014 03 06	23.1	4-5 (?)	≥ 0.30

Table 1. The number/provisional designation, date of observations, range of phase angles, rotation period and amplitude for the observed asteroids.

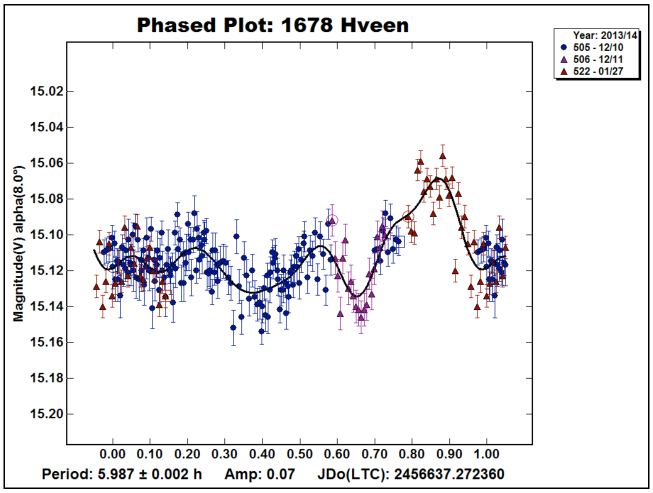

Figure 1. The phased lightcurve for 1678 Hveen with a period of about 6 h and low amplitude.

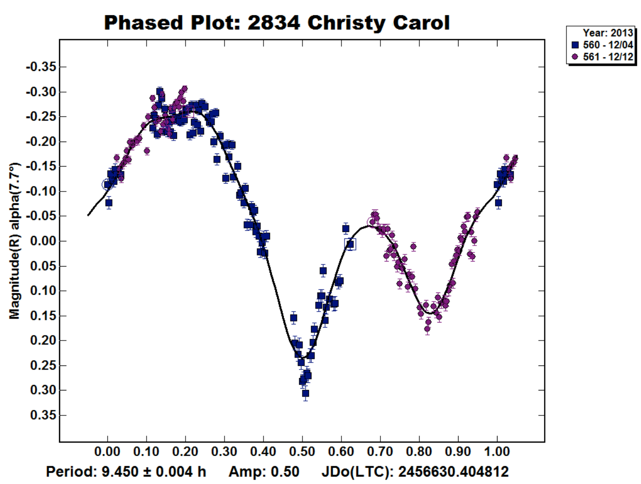

Figure 2. The phased lightcurve for 2834 Christy Carol.

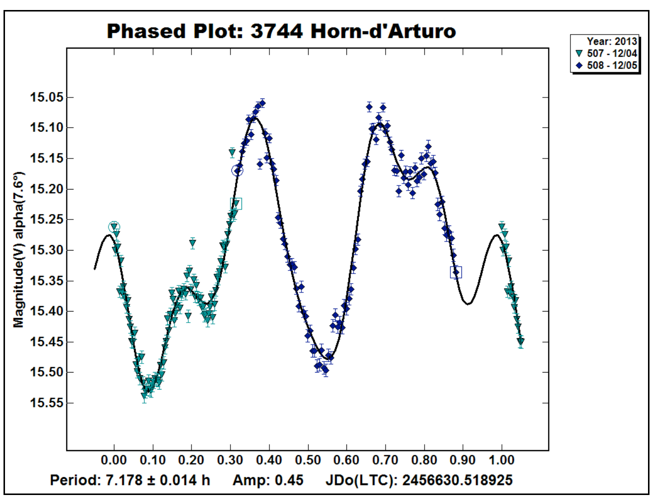

Figure 3. The lightcurve for the first two sessions of 3744 Horn-d'Arturo.

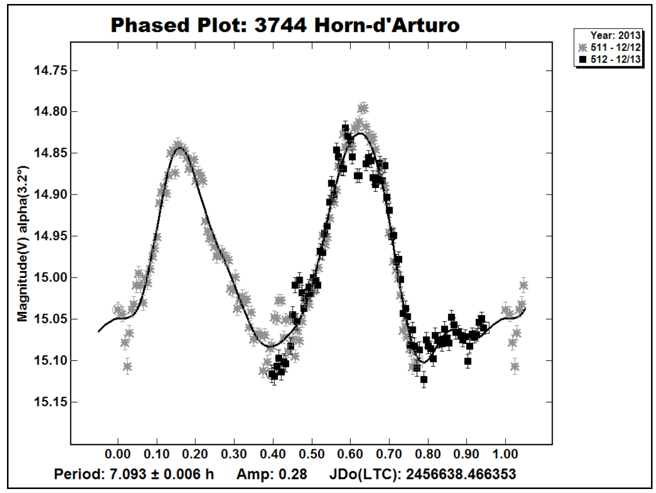

Figure 4. The lightcurve for the last three sessions of 3744 Horn-d'Arturo. The difference with the previous figure is evident.

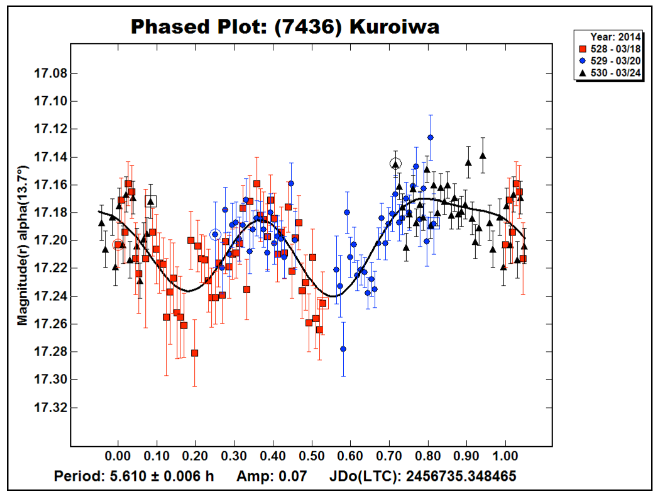

Figure 5. The full lightcurve of 7436 Kuroiwa with a period of about 5.6 h.

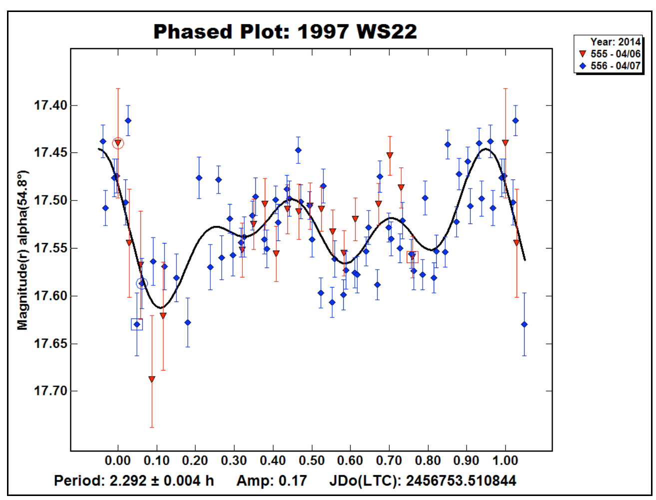

Figure 6. The lightcurve of (21374) 1997 WS22.

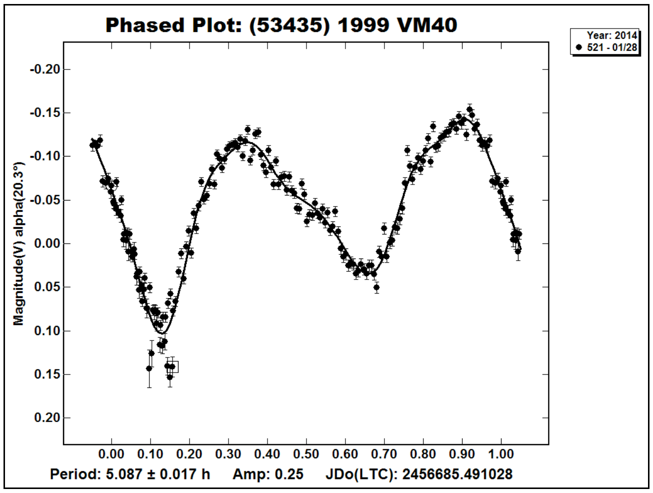

Figure 7. The lightcurve of (53435) 1999 VM40 from a single session.

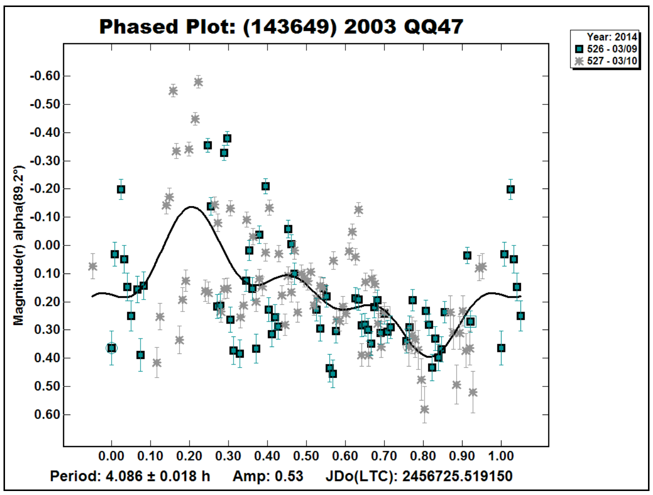

Figure 8. The noisy lightcurve of the Apollo-PHA object (143649) 2003 QQ47.

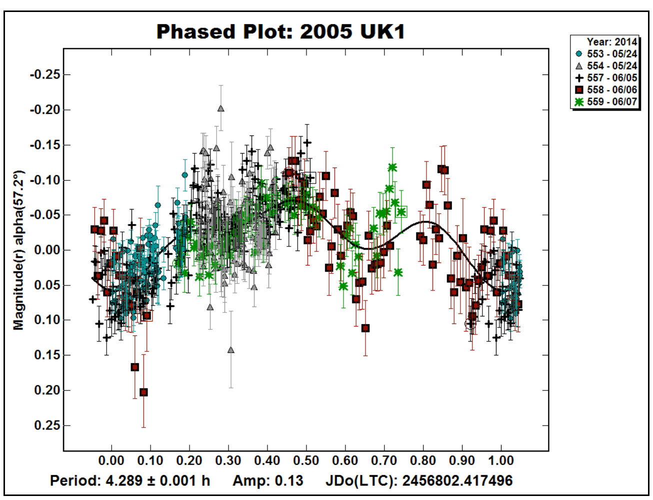

Figure 9. The lightcurve of the Apollo-PHA (242708) 2005 UK1.

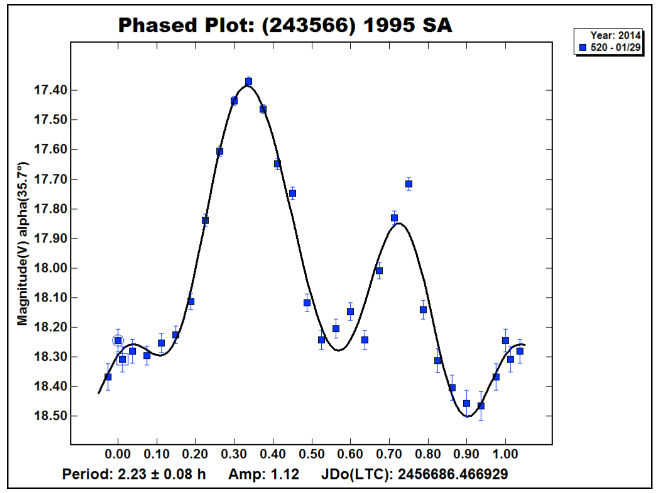

Figure 10. The good lightcurve of the Apollo object (243566) 1995 SA.

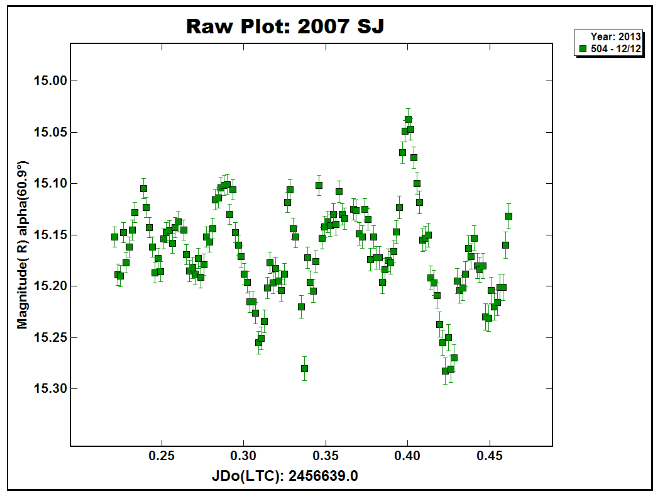

Figure 11. The raw lightcurve of (251346) 2007 SJ. The height of the main peak of the curve (in 0.29 and 0.40) is changed during the same session. Also the minimum (in 0.31 and 0.42) is changed.

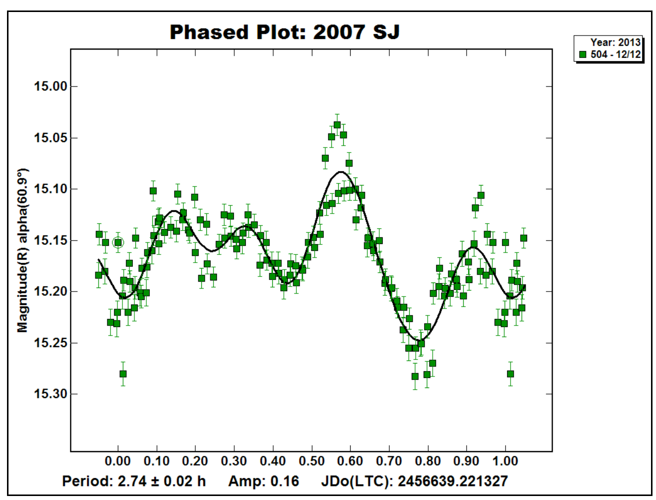

Figure 11a. The full lightcurve of (251346) 2007 SJ.

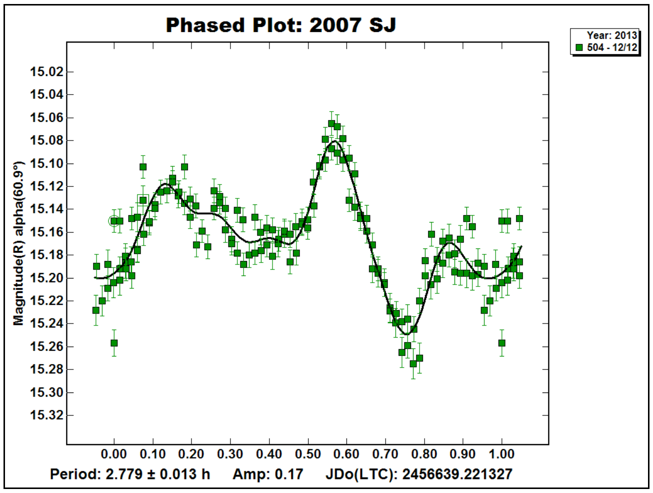

Figure 11b. The phased lightcurve for the primary period only of (251346) 2007 SJ.

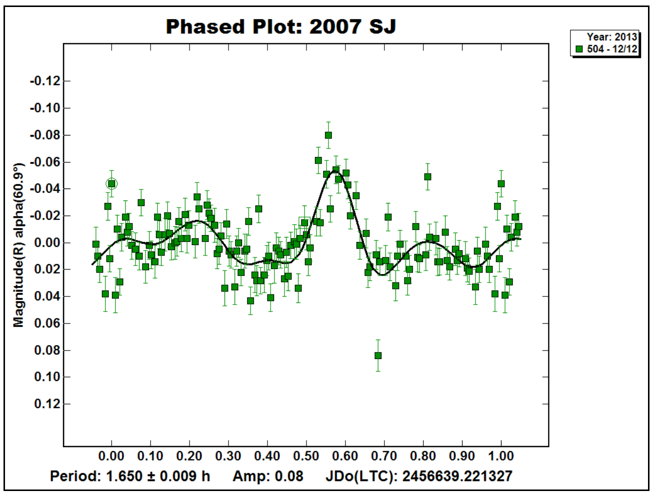

Figure 11c. The lightcurve for the secondary rotation period of (251346) 2007 SJ.

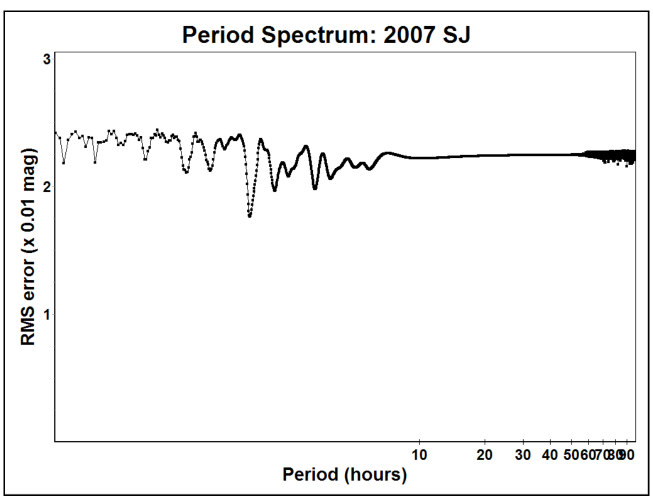

Figure 11d. The period spectrum for the secondary rotation period of (251346) 2007 SJ.

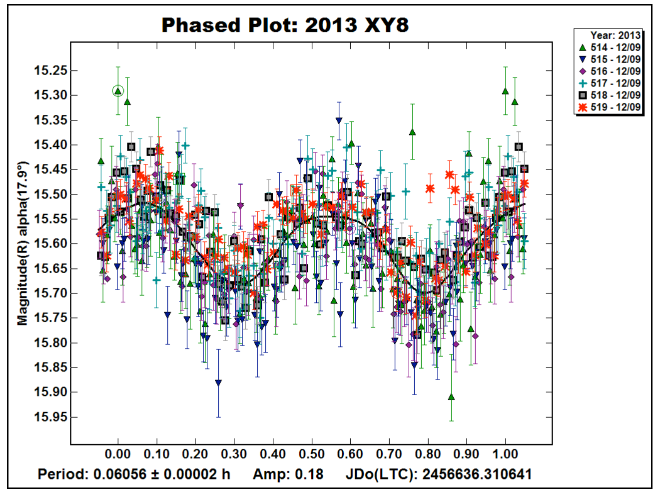

Figure 12. The bimodal lightcurve of the Apollo object 2013 XY8.

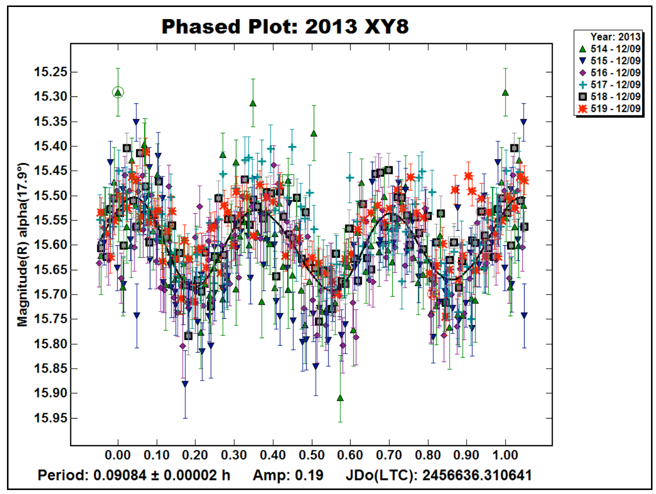

Figure 13. The trimodal lightcurve for 2013 XY8.

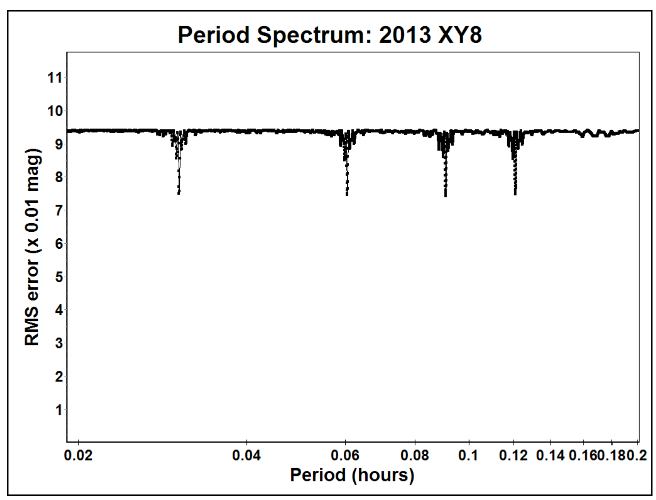

Figure 14. The period spectrum for 2013 XY8. From left to right: P/2, P, 3P/2, 2P peaks.

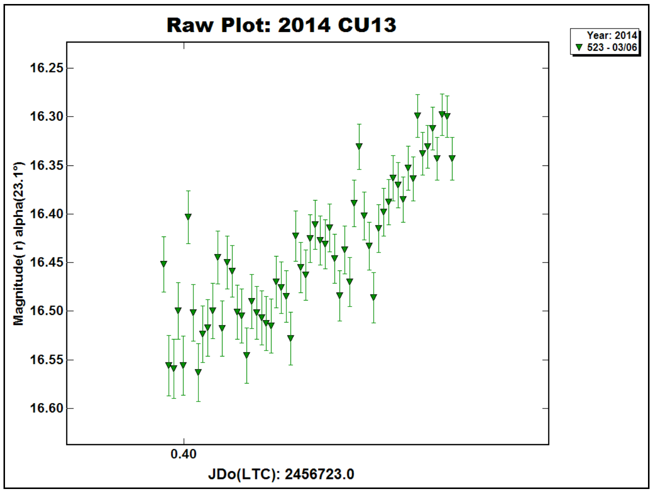

Figure 15. The raw lightcurve of the Apollo-PHA object 2014 CU13. The data are insufficient to constrain a rotational period.

TARGET ASTEROIDS! OBSERVING TARGETS FOR OCTOBER THROUGH DECEMBER 2014

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Asteroids to be observed by the *Target Asteroids!* program during the period of October to December 2014 are presented. In addition to asteroids on the original *Target Asteroids!* list of easily accessible spacecraft targets, an effort has been made to identify other asteroids that are 1) brighter and easier to observe for small telescope users and 2) analogous to (101955) 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, the target asteroid of the NASA OSIRIS-REx sample return mission. Most target asteroids are near-Earth asteroids (NEA) though observations of relevant Main Belt asteroids may also be requested.

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

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

Quarterly Targets

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

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

Asteroid Number	Name	Peak V Mag	Time of Peak Brightness
(68278)	2001 FC7	21.9	late Dec
(89136)	2001 US16	21.1	late Dec
(141018)	2001 WC47	19.8	early Oct
(163000)	2001 SW169	21.8	late Dec
(173664)	2001 JU2	21.7	mid Oct
(190491)	2000 FJ10	20.7	early Oct/late Dec
	1996 FO3	19.9	early Nov
	2002 TD60	20.9	late Dec
	2006 YF	22.0	early Nov
	2008 DG5	21.4	late Dec
	2014 MK55	20.2	late Dec

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

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

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

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

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

Carbonaceous Target Asteroids! List objects

None this quarter.

Target Asteroids! List objects of unknown type

(136635) 1994 VA1 (a=1.57 AU, e=0.17, i=7.6°, H = 18.9)
Little is known about this object's physical characteristics. It reaches a peak brightness of V ~ 18.5 in late January 2015. Unfortunately, its phase angle does not cover a very large range. Hopefully large aperture telescopes can obtain lightcurve and color photometry.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/21	07 15.3	+18 41	1.14	1.63	21.7	37	100
10/31	07 31.9	+16 54	1.03	1.61	21.5	37	105
11/10	07 46.2	+14 51	0.93	1.59	21.2	36	111
11/20	07 57.9	+12 35	0.83	1.56	20.9	34	118
11/30	08 06.2	+10 07	0.74	1.54	20.5	32	125
12/10	08 10.6	+07 31	0.66	1.51	20.1	28	133
12/20	08 10.2	+04 53	0.59	1.49	19.7	23	142
12/30	08 04.8	+02 24	0.53	1.46	19.3	20	150

(303450) 2005 BY2 (a=1.27 AU, e=0.33, i=7.3°, H = 20.4)
2005 BY2 is similar to 1994 VA1. We have no information on its physical characteristics, it will peak at V ~ 18.5 (in early January 2015) and it covers a small range of phase angles when bright enough for observation. Again, it is hoped that large aperture facilities will be able to obtain lightcurve and color photometry.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/10	07 07.1	+21 26	0.68	1.47	21.8	35	122
11/20	07 16.9	+22 34	0.58	1.43	21.3	32	130
11/30	07 22.9	+24 23	0.48	1.39	20.8	28	139
12/10	07 23.8	+27 10	0.40	1.34	20.1	23	149
12/20	07 17.4	+31 19	0.32	1.29	19.4	16	159
12/30	07 00.2	+37 06	0.27	1.24	18.7	12	165

Non-carbonaceous Target Asteroids! List objects

(137799) 1999 YB (a=1.32 AU, e=0.07, i=6.8°, H = 18.5)
This ~0.6 km near-Earth asteroid has a low relative delta-V. Spectroscopy has identified it as an Sq-type object. No lightcurve photometry has been published for it. Its phase angle ranges from 7° in early October to 44° at the end of the year.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	00 49.8	-04 43	0.40	1.40	17.8	7	171
10/11	00 29.9	-04 11	0.42	1.41	18.0	10	166
10/21	00 13.4	-03 13	0.45	1.41	18.4	18	154
10/31	00 02.8	-01 52	0.49	1.41	18.9	25	143
11/10	23 58.7	-00 13	0.55	1.42	19.3	31	118
11/20	00 00.4	+01 38	0.61	1.42	19.6	36	125
11/30	00 07.0	+03 41	0.68	1.42	20.0	39	134
12/10	00 17.5	+05 51	0.76	1.42	20.3	41	146
12/20	00 31.2	+08 07	0.83	1.42	20.5	43	158
12/30	00 47.4	+10 26	0.91	1.42	20.7	44	169

(138911) 2001 AE2 (a=1.35 AU, e=0.08, i=1.7°, H = 19.1)
2001 AE2 is a ~0.35 km diameter object with a high albedo of 0.34. There is some uncertainty in its taxonomy. Both an S-type and T-type taxonomy has been found for it. The high albedo suggests the S-type taxonomy may be closer to the truth. AE2 reaches a minimum phase angle of 3° and magnitude of V ~ 18.6 in mid-November.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	04 07.0	+18 33	0.64	1.46	20.4	35	124
10/11	04 09.4	+18 07	0.58	1.46	20.0	30	134
10/21	04 05.6	+17 22	0.53	1.46	19.6	23	144
10/31	03 55.6	+16 19	0.49	1.46	19.2	16	157
11/10	03 40.3	+15 03	0.47	1.46	18.8	7	170
11/20	03 22.6	+13 43	0.47	1.45	18.7	5	173
11/30	03 06.2	+12 35	0.48	1.45	19.1	14	160
12/10	02 54.3	+11 55	0.51	1.44	19.5	22	147
12/20	02 48.4	+11 47	0.56	1.43	19.9	29	135
12/30	02 48.6	+12 10	0.61	1.43	20.2	34	125

Other Asteroids Analogous to the OSIRIS-REx Target (101955) Bennu

(112) Iphigenia (a=2.43 AU, e=0.13, i=2.6°, H = 9.8)
Iphigenia is a ~70-80 km carbonaceous asteroid located in the inner Main Belt. Its orbit is similar to those of the Polana and Eulalia carbonaceous families and Iphigenia may be related to these families and to the OSIRIS-REx target asteroid (101955) Bennu (Walsh et al. 2013).

Quite a bit is known about Iphigenia. It has a dark 0.039 albedo, a hydrated Ch taxonomy, and a slow rotation period of ~31.4 h. It reached a minimum phase angle of 0.2° on August 11.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	20 59.4	-16 14	1.38	2.12	13.3	23	125
10/11	21 03.8	-15 45	1.48	2.12	13.5	25	116
10/21	21 11.1	-15 04	1.59	2.12	13.7	27	108
10/31	21 20.7	-14 14	1.70	2.12	13.8	27	101
11/10	21 32.4	-13 12	1.81	2.12	14.0	28	94
11/20	21 45.7	-12 01	1.93	2.13	14.1	28	87
11/30	22 00.2	-10 40	2.05	2.13	14.3	27	81
12/10	22 15.8	-09 11	2.17	2.13	14.4	27	75
12/20	22 32.1	-07 34	2.28	2.14	14.4	26	69
12/30	22 49.1	-05 49	2.40	2.14	14.5	24	63

(635) Vundtia (a=3.14 AU, e=0.08, i=11.0°, H = 9.0)

As with most large Main Belt asteroids, much is known about Vundtia such as its taxonomy (either a C- or B-type), low albedo (0.045) and diameter (~98 km). It has a long rotation period that is estimated to be around 11.8 h in length with a low 0.15-0.30 magnitude amplitude. Vundtia can be observed from an extreme minimum phase angle of 0.04° on September 26 UT. A peak brightness of V = 13.0 is also reached on that date.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	00 06.2	+00 29	1.96	2.96	13.1	2	174
10/11	23 59.9	-00 48	1.99	2.95	13.3	6	162
10/21	23 54.7	-01 56	2.04	2.95	13.5	10	151
10/31	23 51.3	-02 50	2.12	2.94	13.7	13	140
11/10	23 49.9	-03 27	2.22	2.94	13.9	15	129
11/20	23 50.6	-03 47	2.33	2.94	14.1	17	119
11/30	23 53.3	-03 50	2.45	2.93	14.2	19	109
12/10	23 58.1	-03 37	2.58	2.93	14.4	19	101
12/20	00 04.6	-03 11	2.72	2.93	14.5	20	92
12/30	00 12.6	-02 33	2.86	2.92	14.6	20	84

(1862) Hathor (a=0.84 AU, e=0.45, i=5.9°, H = 20.0)

Hathor is an Aten near-Earth asteroid with an SQ-type taxonomy. It has a very high albedo of 0.60 indicating a 0.3-km diameter. The high albedo also calls into the question whether Hathor is actually an SQ-type asteroid.

On October 22 UT, Hathor passes within 0.05 AU of Earth. Observability begins in mid-October when Hathor can be seen at phase angles larger than 100°. Peak brightness is reached on October 27/28 at V ~ 15.0. Minimum phase angle occurs on October 31 at 7°. Radar observations are planned for this apparition. This is one of the few asteroids for which the Yarkovsky Effect has been measured (Farnocchia et al. (2013).

Color and lightcurve photometry are requested in addition to phase function observations.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/11	10 08.8	+23 09	0.09	0.95	19.7	124	52
10/16	08 53.0	+26 56	0.06	0.98	17.7	102	74
10/21	06 25.8	+26 43	0.05	1.01	15.8	66	112
10/26	03 49.9	+15 46	0.06	1.05	15.0	25	153
10/31	02 28.2	+06 15	0.08	1.07	15.2	7	172
11/05	01 49.3	+01 18	0.11	1.10	16.3	17	161
11/10	01 28.8	-01 13	0.15	1.12	17.2	25	151
11/15	01 17.3	-02 33	0.18	1.14	17.9	31	143
11/20	01 11.1	-03 10	0.22	1.16	18.5	36	137
11/25	01 08.1	-03 22	0.26	1.18	19.0	39	131
11/30	01 07.5	-03 17	0.30	1.19	19.4	42	126
12/05	01 08.5	-03 00	0.34	1.20	19.8	44	122

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

Phaethon is well known as the parent object of the Geminid meteor shower. 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.

Phaethon peaks in brightness at V ~ 16.1 in early December. Its phase angle ranges from a minimum of 9° in late November to over 100° in early March 2015.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	05 37.6	+36 32	1.75	2.18	18.7	27	102
10/11	05 37.8	+37 18	1.56	2.14	18.4	26	111
10/21	05 32.9	+38 08	1.38	2.08	18.0	24	122
10/31	05 20.9	+38 56	1.21	2.02	17.6	21	133
11/10	04 59.9	+39 28	1.05	1.95	17.1	17	146
11/20	04 28.3	+39 15	0.92	1.88	16.5	12	158
11/30	03 47.4	+37 36	0.83	1.80	16.1	10	162
12/10	03 03.1	+34 06	0.78	1.71	16.1	16	151
12/20	02 23.5	+29 07	0.76	1.61	16.2	26	134
12/30	01 53.3	+23 42	0.78	1.50	16.4	36	116

(68267) 2001 EA16 (a=1.51 AU, e=0.43, i=38.8°, H = 16.8)

One of the brighter NEAs of the quarter, 2001 EA16 peaks at V ~ 15.7 in mid-October. Surprisingly for such a large, bright NEA, little has been published on its characteristics. Photometry over a range of phase angles from 129° to 42° is possible this quarter. Lightcurve and color photometry are also requested.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	14 05.2	-43 20	0.13	0.92	17.7	129	46
10/11	17 23.3	+15 56	0.11	0.96	15.8	106	68
10/21	19 01.4	+41 59	0.21	1.02	16.2	78	90
10/31	19 47.3	+48 59	0.34	1.08	17.0	67	95
11/10	20 17.3	+51 13	0.46	1.14	17.5	60	97
11/20	20 42.9	+52 50	0.58	1.21	18.0	54	97
11/30	21 08.2	+54 04	0.69	1.27	18.4	50	97
12/10	21 34.6	+55 12	0.80	1.34	18.7	47	97
12/20	22 03.1	+56 19	0.91	1.40	19.0	44	96
12/30	22 34.1	+57 26	1.01	1.47	19.3	42	95

(85713) 1998 SS49 (a=1.92 AU, e=0.64, i=10.8°, H = 15.6)

No taxonomy has been determined for 1998 SS49. NEOWISE found an albedo of 0.076, which is consistent with a carbonaceous nature. The low albedo also suggests that it is a relatively large object with a diameter on the order of 3.5 km. Due to its bright H value, it is 17th magnitude or brighter for the entire quarter. Phase angle observations over a range from 36° to 113° are possible. Peak brightness is reached in early/mid-November at V ~ 14.6. Lightcurve and color photometry are requested in addition to phase function photometry.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	04 28.2	+18 06	0.72	1.49	17.2	36	119
10/11	04 52.1	+20 32	0.57	1.39	16.6	37	123
10/21	05 24.7	+24 03	0.43	1.29	15.9	39	125
10/31	06 17.8	+29 23	0.31	1.19	15.1	44	123
11/10	08 04.7	+35 57	0.22	1.09	14.6	58	111
11/20	11 07.7	+33 12	0.19	0.99	15.0	85	84
11/30	13 22.8	+18 35	0.24	0.89	16.2	107	60
12/10	14 29.2	+07 07	0.34	0.80	17.1	113	49
12/20	15 09.7	-00 39	0.46	0.74	17.3	109	45
12/30	15 42.5	-06 39	0.59	0.70	17.3	99	45

(137032) 1998 UO1 (a=1.60 AU, e=0.76, i=25.5°, H = 16.6)

1998 UO1 is a ~1.1 km Sq-type NEA with an albedo of ~0.18. No lightcurve information has been published. During the October-December quarter, its phase angle ranges from a high of 126° in early October to 32° in late December. Peak brightness occurs at V ~ 16.5 in mid-October.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	14 52.2	-22 36	0.30	0.80	18.8	126	40
10/11	17 56.2	-14 04	0.24	0.95	16.8	94	72
10/21	20 14.5	-00 35	0.34	1.09	16.7	64	98
10/31	21 21.2	+06 14	0.50	1.23	17.4	51	106
11/10	21 59.1	+09 40	0.68	1.35	18.1	45	107
11/20	22 25.5	+11 48	0.87	1.47	18.7	41	104
11/30	22 46.8	+13 22	1.07	1.58	19.3	38	100
12/10	23 05.4	+14 43	1.27	1.68	19.7	36	96
12/20	23 22.7	+15 58	1.47	1.77	20.1	34	90
12/30	23 39.2	+17 12	1.68	1.86	20.4	32	85

(175114) 2004 QQ (a=2.25 AU, e=0.67, i=5.7°, H = 16.7)

The Apollo near-Earth asteroid 2004 QQ is observable over a wide range of phase angles this quarter. Minimum phase is reached on November 28 at 8°. On October 1st, its phase angle is 104° though it is possible even higher phase angles can be observed during the preceding month (~120-130°). QQ is at maximum brightness for much of late-October/early November at V ~ 16.2. Little is known about this object so photometry of all types is encouraged.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	09 08.8	+43 33	0.21	0.93	17.0	104	64
10/11	07 40.8	+46 35	0.24	1.02	16.4	78	89
10/21	06 27.8	+45 51	0.27	1.12	16.2	57	110
10/31	05 28.0	+43 02	0.32	1.22	16.2	38	130
11/10	04 41.2	+39 04	0.37	1.32	16.3	23	149
11/20	04 07.6	+34 53	0.45	1.43	16.4	11	164
11/30	03 45.7	+31 09	0.55	1.53	16.9	8	167
12/10	03 33.3	+28 13	0.67	1.62	17.6	13	158
12/20	03 27.9	+26 06	0.80	1.72	18.3	18	148
12/30	03 27.8	+24 39	0.96	1.81	18.9	22	138

(204131) 2003 YL (a=1.15 AU, e=0.63, i=5.7°, H = 19.8)

Physical characteristics of this asteroid are lacking. It brightens to a peak V of ~16.5 in mid-December when it will be as close as 0.07 AU from Earth. Phase angle will range from higher than 130° in early December to 37° at the end of the year.

DATE	RA	DEC	Δ	r	V	PH	Elong
12/05	17 49.9	+00 38	0.14	0.87	23.2	148	28
12/10	18 54.9	+15 14	0.09	0.93	20.0	130	47
12/15	21 55.6	+39 20	0.07	0.99	17.1	88	88
12/20	01 24.1	+40 07	0.10	1.04	16.8	53	122
12/25	02 43.7	+33 40	0.15	1.10	17.5	41	134
12/30	03 17.8	+29 40	0.22	1.15	18.3	37	136

(214088) 2004 JN13 (a=2.87 AU, e=0.70, i=13.3°, H = 15.0)

2004 JN13 will become one of the brightest near-Earth asteroids of the quarter peaking at V ~ 12.7 in late November. The brightness is a combination of its large size (3km diameter) and close approach to Earth (0.14 AU). Past characterization efforts have identified JN13 as an ordinary chondritic Sq-type asteroid with an albedo of 0.25. No lightcurve information has been published for this asteroid.

This quarter its phase angle spans from a maximum of 108° in late October to a minimum of 8° in mid-December. In late October, it is a far southern object around V ~ 16. It races north and becomes visible for most northern observers during the 2nd half of November.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	15 42.7	-49 21	0.42	0.89	16.2	94	62
10/11	15 43.4	-56 23	0.34	0.87	16.1	102	59
10/21	15 26.0	-65 18	0.27	0.88	15.9	107	58
10/31	13 47.1	-76 27	0.20	0.92	15.3	106	63
11/10	07 39.4	-72 08	0.15	0.98	14.1	91	80
11/20	05 53.5	-39 48	0.14	1.05	12.9	60	113
11/30	05 21.8	-08 18	0.17	1.13	12.7	29	147
12/10	05 06.2	+09 46	0.25	1.23	13.1	11	167
12/20	04 58.1	+19 12	0.34	1.32	13.9	10	167
12/30	04 55.4	+24 23	0.46	1.42	14.9	16	157

(275976) 2001 XV10 (a=2.21 AU, e=0.58, i=22.3°, H = 16.0)

There are no published physical characteristics for this asteroid. Throughout the October-December quarter, it is reasonably bright at V ~ 16.8 to 17.6. Its phase angle spans from 92° down to 32° during the same period. A minimum phase angle of 24° is reached in early February 2015 when the asteroid will be around V ~ 18.5. Any photometry (color, phase function lightcurve) will greatly increase our knowledge of this Apollo near-Earth asteroid.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	08 03.3	+15 28	0.34	0.93	16.8	92	68
10/11	08 37.8	+27 05	0.38	0.96	16.8	85	73
10/21	09 11.8	+35 29	0.44	1.00	16.9	77	78
10/31	09 43.4	+41 39	0.49	1.06	17.0	69	84
11/10	10 10.7	+46 28	0.53	1.13	17.1	61	91
11/20	10 32.2	+50 37	0.58	1.21	17.2	54	97
11/30	10 46.3	+54 31	0.62	1.29	17.3	48	104
12/10	10 51.1	+58 18	0.66	1.37	17.4	42	111
12/20	10 44.2	+61 53	0.70	1.45	17.5	37	118
12/30	10 23.2	+64 52	0.74	1.53	17.6	32	125

References

Belskaya, I., Shevchenko, V. (2000). “The Opposition Effect of Asteroids”. *Icarus* **147**, 94-105.

Farnocchia, D. et al. (2013). “Near-Earth Asteroids with Measurable Yarkovsky Effect.” *Icarus* **224**, 1-13.

Hergenrother, C., Hill, D. (2013). “The OSIRIS-REx *Target Asteroids!* Project: A Small Telescope Initiative to Characterize Potential Spacecraft Mission Target Asteroids.” *Minor Planet Bulletin* **40**, 164-166.

Jewitt, D., Li, J., Agarwal, J. (2013). “The Dust Tail of Asteroid (3200) Phaethon.” *Astrophys. J. L.* **771**, article id. L36.

Li, J., Jewitt, D. (2013). “Recurrent Perihelion Activity in (3200) Phaethon.” *AJ* **145**, article id. 154.

Walsh, K., Delbo, M., Bottke, W., Vokrouhlicky, D., Lauretta, D. (2013). “Introducing the Eulalia and New Polana Asteroid Families: Re-assessing Primitive Asteroid Families in the Inner Main Belt.” *Icarus* **225**, 283-297.

LIGHTCURVE ANALYSIS FOR THREE ASTEROIDS: 4000 HIPPARCHUS, 5256 FARQUHAR, AND 5931 ZHVANETSKIJ

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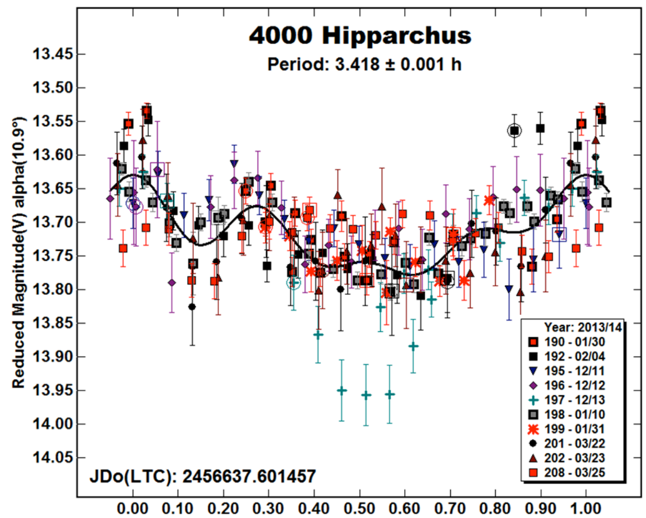
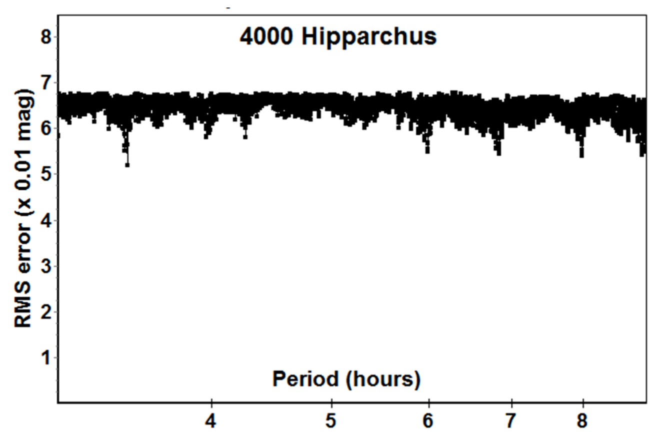
Lightcurves for asteroids 4000 Hipparchus, 5256 Farquhar, and 5931 Zhvanetskij were obtained at the Phillips Academy Observatory (PAO) and HUT Observatory between 2013 October and 2014 March.

Lightcurves for three asteroids were obtained from Phillips Academy Observatory and HUT Observatory between 2013 October and 2014 March. The two observatories have twin telescopes: 0.40-m *f*/8 Ritchey-Chrétien reflectors by DFM Engineering. Phillips Academy Observatory used an SBIG STL-1301E with a 1280x1024 array of 16-micron pixels. The resulting image scale was 1.0 arcsecond per pixel. Exposures were primarily 300 seconds working at –30°C and unfiltered. All images were dark and flat-field corrected, guided, and unbinned. HUT observations were made with an Apogee Alta U47 CCD. Exposures were 300 seconds working at –40° C. All images were dark and flat-field corrected and binned 2x2 for an effective image scale of 1.65 arcseconds per pixel.

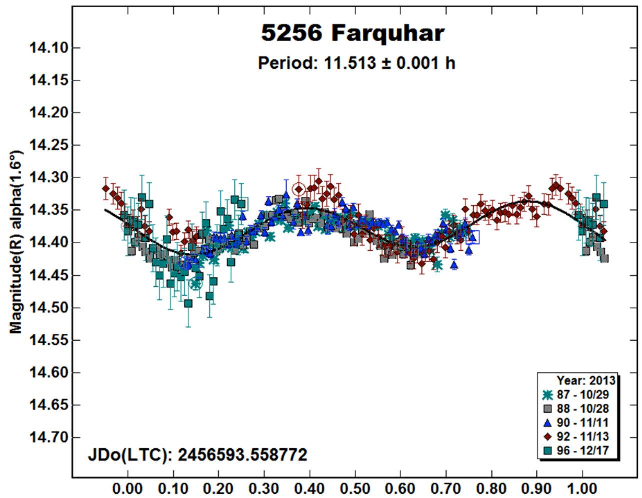
Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. All comparison stars were selected to near solar color by using the “comp star selector” tool of *MPO Canopus*. Data merging and period analysis were also done with *MPO Canopus* using an implementation of the Fourier analysis algorithm of Harris (FALC; Harris *et al*., 1989). The combined data sets from both observatories were analyzed collaboratively by high school students enrolled in an astronomy research class taught by Odden at Phillips Academy. The final lightcurves appearing here were contributed by Aggarwal and Yoon. A search of the Asteroid Lightcurve Database (LCDB; Warner *et al*., 2009) and other sources did not reveal previously reported lightcurve results for these asteroids.

4000 Hipparchus. Astronomers Seiji Ueda and Kaneda Hisroshi discovered asteroid 4000 Hipparchus in 1989 and named it after the famed Greek astronomer. Images were taken from 2013 October to 2014 March at PAO and HUT observatories. To make the graph more legible, data points have been binned in pairs with a maximum of ten minutes between points. The resulting plot consists of 190 data points derived from images taken on ten separate nights. The asteroid was passing through the Milky Way at opposition. Although the authors were careful to eliminate images in which the asteroid was passing near a background star, there is quite a bit of scatter in the resulting plot. Because the field was so dense, there may have been undetected background stars affecting the photometry. A period search of the data favored a period of 3.418 hours, but the period spectrum leaves the possibility open for other solutions. Given the short period of the asteroid and the presence of odd dips in the object's brightness when no adjacent star was obviously present, the authors attempted a dual period search. No strong dual period solution emerged. Follow-up work on this asteroid is warranted.

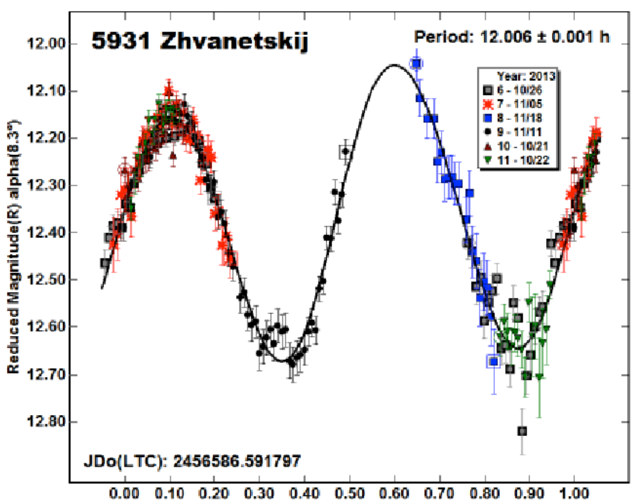




5256 Farquhar. Astronomers E.F. Helin, C. Mikolajczak, and R. Coker found asteroid 5256 Farquhar in 1998. Images were taken at PAO on 2013 October 28-29 and December 17. HUT observatory imaged the asteroid on 2013 November 11 and 13. The resulting bimodal lightcurve consists of 342 data points. The period spectrum suggests a synodic period $P = 11.513 \pm 0.001$ hours and amplitude 0.07 mag. A second dip in the period spectrum is also noted at 5.755 hours (1/2 P). Although several additional imaging runs were attempted, the asteroid dimmed too quickly for adequate signal-to-noise to be achieved. Thus, further attempts to image the asteroid were not pursued.



5931 Zhvanetskij. This asteroid was discovered in 1976 by Russian Astronomer N.S. Chernykh. Images were taken at PAO on five nights from 2013 October 21 through November 18. HUT Observatory imaged the asteroid on 2013 November 11. The resulting lightcurve consists of 204 data points. The amplitude of the lightcurve is 0.63 mag, sufficient to ensure a bimodal solution. The period spectrum strongly suggests the period of P = 12.006 ± 0.001 hours. Because the asteroid completes its rotation almost exactly twice each day, all of the image runs taken from Andover cover the same portion of the lightcurve. The images provided by HUT extended observations, but a gap remains.



Acknowledgements

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References

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.

Minor Planet Center Database Search Engine *http://www.minorplanetcenter.net/db_search*

Warner, B.D. (2010). *The MPO Users Guide: A Companion Guide to the MPO Canopus/PhotoRed Reference Manuals*. BDW Publishing, Colorado Springs, CO.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28. *http://www.minorplanet.info/lightcurvedatabase.html*

LIGHTCURVE ANALYSIS OF ASTEROIDS FROM BLUE MOUNTAINS OBSERVATORY IN 2013

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Analysis of CCD photometric observations made in 2013 from Kingsgrove Observatory and Blue Mountains Observatory found the synodic rotation period for 30 asteroids.

Leura Observatory has undergone a reconstruction and an extension to accommodate additional telescopes. When it is in full operation, there will be five telescopes of assorted sizes and configurations, all of which will be dedicated to asteroid photometry and astrometry. They are: a 0.12-m refractor for wide field and NEA asteroid photometry, a 0.30-m reflector, a 0.35-m reflector for general photometry and astrometry, a 0.25-m or 0.35-m wide-field telescope for photometry, and a 0.61-m reflector. The objective will be full automation for research and education in astronomy, concentrating on minor planet work. To commemorate the observatory transformation, Leura has been renamed Blue Mountains Observatory with a new MPC code of Q68.

The instrument configurations used at Kingsgrove and Blue Mountains Observatory (BMO) for this work are given in Table I. At Kingsgrove, all exposures were 300 s and unfiltered, with the exception of 357 Ninina where an R filter was also used. Asteroid selection was mainly from the CALL website (Warner, 2013) with the selection criteria being an average magnitude during closest approach of V = 13-15 and a southerly declination facilitating maximum nightly observations due to local geographical restrictions. The telescopes in Blue Mountains Observatory were used mainly on fainter targets selected from Photometric Survey for Asynchronous Binary Asteroid (PSABA) for follow up and detection work coordinated by Pravec (2013).

MPO Canopus v.10.2.0.1 software, which incorporates the Fourier algorithm developed by Harris (Harris *et al.*, 1989), was used for period analysis. All lightcurve data were linked internally using the "Derived Mags" algorithm and the Comp Star Selector feature in *MPO Canopus* (see Stephens, 2008) where 2MASS to BVRI values were used (Warner, 2007). Although a clear filter is used in the observations, R catalog magnitudes were selected in order to match the CCD camera's greater sensitivity at the red end of the visible spectrum. Comparison stars were selected based on a near-solar color index of $0.5 \leq B\text{-}V \leq 0.9$.

<u>357 Ninina</u> was observed by Behrend *et al.* (2013) and found to have a synodic period of 35.98 h with a comment translated from French as "ill defined" amplitude. Observations of this asteroid were done in 2007 at Kingsgrove and in 2013 at BMO. The lightcurve from 2013 was reduced and plotted using the CSS method. The best period found was 36.0105 ± 0.0001 h with some adjustment done to the nightly zero points (the DeltaComp values in *MPO Canopus*). However, without the adjustments it was found to have a scatter of 0.1 magnitude; that is too high to be explained by catalog error alone. Due to the long period nature of this asteroid, such phenomena may be due to the asteroid being in non-principle axis rotation, or *tumbling* (Pravec, 2005). The data for 357 Ninina obtained in 2007 were never published since, without CSS method to link the nightly observations to standard magnitude, the period cannot be determined with confidence. The data were re-measured and a period of 35.9 ± 0.1 h was found, albeit with a low amplitude of 0.12 mag.

<u>2077 Kiangsu</u> has not, as best could be determined, been observed in the past. The sparse data obtained were not sufficient to get a unique solution for its period. One solution obtained was 48 h and this is commensurate with earth rotation period. To identify the correct period will require collaboration from different geographical locations.

<u>6401 Roentgen</u> was observed by Behrend (2013), who derived a period of 15.98 h using observations from only one night. Warner (2014) found the period to be 15.96 h. Analysis of the BMO data found a period of 15.9 h, which is consistent with both observations despite the short duration for each session.

<u>13921 Sgarbini</u>. Observations were done on two nights with the 0.61-m system. From the first night, the lightcurve did not remain on the same zero point throughout, suggesting a longer period lightcurve. The CSS feature in *MPO Canopus* was used but, even so, adjustments of the zero points by up to 0.2 mag were required to get the 7.3681 h period. This result was consistent with observations that were done previously. However, the error for CSS should be less than 0.05 mag. When the period was searched based on no vertical adjustment of the zero points, a longer period of 43 h was found. Pravec (private communication) found that the 43 h period was not unique and it may represent a second period of a two periodic binary component. Further observations of this asteroid are desirable.

Another asteroid with similar photometric behavior as 357 Ninina and 13921 Sgarbini was (43904) 1995 WO. It was a target selected from PSABA (2013). There had been no previous work reported for this asteroid. The short period was found to be 4.5894 h by adjusting the zero point of the lightcurves. Again with the amplitude of only 0.07 mag, this may be the result of a period search that latched on to an incorrect value. Once the period search was done without any zero point adjustments, a 99 h period was found, suggesting a slow rotating asteroid with the possibility non-principle axis rotation. This will be confirmed on future work with better linkages of data.

The long period asteroids (53008) 1998 VY5 and (12854) 1998 HA13 conform very nicely to the phased plots with the exception of the observation on 2013 August 4 for 1998 HA13, where a 0.11 magnitude adjustment was required.

References

Behrend, R. (2013). Observatoire de Geneve web site. *http://obswww.unige.ch/~behrend/page2cou.html*

Blue Mountains Observatory (2013). Website. *http://www.bluemountainsobservatory.com.au/asteroid*

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., Zeigler, K.W. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Observatory	Diameter (code)	f/	CCD Camera	Pixels (microns)	Bin	Scale ″/pix
Kingsgrove (E19)	0.25m (10)	11	ST-402ME (SBIG)	9	1x1	1.41
BMO (Q68)	0.35m (14)	6	ST8-XME (SBIG)	9	1x1	0.88
BMO (Q68)	0.61m (24)	6.8	U16M (Apogee)	27	3x3	1.40

Table I. Telescope/camera systems.

#	Name	mm/dd 2013 (*2014)	Scope	Period (h)	PE	Amp (mag)	AE	H	Dia (km)	PA	LPAB	BPAB
357	Ninina	07/24-11/06	10	36.0105	0.0001	0.24	0.05	8.72	99.5	14.7,3.3,17.9	344	-8
1367	Nongoma	04/25-08/09	14	94.8	0.1	0.83	0.05	12.00	12.47	26.9,1.4,9.4	271	-7
1387	Kama	07/28-09/30	14	52.5	0.1	0.57	0.05	13.30	6.85	20.2,5.1,16.2	335	6
1717	Arlon	04/17-06/09	14	5.148	0.001	0.09	0.05	12.20	11.37	4.1,3.7,20.9	212	-6
1830	Pogson	03/09-03/17	14	2.6036	0.0001	0.17	0.1	12.45	10.14	18.1,20.8	137	0
1979	Sakharov	02/06-02/08	14	7.5891	0.0001	0.22	0.02	13.60	5.97	5.4,4.7	144	-7
2055	Dvorak	07/24-07/27	24	4.4106	0.0001	0.17	0.01	12.60	9.46	16.9	294	-23
2077	Kiangsu	11/12-12/10	10,14	47.8	0.1	0.5	0.1	13.60	4.74	18.8,25.8	41,45	-21,-9
2897	Ole Romer	04/12-04/14	14	2.6024	0.0001	0.12	0.02	13.20	7.18	17.0,17.9	174	5
3060	Delcano	08/08-09/11	24	2.8027	0.0001	0.18	0.01	13.00	7.87	17.7,2.5,3.7	342	2
3951	Zichichi	10/11-11/07	14	3.4120	0.0001	0.35	0.05	12.60	9.46	8.5,	6	7
4905	Hiromi	09/29	24	5.62	0.01	0.40	0.01	12.10	11.91	10.4	23	0
6265	1985 TW3	04/12-05/19	14	2.70933	0.00001	0.27	0.05	13.40	6.54	7.8,0.5,12.3	216	1
6401	Roentgen	07/28-08/05	14	11.99	0.01	0.35	0.05	12.70	9.03	23.7, 24.5	248	13
10484	Hecht	04/01	14	2.5788	0.0001	0.17	0.01	13.8	5.44	4.8	185	-7.1
11901	1991 PV11	06/07-07/02	14	9.3759	0.0001	0.59	0.02	13.6	5.97	12.0, 17.8	254	17
12854	1998 HA13	07/26-08/08	24	50.59	0.01	0.34	0.05	14.9	3.28	11,7.7	314	9
13921	Sgarbini	12/02-01/05*	14,24	7.3681	0.0001	0.10	0.02	14.5	3.94	9, 22	67	12
13921	Sgarbini	12/02-01/05*	14,24	43.4	0.1	0.28	0.1					
26636	2000 HX57	04/06-04/07	14	4.2744	0.0001	0.25	0.02	12.9	8.24	5.6	197	11
26984	Fernand-Roland	08/08	24	20	1	0.30	0.01	12.20	20.04	5.7	310	14
29818	1999CM 117	05/01	14	14	1	0.41	0.02	14.5	3.94	2.5	216	0.6
34706	2001 OP83	04/06-04/18	14	2.5949	0.0001	0.15	0.05	14.8	3.43	7.3,9.3	197	10
43904	1995 WO	07/26-08/16	24	98	1	0.26	0.05	15.0	3.13	11.0,12.8	310	12
49636	1999 HJ1	07/28-08/10	24	2.8208	0.0001	0.26	0.05	13.9	5.2	33.9,35.2	258	28
53008	1998 VY5	12/06-01/03*	14	44.6	0.1	0.25	0.03	13.5	6.25	11.2 21.7	62.5 66.7	-13.4 -9.3
67747	2000 UF43	07/08	24	3.111	0.001	0.26	0.02	15.7	2.27	16.8	259	4.1
99942	Apophis	01/07-02/13	14	30.528	0.001	1.0	0.1	19.2	0.45	53.2 31.5 44.5	129 123 124	-22.2 -18.4 -12.2
163364	2002 OD20	06/17-06/19	24	2.4201	0.0001	0.11	0.01	18.8	0.55	20	253	1
285263	1998 QE2	05/20-0604	14	2.726	0.001	0.11	0.02	17.3	1.09	68.7 17.2 18.0	211 248	-27.4 8

Table II. Observing circumstances and analysis results.

Oey, J. (2008). "Lightcurve Analysis of Asteroids from Kingsgrove and Leura Observatories in the 2nd half of 2007." *Minor Planet Bulletin* ***35**, 132-135.*

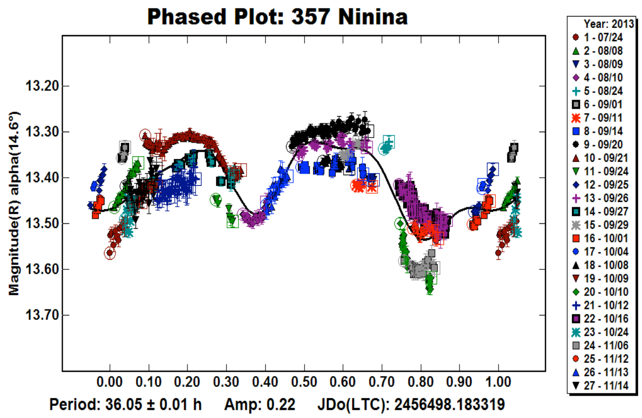
Pravec, P. (2013). "Photometric Survey of Asynchronous Binary Asteroids." *http://www.asu.cas.cz/~asteroid/binastphotsurvey.htm*

Pravec, P. Harris, A.W., Scheirich, P., Kušnirák, P., Šarounová, L., Hergenrother, C.W., Mottola, S., Hicks, M.D., Masi, G., Krugly, Yu.N., Shevchenko, V.G., Nolan, M.C., Howell, E.S., Kaasalainen, M., Galád, A., Brown, P., DeGraff, D.R., Lambert, J.V., Cooney Jr., W.R., Foglia, S. (2005). "Tumbling Asteroids." *Icarus* **173**, 108-131.

Stephens, R.D. (2008). "Long period asteroids observed from GMARS and SANTANA observatories." *Minor Planet Bulletin* **35**, 21-22.

Warner, B.D. (2013). CALL website. *http://www.minorplanet.info/PHP/call_OppLCDBQuery.php*

Warner, B. D. (2014). "Asteroid Lightcurve Analysis at CS3-Palmer Divide station: 2013 June – September." *Minor Planet Bulletin* **40**, 54-57.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1 - 07/24
2 - 08/08
3 - 08/09
4 - 08/10
5 - 08/24
6 - 09/01
7 - 09/11
8 - 09/14
9 - 09/20
10 - 09/21
11 - 09/24
12 - 09/25
13 - 09/26
14 - 09/27
15 - 09/29
16 - 10/01
17 - 10/04
18 - 10/08
19 - 10/09
20 - 10/10
21 - 10/12
22 - 10/16
23 - 10/24
24 - 11/06
25 - 11/12
26 - 11/13
27 - 11/14
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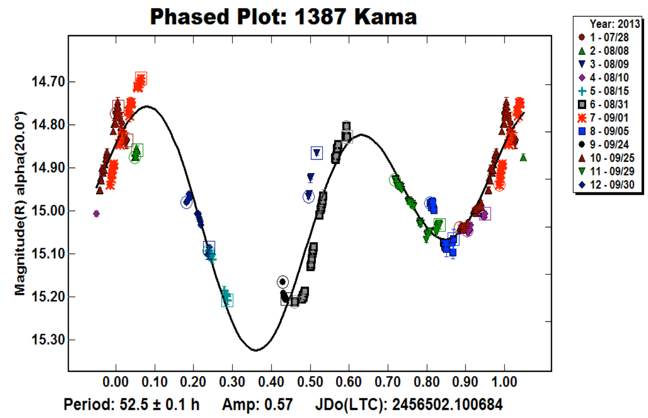
Phased Plot: 1387 Kama
Magnitude(R) alpha(20.0°)
Year: 2013
1 - 07/28
2 - 08/08
3 - 08/09
4 - 08/10
5 - 08/15
6 - 08/31
7 - 09/01
8 - 09/05
9 - 09/24
10 - 09/25
11 - 09/29
12 - 09/30
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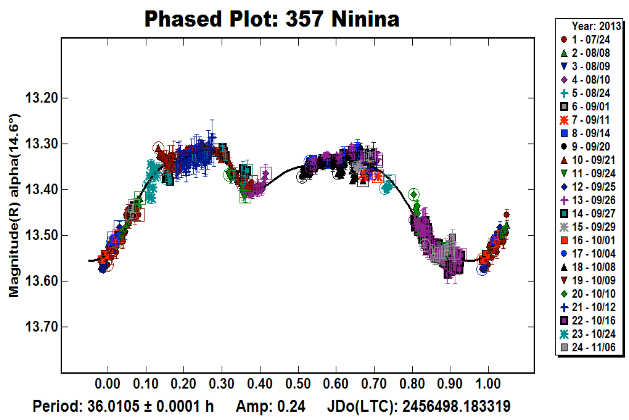
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Magnitude(R) alpha(14.6°)
Year: 2013
1 - 07/24
2 - 08/08
3 - 08/09
4 - 08/10
5 - 08/24
6 - 09/01
7 - 09/11
8 - 09/14
9 - 09/20
10 - 09/21
11 - 09/24
12 - 09/25
13 - 09/26
14 - 09/27
15 - 09/29
16 - 10/01
17 - 10/04
18 - 10/08
19 - 10/09
20 - 10/10
21 - 10/12
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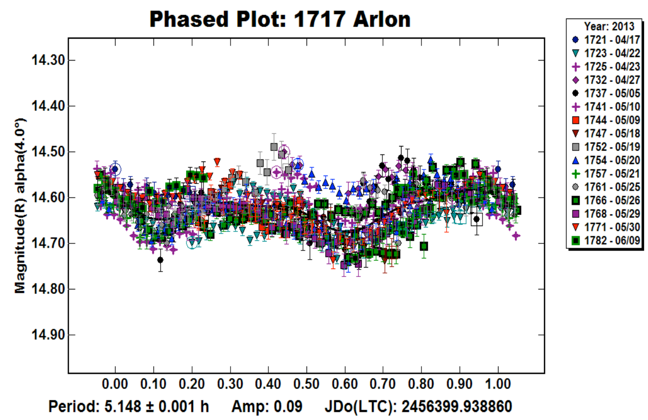
Phased Plot: 1717 Arlon
Magnitude(R) alpha(4.0°)
Year: 2013
1721 - 04/17
1723 - 04/22
1725 - 04/23
1732 - 04/27
1737 - 05/05
1741 - 05/10
1744 - 05/09
1747 - 05/18
1752 - 05/19
1754 - 05/20
1757 - 05/21
1761 - 05/25
1766 - 05/26
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1771 - 05/30
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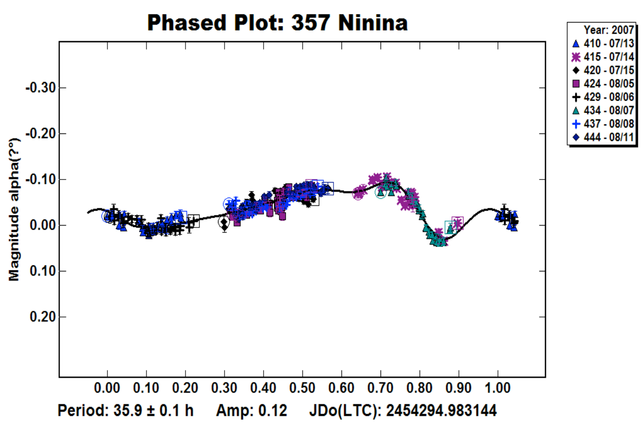
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Year: 2007
410 - 07/13
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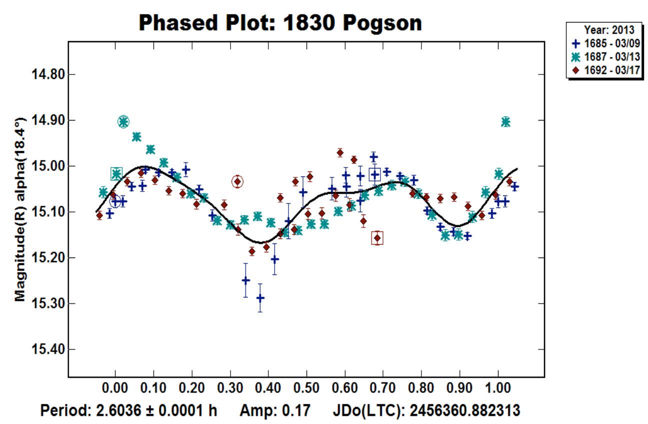
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Magnitude(R) alpha(18.4°)
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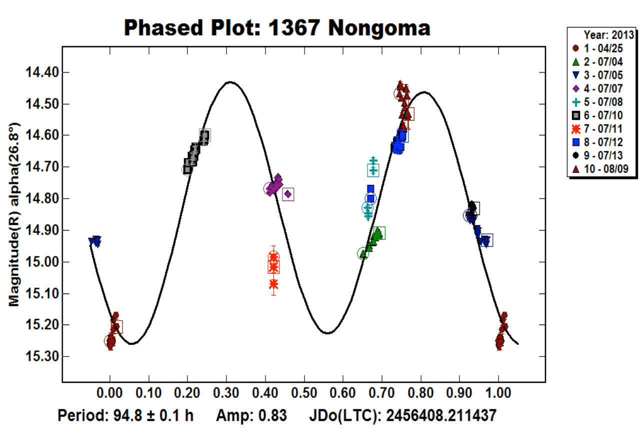
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2 - 07/04
3 - 07/05
4 - 07/07
5 - 07/08
6 - 07/10
7 - 07/11
8 - 07/12
9 - 07/13
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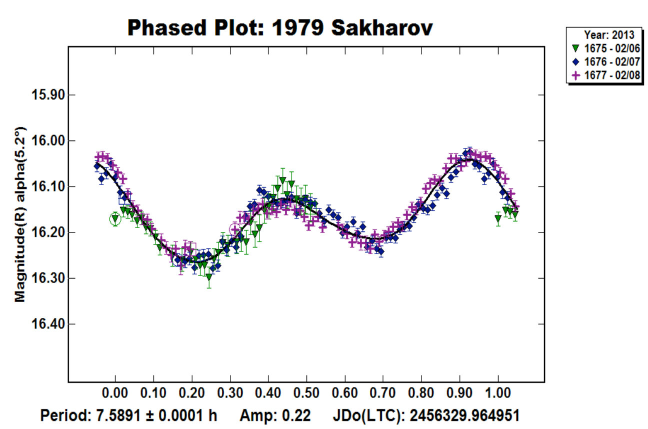
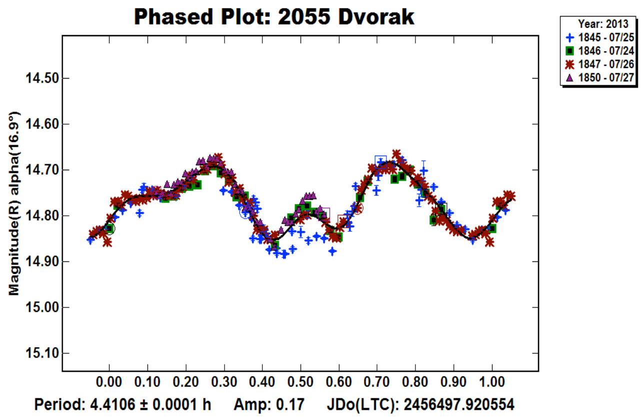
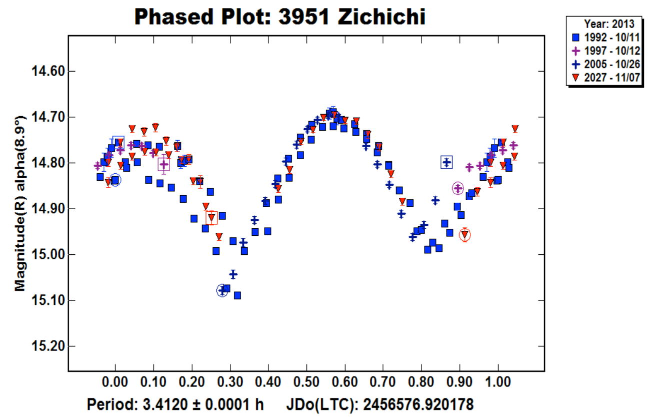
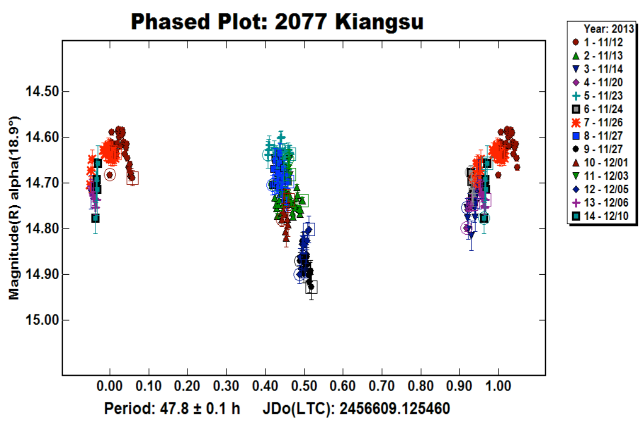

Phased Plot: 1979 Sakharov
Magnitude(R) alpha(5.2°)
Year: 2013
1675 - 02/06
1676 - 02/07
1677 - 02/08
Period: 7.5891 ± 0.0001 h Amp: 0.22 JDo(LTC): 2456329.964951


Phased Plot: 2055 Dvorak
Year: 2013
1845 - 07/25
1846 - 07/24
1847 - 07/26
1850 - 07/27
Magnitude(R) alpha(16.9°)
Period: 4.4106 ± 0.0001 h Amp: 0.17 JDo(LTC): 2456497.920554


Phased Plot: 3951 Zichichi
Year: 2013
1992 - 10/11
1997 - 10/12
2005 - 10/26
2027 - 11/07
Magnitude(R) alpha(8.9°)
Period: 3.4120 ± 0.0001 h JDo(LTC): 2456576.920178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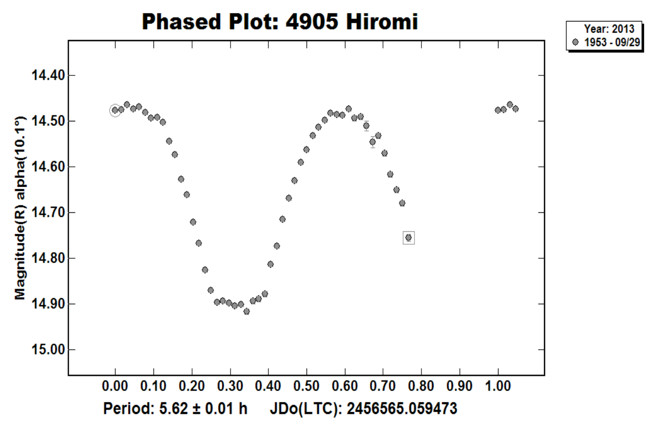
Year: 2013
1 - 11/12
2 - 11/13
3 - 11/14
4 - 11/20
5 - 11/23
6 - 11/24
7 - 11/26
8 - 11/27
9 - 11/27
10 - 12/01
11 - 12/03
12 - 12/05
13 - 12/06
14 - 12/10
Magnitude(R) alpha(18.9°)
Period: 47.8 ± 0.1 h JDo(LTC): 2456609.125460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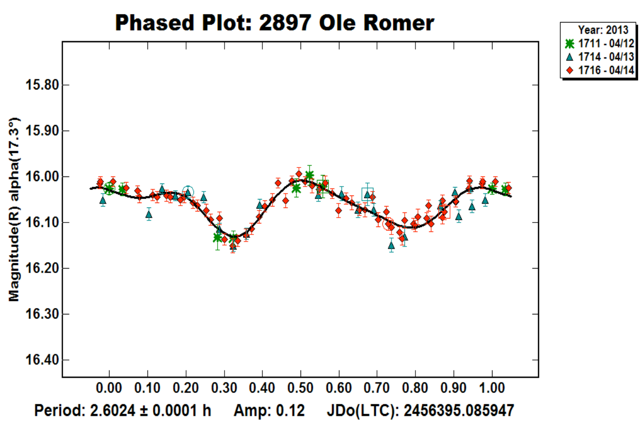
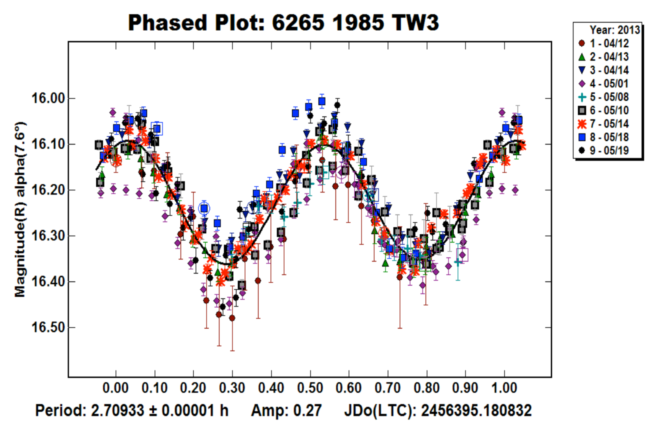
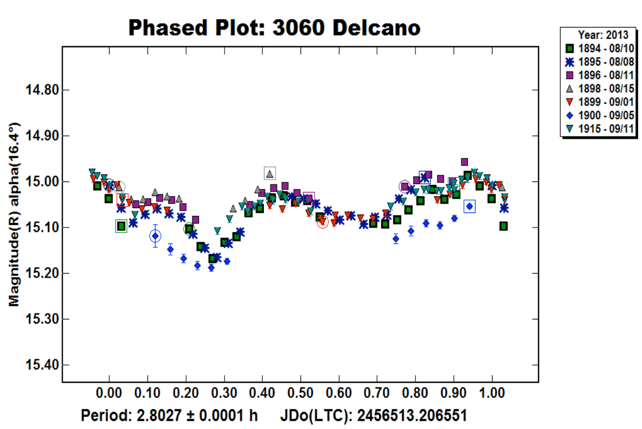
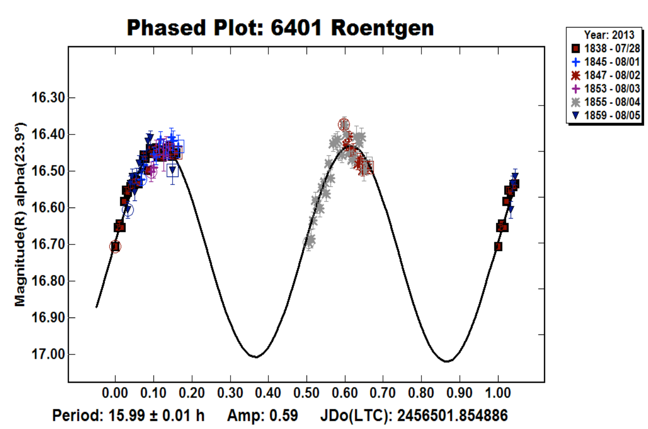
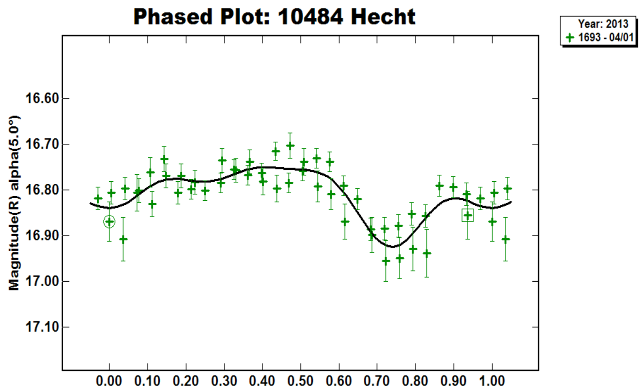
Year: 2013
1953 - 09/29
Magnitude(R) alpha(10.1°)
Period: 5.62 ± 0.01 h JDo(LTC): 2456565.059473


Phased Plot: 2897 Ole Romer
Year: 2013
1711 - 04/12
1714 - 04/13
1716 - 04/14
Magnitude(R) alpha(17.3°)
Period: 2.6024 ± 0.0001 h Amp: 0.12 JDo(LTC): 2456395.085947

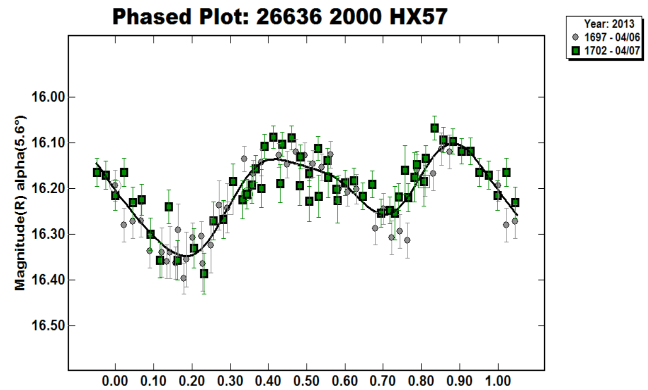

Phased Plot: 6265 1985 TW3
Year: 2013
1 - 04/12
2 - 04/13
3 - 04/14
4 - 05/01
5 - 05/08
6 - 05/10
7 - 05/14
8 - 05/18
9 - 05/19
Magnitude(R) alpha(7.6°)
Period: 2.70933 ± 0.00001 h Amp: 0.27 JDo(LTC): 2456395.180832


Phased Plot: 3060 Delcano
Year: 2013
1894 - 08/10
1895 - 08/08
1896 - 08/11
1898 - 08/15
1899 - 09/01
1900 - 09/05
1915 - 09/11
Magnitude(R) alpha(16.4°)
Period: 2.8027 ± 0.0001 h JDo(LTC): 2456513.206551

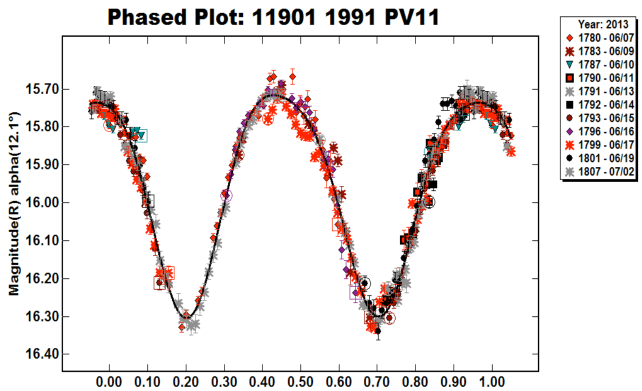

Phased Plot: 6401 Roentgen
Year: 2013
1838 - 07/28
1845 - 08/01
1847 - 08/02
1853 - 08/03
1855 - 08/04
1859 - 08/05
Magnitude(R) alpha(23.9°)
Period: 15.99 ± 0.01 h Amp: 0.59 JDo(LTC): 2456501.854886



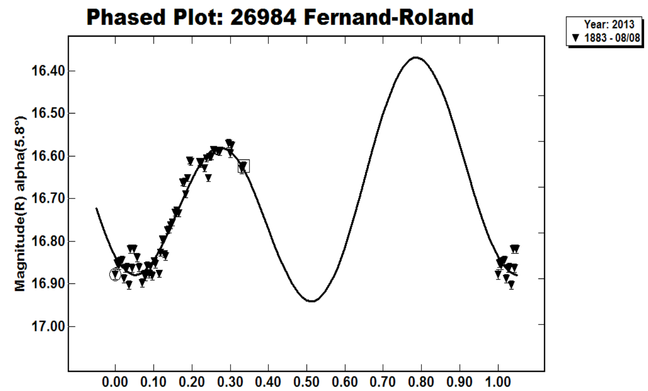
Period: 2.5788 ± 0.0001 h Amp: 0.17 JDo(LTC): 2456384.057305



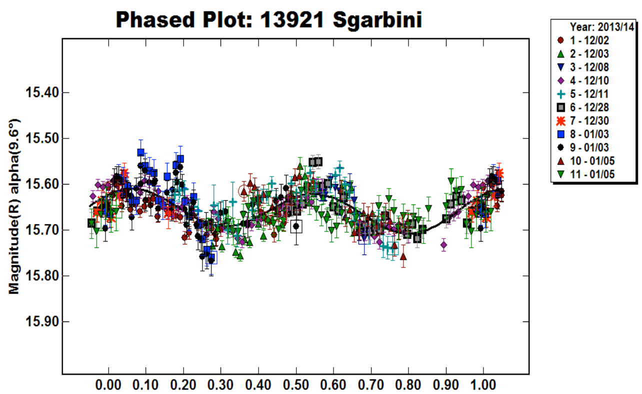
Period: 4.2744 ± 0.0001 h Amp: 0.25 JDo(LTC): 2456389.000294



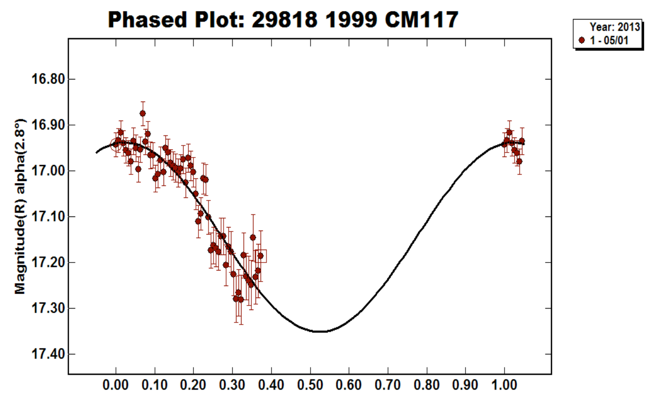
Period: 9.3759 ± 0.0001 h Amp: 0.59 JDo(LTC): 2456450.980054



Period: 20.0 ± 0.1 h Amp: 0.57 JDo(LTC): 2456512.912138



Period: 7.3681 ± 0.0001 h Amp: 0.10 JDo(LTC): 2456629.057693



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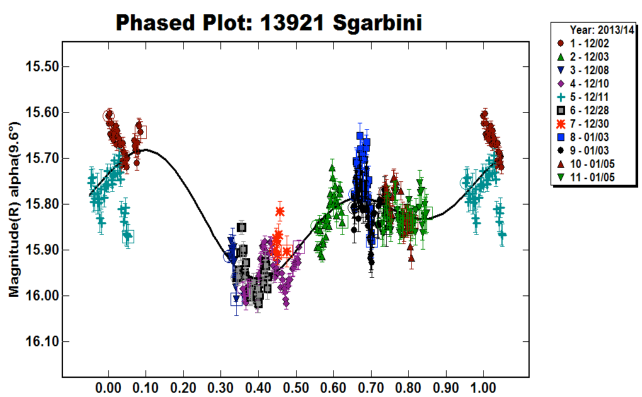
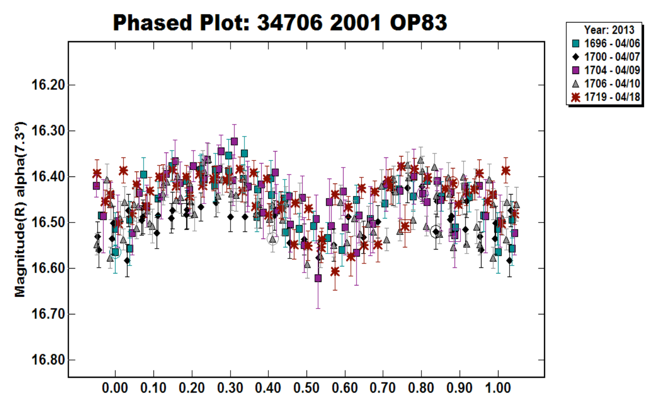
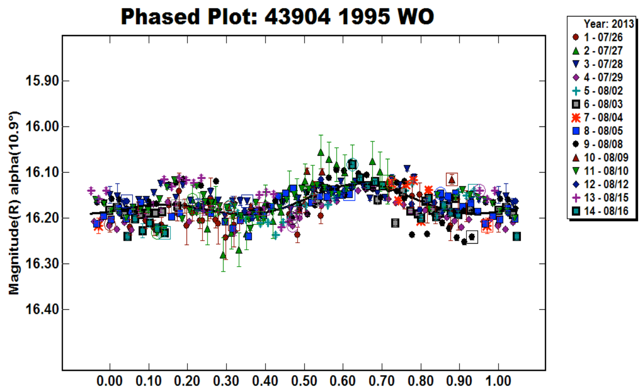


Period: 43.4 ± 0.1 h Amp: 0.28 JDo(LTC): 2456629.057693



Period: 2.5949 ± 0.0001 h JDo(LTC): 2456388.999737



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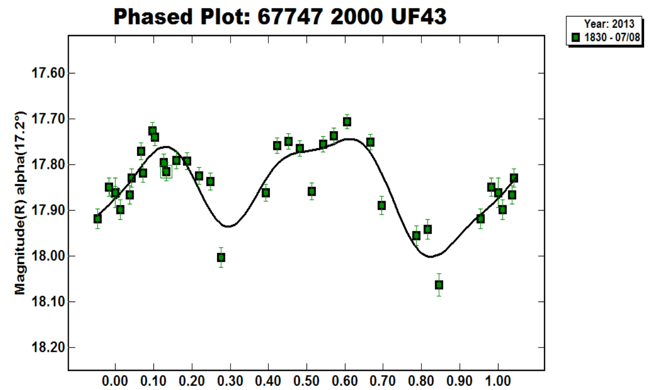

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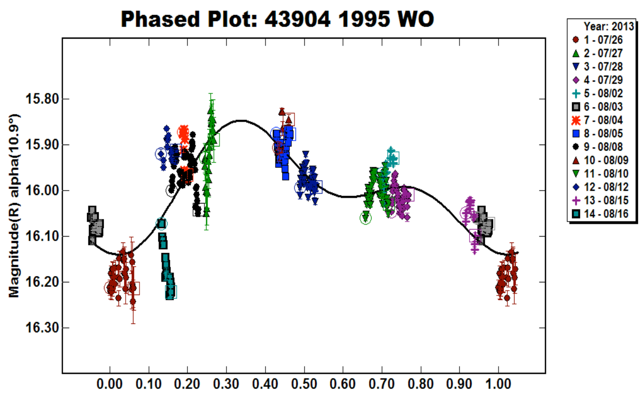
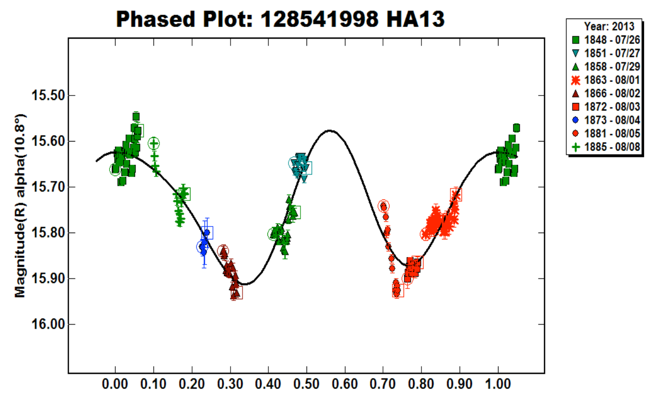
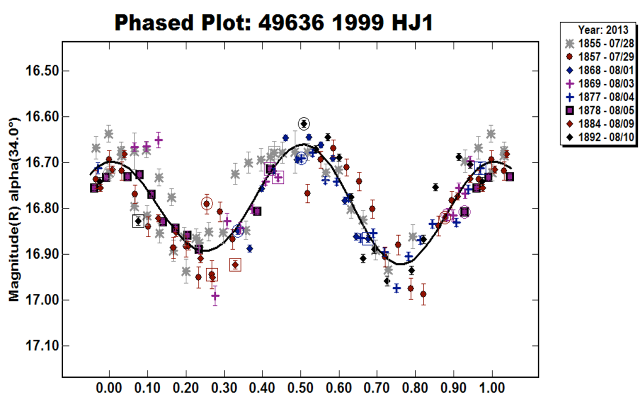


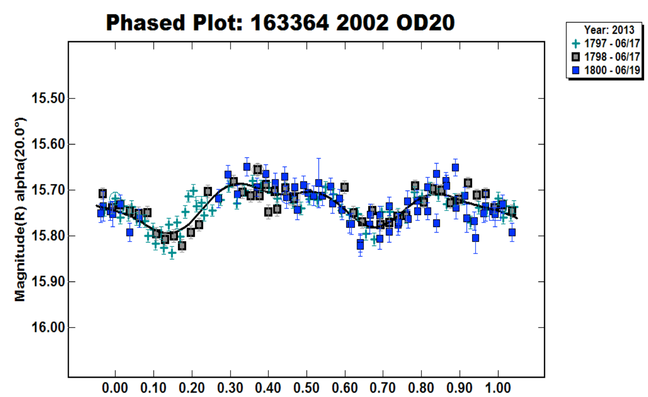
Period: 98.0 ± 1.0 h Amp: 0.29 JDo(LTC): 2456500.018598



Period: 50.59 ± 0.01 h Amp: 0.34 JDo(LTC): 2456500.062127



Period: 2.8208 ± 0.0001 h Amp: 0.26 JDo(LTC): 2456501.881953



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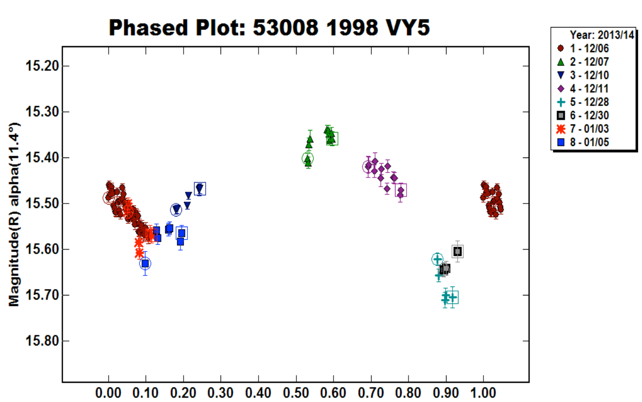
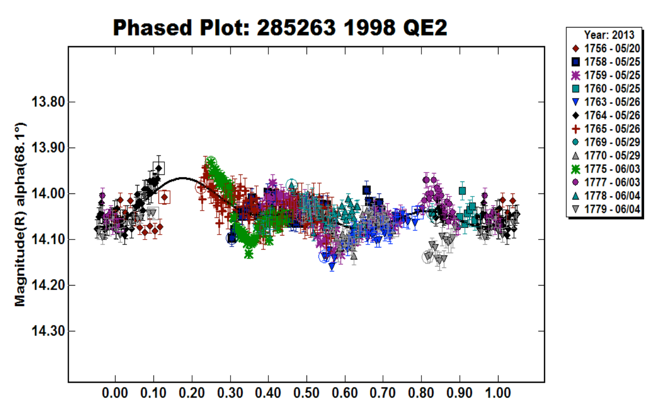


Period: 44.6 ± 0.1 h JDo(LTC): 2456633.004009



Period: 2.726 ± 0.001 h Amp: 0.11 JDo(LTC): 2456433.002709

SIDEREAL PHOTOMETRIC ASTROMETRY AS EFFICIENT INITIAL SEARCH FOR SPIN VECTOR

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I describe how to use the Sidereal Photometric Astrometry method of spin vector determination (Drummond *et al.*, 1988) to identify the specific plausible candidate combinations of sidereal periods and pole solution regions that are consistent with a lightcurve epoch data set, to use as initial inputs to the convex inversion method of shape determination (Kaasalainen *et al.*, 2001).

Introduction

The means to calculate asteroid spin vectors and model shapes from asteroid lightcurves is accessible to the community of observers as available code implementing the powerful and elegant convex inversion approach (Kaasalainen *et al.*, 2001), which uses an iterative nonlinear algorithm that requires initial values for sidereal period and pole location.

Constraining the sidereal period is discussed in the pair of papers (Slivan, 2012) and (Slivan, 2013), hereafter “paper I” and “paper II” respectively, which describe a robust approach to establish the best constraints by deliberately managing the possible ambiguities. Its results can help in judging whether a set of epoch data are sufficient to proceed with spin vector analyses, and they also identify the candidate period solutions once there are enough data.

This paper addresses the remaining issue of the initial values for the pole location. An exhaustive approach is to scan a grid of trial poles and look for minima in some goodness-of-fit metric, but a 1°-resolution grid of candidate poles on the celestial sphere numbers over 64,000 poles, and running that many trials of convex inversion is computationally expensive. Choosing a 10° resolution instead, as has been used by authors publishing analyses in the *Minor Planet Bulletin*, reduces the needed computation by a factor of 100×, but the lower resolution makes it difficult to understand the behavior of the search space, and thus to distinguish true possible pole regions from spurious solutions and other fluctuations in the metric. It is preferable and more robust instead to use where possible some other method to locate the pole regions before invoking convex inversion shape modeling. In this paper I describe how to efficiently identify the regions of possible pole solutions and exclude spurious results using Sidereal Photometric Astrometry (Drummond *et al.*, 1988).

Method

Sidereal Photometric Astrometry (SPA) is a statistical least-squares fitting approach to deduce the spin axis orientation and also the direction of spin from a set of epochs t_i, making the assumption that every epoch corresponds to the same rotational phase of the asteroid to within a possible half-rotation ambiguity, an assumption which must be made with caution as is discussed in Paper II.

SPA makes use of the fact that the number of rotations elapsed between any two epochs includes a fraction of a rotation that depends on the change in viewing aspect angle with respect to the asteroid's spin vector, an effect that was ignored in Paper II. Including all of the contributions, the number of sidereal rotations N_i (integer number of half-rotations) that elapse during a time interval T_i between epochs, here correcting a typographic error in Drummond *et al.* (1988, Eq. 2), is

$$N_i = 0.5\ \mathrm{INT}\ (2T_i/P_{\mathrm{sid}} - 2k_i + 0.5) \qquad \text{(Eq. 1)}$$

The candidate sidereal period values P_{sid} are directly available from the method described in Paper II. The observed intervals T_i since the earliest epoch are $t_i - t_1$ where $i = 1$ is the index of the earliest epoch. Each corresponding fraction of a rotation k_i is how much the body would have to turn between epochs t_1 and t_i for the same asterocentric longitude to be facing the observer—it's the difference between the asterocentric longitudes L_{SP} of the sub-observer point at the two epochs, and it includes contributions from both the direction vector change and the polar angle change. For longitudes in radians this is

$$k_i = (L_{\mathrm{SP},i} - L_{\mathrm{SP},1})/2\pi \qquad \text{(Eq. 2)}$$

Calculation of (B_{SP}, L_{SP}), the pole-dependent asterocentric latitude and longitude of the sub-observer point, will require the ecliptic coördinates of the sub-observer direction (β_{SP}, λ_{SP}) which are the reflex of the asteroid direction. Here the asteroid direction (β, λ) is represented by the phase angle bisector (Harris, 1984) to allow for the effect of nonzero solar phase angle on observed times of epochs:

$$\beta_{\mathrm{SP}} = -\beta \qquad \text{(Eq. 3)}$$

$$\lambda_{\mathrm{SP}} = \lambda + \pi \quad (0 \le \lambda_{\mathrm{SP}} < 2\pi) \qquad \text{(Eq. 4)}$$

The equations to transform these ecliptic coördinates to B_{SP} and L_{SP} referenced to the asteroid pole location (β_p, λ_p) are from Taylor (1979), here correcting a typographic error in case (f):

$$B_{\mathrm{SP}} = \sin^{-1}[\sin\beta_{\mathrm{SP}} \sin\beta_p + \cos\beta_{\mathrm{SP}} \cos\beta_p \cos(\lambda_{\mathrm{SP}} - \lambda_p)] \qquad \text{(Eq. 5)}$$

$$L'_{\mathrm{SP}} = \sin^{-1}[\cos\beta_{\mathrm{SP}} \sin(\lambda_{\mathrm{SP}} - \lambda_p)/\cos B_{\mathrm{SP}}] \qquad \text{(Eq. 6)}$$

$$L_{\mathrm{SP}} = \begin{cases} 0, & \text{if } \sin L'_{\mathrm{SP}} = 0 \text{ and } Q < 0 & \text{(a)} \\ |L'_{\mathrm{SP}}|, & \text{if } \sin L'_{\mathrm{SP}} > 0 \text{ and } Q < 0 & \text{(b)} \\ \pi/2, & \text{if } \sin L'_{\mathrm{SP}} > 0 \text{ and } Q = 0 & \text{(c)} \\ \pi - |L'_{\mathrm{SP}}|, & \text{if } \sin L'_{\mathrm{SP}} > 0 \text{ and } Q > 0 & \text{(d)} \\ \pi, & \text{if } \sin L'_{\mathrm{SP}} = 0 \text{ and } Q > 0 & \text{(e)} \\ \pi + |L'_{\mathrm{SP}}|, & \text{if } \sin L'_{\mathrm{SP}} < 0 \text{ and } Q > 0 & \text{(f)} \\ 3\pi/2, & \text{if } \sin L'_{\mathrm{SP}} < 0 \text{ and } Q = 0 & \text{(g)} \\ 2\pi - |L'_{\mathrm{SP}}|, & \text{if } \sin L'_{\mathrm{SP}} < 0 \text{ and } Q < 0 & \text{(h)} \end{cases} \qquad \text{(Eq. 7)}$$

where determining the quadrant of the longitude involves the sign of the auxiliary value Q:

$$Q = (\sin\beta_{\mathrm{SP}} - \sin\beta_p \sin B_{\mathrm{SP}})/\cos\beta_p \cos B_{\mathrm{SP}} \qquad \text{(Eq. 8)}$$

The straight line model fitted to the epochs is

$$T_i = P'_{\mathrm{sid}}(N_i + k_i) + T'_1 \qquad \text{(Eq. 9)}$$

where T_i is the dependent variable, $N_i + k_i$ is the independent variable, and the primes indicate the fitted parameters. The T'_1 result is discarded as it will be simply the error in the first epoch T_1 = 0.

Given a candidate sidereal period, the algorithm to locate pole solution regions by generating a graph of the goodness of fit of trial pole locations is:

for all trial poles (λ_p, β_p) on celestial sphere **do**
  for all epochs (T_i, λ_i, β_i) in input data **do**
    calculate k_i and N_i (Eqs. 1–8)
  end for
  fit the straight line model $T_i = P'_{sid}(N_i + k_i) + T'_1$ (Eq. 9)
  if fitted P'_{sid} is within initial period constraint range **then**
    include RMS error of this fit on graph as function of (λ_p, β_p)
  end if
end for

As an example of the method, I continue the analysis begun in Paper II of the lightcurve epoch observations of main-belt asteroid (1223) Neckar given in Table I by checking the three candidate sidereal periods for possible pole solution regions. The epochs were weighted equally for the fitting, and the resulting three RMS error graphs are shown in Fig. 1.

The graphs corresponding to candidate periods 7.82133 h retrograde (Fig. 1a) and 7.82124 h prograde (Fig. 1b) reveal that in both cases there are indeed well-behaved minima corresponding to possible pole solutions, which are summarized in Table II.

In contrast, the graph corresponding to candidate period 7.82115 h retrograde (Fig. 1c) has a fragmented appearance. Discontinuities in the RMS error pattern indicate that the best epoch fits for adjacent trial pole orientations are requiring different numbers of rotations N between some pair of epochs, which would not be the case near a possibly correct pole solution. Based on the lack of any well-behaved minima regions in this graph I confidently reject this period; this is not a surprising outcome because it was already flagged in Paper II as suspiciously sensitive to the uncertainties estimated for the epochs.

Table I: Summary of (1223) Neckar lightcurve epoch observations 1977–1996, one epoch t per observed apparition as measured using the Fourier filtering approach described by Slivan et al. (2003). λ and β are ecliptic longitude and latitude (J2000) of the phase angle bisector. Lightcurve data references: a, Tedesco (1979); b, Binzel (1987); c, Slivan and Binzel (1996); d, Michałowski *et al.* (2000).

t (MJD)	λ(°)	β(°)	UT date	Ref.
43187.0000	132.4	+3.2	1977 Feb 13	a
45469.2539	230.3	-0.5	1983 May 15	b
46885.0147	158.1	+2.6	1987 Mar 31	c
47776.1156	328.4	-3.0	1989 Sep 07	c
48210.1221	71.9	+1.4	1990 Nov 15	c
49131.0887	253.0	-1.6	1993 May 24	c
50098.0010	87.5	+2.5	1996 Jan 16	d

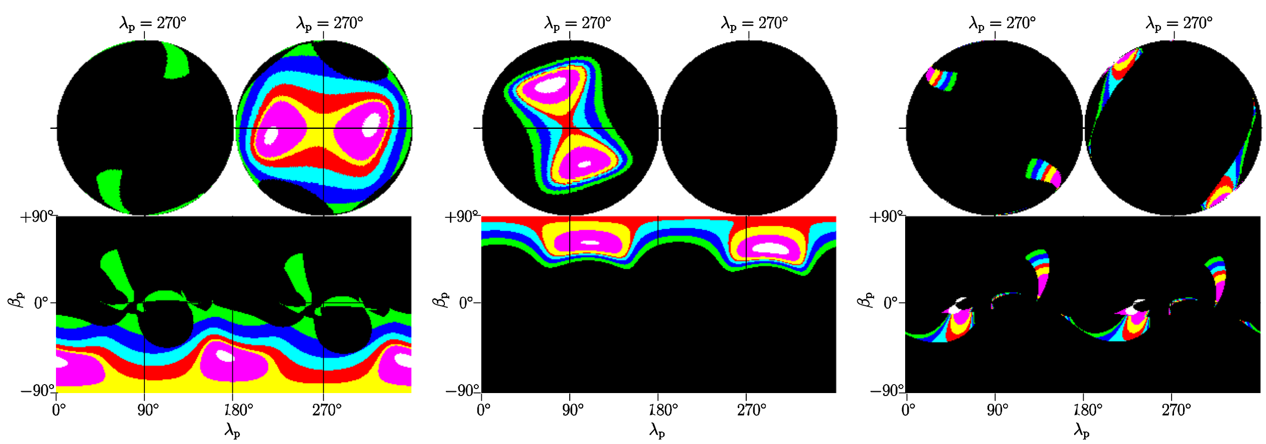
Table II: Candidate spin vector solution results for (1223) Neckar lightcurve epoch observations given in Table I.

sidereal period (h)	poles (ecliptic J2000)
7.82133	(170°;-50°) and (355°;-55°)
7.82124	(110°;+65°) and (295°;+60°)

Discussion

Because SPA is a spin vector analysis approach that makes use of epoch information, its success depends on having enough epochs for fitting and counting elapsed rotations, sufficient aspect coverage, and the total observed time span being long enough. SPA in particular also depends on how well the epochs satisfy the underlying assumption of unchanging asterocentric longitude.

The example epochs are sufficient in number, aspect coverage, and total length of time spanned to narrow the solution possibilities to only two candidate periods, one retrograde and one prograde. Each period has two possible pole solution regions about 180° apart in ecliptic longitude, whose differences in RMS errors are not significant and cannot be used to distinguish between the pair of solution regions.



(a) (b) (c)

Fig. 1: (a) Contour graph of the RMS error "goodness of fit" of trial poles of (1223) Neckar from SPA analysis of the epoch observations in Table I for candidate sidereal period 7.82133 h. The resolution of trial poles is 1° and regions of best fit are colored white. The lower half of each graph represents the celestial sphere projected on a rectangular grid for easy measurement of longitude and latitude coördinates. The same data in a polar format undistorted near the ecliptic poles appear in the upper half of each graph, where north- and south-hemisphere views are plotted separately. For this sidereal period, retrograde pole regions are found near (170°;−50°) and (355°;−55°). (b) Graph for sidereal period 7.82124 h, locating prograde pole regions near (110°;+65°) and (295°;+60°). (c) Graph for sidereal period 7.82115 h. Here the regions of lowest RMS error are not well-behaved minima and they do not correspond to possible pole solutions.

SPA doesn't use lightcurve amplitudes or brightnesses, which contain the pole longitude information that's needed to identify which of the two example period solutions is the correct one, and to more accurately locate the pole within its region. Here this isn't a problem because SPA is used only to identify the pole solution regions that are consistent with the epochs, to then be checked using convex inversion which uses both epoch and amplitude information for analysis. After SPA narrowed the example possible solutions to only one pair of poles for each of two sidereal periods, convex inversion had no trouble definitively identifying the prograde period and poles as the correct solution (Slivan *et al.*, 2003).

Conclusion

SPA is a computationally efficient approach to identify plausible pole solution regions, and is quite robust because the only assumption is unchanging asterocentric longitudes of the epochs. It permits pole searches of sufficient resolution to be able to see the behavior of the search space near RMS error minima, and thus reveal whether the data are in fact sufficient for spin vector solutions, identify true possible pole regions, and exclude spurious solutions and other fluctuations in the metric. Using SPA speeds determination of creditable poles by reducing the number of trial poles that have to be tested through convex inversion, and provides the needed initial values for the pole location.

After Paper II was published, its algorithm to constrain sidereal period was implemented as a Web application at the site *http://www.koronisfamily.com*. A Web application implementing the SPA algorithm described in this paper is presently in development for the same site.

References

Binzel, R.P. (1987). “A photoelectric survey of 130 asteroids.” *Icarus* **72**, 135–208.

Drummond, J.D., Weidenschilling, S.J., Chapman, C.R., Davis, D.R. (1988). “Photometric geodesy of main-belt asteroids. II. Analysis of lightcurves for poles, periods, and shapes.” *Icarus* **76**, 19–77.

Harris, A.W., Young, J.W., Scaltriti, F., Zappalà, V. (1984). “Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis.” *Icarus* **57**, 251–258.

Kaasalainen, M., Torppa, J., Muinonen, K. (2001). “Optimization methods for asteroid lightcurve inversion. II. The complete inverse problem.” *Icarus* **153**, 37–51.

Michałowski, T., Pych, W., Berthier, J., Kryszczyńska, A., Kwiatkowski, T., Boussuge, J., Fauvaud, S., Denchev, P., Baranowski, R. (2000). “CCD photometry, spin and shape models of five asteroids: 225, 360, 416, 516, and 1223.” *Astronomy and Astrophysics Supplement Series* **146**, 471–479.

Slivan, S.M. (2012). “Epoch data in sidereal period determination. I. Initial constraint from closest epochs.” *Minor Planet Bulletin* **39**, 204–206.

Slivan, S.M. (2013). “Epoch data in sidereal period determination. II. Combining epochs from different apparitions.” *Minor Planet Bulletin* **40**, 45–48.

Slivan, S.M., Binzel, R.P. (1996). “Forty-eight new rotation lightcurves of 12 Koronis family asteroids.” *Icarus* **124**, 452–470.

Slivan, S.M., Binzel, R.P., Crespo da Silva, L.D., Kaasalainen, M., Lyndaker, M.M., Krčo, M. (2003). “Spin vectors in the Koronis family: Comprehensive results from two independent analyses of 213 rotation lightcurves.” *Icarus* **162**, 285–307.

Taylor, R.C. (1979). “Pole orientations of asteroids.” in *Asteroids* (T. Gehrels, ed.) pp. 480–493. University of Arizona Press, Tucson.

Tedesco, E.F. (1979). “A Photometric Investigation of the Colors, Shapes and Spin Rates of Hirayama Family Asteroids.” Ph.D. thesis. New Mexico State University.

NEW PHOTOMETRIC OBSERVATIONS OF THE BINARY NEAR-EARTH ASTEROID (137170) 1999 HF1

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Photometric observations of the binary near-Earth asteroid 1999 HF1 were made during 6 nights in the interval 2014 May 21 to June 18 using the Cassegrain telescope at the Bucharest Astronomical Institute (UAI code: 073). These observations confirm that the asteroid's lightcurve has two components. The short period variation was estimated to P = 2.5662 ± 0.0034 h, close to the value 2.3191 hours found in the literature.

(137170) 1999 HF1 is a near-Earth asteroid (NEA) having an Aten type orbit. It has a low albedo (0.10) and it is classified based on its visible and near-infrared spectra as an X or C taxonomic type (Thomas *et al*., 2011). There are several lightcurves available in the asteroid lightcurve database (LCDB; Warner *et al*., 2009), the first entry being recorded in 2001 May, 08 by Pravec *et al*. (2002a). Pravec *et al*. (2002b) found that this asteroid lightcurve has two components of low amplitudes (0.10-0.12) and periods of 2.319 h and 14.02 h, concluding that it is a binary candidate.

We observed this object during 6 nights in 2014 May – June with the purpose of obtaining its lightcurve. The 0.5-m *f*/15 Cassegrain telescope at the Astronomical Institute of the Romanian Academy was used. The observation circumstances are given in Table I. The images were acquired using and SBIG STL-1100M CCD camera cooled to – 20°C. This gave a field-of-view of 16x11 arcmin. In order to improve the signal-to-noise ratio, no filters were used during image acquisition.

Date/2014	V. Mag	Φ[°]	Exp[s]	SNR
May,21/22	15.68	65.17	60	27
May,26/27	15.62	67.05	60	21
May,28/29	15.60	68.64	60	31
Jun,08/09	15.51	76.11	60	25
Jun,09/10	15.51	76.93	60	28
Jun,14/15	15.50	81.51	45	16

Table I. Observation circumstances: the date, the apparent V. magnitude, the phase angle, the integration time and the signal-to-noise ratio are given for each observing night.

The data reduction procedure included dark subtraction and flat-field corrections. A set of sky flats and dark images were taken at the beginning of each observing night. All images were measured using *MaximDL* software. The reference stars were selected from the NOMAD and APASS (AAVSO Photometric All-Sky Survey) catalogs. For each set of observations, we selected 4 reference stars close to the asteroid path. The V magnitude of the reference stars were used in the measurements.

For data analysis, the V apparent magnitude of the asteroid, computed using IMCCE ephemerides calculator (*www.imcce.fr*), was subtracted from each of the measured magnitudes. No other phase angle corrections were applied. The values with an error bar larger than 0.05 mag were removed.

The period analysis was carried out using *Peranso* software. We used the FALC (Fourier Analysis of Light Curves) method developed by Harris (Harris *et al*., 1989) to determine the period. Due to the lack of data, we cannot highlight the long period. However, Fig. 1 shows a clear variation of average magnitudes between the six observing sets. In order to find the short period, the data were aligned by subtracting the average magnitude of each set corresponding to an observing night. The most important harmonic corresponded to a period of *P* = 2.5662 ± 0.0034 h. There are two secondary harmonics that cannot be neglected, those corresponding to periods of *P* = 2.7109 and *P* = 2.3189. The latter value corresponds, within the error bars, with the value found by Pravec *et al.* (2002b).

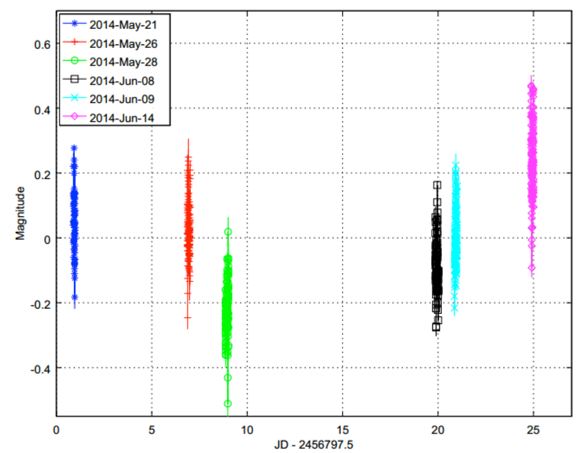

Fig. 1 Photometric observations of (137170) 1999 HF1.

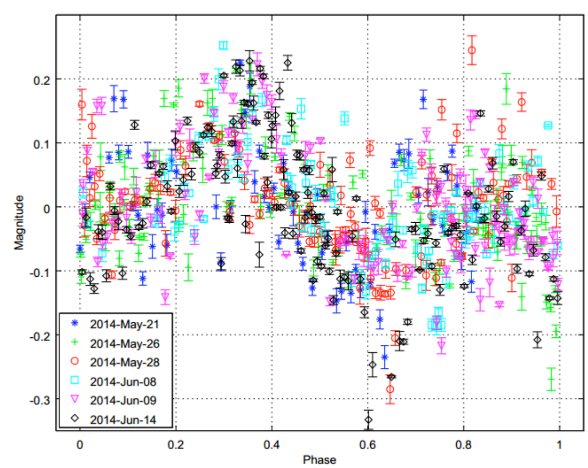

Fig. 2 The short period component of 1999 HF1. A period of P = 2.5662 ± 0.0034 h was used, as determined by using the FALC algorithm in *Peranso*.

References

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., Zeigler, K. (1989). "Photoelectric Observations of Asteroids 3, 24, 60, 261, and 863." *Icarus* **77**, 171-186.

Pravec, P., Šarounová, L., Hicks, M.D., Rabinowitz, D.L., Wolf, M., Scheirich, P., Krugly, Y.N. (2002a). "Doubly-periodic Lightcurve of 1999 HF1 - A Binary NEA Candidate." *Minor Planet Bulletin* **29**, 23-25.

Pravec, P., Šarounová, L., Hicks, M.D., Rabinowitz, D.L., Wolf, M., Scheirich, P., Krugly, Y.N. (2002b). "Two Periods of 1999 HF1 – Another Binary NEA Candidate." *Icarus* **158**, 276-280.

Thomas, C.A., Trilling, D.E., Emery, J.P., Mueller, M., Hora, J. L., Benner, L.A.M., Bhattacharya, B., Bottke, W.F., Chesley, S., Delbó, M., Fazio, G., Harris, A.W., Mainzer, A., Mommert, M., Morbidelli, A., Penprase, B., Smith, H.A., Spahr, T.B., Stansberry, J.A. (2011). "ExploreNEOs. V. Average Albedo by Taxonomic Complex in the Near-Earth Asteroid Population." (2011). *Astronomical Journal* **142**, A85.

Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2014 February 28 *http://www.MinorPlanet.info/lightcurvedatabase.html*

LOWELL OBSERVATORY NEAR-EARTH ASTEROID PHOTOMETRIC SURVEY (NEAPS) – 2009 JANUARY THROUGH 2009 JUNE

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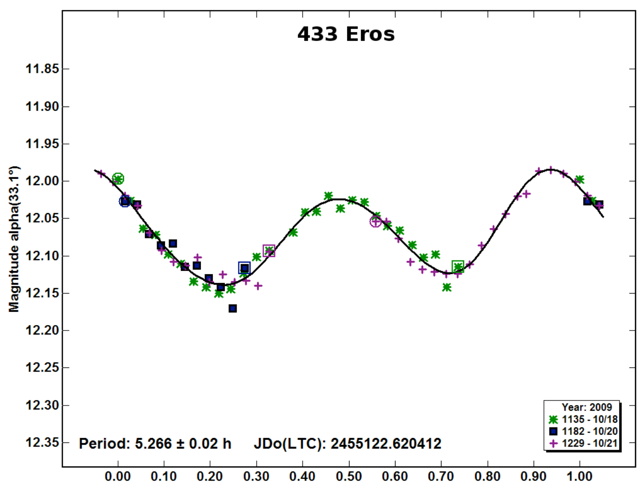
We report the results of the Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) for the period between 2009-01-01 and 2009-06-30. During this period, we obtained our first photometric data for 40 asteroids including 433 Eros, 1943 Anteros, 3554 Amun, 5011 Ptah, (5604) 1992 FE, 5620 Jasonwheeler, (5693) 1993 EA, (8566) 1996 EN, (14402) 1991 DB, (16834) 1997 WU22, (22753) 1998 WT, (35107) 1991 VH, (52768) 1998 OR2, (68350) 2001 MK3, (85867) 1999 BY9, (138883) 2000 YL29, (141052) 2001 XR1, (143651) 2003 QO104, (154244) 2002 KL6, 161989 Cacus, (162385) 2000 BM19, (163758) 2003 OS13, (175706) 1996 FG3, (194386) 2001 VG5, (203217) 2001 FX9, (207945) 1991 JW, (208023) 1999 AQ10, (212546) 2006 SV19, (256412) 2007 BT2, 2001 FE90, 2004 LV3, 2005 BC, 2005 SG19, 2008 QT3, 2008 WL60, 2009 DE47, 2009 DO111, 2009 EP2, 2009 FD, and 2009 JM2. We also report our analysis of 5261 Eureka, a Mars Trojan.

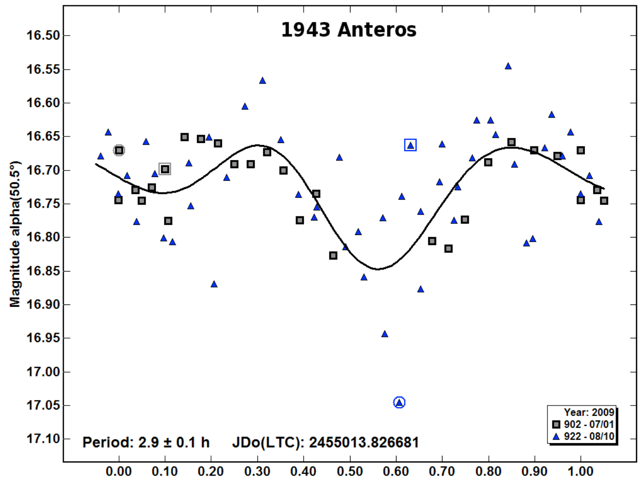
This is the second in a series of papers describing the results of Lowell Observatory's Near-Earth Asteroid Photometric Survey (NEAPS). In our first paper (Skiff 2012), we described our observing and data reduction techniques. We also described the 24-inch Schmidt telescope that was the workhorse of this survey.

The following section describes the photometric results, including the rotational periods where possible, of all the asteroids we first observed between 2009-01-01 and 2009-06-30 plus 5261 Eureka first observed in 2011. Many of the asteroids with periods also have period quality ratings denoted by the letter U. A full description of the meaning of U values is available (Warner 2009b). The values for the U codes were taken from the Lightcurve Database (Warner 2009c). All the reduced data for the asteroids in this paper can be found at the Minor Planet Center (MPC) web site (*http://www.minorplanetcenter.net/light_curve*).

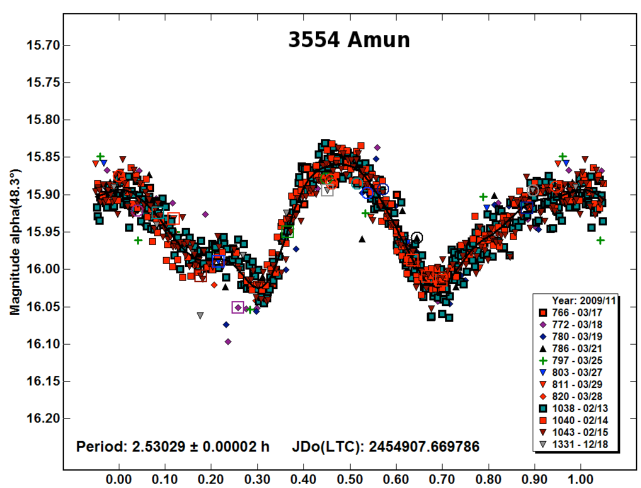
433 Eros. This well studied Amor asteroid has a published period of 5.270 h, U = 3, produced by Hicks (1999b) and supported by observations from a host of other astronomers, notably Behrend (2009) and Campa (1938). We observed this asteroid on 17 nights, with the LONEOS Schmidt, between 2009-06-18 and 2010-01-10 and obtained 265 usable observations. The observations from 2009-10-18 to 2009-10-21 provided the only useful data set and from that data set we obtained a period of 5.266 ± 0.02 h, generated with an order 4 fit. Other lunations were inconsistent or too sparse to be useful. The peak-to-peak amplitude is Δr' = 0.16 and the mean magnitude is r' = 12.06 (normalized to 2009-10-18). Other lunations suggest that the amplitude can be larger than Δr' = 0.50.



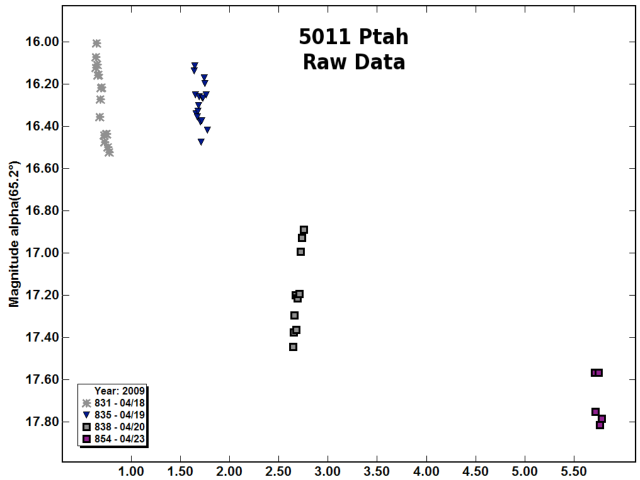
1943 Anteros. This Amor asteroid has a known period of 2.8695 h, U = 3 (Pravec 1998). We observed this asteroid on 5 nights between 2009-06-18 and 2009-08-10 using the LONEOS Schmidt and obtained 105 usable observations. None of the data produced a convincing lightcurve. The residuals from a third order fit using data from 2009-07-01 and 2009-08-10 (shown in the graph) were large and had a very broad minimum. The mean magnitude is r' = 16.76 and the amplitude is Δr' = 0.16. The period of 2.9 ± 0.1 h could not be duplicated using data from a single night nor from any other combinations of nights. The fact that our period matched Pravec's is probably accidental.



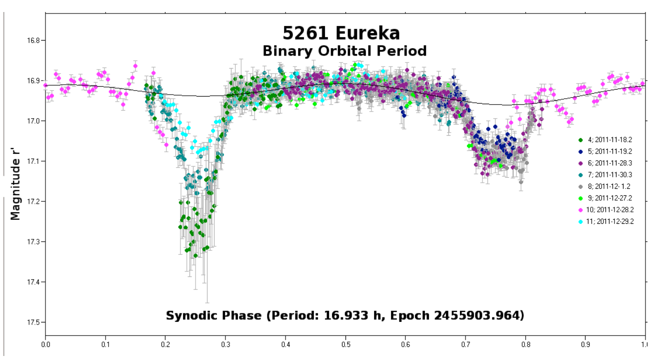
3554 Amun. This Aten asteroid has a published period of 2.53001, U = 3 (Behrend 2010; Wisniewski 1997). We observed this asteroid during three apparitions. During the first apparition we observed on 8 nights between 2009-03-17 and 2009-03-28 using the LONEOS Schmidt, and made 109 usable observations. We found a period of 2.530 ± 0.001 h with a mean magnitude r'=15.97 and an amplitude of Δr' = 0.22. Observations from the third apparition we obtained between 2011-02-13 and 2011-02-15 using the LONEOS Schmidt and the NURO telescope. We had three full nights and obtained 758 usable observations. In the third apparition, we found a period of 2.530 ± 0.002 h with a mean magnitude of r'=15.73 and an amplitude of Δr' = 0.13. We combined the two sets of observations to obtain a two year baseline for the period. Because we have a single night on the second apparition midway between the first and third (2009-12-18), we are reasonably sure that the two year baseline produces a valid period of 2.53029 ± 0.00002 h.

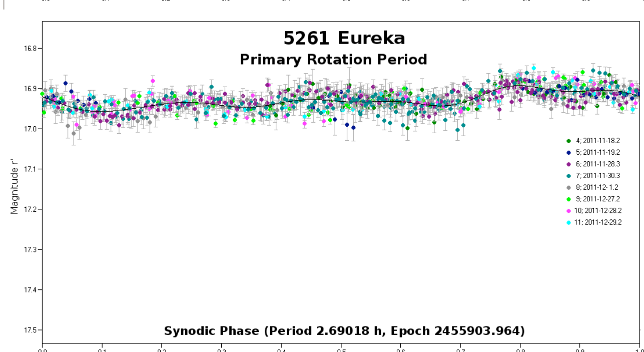


5011 Ptah. This Apollo and potentially hazardous asteroid (PHA) has no published period. We observed it on four nights from 2009-04-18 to 2009-04-23 using the LONEOS Schmidt and obtained 49 usable measurements. The nights of 2009-04-18 and 2009-04-20 show a monotonic change in magnitude of at least Δr' = 0.5. Our attempts to fit either of these single nights indicated that the period is at least 20 h. We could find no period consistent with all the data. Generalizing from our experience with large amplitude, hard to fit, slow rotators, it is possible that this asteroid is a tumbler. See the mean magnitudes and amplitudes in the tables at the end of this paper.

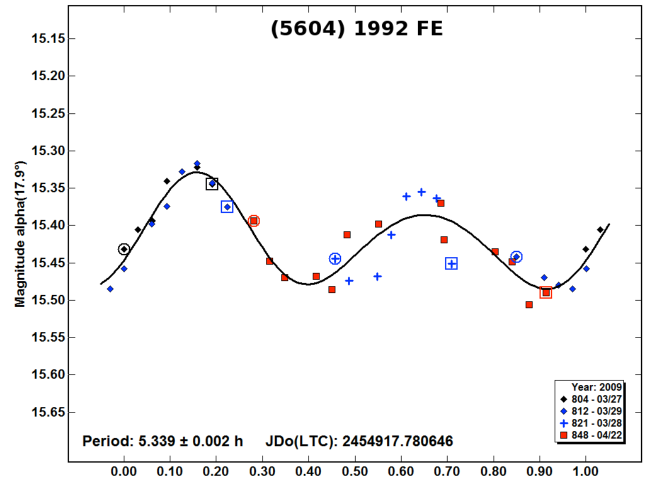


<u>5261 Eureka.</u> This Mars Trojan asteroid has a published period of 6 h, U = 1 but lack of data precluded any believable period analysis (Rivkin 2003). Bowell first noted Eureka was a Mars Trojan (Marsden 1990), and it received additional spectroscopic study by Rivkin (2003). We observed the asteroid on eight nights from 2011-11-28 to 2011-12-29 using the Lowell 0.7-m and 1.1-m reflectors and obtained 1302 usable measurement. The complex lightcurve was indicative of a binary, so we asked Petr Pravec to analyze the data. He found that the orbit period is 16.93 ± 0.01 h with minima approximately 0.2 and 0.15 mag deep. The nearly flat lightcurve of the primary has a period of 2.6902 ± 0.0003 h and amplitude 0.064 mag. The period uncertainties are dominated by the synodic-sidereal effect for both. The secondary-to-primary mean-diameter ratio has a lower limit of 0.39 ± 0.02.

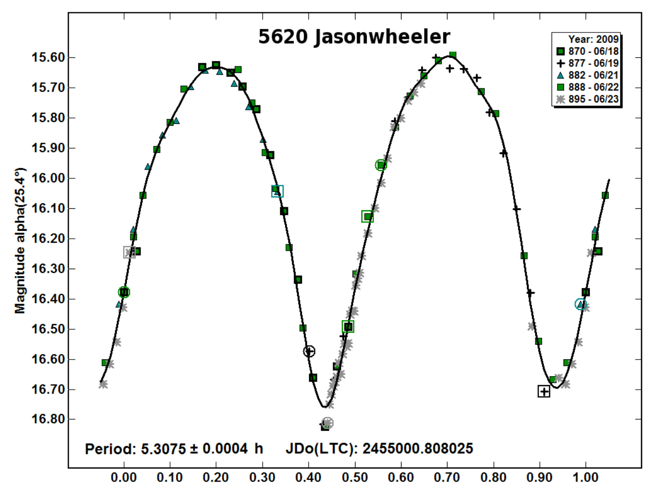




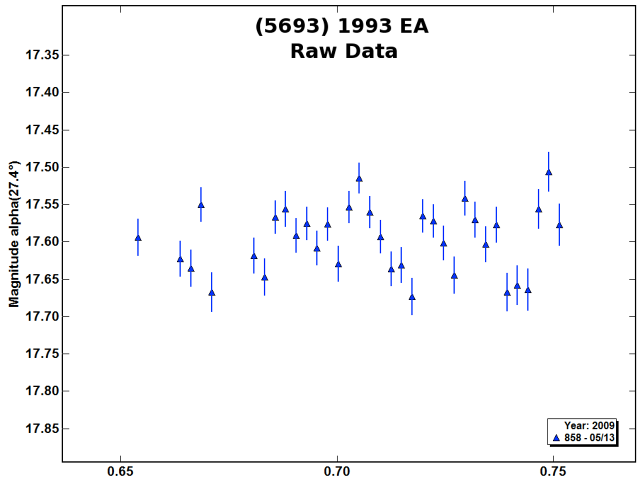
<u>(5604) 1992 FE.</u> This Aten (PHA) asteroid has a period of 5.3375 h, U = 3 (Higgins 2009). Another published period of 6.026 h, U = 2 was slightly longer (Bembrick 2003). We observed this asteroid on four nights between 2009-03-27 and 2009-04-22 using the LONEOS Schmidt and obtained 39 usable observations. The plot shown in this paper has been coerced to 5.339 ± 0.002 h in order to match Higgins' period. However, the small formal error is somewhat misleading. There were many periods between four and six hours that had essentially the same value for the residuals so we should more suggestively write the error as ±1 h. The night of 2009-04-22 was from the next lunation and required an offset of Δr' = 0.19 to fit the other nights. The mean magnitude, normalized to 2009-03-27 is r' =15.40 and the amplitude is Δr' = 0.15.



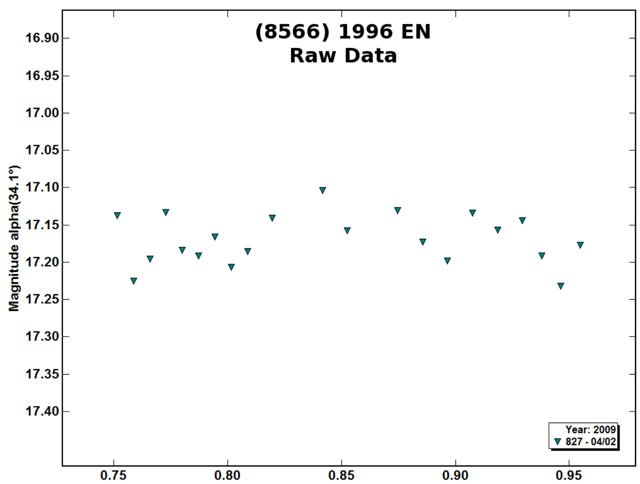
<u>5620 Jasonwheeler.</u> This Amor asteroid has a published period of 5.307 h, U = 3 (Durkee 2010). We observed this asteroid on 5 nights between 2009-06-18 and 2009-06-23 using the LONEOS Schmidt and obtained 102 usable observations. We found a period of 5.3075 ± 0.0004 h but, because we cover only 25 rotations, the formal error is optimistic and should probably be at least 0.005 h. The mean magnitude, normalized to 2009-06-09, is r'=16.20 with an amplitude of Δr' = 1.20.



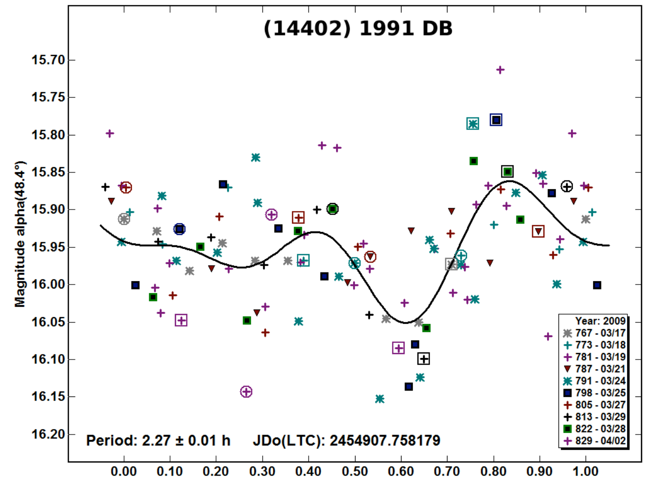
<u>(5693) 1993 EA.</u> This Apollo (PHA) asteroid has an uncertain published period of 2.497 h, U = 2 (Polishook 2012). We observed this asteroid on the single night of 2009-05-13 using the LONEOS Schmidt and obtained 35 usable measurements. From those, we found a mean magnitude of r'=17.57 with an amplitude, or more likely, scatter, of Δr' = 0.18. Although we tried to coerce the period to Polishook's value and tried very short periods, we could find none that were convincing. Because the magnitude of this asteroid was fainter than we like to use for the Schmidt, and because the amplitude is small, we cannot make any conjecture about the rotation of this asteroid.

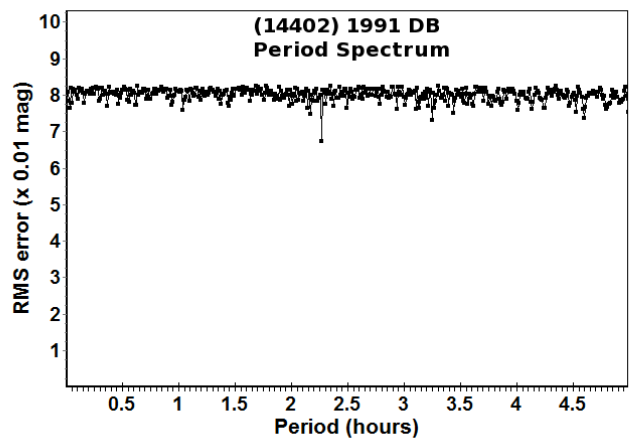


(8566) 1996 EN. This Apollo (PHA) asteroid has no published period. As the reader can see from the plot, we have insufficient data to make any conjectures about the period of this asteroid. Please refer to the table at the end of the paper for further details.



(14402) 1991 DB. This Amor asteroid has a published a period of 2.2656 h, U = 3 (Pravec 2000). Both Behrend (2009) and Durkee (2011) published periods that were more than an hour longer but they were more uncertain about their value than Pravec. We observed this asteroid between 2009-03-17 and 2009-04-02 using the LONEOS Schmidt and obtained 110 usable measurements over 10 nights. Our data were very noisy over the entire interval but we managed to duplicate Pravec's published period by forcing the correct period and then making small magnitude offsets to each night to minimize the residuals. We have included the period spectrum to indicate the frailness of our derived period.

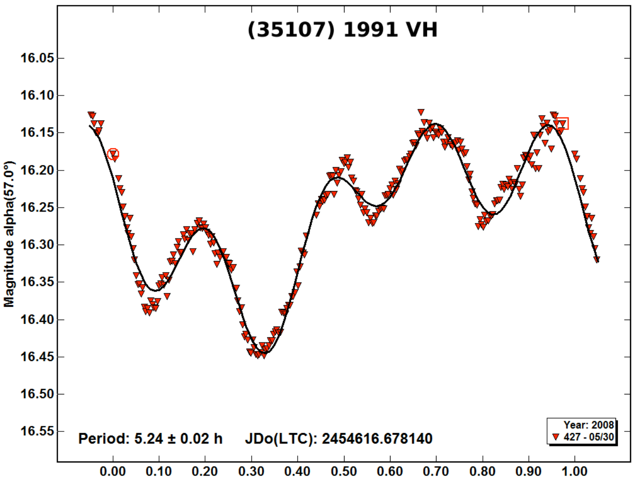




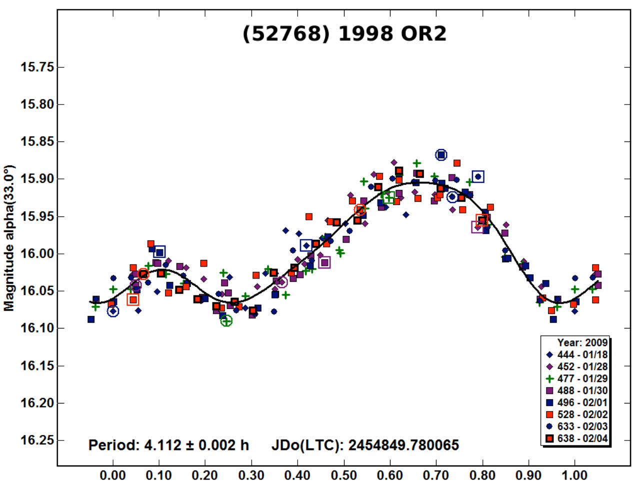
(16834) 1997 WU22. This Apollo asteroid has published period of 9.345 h, U = 3 (Pravec 2000). We had insufficient data to perform a meaningful period analysis so we present only the mean magnitudes and amplitudes for each of the four nights in a table at the end of the paper.

(22753) 1998 WT. This Apollo (PHA) has a published a period of 10.24 h, U = 2 (Galád 2005). Benner (2011) found a period of less than 11 hours. Our data proved insufficient to perform a meaningful period analysis so we present our summary data in the table at the end of the paper.

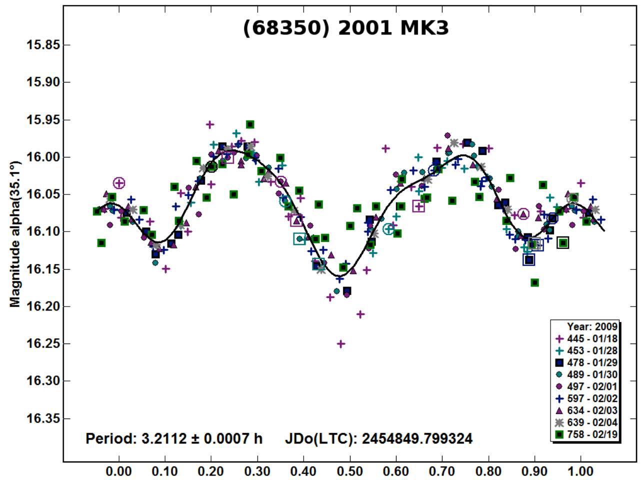
(35107) 1991 VH. This Apollo (PHA) asteroid has a published period of 2.6236 h, U = 3 (Pravec 2006). Vander Haagen (2010) studied this binary carefully and found a similar period for the primary He also found other periods associated with the system. We observed on 11 nights between 2009-05-08 and 2010-01-18 obtaining 575 usable observations. We did not attempt to disentangle the lightcurves of the two bodies. Hence, our data do not produce a cohesive lightcurve. We present a plot of the raw data from a single night, 2008-05-30, to hint at the complexity of the situation. The period is perfectly ignorable. It is nearly the same as the length of the observing run on that night. Our raw data are available at the MPC lightcurve database and our summary information is listed in the table at the end of the paper.



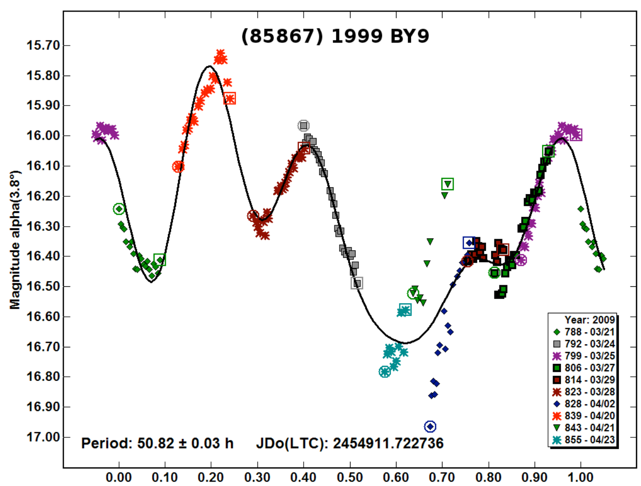
(52768) 1998 OR2. Betzler (2009) found a period of 3.198 h, U = 2, for this Amor (PHA) asteroid. We made observations between 2009-01-18 and 2009-02-04 and got 199 usable measurements over 9 nights. We found a period of 4.112 ± 0.002 h with an order 4 fit. The mean magnitude, normalized to 2009-01-18, is r' = 16.00 mag with an amplitude of Δr' =0.16 mag.



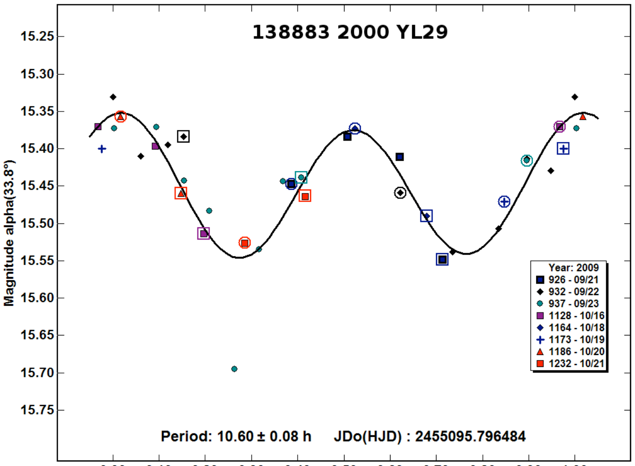
(68350) 2001 MK3. This Amor asteroid has a published period of 3.273 h, U = 3 from Carbognani (2011). We observed this asteroid between 2009-01-16 and 2009-02-19 and obtained 281 usable measurements over 10 nights. We found a period of 3.2112 ± 0.0007 h with an order 5 fit. The mean magnitude, normalized to 2009-01-18 is r' = 16.07 mag with an amplitude of Δr' =0.17 mag. The first and last nights shown in the graph are somewhat noisy but they allowed us to reduce the uncertainty by an order of magnitude. The graph shows two major and one minor maximum.

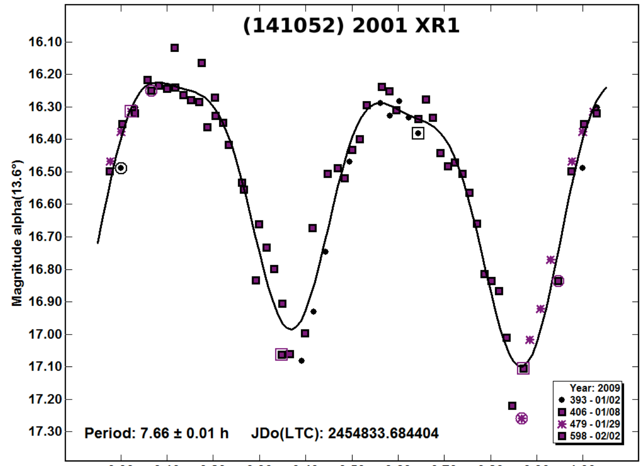


(85867) 1999 BY9. This Amor asteroid has no published period. We observed this asteroid between 2009-03-21 and 2009-04-23 and obtained 201 usable observations over 10 nights. As the reader can see from the graph, the asteroid may be a "slow" tumbler. The graph suggests one of the periods is about 25 h. The reader may find summary magnitude and amplitude data in the table at the end of the paper.

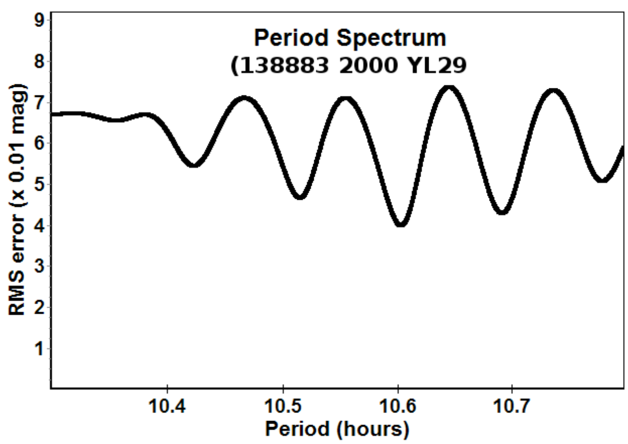


(138883) 2000 YL29. We targeted this Apollo asteroid between 2009-04-22 and 2009-10-21 and obtained 312 usable observations over 9 nights. This asteroid has no published period. The night of 2009-04-22 was isolated from all the other nights so we omitted it from our analysis. The best fit occurred when the period was 5.3 h but it had a single maximum. We forced the period to double that and the best fit indicated a period of 10.60 ± 0.08. The graph was created with an order 2 fit. It has a mean magnitude of r' = 15.45 mag and an amplitude of Δr' =0.20 mag normalized to 2009-09-21.



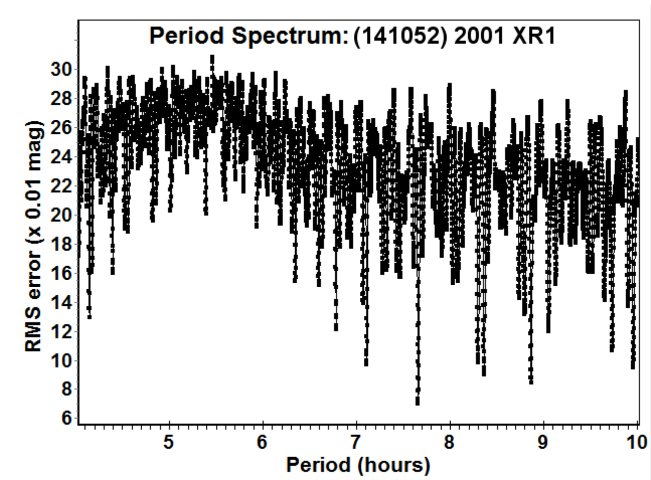


We felt the formal error returned by Canopus was too small. Because of the obvious noise in the fit, a phasing error between September and October was possible. Analysis of the period spectrum indicates a more suggestive error is 0.08 h.

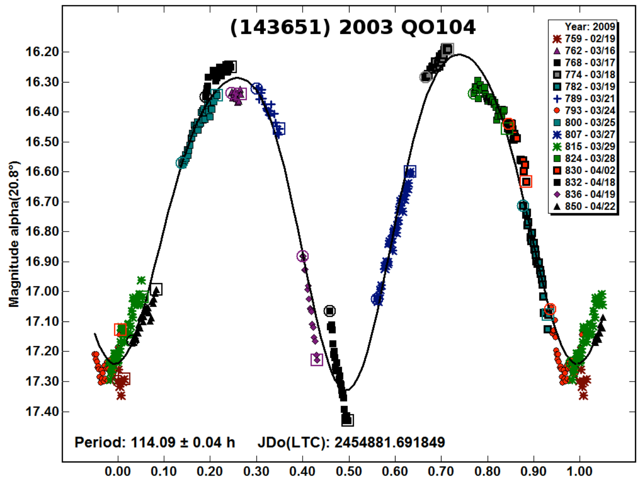


As the reader can see in the preceding graph, the minima near the best fit indicate residuals nearly as small as the best fit. These other minima are the result of a phase shift between September and October that occurs when the period is changed by about 0.08 h.

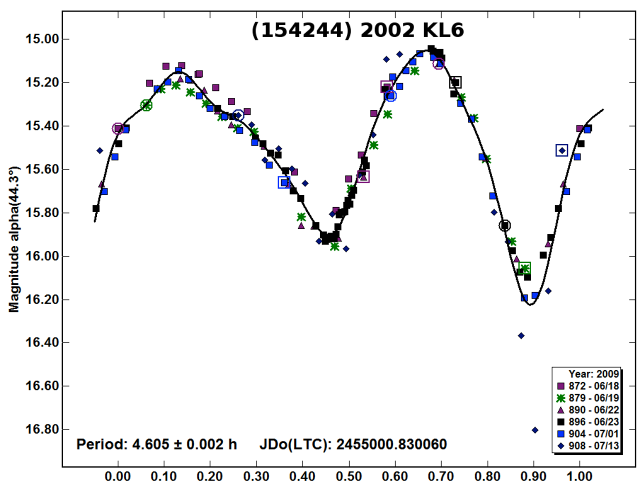
(141052) 2001 XR1. This Apollo asteroid has no published period. We made observations between 2009-01-02 and 2009-02-02 and obtained 72 usable measurements over 4 nights. We found a period of 7.66 ± 0.01 h. We believe this period is of low quality because the RMS values, seen in the period spectrum, show a number of minima with values near the absolute minima. When we forced the fit to match some of these minima, several graphs were as compelling as the one we present here. The mean magnitude, normalized to 2009-01-02 is r' = 16.66 mag with an amplitude of Δr' = 0.88 mag.



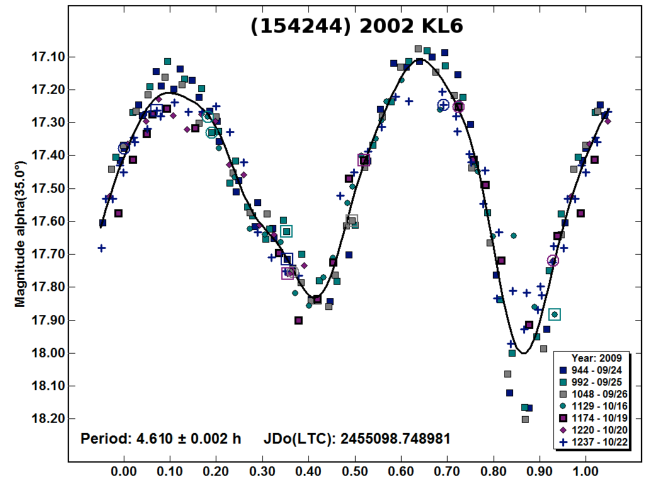
(143651) 2003 QO104. This Apollo (PHA) asteroid, a possible tumbler, has a published period of 115. h, U = 3, from Warner (2009a). Birtwhistle (2009) published a slightly smaller but more uncertain value. We observed this asteroid between 2009-02-19 and 2009-04-22 and obtained 403 usable observations over 15 nights. Our sparsely populated fit optimistically indicates a period of 114.09 ± 0.04h generated with an order 4 fit. The poor quality of the fit indicates the asteroid may be tumbling, in agreement with Warner's assessment. The summary magnitude data, found in a table at the end of this paper may be useful in planning observations.



(154244) 2002 KL6. We observed this Amor asteroid between 2009-06-18 and 2009-10-22 and obtained 360 usable measurements over 13 nights. This asteroid has a published period of 4.6063, U = 3 (Galád 2010). Our observations were spread over five lunations so we present graphs from the first two lunations, the last two lunations and a summary graph of all lunations. The two groupings combine observations where the observing circumstances were similar. The first graph indicates a period of 4.605 ± 0.002 h generated with an order 5 fit. The period is in agreement with Galád's value. The mean magnitude, normalized to 2009-06-18 is r' = 15.63 mag with an amplitude of Δr' = 1.15 mag.

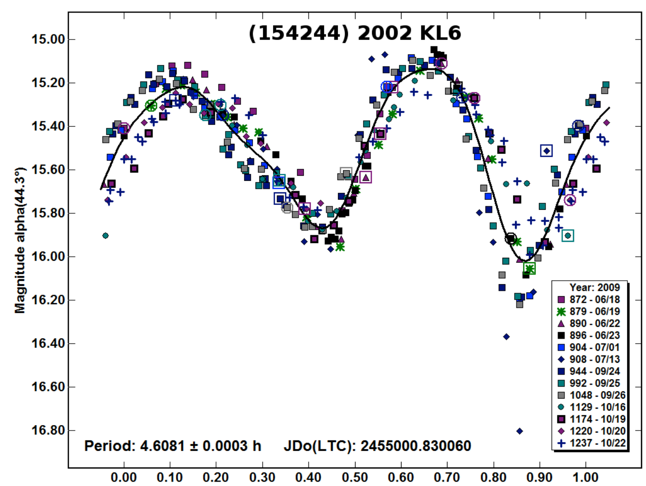


The second graph indicates a period of 4.610 ± 0.002 h generated with an order 5 fit. The mean magnitude, normalized to 2009-09-24 is r' = 17.55 mag with an amplitude of Δr' = 0.90 mag.

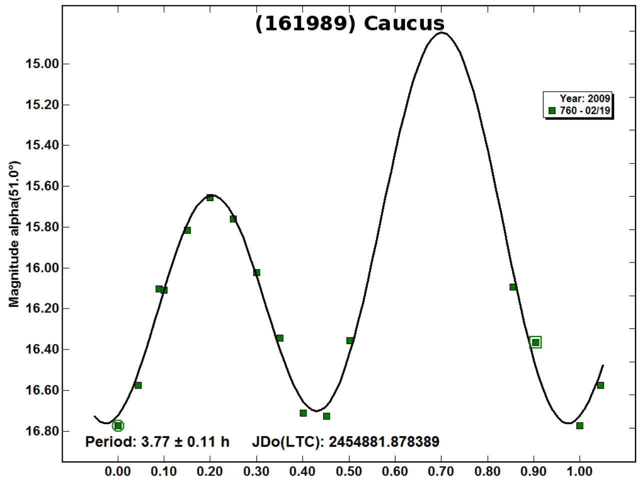


The period is in general agreement with Galád's value.

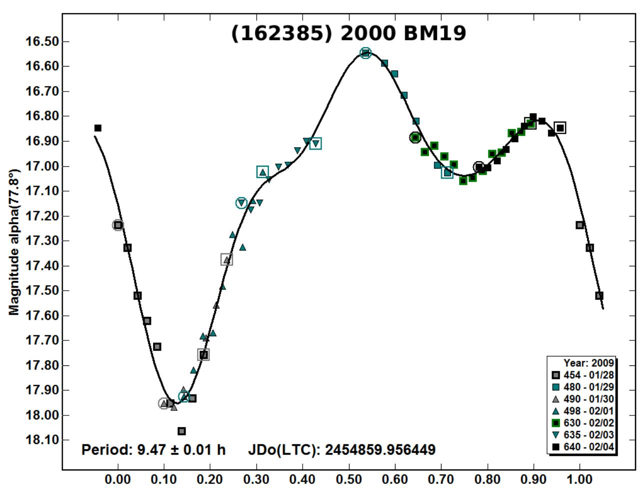
The third graph indicates the period when all the data are combined. Because there is a 73 day interval between the first and second data sets, we verified that the maximum accumulated formal error between data sets could not be greater than one hour. That fact allowed us to combine the data sets with the assurance that a rotational phasing error was highly unlikely. The result for all nights is a period of 4.6081 ± 0.0003 h. The unambiguous time span for observations is 126 days.



161989 Cacus. We observed this Apollo (PHA) asteroid on the single night of 2009-02-19 and obtained 14 usable measurements. This asteroid has a published period of 3.7538 h, U = 3 provided by Pravec (2003). Both Degewij (1978) and Schuster (1979) published similar values for the period. With our extremely limited dataset we found a period of 3.77 ± 0.11 h in relatively good agreement with the published period. The deep amplitude of the magnitude made our analysis possible. Since the graph is not well constrained, the mean magnitude and amplitude should be taken from the table at the end of the paper.

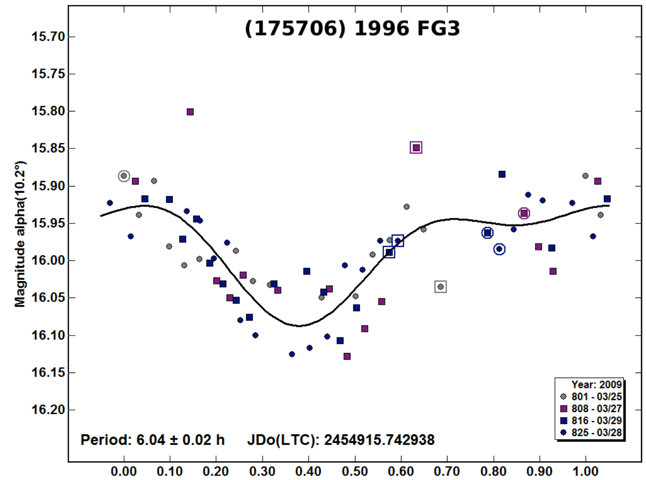


(162385) 2000 BM19. We observed this Aten asteroid between 2009-01-28 and 2009-02-04 and obtained 63 usable measurements over 7 nights. This asteroid has no published period. Our analysis produced a period of 9.47 ± 0.01 h. We know the quality of the fit is not robust because we have gaps in the coverage and we had to use some fairly large offsets in the order 4 fit. However, he residuals of the fitting routine clearly indicate the period we show. The mean magnitude, normalized to 2009-01-28 is r' = 17.24 mag with an amplitude of Δr' = 1.38 mag.

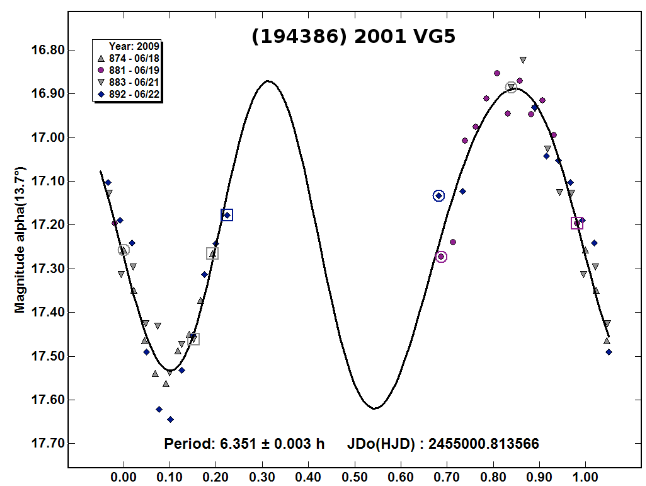


(163758) 2003 OS13. This Apollo asteroid has no published period. We targeted this asteroid on three nights between 2009-06-18 and 2009-06-22 and obtained 14 usable observations. The data provide no real hint of the period so we refer the reader to the summary information at the end of the paper.

(175706) 1996 FG3. This Apollo (PHA) asteroid has a published period of 3.5942 h, U = 3 by Pravec (2006). Mottola (2000) found a similar value. We made observations between 2009-03-25 and 2009-04-22 and obtained 88 usable measurements over 5 nights. In our fit analysis, we used only four nights because the last night was in the next lunation and it made the analysis much more difficult. We used an order 2 fit and found a period of 6.04 ±0.02 h. The fit residuals were rather large and there were at least four other minima in the residuals that were nearly as small as the one we chose. No single night could reproduce the indicated period and changing the order of fit also changed the period significantly.



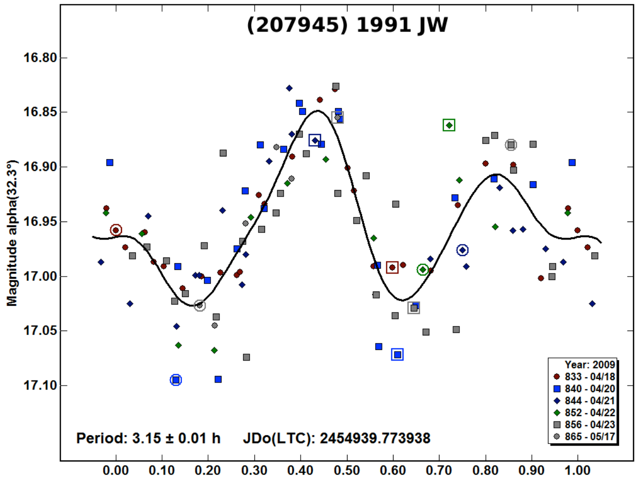
(194386) 2001 VG5. This Apollo asteroid has a published period. 6.6 h, U = 2, found by Polishook (2009). We made observations between 2009-01-15 and 2009-06-22 with 121 usable observations over 6 nights. The first night was in January and the last five nights in June. Reductions for 2009-06-15 had problems and the night 2009-01-15 was so distant in time that we based our analysis primarily on 50 observations from the remaining four nights.



Although the phase coverage on this graph is poor, the remaining two nights provide almost full phase coverage and when those data are included, the period remains 6.351 ± 0.003 h using a third order solution. The large amplitude of the lightcurve made the period analysis easier. Because of reduction problems on the night of 2009-06-15, we cannot state the amplitude of this lightcurve.

(203217) 2001 FX9. This Amor asteroid has no published period. We observed this asteroid on 2009-01-28 and 2009-01-29 and obtained 14 usable observations. The data were insufficient to perform a meaningful period analysis so we present only our summary data in the table at the end of the paper.

(207945) 1991 JW. This Apollo (PHA) asteroid has no published period. We targeted this asteroid between 2009-04-18 and 2009-05-17 and obtained 119 usable measurements over 6 nights. From those measurements we found a period of 3.15 ± 0.01 h using an order 3 fit. The mean magnitude, normalized to 2009-04-18, is r' = 16.93 mag with amplitude Δr' = 0.17 mag. The sixth night is in the next lunation and the uncertainty in the first five nights is large enough that a phasing error could occur so our formal uncertainty remains rather large.

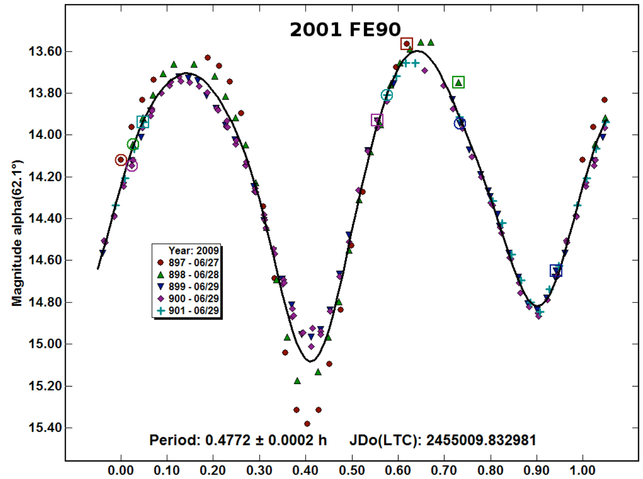


<u>(208023) 1999 AQ10.</u> This Aten (PHA) asteroid has a published period of 2.67 h, U = 2+ by Behrend (2009). Betzler (2009) found a slightly longer value. We made observations between 2009-01-30 and 2009-02-04, and obtained 53 usable observations in 5 nights. The lightcurve was flat to within our uncertainty. The mean magnitude, was r' = 16.95 mag normalized to 2009-01-03 with an uncertainty of ± 0.05 mag. We could not coerce the period to 2.67 h to match Behrend's period.

<u>(212546) 2006 SV19.</u> This Amor (PHA) asteroid has no published period. We observed this asteroid on two nights, 2009-06-21 and 2009-06-22 and obtained 24 usable observations. The asteroid was relatively faint with a mean magnitude of r' = 17.8 and an amplitude/uncertainty of about ±0.10 mag. We could find no believable period so refer to the summary information at the end of this paper.

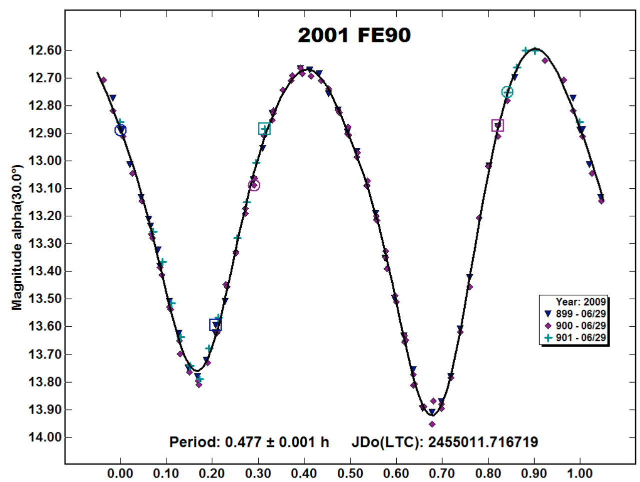
<u>(256412) 2007 BT2.</u> This Amor asteroid has no published period. We observed this asteroid on 4 nights between 2009-03-27 and 2009-04-22 and obtained 35 usable observations. Although we could not produce a publishable lightcurve, we believe the period is on the order of 18 hours. The asteroid had a mean magnitude, normalized to 2009-03-27, of r' = 16.4 mag and an amplitude of Δr' = 0.2 mag.

<u>2001 FE90.</u> This Apollo (PHA) asteroid has a published period of 0.4777 h, U = 3 by Hicks (2009). Oey (2011) also observed this asteroid and obtained a similar period. We observed this asteroid between 2009-06-21 and 2009-06-29 and obtained 202 usable observations over 5 nights. The first graph shows the period obtained from all the data.



The graph reveals the changing aspect of the asteroid by the scatter at the maxima and minima of the lightcurve.

The second graph shows the data from only 2009-06-29. The graph covers almost five full periods. The effects of changing aspect are almost undetectable and our confidence in the indicated uncertainty is good. Both curves were generated with an order six fit. The mean magnitude on the night of 2009-06-29 is r' = 13.25 and the peak-to-peak amplitude of the lightcurve is Δr' = 1.30 mag.



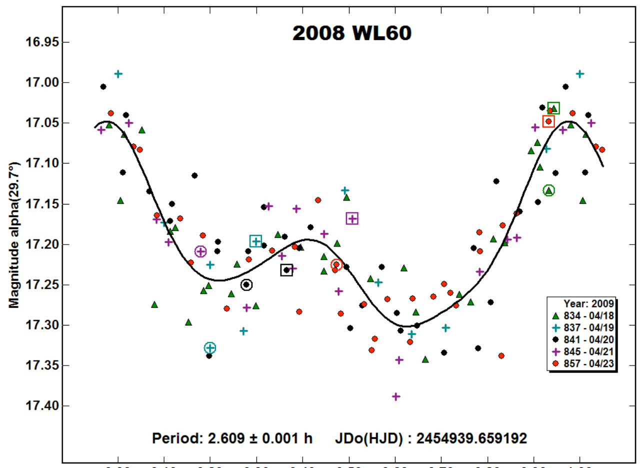
<u>2004 LV3.</u> This Apollo (PHA) asteroid has no published period. We observed the asteroid between 2009-01-01 and 2009-01-03 and obtained 14 usable observations over 3 nights. The observations were too sparse for an effective period analysis. The reader may find summary information at the end of this paper.

<u>2005 BC</u>. This Apollo (PHA) asteroid has no published period. We observed this asteroid on two nights between 2009-01-16 and 2009-01-18 and obtained 10 usable observations. The observations were too sparse for an effective period analysis. The reader may find summary information at the end of this paper.

<u>2005 SG19.</u> This Amor asteroid has no published period. We observed this asteroid on a single night, 2009-03-29 and obtained 11 usable observations. Again, the observations were too sparse for an effective period analysis. The reader may find summary information at the end of this paper.

2008 QT3. This Apollo (PHA) asteroid has no published period. We observed on three nights between 2009-01-18 and 2009-01-29 and obtained 25 usable observations. The observations were too sparse for an effective period analysis. The reader may find summary information at the end of this paper.

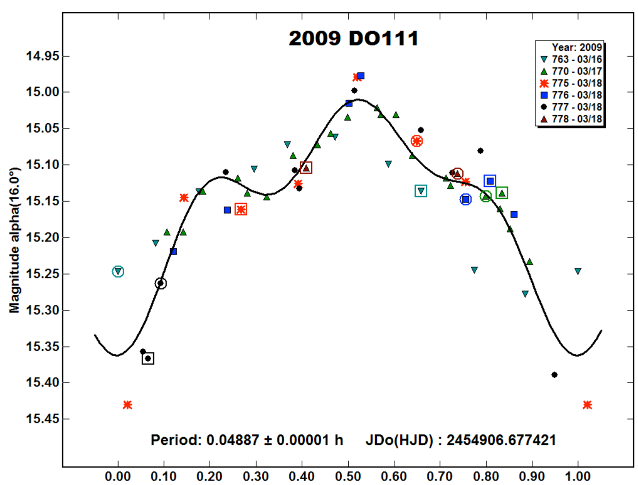
2008 WL60. This Amor asteroid has no published period. We observed this asteroid on five nights between 2009-04-18 and 2009-04-23 obtaining 129 usable observations. We found a period of P = 2.609 h ±0.002 h using an order 4 fit.



The mean magnitude is r' = 17.18, normalized to 2009-04-18. The amplitude of the lightcurve is Δr' = 0.12 mag.

2009 DE47. This Apollo asteroid has no published period. We observed this asteroid on 2 nights, 2009-04-20 and 2009-04-21, and obtained 17 usable observations. The observations were too sparse for an effective period analysis. The reader may find summary information at the end of this paper.

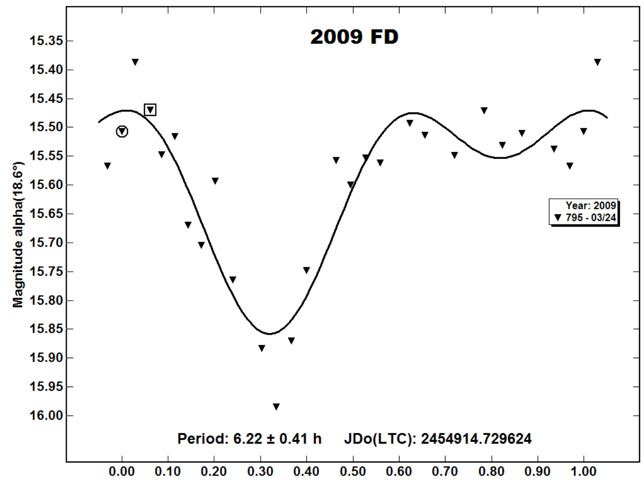
2009 DO111. This Apollo asteroid has a published period of 0.04890 h, U = 3 (Behrend 2009).



We have 58 usable observations obtained on three nights between 2009-03-16 and 2009-03-18. We were able to duplicate Behrend's period with P = 0.04887 h ± 0.00001 h shown above for each night considered independently. However, the magnitudes obtained each night had to be shifted significantly to produce the graph shown here. Most troubling is the fact that the night of the 2009-03-18 was broken into several sub-sessions and each session had to be significantly shifted in magnitude for the fit to work. The fit above may be an alias of a longer period of about 0.09 h. The longer period is more pleasing because it has two significant maxima.

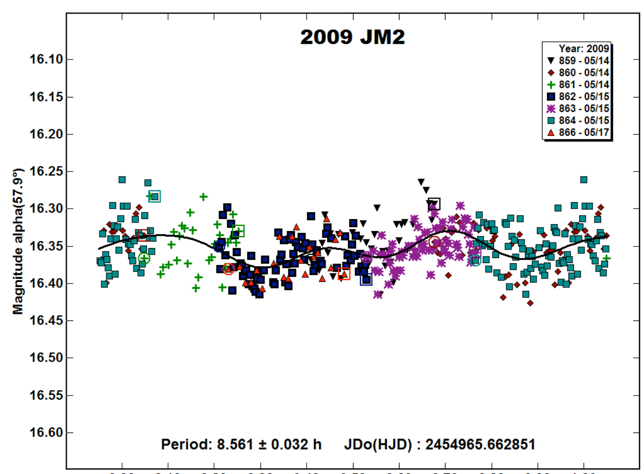
2009 EP2. This Aten (PHA) asteroid has no published period. We observed this asteroid on 2009-03-16 and obtained 8 usable observations. The reader may find summary information at the end of this paper.

2009 FD. This Apollo asteroid has a published periods of 4.0 h, U = 2+ by Behrend (2009) and 5.87 h, U = 2- by Carbognani (2011a). We observed this asteroid on the single night of 2009-03-24 and obtained 26 usable observations.



Our period analysis shows one strong unambiguous minimum. However, there is no evidence that we observed the minimum a second time. Because of the strength of the single minimum we can assert that the period is at least 6.22 h. We can place no upper limit on the period.

2009 JM2. This Apollo asteroid has no published period. We were able to observe on three nights between 2009-05-14 and 2009-05-17, and obtain 381 usable observations.



Although the graph indicates a period, we assert that the lightcurve is flat to within the errors. Each night plotted separately is flat. The structure within the graph shown here is likely due to minor night-to-night changes in seeing, and choice of reference stars.

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References

Adelman-McCarthy, J.K., et al. (2008). "The Sixth Data Release of the Sloan Digital Sky Survey." *The Astrophysical Journal Supplement Series* **175**, 297-313.

Behrend, R. (2009). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html.*

Behrend, R. (2010). Observatoire de Geneve web site, *http://obswww.unige.ch/~behrend/page_cou.html.*

Bembrick, C., Pereghy, B. (2003). "A Period Determination for the Aten Asteroid (5604) 1992 FE." *Minor Planet Bull.* **30**, 43-44.

Benner, L.A.M. (2011) *http://echo.jpl.nasa.gov/~lance/radar.nea.periods.html*

Betzler, A.S., Novaes, A.B. (2009). "Photometric Observations of 1998 OR2,1999 AQ10, and 2008 TC3." *Minor Planet Bulletin* **36**, 145-147.

Birtwhistle, P. (2009). "Lightcurves for Five Close Approach Asteroids." *Minor Planet Bulletin* **36**, 186-187.

Campa, M. (1938). "Rotation Period of 433 Eros." *Memorie della Societa Astronomica Italiana*, 11, 285-301.

Carbognani, A. (2011). "Lightcurves and periods of eighteen NEAs and MBAs." *Minor Planet Bulletin* **38**, 57-63.

Degewij, J. (1978). "Messenger 13, 5." *IAUC* **3193**.

Durkee, R.I. (2010). "Asteroids Observed from The Shed of Science Observatory: 2009 July-September." *Minor Planet Bulletin* **37**, 18-19.

Durkee, R.I. (2011). *http://home.earthlink.net/~shedofscience/index.html*

Galád, A., Pravec, P., Kušnirák, P., Gajdoš, Š., Kornoš, L., Világi, J. (2005). "Joint Lightcurve Observations of 10 Near-Earth Asteroids from Modra and ONDŘEJOV." *Earth, Moon, and Planets*, **97**, 147-163.

Galad, A., Kornoš, L., Vilagi, J. (2010). "An Ensemble of Lightcurves From Modra." *Minor Planet Bulletin* **37**, 9-15.

Hicks, M., Buratti, B.J., Rabinowitz, D.L., Genevier, G. (1999). "The Lightcurve and Geometric Albedo of 433 Eros during the 1998 Apparition." I*carus* **141**, 411-414.

Hicks, M., Lawrence, K., Rhoades, H., Somers, J, McAuley, A., Barajas, T. (2009). "2001 FE90: An elongated and rapidly rotating near-Earth asteroid." *Astronomer's Telegram* **2116**. *http://www.astronomerstelegram.org*

Higgins, D., Warner, B.D. (2009). "Lightcurve Analysis At Hunters Hill Observatory And Collaborating Stations – Autumn 2009." *Minor Planet Bulletin* **36**, 159-160.

Ivezić, Z., et al. (2004). "SDSS data management and photometric quality assessment." *Astronomische Nachrichten* **325**, 583.

Marsden, B.G. (1990). "1990 MB" *IAU Circular*, **5067**, *http://www.cbat.eps.harvard.edu/iauc/05000/05067.html*

Mottola, S., Lahulla, F. (2000). "Mutual Eclipse Events in Asteroidal Binary System 1996 FG3: Observations and a Numerical Model." *Icarus* **146**, 556-567.

Oey, J. (2011). *http://minorplanet.haoeydental.com.au*

Padmanabhan, N., et al. (2008). "An improved photometric calibration of the Sloan Digital Sky6 Survey imaging data." *Astrophysical Journal*, **674**, 1217.

Polishook, D. (2009). "Lightcurves and Spin Periods from the Wise Observatory: 2008 August – 2009 March." *Minor Planet Bulletin* **36**, 104-107.

Polishook, D. (2012). "Lightcurves and Spin Periods of Near-Earth Asteroids, The Wise Observatory, 2005-2010." *Minor Planet Bulletin* **39**, 187-192.

Pravec, P., Wolf, M., Sarounova, L. (1998). "Lightcurves of 26 Near-Earth Asteroids." *Icarus* **136**, 124-153.

Pravec, P., Wolf, M., Šarounovà, L. (2000). *http://www.asu.cas.cz/~ppravec/neo.htm.*

Pravec, P., Wolf, M., Šarounovà, L. (2003). *http://www.asu.cas.cz/~ppravec/neo.htm.*

Pravec, P., Scheirich, P., Kušnirák, P., Šarounovà, L., Mottola, S., Hahn, G., Brown, P., Esquerdo, G., Kaiser, N., Krzeminski, Z., Pray, D.P., et al. (2006). "Photometric survey of binary near-Earth asteroids." *Icarus* **181**, 63-93.

Rivkin, A.S., Binzel, R.P., Howell, E.S., Bus, S.J., Grier, J.A. (2003). "Spectroscopy and Photometry of Mars Trojans." *Icarus* **165**, 349-354.

Schuster, H.E., Surdej, A., Surdej, J. (1979). "Photoelectric observations of two unusual asteroids - 1978 CA and 1978 DA." *Astronomy & Astrophysics Supplement Service* **37**, 483-486.

Skiff, B.A., Bowell, E.L.G.B, Koehn, B.W., Sanborn, J.J., McLelland, K.P., Warner, B.D. (2012). "Lowell Observatory Near-Earth Asteroid Photometric Survey (NEAPS) - 2008 May through 2008 December." *Minor Planet Bulletin*, **39**, 111-130.

Skrutskie, M.F., et al. (2006). "The Two Micron All Sky Survey (2MASS)." *Astronomical Journal*, **131**, 1163.

Smith, J.A., et al. (2002). "The u'g'r'i'z' standard-star system." *Astronomical Journal* **123**, 2121.

Tucker, D., et al. (2006). "The Sloan Digital Sky Survey monitor telescope pipeline." *Astronomical Notes* **327**, 821.

Vander Haagen, G. (2010). "(35107) 1991 VH: An Apollo Binary Asteroid." *Minor Planet Bulletin* **37**, 36.

Warner, B.D. Stephens, R.D. Carbognani, A. (2009a). "Analysis of The Slow Rotator (143651) 2003 QO104." *Minor Planet Bulletin* **36**, 179-180.

Warner, B.D., Harris, A.W. Pravec, P. (2009b). "The asteroid Lightcurve database." *Icarus* **2002**, 134-146.

Warner, B.D. (2009c). *http://www.minorplanet.info/lightcurvedatabase.html.*

Wisniewski, W.Z., Michalowski, T.M., Harris, A.W., McMillan, R.S. (1997). "Photometric Observations of 125 asteroids." *Icarus* **126**, 395-449.

Minor Planet	Date of Observation	Sun Distance (AU)	Earth Distance (AU)	Phase Angle (deg)	BPAB (deg)	LPAB (deg)	Obs. Count (deg)	Avg. Mag.	Mag. Delta	Observer
433 Eros	2009-06-18	1.77845	1.25897	-33.93	1.6	327.8	13	13.45	0.43	Skiff
433 Eros	2009-06-19	1.77800	1.24833	-33.84	1.6	328.1	3	13.61	0.05	Skiff
433 Eros	2009-06-22	1.77653	1.21652	-33.53	1.9	329.0	15	13.22	0.39	Skiff
433 Eros	2009-10-10	1.59958	0.78084	29.64	13.5	341.5	13	11.88	0.12	Skiff
433 Eros	2009-10-11	1.59697	0.78585	30.11	13.5	341.7	24	11.88	0.18	Skiff
433 Eros	2009-10-18	1.57826	0.82291	33.13	13.6	343.2	28	12.08	0.15	Skiff
433 Eros	2009-10-20	1.57278	0.83403	33.90	13.7	343.7	11	12.15	0.14	Skiff
433 Eros	2009-10-21	1.57002	0.83965	34.27	13.7	344.0	31	12.14	0.15	Skiff
433 Eros	2009-11-17	1.49068	0.99684	41.14	13.6	353.6	22	12.49	0.08	Skiff
433 Eros	2009-11-21	1.47825	1.01950	41.75	13.6	355.4	18	12.54	0.04	Skiff
433 Eros	2009-11-22	1.47512	1.02509	41.90	13.6	355.9	19	12.57	0.08	Skiff
433 Eros	2009-11-24	1.46884	1.03616	42.16	13.5	356.8	12	12.58	0.05	Skiff
433 Eros	2009-11-25	1.46569	1.04165	42.29	13.5	357.3	14	12.59	0.05	Skiff
433 Eros	2009-11-26	1.46253	1.04709	42.41	13.5	357.7	18	12.32	0.06	Skiff
433 Eros	2009-12-19	1.38840	1.16011	44.31	12.9	10.0	8	12.70	0.12	Skiff
433 Eros	2009-12-20	1.38515	1.16443	44.36	12.8	10.6	9	12.49	0.12	Skiff
433 Eros	2010-01-10	1.31740	1.24239	45.07	11.8	23.8	7	12.77	0.13	Skiff
1943 Anteros	2009-06-18	1.22523	0.56488	-55.31	11.5	321.1	10	16.84	0.22	Sanborn
1943 Anteros	2009-06-19	1.22880	0.56385	-54.98	11.7	321.7	14	16.84	0.17	Sanborn
1943 Anteros	2009-06-22	1.23959	0.56055	-53.95	12.2	323.4	12	16.80	0.14	Sanborn
1943 Anteros	2009-07-01	1.27273	0.54907	-50.57	13.5	328.1	24	16.72	0.18	Vickowski
1943 Anteros	2009-08-10	1.42367	0.50106	-28.78	17.3	340.2	45	16.16	0.50	Sanborn
3554 Amun	2009-03-17	1.22039	0.41181	48.29	17.0	137.5	9	15.93	0.15	Sanborn
3554 Amun	2009-03-18	1.22204	0.41717	48.42	16.3	137.9	22	15.89	0.26	Sanborn
3554 Amun	2009-03-19	1.22364	0.42266	48.56	15.7	138.2	25	15.99	0.24	Sanborn
3554 Amun	2009-03-21	1.22668	0.43403	48.85	14.4	139.0	18	16.03	0.18	Koehn
3554 Amun	2009-03-25	1.23212	0.45813	49.49	12.0	140.6	11	16.29	0.21	Sanborn
3554 Amun	2009-03-27	1.23452	0.47079	49.83	10.8	141.5	9	16.26	0.17	Sanborn
3554 Amun	2009-03-28	1.23564	0.47726	50.00	10.2	141.9	7	16.35	0.15	Sanborn
3554 Amun	2009-03-29	1.23671	0.48381	50.17	9.7	142.4	8	16.33	0.17	Sanborn
3554 Amun	2009-12-18	0.95841	0.46372	-79.29	50.3	139.1	7	15.72	0.24	Nelson
3554 Amun	2011-02-13	1.21317	0.38540	-46.34	19.8	179.0	378	16.53	0.17	Skiff
3554 Amun	2011-02-14	1.21503	0.37938	-45.59	19.5	179.2	169	15.59	0.21	Skiff
3554 Amun	2011-02-15	1.21683	0.37339	-44.82	19.1	179.4	211	15.69	0.21	Skiff
5011 Ptah	2009-04-18	1.09270	0.30117	65.17	-0.6	159.8	16	16.28	0.52	Sanborn
5011 Ptah	2009-04-19	1.10026	0.30573	63.98	-0.9	161.3	17	16.60	0.36	Sanborn
5011 Ptah	2009-04-20	1.10784	0.31065	62.83	-1.2	162.7	11	17.17	0.76	Sanborn
5011 Ptah	2009-04-23	1.13074	0.32745	59.61	-2.0	167.0	5	17.79	0.25	Koehn
(5604) 1992 FE	2009-03-27	1.21313	0.22880	-17.93	-12.7	189.4	7	15.37	0.11	Sanborn
(5604) 1992 FE	2009-03-28	1.21667	0.23166	-17.53	-12.7	189.1	8	15.48	0.17	Sanborn
(5604) 1992 FE	2009-03-29	1.22015	0.23471	-17.30	-12.7	188.7	11	15.46	0.12	Sanborn
(5604) 1992 FE	2009-04-22	1.28184	0.35400	33.38	-10.9	186.3	13	16.78	0.14	Sanborn
5620 Jasonwheeler	2009-06-18	1.26500	0.28369	25.41	16.0	255.6	14	16.14	1.20	Sanborn
5620 Jasonwheeler	2009-06-19	1.26321	0.28214	25.61	15.8	256.1	16	16.10	1.22	Sanborn
5620 Jasonwheeler	2009-06-21	1.25986	0.27929	26.02	15.4	257.1	12	15.86	0.77	Vickowski
5620 Jasonwheeler	2009-06-22	1.25830	0.27799	26.22	15.2	257.7	25	16.01	1.08	Sanborn
5620 Jasonwheeler	2009-06-23	1.25681	0.27679	26.42	15.0	258.2	35	16.32	1.12	Vickowski
5261 Eureka	2011-11-10	1.48907	0.52701	-15.26	7.6	61.1	181	16.54	0.58	Skiff
5261 Eureka	2011-11-18	1.49607	0.51425	-7.57	4.8	61.4	107	16.51	2.22	Skiff
5261 Eureka	2011-11-19	1.49696	0.51371	-6.60	4.4	61.5	86	15.64	0.70	Skiff
5261 Eureka	2011-11-28	1.50499	0.52010	3.89	1.1	61.7	244	16.06	0.44	Skiff
5261 Eureka	2011-11-30	1.50679	0.52431	5.64	0.4	61.7	295	16.15	0.37	Skiff
5261 Eureka	2011-12-01	1.50769	0.52678	6.56	0.1	61.7	160	16.13	0.23	Skiff
5261 Eureka	2011-12-27	1.53116	0.66506	26.70	-8.0	64.8	77	17.25	0.33	Skiff
5261 Eureka	2011-12-28	1.53206	0.67262	27.24	-8.2	65.1	78	17.35	0.36	Skiff
5261 Eureka	2011-12-29	1.53295	0.68031	27.77	-8.4	65.3	75	17.37	0.55	Skiff
(5693) 1993 EA	2009-05-13	1.47093	0.55579	27.41	8.1	205.2	35	17.60	0.17	Skiff
(8566) 1996 EN	2009-04-02	1.39934	0.53838	34.03	21.6	164.8	21	17.17	0.13	Koehn
(14402) 1991 DB	2009-03-17	1.06683	0.11323	-48.28	24.3	193.2	9	15.97	0.14	Sanborn
(14402) 1991 DB	2009-03-18	1.06400	0.11376	-50.40	25.5	194.6	7	16.04	0.10	Sanborn
(14402) 1991 DB	2009-03-19	1.06126	0.11456	-52.48	26.8	196.0	12	16.03	0.28	Sanborn
(14402) 1991 DB	2009-03-21	1.05607	0.11693	-56.45	29.1	199.0	9	16.24	0.15	Koehn
(14402) 1991 DB	2009-03-24	1.04900	0.12218	-61.79	32.2	203.6	19	16.48	0.36	Koehn
(14402) 1991 DB	2009-03-25	1.04684	0.12432	-63.39	33.1	205.1	9	16.56	0.35	Sanborn
(14402) 1991 DB	2009-03-27	1.04283	0.12909	-66.29	34.7	208.2	9	16.77	0.20	Sanborn
(14402) 1991 DB	2009-03-28	1.04098	0.13169	-67.59	35.4	209.7	9	16.97	0.24	Sanborn
(14402) 1991 DB	2009-03-29	1.03923	0.13441	-68.79	36.1	211.2	7	16.92	0.22	Sanborn
(14402) 1991 DB	2009-04-02	1.03330	0.14630	-72.71	38.2	217.5	20	17.36	0.42	Koehn
(16834) 1997 WU22	2009-06-18	0.97670	0.51876	-79.16	17.7	335.8	4	16.89	0.19	Sanborn
(16834) 1997 WU22	2009-06-19	0.98290	0.52353	-78.36	18.0	336.5	7	17.18	0.52	Sanborn
(16834) 1997 WU22	2009-06-22	1.00184	0.53721	-76.06	19.0	338.6	9	16.88	0.33	Sanborn
(16834) 1997 WU22	2009-08-10	1.33782	0.63546	-46.70	27.3	2.0	4	17.31	0.64	Sanborn
(22753) 1998 WT	2009-01-30	1.44101	0.46010	-6.42	-0.7	136.5	10	17.22	0.15	Sanborn
(22753) 1998 WT	2009-02-02	1.41939	0.43468	-2.96	-0.8	136.1	7	16.89	0.23	Sanborn
(22753) 1998 WT	2009-02-19	1.28624	0.33396	23.38	-2.1	131.3	3	16.61	0.11	Sanborn

Minor Planet	Date of Observation	Sun Distance (AU)	Earth Distance (AU)	Phase Angle (deg)	BPAB (deg)	LPAB (deg)	Obs. Count (deg)	Avg. Mag.	Mag. Delta	Observer
(35107) 1991 VH	2009-01-01	1.17107	0.26784	40.62	-28.1	88.5	12	15.75	0.20	Sanborn
(35107) 1991 VH	2009-01-02	1.17328	0.26922	40.26	-27.6	88.8	15	15.72	0.05	Sanborn
(35107) 1991 VH	2009-01-03	1.17547	0.27072	39.92	-27.0	89.0	11	15.75	0.08	Sanborn
(35107) 1991 VH	2009-01-15	1.20083	0.29853	38.19	-20.3	92.7	13	15.95	0.10	Sanborn
(35107) 1991 VH	2009-01-16	1.20286	0.30168	38.22	-19.8	93.0	15	15.95	0.08	Sanborn
(35107) 1991 VH	2009-01-18	1.20686	0.30838	38.37	-18.7	93.7	17	16.08	0.22	Sanborn
(52768) 1998 OR2	2009-01-18	1.34705	0.47513	-33.10	11.4	148.2	14	15.85	0.14	Sanborn
(52768) 1998 OR2	2009-01-28	1.27776	0.38257	-34.16	12.4	155.6	27	15.31	0.17	Sanborn
(52768) 1998 OR2	2009-01-29	1.27107	0.37409	-34.33	12.5	156.5	28	15.26	0.21	Koehn
(52768) 1998 OR2	2009-01-30	1.26443	0.36576	-34.52	12.6	157.3	30	15.32	0.19	Sanborn
(52768) 1998 OR2	2009-02-01	1.25132	0.34954	-34.96	12.8	159.0	29	15.23	0.21	Koehn
(52768) 1998 OR2	2009-02-02	1.24485	0.34165	-35.20	12.9	159.9	27	15.03	0.19	Sanborn
(52768) 1998 OR2	2009-02-03	1.23844	0.33392	-35.46	13.0	160.8	26	14.96	0.19	Koehn
(52768) 1998 OR2	2009-02-04	1.23208	0.32634	-35.75	13.1	161.8	18	14.94	0.19	Sanborn
(68350) 2001 MK3	2009-01-16	1.30116	0.43852	-36.48	3.1	149.7	26	16.09	0.40	Sanborn
(68350) 2001 MK3	2009-01-18	1.30508	0.43251	-35.22	4.6	150.2	29	16.07	0.29	Sanborn
(68350) 2001 MK3	2009-01-28	1.32671	0.41680	-29.36	12.4	152.2	25	15.66	0.18	Sanborn
(68350) 2001 MK3	2009-01-29	1.32905	0.41666	-28.89	13.1	152.3	22	15.82	0.20	Sanborn
(68350) 2001 MK3	2009-01-30	1.33142	0.41679	-28.44	13.9	152.5	29	15.78	0.20	Sanborn
(68350) 2001 MK3	2009-02-01	1.33624	0.41785	-27.66	15.3	152.7	24	15.79	0.21	Sanborn
(68350) 2001 MK3	2009-02-02	1.33870	0.41879	-27.32	16.0	152.8	39	15.79	0.18	Sanborn
(68350) 2001 MK3	2009-02-03	1.34118	0.41999	-27.02	16.8	152.9	29	15.72	0.16	Sanborn
(68350) 2001 MK3	2009-02-04	1.34369	0.42147	-26.77	17.5	153.0	17	15.78	0.17	Sanborn
(68350) 2001 MK3	2009-02-19	1.38437	0.47290	-27.37	26.2	154.0	41	16.23	0.22	Sanborn
(85867) 1999 BY9	2009-03-21	1.27770	0.28228	-3.80	-2.5	182.2	22	16.39	0.22	Koehn
(85867) 1999 BY9	2009-03-24	1.27785	0.28133	3.18	-2.5	183.5	29	16.35	0.52	Koehn
(85867) 1999 BY9	2009-03-25	1.27801	0.28124	3.30	-2.5	183.9	27	16.17	0.44	Sanborn
(85867) 1999 BY9	2009-03-27	1.27849	0.28143	3.99	-2.4	184.7	26	16.50	0.47	Sanborn
(85867) 1999 BY9	2009-03-28	1.27881	0.28170	4.48	-2.4	185.1	24	16.64	0.07	Sanborn
(85867) 1999 BY9	2009-03-29	1.27919	0.28208	5.04	-2.4	185.5	16	16.30	0.28	Sanborn
(85867) 1999 BY9	2009-04-02	1.28124	0.28478	7.55	-2.3	187.1	17	17.04	0.60	Koehn
(85867) 1999 BY9	2009-04-20	1.30089	0.31879	18.95	-1.9	194.9	21	17.00	0.37	Sanborn
(85867) 1999 BY9	2009-04-21	1.30246	0.32169	19.52	-1.8	195.4	9	17.56	0.39	Koehn
(85867) 1999 BY9	2009-04-23	1.30575	0.32782	20.61	-1.8	196.3	10	17.92	0.20	Koehn
(138883) 2000 YL29	2009-04-22	1.27986	0.37864	-37.32	30.1	223.3	14	16.61	0.19	Sanborn
(138883) 2000 YL29	2009-09-21	1.19671	0.24320	-33.89	-3.9	22.7	39	15.45	0.28	Sanborn
(138883) 2000 YL29	2009-09-22	1.20143	0.24528	-32.68	-4.8	22.7	81	15.40	0.31	Koehn
(138883) 2000 YL29	2009-09-23	1.20617	0.24760	-31.52	-5.7	22.7	85	15.45	0.44	Koehn
(138883) 2000 YL29	2009-10-16	1.32008	0.35934	-22.28	-19.0	23.0	25	16.18	0.34	Nelson
(138883) 2000 YL29	2009-10-18	1.33024	0.37350	22.77	-19.7	23.1	18	16.22	0.35	McLelland
(138883) 2000 YL29	2009-10-19	1.33532	0.38080	23.04	-20.0	23.2	11	16.33	0.26	Bevins
(138883) 2000 YL29	2009-10-20	1.34040	0.38823	23.32	-20.3	23.3	20	16.36	0.29	Bevins
(138883) 2000 YL29	2009-10-21	1.34549	0.39581	23.61	-20.5	23.4	19	16.48	0.24	McLelland
(141052) 2001 XR1	2009-01-02	1.33357	0.36423	-13.62	3.7	113.1	11	16.51	0.81	Koehn
(141052) 2001 XR1	2009-01-08	1.28540	0.30412	-5.84	1.6	112.4	43	15.80	0.97	Koehn
(141052) 2001 XR1	2009-01-29	1.10055	0.17945	46.25	-13.6	101.5	7	15.79	0.94	Koehn
(141052) 2001 XR1	2009-02-02	1.06263	0.17698	59.80	-18.0	98.5	11	15.70	0.95	Sanborn
(141052) 2001 XR1	2009-01-02	1.33357	0.36423	-13.62	3.7	113.1	11	16.51	0.81	Koehn
(141052) 2001 XR1	2009-01-08	1.28540	0.30412	-5.84	1.6	112.4	43	15.80	0.97	Koehn
(141052) 2001 XR1	2009-01-29	1.10055	0.17945	46.25	-13.6	101.5	7	15.79	0.94	Koehn
(141052) 2001 XR1	2009-02-02	1.06263	0.17698	59.80	-18.0	98.5	11	15.70	0.95	Sanborn
(143651) 2003 QO104	2009-02-19	1.51499	0.58645	-20.75	21.4	157.7	6	17.30	0.09	Sanborn
(143651) 2003 QO104	2009-03-16	1.33683	0.42221	30.19	23.9	161.8	15	15.64	0.05	Koehn
(143651) 2003 QO104	2009-03-17	1.32993	0.41722	30.86	24.0	162.0	25	16.56	0.36	Sanborn
(143651) 2003 QO104	2009-03-18	1.32306	0.41232	31.55	24.0	162.2	29	15.50	0.10	Sanborn
(143651) 2003 QO104	2009-03-19	1.31622	0.40751	32.26	24.1	162.4	23	16.14	0.41	Sanborn
(143651) 2003 QO104	2009-03-21	1.30262	0.39814	33.71	24.1	162.8	21	15.61	0.15	Koehn
(143651) 2003 QO104	2009-03-24	1.28248	0.38466	35.97	24.2	163.5	39	16.39	0.25	Koehn
(143651) 2003 QO104	2009-03-25	1.27583	0.38030	36.74	24.2	163.7	40	15.60	0.24	Sanborn
(143651) 2003 QO104	2009-03-27	1.26267	0.37176	38.31	24.2	164.2	38	15.94	0.44	Sanborn
(143651) 2003 QO104	2009-03-28	1.25614	0.36756	39.11	24.2	164.4	38	16.23	0.33	Sanborn
(143651) 2003 QO104	2009-03-29	1.24967	0.36342	39.91	24.2	164.7	40	15.48	0.16	Sanborn
(143651) 2003 QO104	2009-04-02	1.22422	0.34724	43.17	24.0	165.8	18	15.55	0.19	Koehn
(143651) 2003 QO104	2009-04-18	1.13203	0.28463	56.66	22.4	171.7	26	15.10	0.11	Sanborn
(143651) 2003 QO104	2009-04-19	1.12690	0.28066	57.51	22.2	172.1	17	15.85	0.34	Sanborn
(143651) 2003 QO104	2009-04-22	1.11203	0.26864	60.06	21.6	173.5	28	15.85	0.18	Sanborn
(154244) 2002 KL6	2009-06-18	1.12613	0.16197	-44.09	11.9	293.3	15	15.34	0.67	Sanborn
(154244) 2002 KL6	2009-06-19	1.12159	0.15933	-45.44	12.2	294.9	19	15.38	0.91	Sanborn
(154244) 2002 KL6	2009-06-22	1.10861	0.15302	-49.70	13.1	299.9	18	15.48	0.90	Sanborn
(154244) 2002 KL6	2009-06-23	1.10450	0.15146	-51.18	13.4	301.6	52	15.54	1.05	Vickowski
(154244) 2002 KL6	2009-07-01	1.07580	0.14876	-62.89	15.0	316.0	28	15.59	1.13	Vickowski
(154244) 2002 KL6	2009-07-13	1.04828	0.17105	-74.67	14.6	335.9	19	16.74	1.74	Sanborn
(154244) 2002 KL6	2009-09-24	1.28889	0.37886	-35.17	2.7	31.3	39	17.44	1.08	Koehn
(154244) 2002 KL6	2009-09-25	1.29552	0.38152	-34.15	2.6	31.5	34	17.36	1.08	Nelson
(154244) 2002 KL6	2009-09-26	1.30219	0.38424	-33.12	2.5	31.7	31	17.46	1.13	Bevins
(154244) 2002 KL6	2009-10-16	1.44259	0.46110	-12.30	0.7	34.7	25	17.39	0.71	Nelson
(154244) 2002 KL6	2009-10-19	1.46444	0.47763	-9.31	0.5	35.0	18	17.41	0.66	Bevins
(154244) 2002 KL6	2009-10-20	1.47175	0.48350	-8.33	0.5	35.0	16	17.36	0.53	Bevins
(154244) 2002 KL6	2009-10-22	1.48642	0.49579	-6.40	0.3	35.2	46	17.37	0.77	Koehn
161989 Cacus	2009-02-19	1.12151	0.23878	-50.95	0.4	187.0	14	16.25	1.12	Sanborn

Minor Planet	Date of Observation	Sun Distance (AU)	Earth Distance (AU)	Phase Angle (deg)	BPAB (deg)	LPAB (deg)	Obs. Count (deg)	Avg. Mag.	Mag. Delta	Observer
(162385) 2000 BM19	2009-01-28	1.00442	0.13468	-77.84	35.6	160.8	9	17.68	0.83	Sanborn
(162385) 2000 BM19	2009-01-29	1.00503	0.13307	-77.58	36.2	160.7	7	16.84	0.48	Koehn
(162385) 2000 BM19	2009-01-30	1.00553	0.13152	-77.36	36.9	160.5	6	17.69	0.60	Sanborn
(162385) 2000 BM19	2009-02-01	1.00623	0.12861	-77.05	38.3	160.0	9	17.30	0.91	Koehn
(162385) 2000 BM19	2009-02-02	1.00641	0.12726	-76.97	39.0	159.7	13	16.82	0.23	Sanborn
(162385) 2000 BM19	2009-02-03	1.00650	0.12598	-76.94	39.6	159.3	9	16.76	0.27	Koehn
(162385) 2000 BM19	2009-02-04	1.00648	0.12478	-76.95	40.3	159.0	10	16.67	0.21	Sanborn
(163758) 2003 OS13	2009-06-18	1.07127	0.30153	-71.39	22.9	315.0	5	17.51	0.63	Sanborn
(163758) 2003 OS13	2009-06-19	1.08437	0.30264	-69.03	23.9	314.0	7	17.49	0.36	Sanborn
(163758) 2003 OS13	2009-06-22	1.12301	0.30959	-62.23	26.7	310.7	2	17.40	0.17	Sanborn
(175706) 1996 FG3	2009-03-25	1.24580	0.25354	-10.29	-5.4	190.1	16	15.99	0.15	Sanborn
(175706) 1996 FG3	2009-03-27	1.23722	0.24288	-8.86	-5.6	190.0	14	15.82	0.32	Sanborn
(175706) 1996 FG3	2009-03-28	1.23286	0.23779	-8.39	-5.8	189.8	21	15.63	0.21	Sanborn
(175706) 1996 FG3	2009-03-29	1.22845	0.23285	-8.16	-5.9	189.7	20	15.85	0.20	Sanborn
(175706) 1996 FG3	2009-04-22	1.10865	0.16280	47.26	-8.5	182.8	17	16.40	0.25	Sanborn
(194386) 2001 VG5	2009-01-15	1.22665	0.48446	49.51	-11.1	69.4	6	17.84	1.19	Sanborn
(194386) 2001 VG5	2009-06-15	1.45321	0.45093	11.71	5.1	254.4	65	16.11	0.85	Vickowski
(194386) 2001 VG5	2009-06-18	1.47967	0.48380	13.68	5.7	255.0	9	17.42	0.31	Sanborn
(194386) 2001 VG5	2009-06-19	1.48848	0.49505	14.30	5.9	255.2	12	17.10	0.42	Sanborn
(194386) 2001 VG5	2009-06-21	1.50609	0.51800	15.47	6.3	255.6	13	17.34	0.72	Vickowski
(194386) 2001 VG5	2009-06-22	1.51488	0.52970	16.03	6.4	255.8	16	17.43	0.72	Sanborn
(203217) 2001 FX9	2009-01-28	1.29984	0.32052	-9.30	-7.3	130.6	5	17.50	0.26	Sanborn
(203217) 2001 FX9	2009-01-29	1.30083	0.32104	-9.00	-7.2	131.0	9	17.45	0.16	Koehn
(207945) 1991 JW	2009-04-18	1.13281	0.15647	-32.38	14.5	223.6	27	16.95	0.20	Sanborn
(207945) 1991 JW	2009-04-20	1.13042	0.14939	-30.61	14.0	224.1	22	16.81	0.26	Sanborn
(207945) 1991 JW	2009-04-21	1.12920	0.14593	-29.68	13.7	224.4	20	16.70	0.21	Koehn
(207945) 1991 JW	2009-04-22	1.12795	0.14252	-28.71	13.4	224.6	12	16.66	0.21	Sanborn
(207945) 1991 JW	2009-04-23	1.12669	0.13917	-27.71	13.1	224.8	32	16.56	0.25	Koehn
(207945) 1991 JW	2009-05-17	1.09036	0.08423	19.52	-0.9	225.0	6	15.17	0.19	Koehn
2001 FE90	2009-06-21	1.00529	0.04570	102.68	31.7	223.7	9	17.35	0.94	Vickowski
2001 FE90	2009-06-22	1.00826	0.04044	100.43	31.0	226.1	8	17.22	0.98	Sanborn
2001 FE90	2009-06-27	1.02504	0.01930	63.54	18.4	249.0	20	14.34	1.82	Sanborn
2001 FE90	2009-06-28	1.02876	0.01797	47.11	13.6	255.4	28	13.56	1.62	Vickowski
2001 FE90	2009-06-29	1.03260	0.01849	30.08	7.1	263.7	41	13.27	1.24	Koehn
2001 FE90	2009-06-29	1.03260	0.01849	30.08	7.1	263.7	79	13.28	1.32	Koehn
2001 FE90	2009-06-29	1.03260	0.01849	30.08	7.1	263.7	17	13.25	1.19	Koehn
2004 LV3	2009-01-01	1.00722	0.09015	72.15	-14.1	61.7	6	15.90	0.15	Koehn
2004 LV3	2009-01-02	1.01116	0.09824	70.85	-17.3	64.2	2	15.89	0.04	Koehn
2004 LV3	2009-01-03	1.01514	0.10706	69.80	-19.8	66.4	6	16.21	0.05	Sanborn
2005 BC	2009-01-16	1.18897	0.24712	-30.37	-15.5	132.6	4	16.21	0.11	Sanborn
2005 BC	2009-01-18	1.19771	0.25484	-29.47	-17.4	132.0	6	16.36	0.09	Sanborn
2005 SG19	2009-03-29	1.37422	0.41707	-21.65	-4.3	207.9	11	16.81	0.16	Sanborn
2008 QT3	2009-01-18	1.03124	0.12876	65.05	-13.2	80.6	6	16.60	0.24	Sanborn
2008 QT3	2009-01-28	1.08402	0.16014	48.35	-15.8	101.1	9	16.50	0.21	Sanborn
2008 QT3	2009-01-29	1.08982	0.16495	47.12	-15.8	102.7	10	16.51	0.22	Koehn
2008 WL60	2009-04-18	1.26182	0.31040	29.74	23.6	206.5	32	17.19	0.31	Sanborn
2008 WL60	2009-04-19	1.26786	0.31329	28.72	22.9	206.9	11	17.13	0.34	Sanborn
2008 WL60	2009-04-20	1.27396	0.31642	27.73	22.1	207.4	34	17.12	0.33	Sanborn
2008 WL60	2009-04-21	1.28011	0.31978	26.78	21.4	207.7	19	16.92*	0.34	Koehn
2008 WL60	2009-04-23	1.29258	0.32723	25.00	19.8	208.6	33	17.19	0.30	Koehn
2009 DE47	2009-04-20	1.29122	0.29307	-10.72	-3.2	218.0	9	17.10	0.15	Sanborn
2009 DE47	2009-04-21	1.29413	0.29450	-9.66	-3.7	217.8	8	17.02	0.24	Koehn
2009 DO111	2009-03-16	1.01469	0.02071	-15.96	8.2	177.0	10	15.16	0.22	Koehn
2009 DO111	2009-03-17	1.00985	0.01556	18.16	9.4	176.6	21	14.42	0.24	Sanborn
2009 DO111	2009-03-18	1.00499	0.01050	23.27	11.5	175.4	7	14.11	0.47	Sanborn
2009 DO111	2009-03-18	1.00499	0.01050	23.27	11.5	175.4	7	13.61	0.26	Sanborn
2009 DO111	2009-03-18	1.00499	0.01050	23.27	11.5	175.4	11	13.74	0.40	Sanborn
2009 DO111	2009-03-18	1.00499	0.01050	23.27	11.5	175.4	2	13.57	0.02	Sanborn
2009 EP2	2009-03-16	1.05004	0.05645	11.58	-1.4	169.5	8	15.93	0.20	Koehn
2009 FD	2009-03-24	1.02707	0.03167	-18.44	5.1	192.1	26	15.60	0.63	Koehn
2009 JM2	2009-05-14	1.06554	0.11241	58.12	31.2	218.3	38	16.36	0.16	Koehn
2009 JM2	2009-05-14	1.06554	0.11241	58.12	31.2	218.3	55	16.35	0.13	Koehn
2009 JM2	2009-05-14	1.06554	0.11241	58.12	31.2	218.3	29	16.31	0.12	Koehn
2009 JM2	2009-05-15	1.07166	0.11105	54.32	29.0	220.1	75	16.27	0.11	Koehn
2009 JM2	2009-05-15	1.07166	0.11105	54.32	29.0	220.1	67	16.33	0.13	Koehn
2009 JM2	2009-05-15	1.07166	0.11105	54.32	29.0	220.1	94	16.25	0.16	Koehn
2009 JM2	2009-05-17	1.08422	0.11047	46.50	24.4	223.4	23	16.04	0.10	Koehn

Minor Planet	NEAPS Period (h)	NEAPS Period Uncert.	Period (h) Published Elsewhere	Published Period Quality	Reference
(433) Eros	5.266	0.02	5.270	3	Campa 1938
(1943) Anteros	2.9	0.1	2.8695	3	Pravec 1998
(3554) Amun	2.53029	0.00002	2.530	3	Behrend 2010
(5011) Ptah	> 20	-	-	-	
(5261) Eureka	2.6902	0.0003	6	1	Rivkin 2003
(5261) Eureka*	16.93	0.01	-	-	*Binary orbital period
(5604) 1992 FE	5	1	5.3375	3	Higgins 2009
(5620) Jasonwheeler	5.3075	0.0004	5.307	3	Durkee 2010
(5693) 1993 EA	-	-	2.497	2	Polishook 2012
(8566) 1996 EN	-	-	-	-	
(14402) 1991 DB	2.27	0.01	2.2656	3	Pravec 2000
(16834) 1997 WU22	-	-	9.345	3	Pravec 2000
(22753) 1998 WT	-	-	10.24	2	Galad 2005
(25107) 1991 VH	-	-	2.6236T	3	Vander Haagen 2010
(52768) 1998 OR2	4.112	0.002	3.198	2	Betzler 2009
(68350) 2001 MK3	3.2112	0.0007	3.273	3	Carbognani 2011
(85867) 1999 BY9	> 20T		-	-	
(138883) 2000 YL29	10.60	0.08	-	-	
(141052) 2001 XR1	7.66	0.01	-	-	
(143651) 2003 QO104	114.09	0.04	115	3	Warner 2009
(154244) 2002 KL6	4.6081	0.002	4.6063	3	Galad 2010
(161989) Cacus	3.77	0.11	3.7538	3	Pravec 2003
(162385) 2000 BM19	9.47	0.01	-	-	
(163758) 2003 OS13	-	-	-	-	
(175706) 1996 FG3	6.04	0.02	3.5942	3	Pravec 2006
(194386) 2001 VG5	6.351	0.003	6.6	2	Polishook 2009
(203217) 2001 FX9	-	-	-	-	
(207945) 1991 JW	3.15	0.01	-	-	
(208023) 1999 AQ10	-	-	2.67	2+	Behrend 2009
(212546) 2006 SV19	-	-	-	-	
(256412) 2007 BT2	> 18	-	-	-	
2001 FE90	4.772	0.0002	0.4777	3	Hicks 2009
2004 LV2	-	-	-	-	
2005 BC	-	-	-	-	
2005 SG19	-	-	-	-	
2008 QT3	-	-	-	-	
2008 WL60	2.608	0.002	-	-	
2009 DE47	-	-	-	-	
2009 DO111	0.04887	0.00001	0.04890	3	Behrend 2009
2009 EP2	-	-	-	-	
2009 FD	>6	-	4.0	2	Behrend 2009
2009 JM2	-	-	-	-	

LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2014 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 several lists of asteroids that are prime targets for photometry during the period 2014 October-December.

In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the asteroid lightcurve data base (LCDB) documentation for an explanation of the U code:

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

The ephemeris 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

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

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

http://www.minorplanetcenter.net/light_curve

We believe this to be the largest publicly available database of raw lightcurve data that contains 1.5 million observations for more than 2300 objects.

Lightcurve Opportunities

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.

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

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
6425	1994 WZ3*	10 01.7	14.2	+13	103.9	0.92	2
450	Brigitta*	10 05.1	13.5	+4	10.75	0.18	2
589	Croatia*	10 05.8	13.1	+1	24.821	0.16-0.25	2+
4908	Ward*	10 07.3	13.9	+5	10.96	0.93	2
879	Ricarda*	10 08.2	13.6	+28	82.9	0.37	2
1550	Tito*	10 09.2	13.0	-9	54.2	0.16-0.40	2
1615	Bardwell*	10 12.8	14.6	+6	>18.	0.2	1
1351	Uzbekistania*	10 13.5	14.0	+10	73.9	0.20-0.34	2
7330	Annelemaitre*	10 13.5	14.6	+1			
8041	Masumoto*	10 14.4	14.9	+23	34.	0.27-0.39	2
1463	Nordenmarkia*	10 21.4	13.9	+20	5.92	0.13	2
2649	Oongaq*	10 21.8	14.7	+23	8.64	0.28	2
2340	Hathor*	10 27.7	15.0	+11			
11065	1991 XE2*	10 31.3	15.0	+6	> 8.	0.1	1+
3176	Paolicchi*	11 01.6	14.9	+7	20.4	0.31	2
619	Triberga*	11 04.5	13.0	+3	29.412	0.30-0.45	2
1057	Wanda*	11 05.4	13.4	+19	28.8	0.14-0.41	2
5176	Yoichi*	11 05.6	14.1	+5			
1042	Amazone*	11 06.9	14.0	+12	540.	0.10-0.25	2
1392	Pierre*	11 09.1	14.1	+34	18.	0.09	2
1355	Magoeba*	11 10.0	14.5	+15	2.975	0.06-0.22	2
1952	Hesburgh*	11 10.1	14.0	+5	47.7	0.18	2
6176	Horrigan*	11 11.2	14.9	+8			
1213	Algeria*	11 11.6	15.0	+31	>16.	0.19	2
6086	1987 VU*	11 14.2	14.7	+14			
2976	Lautaro*	11 14.4	14.6	+12	17.41	0.12	2-
2623	Zech*	11 16.8	14.4	+27			
570	Kythera*	11 19.0	12.9	+19	8.12	0.15-0.20	2
4070	Rozov*	11 23.8	14.6	+22			
31723	1999 JT61*	11 24.3	14.4	+17			
214088	2004 JN13*	11 27.2	12.6	-16			
3841	Dicicco*	11 29.8	14.4	+25			
481	Emita*	12 01.9	11.1	+23	14.35	0.09-0.30	2
7870	1987 UP2*	12 09.6	14.2	+20	12.	0.06-0.07	1
569	Misa*	12 10.4	12.3	+25	13.52	0.25	2
4467	Kaidanovskij*	12 11.4	14.9	+41	>12.	0.03	1
1965	van de Kamp*	12 15.0	14.4	+23	>6.	0.5	1
549	Jessonda*	12 15.5	12.8	+27	2.971	0.04-0.10	2-
19144	1989 UP1*	12 15.5	14.9	+24			
43815	1991 VD4*	12 15.5	14.7	+18			
2655	Guangxi*	12 15.9	14.7	+21			
1461	Jean-Jacques*	12 21.3	14.1	+17	16.56	0.09	2
1149	Volga*	12 21.4	14.2	+21	27.5	0.26	2
2088	Sahlia*	12 22.5	14.5	+34	10.37	0.12	2
2290	Helffrich*	12 26.7	14.5	+4		0.10	

Low Phase Angle Opportunities

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 at least half a cycle 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. This reduction requires that you determine the period and the amplitude of the lightcurve; for long period objects that can be tricky. Refer to Harris, *et al.* ("Phase Relations of High Albedo Asteroids." *Icarus* **81**, p365 ff) for the details of the analysis procedure.

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 when using average light, which is the method used for values listed by the Minor Planet Center.

#	Name	Date	α	V	Dec	Period	Amp	U
253	Mathilde	10 01.0	0.94	12.0	+01	417.7	0.45-0.50	3
305	Gordonia	10 02.3	0.69	12.9	+05	16.2	0.16-0.17	2
830	Petropolitana	10 02.4	0.86	13.3	+06	39.0	0.15	2
720	Bohlinia	10 03.1	0.54	13.5	+02	8.919	0.16-0.46	3
450	Brigitta	10 05.1	0.30	13.5	+04	10.75	0.18	2
268	Adorea	10 05.3	0.92	13.2	+02	7.80	0.15-0.20	3
150	Nuwa	10 05.8	0.34	11.4	+06	8.135	0.08-0.31	3
252	Clementina	10 09.0	0.60	13.6	+08	10.864	0.32-0.44	3
37	Fides	10 09.2	0.35	9.8	+07	7.334	0.10-0.25	3
1351	Uzbekistania	10 13.5	0.86	14.0	+10	73.9	0.20-0.34	2
332	Siri	10 16.7	0.29	12.8	+08	8.007	0.10-0.35	3
250	Bettina	10 23.0	0.63	11.5	+13	5.055	0.11-0.60	3
1223	Neckar	11 01.8	0.12	14.0	+14	7.81	0.16-0.45	3
713	Luscinia	11 03.8	0.31	12.9	+14	8.28	0.09-0.40	3
171	Ophelia	11 04.2	0.95	12.8	+12	6.665	0.14-0.46	3
401	Ottilia	11 08.9	0.45	13.6	+18	6.049	0.11-0.24	3
1186	Turnera	11 11.1	0.53	13.0	+19	12.066	0.25-0.34	2+
374	Burgundia	11 11.3	0.75	12.7	+15	6.972	0.05-0.18	3
336	Lacadiera	11 17.9	0.06	12.5	+19	13.70	0.27-0.34	3
570	Kythera	11 19.0	0.18	12.9	+19	8.120	0.15-0.18	2
774	Armor	11 21.4	0.46	13.4	+21	25.162	0.13-0.34	2
503	Evelyn	11 21.8	0.61	11.9	+19	38.7	0.30-0.5	2
3722	Urata	11 22.4	0.91	14.0	+19	5.567	0.04-0.58	3
104	Klymene	11 28.1	0.66	11.6	+23	8.984	0.26-0.3	3
596	Scheila	11 30.7	0.29	13.6	+21	15.851	0.06-0.09	2+
481	Emita	12 01.9	0.33	11.2	+23	14.35	0.09-0.30	2
23	Thalia	12 03.0	0.54	9.2	+23	12.312	0.10-0.14	3
363	Padua	12 03.1	0.35	12.4	+23	8.401	0.14	3
196	Philomela	12 10.1	0.30	10.8	+24	8.334	0.07-0.40	3
569	Misa	12 10.4	0.75	12.3	+25	13.52	0.25	2
321	Florentina	12 10.9	0.89	13.6	+25	2.871	0.31-0.52	3
419	Aurelia	12 11.6	0.87	12.8	+20	16.784	0.07-0.27	3
263	Dresda	12 19.0	0.55	13.8	+22	16.809	0.32-0.55	3
825	Tanina	12 20.7	0.57	14.0	+22	6.940	0.20-0.54	3
541	Deborah	12 22.4	0.18	13.9	+23	13.91	0.04-0.07	2+
404	Arsinoe	12 27.8	0.44	12.5	+25	8.887	0.27-0.38	3
10	Hygiea	12 30.9	0.13	10.0	+24	27.623	0.09-0.33	3

<u>Shape/Spin Modeling Opportunities</u>

Those doing work for modeling should contact Josef Ďurech at the email address above 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

if looking to add lightcurves for objects already in the DAMIT database.

Below is a list of objects reaching brightest this quarter with well-determined periods and for which no pole solution is in the LCDB. However, since they have a high U rating, this means there is at least one dense lightcurve of high quality. An additional dense lightcurve, along with sparse data, could lead to the asteroid being added to or improving one in DAMIT, thus increasing the total number of asteroids with spin axis and shape models.

Note that you can compare and combine the results of searches using the ephemeris generator and LCDB query (limited to with or without a pole solution) at the sites listed above to create your own customized list of objects.

		Brightest			LCDB Data		
#	Name	Date	Mag	Dec	Period	Amp	U
1030	Vitja	10 01.4	15.0	+3	5.7014	0.18-0.21	3-
8147	Colemanhawkins*	10 01.4	15.0	-4			
261	Prymno	10 02.3	12.6	-2	8.002	0.13-0.20	3
2429	Schurer*	10 02.3	15.0	-1	6.66	0.12-0.77	3-
2481	Burgi*	10 02.3	14.9	+3			
582	Olympia	10 02.5	12.8	-22	36.312	0.05-0.23	3
1860	Barbarossa	10 03.5	14.7	-8	3.255	0.28-0.35	3
280	Philia	10 04.0	14.6	+4	70.26	0.15-0.19	3
3296	Bosque Alegre*	10 04.2	14.7	-19			
123	Brunhild	10 04.6	12.2	+13	10.04	0.16-0.21	3
4359	Berlage*	10 04.8	14.6	+4	7.413	0.90	3
48411	Johnventre*	10 04.8	15.0	+5			
10645	Brac*	10 05.0	14.8	+12			
799	Gudula	10 05.9	13.3	+1	14.814	0.30	3
116	Sirona	10 07.8	12.0	+2	12.028	0.42-0.55	3
2235	Vittore	10 08.5	15.0	+10	32.1	0.21	3
252	Clementina*	10 09.0	13.5	+8	10.864	0.32-0.44	3
1562	Gondolatsch	10 09.0	14.7	-1	8.78	0.30-0.35	3-
802	Epyaxa	10 09.1	14.9	+7	4.392	0.40-0.70	3
2642	Vesale*	10 10.1	14.1	+9	5.566	0.12-0.39	3
1442	Corvina*	10 10.3	14.9	+7			
202	Chryseis	10 11.8	12.0	-3	23.67	0.04-0.23	3
14488	1994 TF15	10 12.0	15.0	+12			
4563	Kahnia*	10 12.4	14.7	-1			
611	Valeria*	10 13.9	12.9	+4	6.977	0.08-0.16	3
1739	Meyermann	10 14.0	15.0	+8	2.8219	0.22	3
327	Columbia	10 15.1	13.5	+13	5.932	0.16-0.42	3
647	Adelgunde	10 15.1	13.7	+18	32.202	0.28	3
1662	Hoffmann*	10 15.4	14.2	+14	8.784	0.26	3
533	Sara	10 15.6	13.9	+5	11.654	0.19-0.30	3
2460	Mitlincoln	10 15.8	14.8	+6	3.01	0.03-0.20	3
3755	Lecointe*	10 15.8	14.5	+15			
811	Nauheima	10 15.9	14.5	+4	4.0011	0.08-0.20	3
9120	1998 DR8*	10 16.5	14.8	+17	14.75	0.11-0.12	3
332	Siri	10 16.7	12.7	+8	8.0074	0.10-0.35	3
1643	Brown*	10 17.2	14.2	+16	5.932	0.48	3
498	Tokio	10 17.4	11.6	-5	41.85	0.10-0.23	3
4225	Hobart	10 17.5	14.9	+6			
2315	Czechoslovakia*	10 18.1	14.1	+8	10.0253	0.52	3
756	Lilliana	10 18.8	14.9	+11	7.834	0.18-0.99	3
2150	Nyctimene*	10 19.5	14.4	+5	6.131	0.59-0.66	3
592	Bathseba	10 20.9	13.2	+1	7.7465	0.22-0.32	3
585	Bilkis	10 21.5	13.7	+5	8.5751	0.10-0.41	3-
475	Ocllo*	10 22.0	12.8	+6	7.3151	0.66-0.81	3
3481	Xianglupeak*	10 22.0	14.6	+7	5.3193	0.30-0.44	3
474	Prudentia	10 22.2	13.5	+1	8.572	0.53-0.70	3
1752	van Herk	10 22.8	14.5	+14			
773	Irmintraud	10 23.1	13.4	+34	6.7514	0.05-0.15	3
559	Nanon	10 25.2	13.4	-1	10.059	0.09-0.26	3
3066	McFadden	10 25.5	14.0	-3	13.798	0.04-0.13	3
8159	Fukuoka*	10 25.5	14.8	-12			
3401	Vanphilos	10 25.7	13.9	+52	4.2261	0.50-0.54	3
3730	Hurban	10 26.0	14.6	+24			
950	Ahrensa	10 26.8	14.8	-7	202.	0.40	3
31060	1996 TB6*	10 27.0	14.9	+13	5.103	0.80	3
3700	Geowilliams	10 27.2	14.8	+32	14.387	0.40	3
6024	Ochanomizu*	10 27.3	14.9	+11			
2151	Hadwiger*	10 29.0	13.9	+17	5.872	0.07-0.38	3
3220	Murayama*	10 29.5	14.1	+16	4.8595	0.13-0.16	3
1552	Bessel*	10 30.3	15.0	+20	8.996	0.29	3
1407	Lindelof*	10 30.7	12.9	+22	31.151	0.34	3
370	Modestia	10 30.9	13.2	+27	22.5299	0.24	3
46	Hestia	10 31.3	10.6	+12	21.04	0.08-0.12	3
5598	Carlmurray	11 01.0	14.9	+22	2.9226	0.32	3
815	Coppelia	11 01.7	14.1	+7	4.421	0.17-0.24	3
4820	Fay*	11 02.0	13.9	+35	3.73	0.52	3
245	Vera*	11 03.5	10.9	+12	14.38	0.26	3
2827	Vellamo	11 03.6	15.0	+27			
713	Luscinia*	11 03.7	12.9	+14	8.28	0.09-0.40	3
171	Ophelia	11 04.3	12.8	+12	6.6654	0.14-0.46	3
78	Diana	11 04.6	11.4	+28	7.2991	0.02-0.30	3
10565	1994 AT1*	11 05.0	14.4	+9			
333	Badenia	11 06.0	12.9	+20	8.192	0.20-0.33	3-
2533	Fechtig*	11 06.0	14.9	+15			
943	Begonia	11 06.8	13.9	-2	15.66	0.24-0.34	3
1645	Waterfield	11 08.0	14.6	+17	4.861	0.18-0.20	3
3003	Koncek*	11 08.1	14.8	+1			
2637	Bobrovnikoff	11 08.6	14.7	+25	4.7939	0.13	3
401	Ottilia	11 08.9	13.6	+18	6.049	0.11-0.24	3
5292	1991 AJ1	11 08.9	14.7	-3			
5892	Milesdavis*	11 09.5	14.7	+7	10.59	0.26	3
1277	Dolores	11 10.2	14.8	+21	17.19	0.45	3
374	Burgundia	11 11.3	12.7	+15	6.972	0.05-0.18	3
1756	Giacobini*	11 12.1	13.8	+26	3.8527	0.21	3
85713	1998 SS49	11 12.3	14.7	+37			

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237	Coelestina	11 12.4	13.2	+10	29.215	0.16-0.3	3
1902	Shaposhnikov	11 12.7	14.6	+15	21.2	0.35-0.42	3
2078	Nanking*	11 13.0	14.0	+58	6.473	0.79-0.85	3
1388	Aphrodite	11 14.9	14.9	+18	11.9432	0.34-0.65	3
7369	Gavrilin*	11 15.0	14.6	+53	49.12	0.25	3
2195	Tengstrom*	11 15.6	13.9	+12	2.8211	0.17-0.31	3
2903	Zhuhai*	11 15.6	14.5	+18	5.263	0.32-0.54	3
715	Transvaalia*	11 16.0	13.4	+21	11.8	0.19-0.32	3
2421	Nininger	11 16.0	15.0	+13			
677	Aaltje	11 17.0	13.8	+26	16.608	0.10-0.37	3
3223	Forsius	11 17.5	14.0	+3	2.343	0.20-0.22	3
2331	Parvulesco	11 18.3	14.4	+21	32.03	0.50	3
3177	Chillicothe*	11 18.3	14.4	+29			
706	Hirundo	11 18.5	14.3	+43	22.027	0.39-0.9	3
851	Zeissia	11 18.6	14.0	+15	9.34	0.38-0.53	3
387	Aquitania	11 18.9	12.1	-4	24.144	0.25	3
515	Athalia*	11 20.3	14.5	+17			
1431	Luanda	11 21.0	14.9	+1	4.141	0.77-1.00	3-
2633	Bishop	11 21.1	15.0	+19			
1120	Cannonia	11 21.3	13.6	+12	3.816	0.15-0.16	3
1069	Planckia	11 21.4	14.1	+1	8.665	0.14-0.42	3
4755	Nicky*	11 22.2	14.9	+16	5.057	0.40	3
3673	Levy*	11 22.3	14.5	+31	2.6879	0.13	3
6388	1989 WL1*	11 23.6	14.8	+18			
3511	Tsvetaeva*	11 23.7	14.7	+17	6.2279	0.80-0.87	3
603	Timandra	11 24.8	14.9	+33	41.79	0.10	3-
1416	Renauxa	11 25.9	14.4	+35	8.7	0.1-0.4	3
1467	Mashona	11 27.3	13.9	+51	9.76	0.24-0.25	3
104	Klymene*	11 28.1	11.6	+23	8.984	0.26-0.3	3
37306	2001 KW46*	11 28.2	14.9	+15			
2185	Guangdong	11 28.3	14.8	+23	21.089	0.19	3-
412	Elisabetha	11 28.6	13.0	+7	19.635	0.08-0.20	3
2326	Tololo*	11 29.0	14.2	-3			
1262	Sniadeckia	11 30.6	14.7	+6	17.57	0.10-0.16	3
169	Zelia	11 30.7	12.5	+31	14.537	0.13-0.14	3
596	Scheila	11 30.7	13.6	+21	15.848	0.06-0.10	3
1129	Neujmina*	12 01.0	13.9	+26	5.0844	0.06-0.20	3
1410	Margret	12 01.1	15.0	+6			
7561	Patrickmichel*	12 01.1	14.7	+22			
1176	Lucidor*	12 01.5	14.1	+26	4.0791	0.05-0.06	3
6126	1989 EW1*	12 02.2	14.9	+26			
1041	Asta*	12 02.7	13.6	+26	7.554	0.12-0.14	3-
363	Padua	12 03.0	12.4	+23	8.401	0.14	3
528	Rezia	12 03.2	13.9	+29	7.337	0.36-0.39	3
2083	Smither*	12 03.4	14.5	+28	2.6717	0.09-0.10	3
476	Hedwig	12 04.0	12.4	+32	27.33	0.13	3
967	Helionape	12 04.2	14.4	+21	3.234	0.04-0.12	3
2816	Pien	12 05.2	14.9	+18			
1062	Ljuba*	12 05.4	13.7	+31	33.8	0.17-0.2	3
210	Isabella*	12 07.1	12.3	+29	6.672	0.09-0.38	3
1067	Lunaria*	12 07.4	14.0	+33	6.057	0.13-0.27	3
1405	Sibelius*	12 07.4	14.4	+34	6.051	0.11	3-
3960	Chaliubieju*	12 07.5	13.8	+17	3.986	0.27-0.30	3
1460	Haltia*	12 08.5	14.3	+23	3.56	0.30	3
5596	Morbidelli*	12 10.8	14.8	+23	5.4	0.57	3
1015	Christa	12 11.6	13.2	+14	11.23	0.12-0.20	3-
591	Irmgard	12 12.4	14.7	+41	7.35	0.23-0.26	3
2380	Heilongjiang*	12 12.5	14.7	+26	11.237	0.22	3
101	Helena	12 13.2	12.0	+39	23.08	0.09-0.13	3
482	Petrina	12 13.4	13.8	+3	11.7922	0.07-0.56	3
743	Eugenisis	12 13.6	13.6	+19	10.23	0.10-0.20	3
598	Octavia*	12 14.3	12.1	+20	10.8903	0.28-0.35	3
219	Thusnelda	12 15.1	12.4	+7	29.842	0.19-0.20	3
872	Holda	12 16.0	13.9	+13	5.945	0.20-0.47	3
3965	Konopleva*	12 16.7	14.6	+31			
81	Terpsichore	12 17.8	11.4	+37	10.943	0.06-0.10	3
6050	Miwablock*	12 17.9	14.8	+23	5.7566	0.28	3
207	Hedda	12 18.3	12.7	+29	30.098	0.09-0.11	3
627	Charis	12 18.5	14.2	+15	27.888	0.35	3
2648	Owa*	12 18.5	14.2	+26	3.5641	0.20-0.35	3
2653	Principia	12 18.8	15.0	+16	5.5228	0.34-0.50	3
726	Joella	12 19.1	13.7	+12	13.04	0.12	3
2417	McVittie*	12 19.9	14.9	+24	4.934	0.42	3
1330	Spiridonia	12 20.6	14.7	+1	9.67	0.08-0.16	3
1929	Kollaa*	12 20.9	15.0	+29	2.9887	0.20-0.22	3
718	Erida	12 21.4	14.3	+31	17.447	0.31-0.37	3
3906	Chao	12 21.5	15.0	-10	11.892	0.13	3
633	Zelima	12 21.9	14.2	+10	11.724	0.14-0.53	3-
541	Deborah	12 22.3	14.0	+23	29.368	0.04-0.10	3
2647	Sova*	12 22.8	14.2	+26	9.366	0.23-0.35	3
2350	von Lude*	12 23.2	14.8	+16			
1590	Tsiolkovskaja	12 24.7	15.0	+18	6.731	0.10-0.4	3
513	Centesima	12 26.0	13.8	+9	5.23	0.18-0.45	3
5670	Rosstaylor*	12 26.3	15.0	+21			
1080	Orchis	12 26.6	13.7	+33	16.1	0.23-0.24	3
124	Alkeste	12 27.0	11.9	+19	9.921	0.08-0.15	3
940	Kordula	12 27.5	14.4	+27	15.57	0.36	3
686	Gersuind	12 27.7	13.8	+10	6.3127	0.30-0.37	3
2962	Otto	12 27.7	14.6	+40	2.678	0.14-0.15	3-
2293	Guernica	12 28.7	14.9	+24	6.414	0.48	3
709	Fringilla	12 28.9	13.5	+41	52.4	0.18	3-
6111	Davemckay*	12 28.9	15.0	+23			
7783	1994 JD*	12 29.7	15.0	+25	31.83	0.85	3
839	Valborg	12 30.3	14.7	+39	10.366	0.14-0.19	3

Radar-Optical Opportunities

There are several resources to help plan observations in support of radar.

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

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

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

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

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

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

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

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. Note that *geocentric* positions are given. Use these web sites to generate updated and *topocentric* positions:

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

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

(276049) 2002 CE26 (Aug-Oct, H = 18.4, Binary or Trinary)
Shepard *et al.* (2004, *IAUC* **8397**) using radar observations first reported this NEA as being a binary. Using photometry observations, Pravec *et al.* (2006, *Icarus* **181**, 63-93) reported a rotation period for the primary of 3.2930 h. The orbital period of the satellite was found to be 15.6 hours. The phase angle bisector longitude will be similar during this apparition as it was during the time of the Pravec *et al.* observations. This makes it likely that

mutual events (occultations or eclipses involving the satellite) will be seen. Given that possibility, high-precision observations, on the order of 0.01-0.02 mag, and – preferably – well-calibrated to at least an internal system will be required.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	12 18.9	-85 05	0.35	1.01	17.3	78.1	82	71	+0.41	-22
10/03	11 34.2	-83 56	0.37	1.01	17.4	78.3	80	77	+0.64	-21
10/05	11 07.6	-82 48	0.40	1.00	17.5	78.2	79	87	+0.84	-21
10/07	10 50.5	-81 45	0.42	1.00	17.7	77.9	78	98	+0.97	-20
10/09	10 38.6	-80 47	0.45	0.99	17.8	77.6	76	105	-1.00	-19
10/11	10 29.9	-79 54	0.47	0.99	17.9	77.1	75	108	-0.92	-19
10/13	10 23.4	-79 06	0.50	0.99	17.9	76.5	74	106	-0.76	-18
10/15	10 18.3	-78 22	0.52	0.99	18.0	75.9	74	100	-0.58	-18

2340 Hathor (Oct-Nov, H = 20.0, PHA)
The LCDB has no listing for a period for this NEA. Given that it is listed as a potentially hazardous asteroid, characterization work such as rotation period and refinement of the H-G values would be highly beneficial.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/20	07 01.0	+27 41	0.05	1.01	16.1	74.4	103	59	-0.14	+14
10/25	04 15.2	+18 17	0.05	1.04	15.1	32.4	146	159	+0.01	-23
10/30	02 40.0	+07 43	0.07	1.07	15.1	7.8	172	109	+0.38	-46
11/04	01 55.1	+02 03	0.10	1.09	16.1	14.9	164	27	+0.89	-57
11/09	01 32.0	-00 51	0.14	1.12	17.1	23.8	153	51	-0.95	-62
11/14	01 19.1	-02 21	0.18	1.14	17.8	30.1	145	116	-0.56	-64
11/19	01 12.0	-03 06	0.21	1.16	18.4	34.8	138	170	-0.13	-65
11/24	01 08.5	-03 22	0.25	1.17	18.9	38.5	132	114	+0.03	-66

(68267) 2001 EA16 (Nov-Dec, H = 16.8)
There are no known lightcurve parameters for 2001 EA16. The estimated size is 1.3 km, meaning that it is unlikely to have a rotation period shorter than about 2.2 hours. Keep in mind that observations at very high phase angles may produce lightcurves that include deep shadowing effects. For example, even a nearly spheroidal body can have a large amplitude lightcurve due to a large concavity. If observations are obtained over a large range of phase angles, it may be necessary to divide the entire data set into subsets where the amplitude and shape are similar within each subset.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/15	18 13.3	+31 29	0.14	0.98	15.8	91.0	81	130	-0.58	+21
10/25	19 23.0	+45 27	0.26	1.04	16.5	72.6	93	85	+0.01	+14
11/04	20 00.2	+49 50	0.39	1.10	17.2	63.4	96	70	+0.89	+10
11/14	20 27.7	+51 57	0.51	1.17	17.7	57.2	97	116	-0.56	+8
11/24	20 52.9	+53 22	0.63	1.23	18.2	52.6	97	85	+0.03	+6
12/04	21 18.5	+54 32	0.74	1.30	18.5	48.8	97	73	+0.93	+4
12/14	21 45.7	+55 39	0.84	1.36	18.8	45.8	96	119	-0.55	+2
12/24	22 15.2	+56 46	0.95	1.43	19.1	43.3	95	78	+0.05	+0

2005 YQ96 (Dec, H = 20.4, PHA)
The estimated size of YQ96 is about 250 meters. There are no lightcurve parameters listed in the LCDB.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/21	13 33.0	+39 59	0.10	0.99	18.3	86.4	88	75	-0.02	+75
12/22	13 37.0	+38 59	0.09	0.98	18.2	87.3	87	84	+0.00	+75
12/23	13 41.4	+37 49	0.08	0.98	18.1	88.3	87	92	+0.01	+75
12/24	13 46.4	+36 26	0.08	0.98	17.9	89.5	86	101	+0.05	+75
12/25	13 52.2	+34 46	0.07	0.98	17.8	91.1	85	110	+0.12	+75
12/26	13 58.8	+32 43	0.06	0.98	17.7	93.0	83	119	+0.20	+74
12/27	14 06.6	+30 10	0.06	0.98	17.5	95.4	81	127	+0.31	+73
12/28	14 15.9	+26 57	0.05	0.97	17.4	98.5	79	135	+0.42	+71

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The deadline for the next issue (42-1) is October 15, 2014. The deadline for issue 42-2 is January 15, 2015.