THE MINOR PLANET BULLETIN

BULLETIN OF THE MINOR PLANETS SECTION OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

VOLUME 43, NUMBER 4, A.D. 2016 OCTOBER-DECEMBER

LIGHTCURVES FOR TWO NEAR-EARTH-ASTEROIDS BY ASTEROIDS OBSERVERS (OBAS) – MPPD: 2016 APRIL - MAY

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(Received: 2016 Jun 14)

We report on the results of photometric analysis of two near-Earth asteroids (NEA) by Asteroids Observers (OBAS). This work is part of the Minor Planet Photometric Database (MPPD) project initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

In this paper we publish the results of lightcurve analysis for two near-Earth asteroids observed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). The data and results were made possible thanks to the collaboration of the Astronomical Center Alto Turia (CAAT) Observatory located in Aras de los Olmos and operated by members of the Valencia Astronomy Association (AVA) (*http://www.astroava.org*).

Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 NW	Atik 414L+

Table I. List of instruments used for the observations. SCT is Schmidt-Cassegrain. R-C is Ritchey-Chrétien. DK is Dall-Kirkham. NW is Newton.

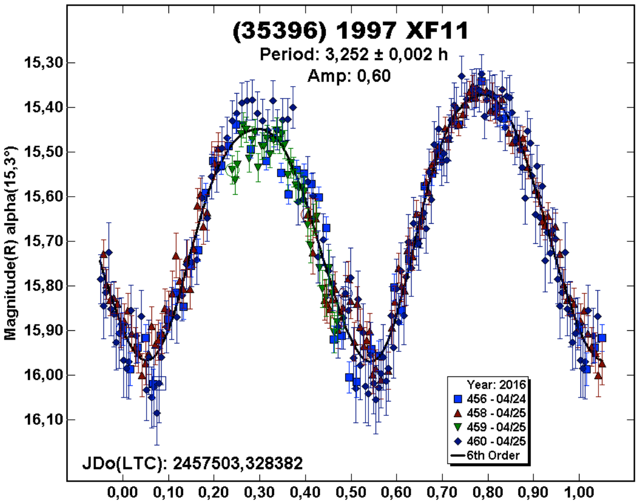
Table I shows the equipment at the observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website at (*http://www.minorplanet.info/call.html)* and Minor Planet Center (*http://www.minorplanet.net*)

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique.

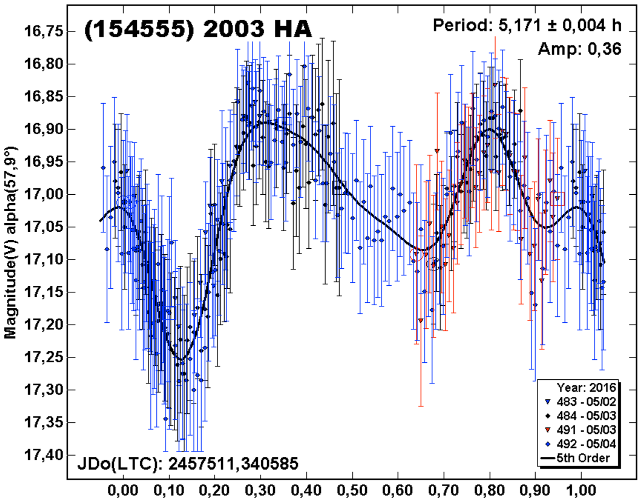
(35396) 1997 XF11 was discovered in 1997 December (Sugie *et al*., 1997) and remained fainter than V ~ 18 until its predicted brightening to V = 13.4 in mid-2002. It won't reach this brightness again until 2028.

In 1998 March, then-unnumbered 1997 XF11 made headlines in the popular media after some interpretations of preliminary calculations of its orbit suggested that it could collide with Earth in 2028. Disagreement among researchers about how close it was likely to pass to Earth and how to characterize the uncertainties involved Marsden (1999), Chodas and Yeomans (1999), Milani and Valsecchi (1999) Yeomans *et al*. (1998), Helin *et al*. (1998), and Scotti and Shelus (1998) and how best to communicate such information to the media. This led to confusion and sensationalism. The incident raised important issues about impact risk assessment and how best to balance the interests of scientific research with those of the public's right to know.

The OBAS group obtained images of (35396) 1997 XF11 on three nights 2016 April, when the sky motion was 3 arcsec/min and so exposures were no more than 60 seconds. Three OBAS group observatories worked together to obtain these results, especially the team of the Astronomical Center Alto Turia (CAAT). From our data, we derived a rotation period of 3.252 ± 0.002 h and amplitude of 0.60 mag.



(154555) 2003 HA was discovered in 2003 April by LINEAR. The OBAS group obtained images on three nights in 2016 May. At the time, the asteroid's sky motion was 4 arcsec/min, which limited exposures to 60 seconds or less. From our data we derive a rotation period of 5.171 ± 0.004 hours and amplitude of 0.36 magnitudes. Three OBAS group observatories worked together to obtain these results, especially the team of the Astronomical Center Alto Turia (CAAT).



Acknowledgements

We would like to express our gratitude to Brian Warner for supporting the CALL web site and his suggestions made to the OBAS group.

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THE ROTATION PERIOD OF ASTEROIDS 4931 TOMSK AND 5232 JORDAENS

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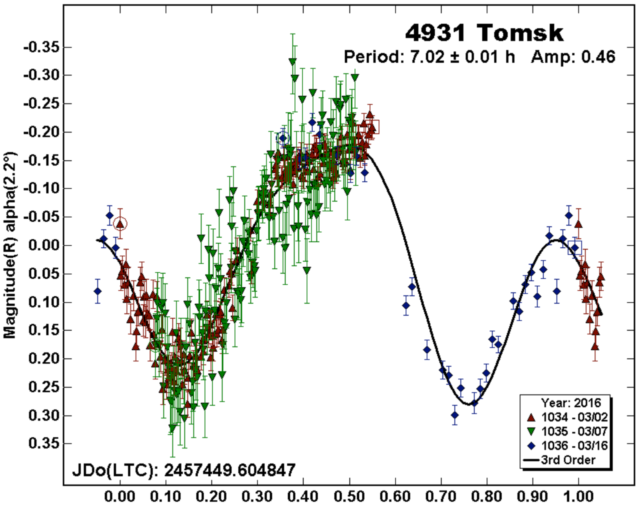
(Received: 2016 Jun 25)

CCD observations of two main-belt asteroids were made in 2016 March and May. Analysis of the data for 4931 Tomsk indicates a synodic period of $P = 7.02 \pm 0.01$ h, $A = 0.46 \pm 0.10$ mag. For 5232 Jordaens, the analysis indicates a synodic period of $P = 10.58 \pm 0.01$ h, $A = 0.73 \pm 0.15$ mag.

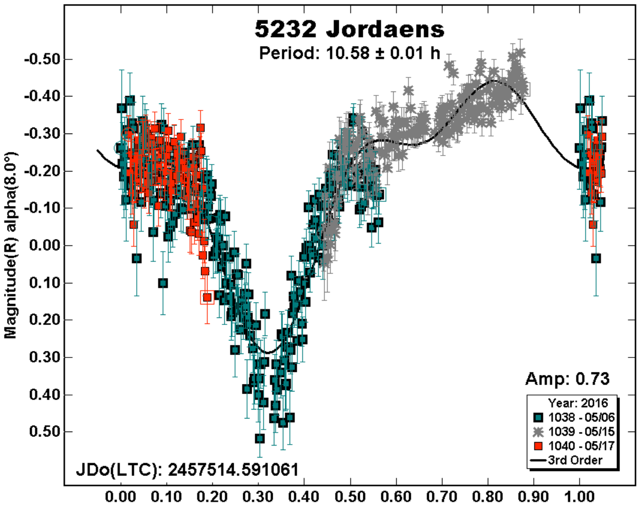
CCD photometry observations of the main-belt asteroids 4931 Tomsk and 5232 Jordaens were made in 2016. At the Shed of Science Observatory, a 0.35-m Schmidt Cassegrain (SCT) working at *f*/8.5 and SBIG ST-10XE CCD camera were used. The resulting plate scale was 0.94 acrsec/pixel. Exposures were made through a Celestron UHC LPR filter. The R-COP telescope at Perth Observatory used a 0.35-m Schmidt Cassegrain (SCT) working at *f*/6.0 and SBIG ST-10XME camera. The plate scale was 0.67 arcsec/pixel. The exposures were unfiltered.

All images were dark and flat-field corrected. Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. The *MPO Canopus* Comp Star Selector was used to link sessions. The data were light-time corrected. Period analysis was also done with *MPO Canopus*, incorporating the Fourier analysis algorithm developed by Harris (Harris *et al*., 1989).

4931 Tomsk was observed over two nights in 2016 March from the Shed of Science Observatory. The third night used the R-COP telescope at the Bickley Observatory in Perth, Australia, through the Skynet observatory network. Conditions did not allow more than three nights of observations. As a result, there are possible solutions other than the period given here. Additional observations of this object are required to refine the period.



5232 Jordaens was observed over three nights in 2016 May from the Shed of Science Observatory. Conditions were not suitable for more than three nights of observations before the object became too dim. Additional observations of this object are needed to refine the period.



Acknowledgements

Partial funding for work at the Shed of Science Observatory is provided by 2009 and 2010 Shoemaker NEO Grants from the Planetary Society. Access to the R-COP telescope at the Perth Observatory was made possible thanks to R. Groom and K. Stranger and the Skynet Jr. Scholars Program at the University of Chicago.

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LIGHTCURVE ANALYSIS OF NEA (331471) 1984 QY1: A TUMBLING ASTEROID

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Analysis of CCD photometric observations of the near-Earth asteroid (331471) 1984 QY1 show that it is likely in non-principal axis rotation (NPAR), or tumbling. A single period analysis found a dominant period of 45.5 ± 0.5 h, but the true periods of rotation and precession could not be determined.

CCD photometric observations were made of the near-Earth asteroid (331471) 1984 QY1 from 2016 June 6-20. Table I lists the equipment and dates of observation for each observer.

Obs	Telescope	2016 June
Warner	0.35-m	6-10,12,14,15-17,20
Benishek	0.35-m	8,9,14,17

Table I. List of telescopes used and dates of observations for each observer.

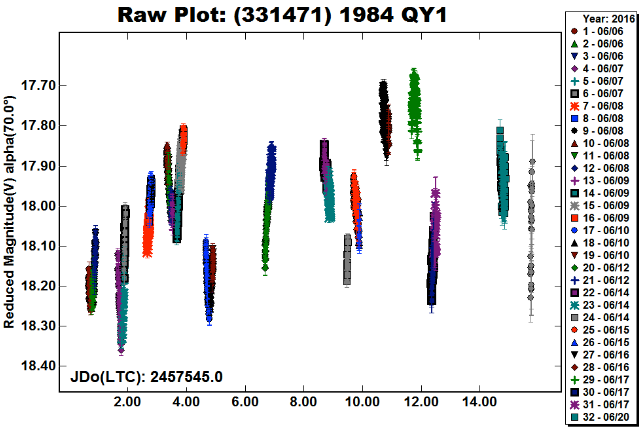
In all, more than 2000 observations were made using a clear or no filter to obtain maximum SNR. Exposures ranged from 60 to 90 seconds, while the asteroid faded from V ~ 15.5 to 16.3. Longer exposures were not possible because of the asteroid's sky motion, which started at about 9 arcsec/min and decreased to 4 arcsec/min.

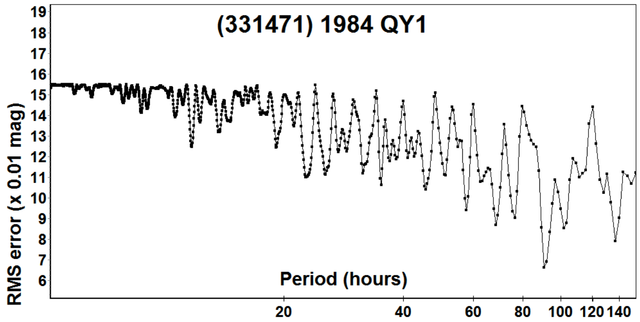
Each observer used *MPO Canopus* to process the raw images with dark and flat field frames and then to perform differential photometry. Because of slight trailing, elliptical apertures were used for the asteroid, the major axis being kept parallel to the asteroid's motion.

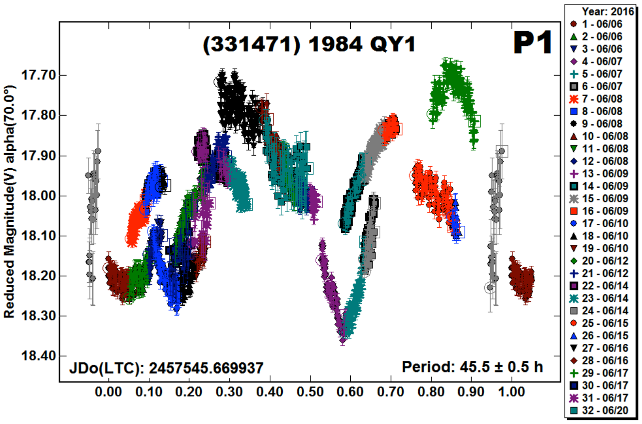
Up to five solar colored comparison stars were used each night to help minimize errors due to color differences between the asteroid and comparison stars. V magnitudes from the MPOSC3 catalog supplied with *MPO Canopus* were used for the comparison stars. This catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) but with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag.

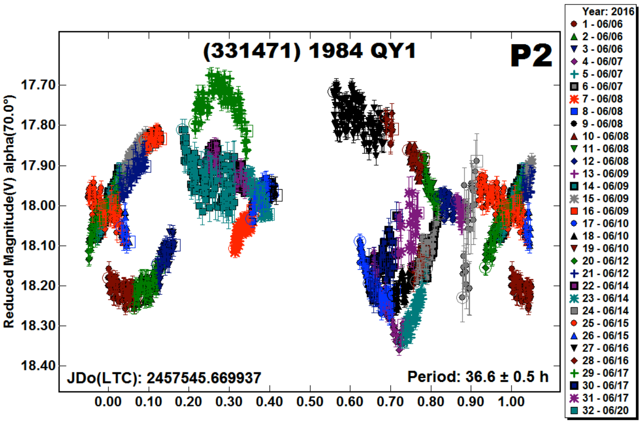
Period analysis was done by Warner using *MPO Canopus*, which incorporates the FALC Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989). However, this found only a dominant period based on a single period analysis. This was clearly not sufficient since the raw and phased plots showed that the asteroid was mostly likely a tumbler, *i.e.*, in non-principal axis rotation (NPAR; see Pravec *et al.*, 2005, 2014).

While the period spectrum showed that a period of about 90 hours was most favored, a plot showed a four-peaked "jumble" of data that was a result of a *fit by exclusion*. This is where the Fourier analysis minimizes the number of overlapping data points while finding a minimum RMS fit. This often leaves large gaps in the lightcurve or multimodal solutions that are physically improbable.









The full data set was sent to Petr Pravec at the Astronomical Institute in Prague, who has developed an analysis program that capable of the simultaneous two-period analysis required to interpret the lightcurves of tumblers. His analysis found a best candidate for the main period of P_1 = 45.2 h, very close to the result using *MPO Canopus*. A candidate for P_2 is 36.6 h, but it is not unique. The lightcurves have been forced to the P_1 found by *MPO Canopus* and Pravec's P_2.

Additional problems included the high phase angle, where shadowing effects can cause significant changes in a lightcurve's amplitude and/or shape, the complications of tumbling notwithstanding. Long period tumblers are among the least understood of all asteroids. From the above, it's easy to understand why.

Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. (*http://svo2.cab.inta-csic.es/vocats/cmc15/).*

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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LIGHTCURVE ANALYSIS OF ASTEROIDS OBSERVED AT THE OAKLEY SOUTHERN SKY OBSERVATORY: 2015 DECEMBER – 2016 APRIL

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(Received: 2016 May 31)

From 2015 December 12 to 2016 April 16, CCD images were taken with the goal of analyzing the photometric data on twenty-five asteroids: 507 Laodica, 1311 Knopfia, 1363 Herberta, 1454 Kalevala, 1480 Aunus, 1597 Laugier, 1714 Sy, 1791 Patsayev, 1911 Schubart, 2087 Kochera, 2179 Platzeck, 2660 Wasserman, 2828 Iku-Turso, 2854 Rawson, 3228 Pire, 3606 Pohjola, 3669 Vertinskij, 3812 Lidaksum, 3829 Gunma, 3840 Mimistrobell, 4640 Hara, 7016 Conandoyle, 8045 Kamiyama, (12551) 1998 QQ39, and (13388) 1999 AE6.

Lightcurve analysis was performed using images taken at the Oakley Southern Sky Observatory in New South Wales, Australia. The images were taken on the nights of 2015 December 12-19, 2016 February 05, 08-17, and 28-29, 2016 March 01-04 and 27-31, 2016 April 01-05, 06-07, and 09-16.

The telescope used to obtain the images was a 0.5-meter *f*/6.71 Planewave with a STX-16803 CCD camera, binned 3x3, using a luminance filter. The telescope operated at a plate scale of 1.63 arcseconds per pixel. The images were calibrated using *Maxim DL* software. *MPO Canopus* was used to measure the images, do Fourier analysis, and produce the lightcurves.

Table I lists the asteroids that were observed as well as the results of analysis, the number of data points in the analysis, and the exposure for each asteroid. If no result is given, the period could not be determined due to excessive noise or an insufficient data set.

Our period of 4.706 ± 0.001 h for 507 Laodica differs from the previously reported 6.737 ± 0.001 h (Warner, 2011). When the previous period was used with the recent data, there was no recognizable pattern. Our period of 19.296 ± 0.021 h for 1311 Knopfia differs from the previously published period of 9.65 ± 0.09 h (Clark, 2010). When we tried to fit our data to 9.65 h, there was no recognizable pattern. It is important to note that the period found here is double the previously reported value. There were no entries in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) for the remaining asteroids reported here.

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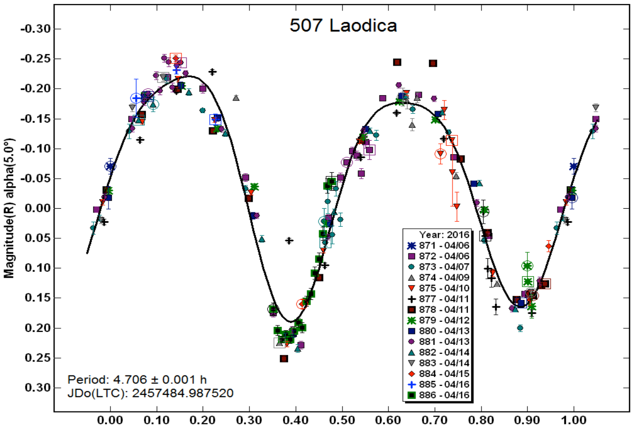
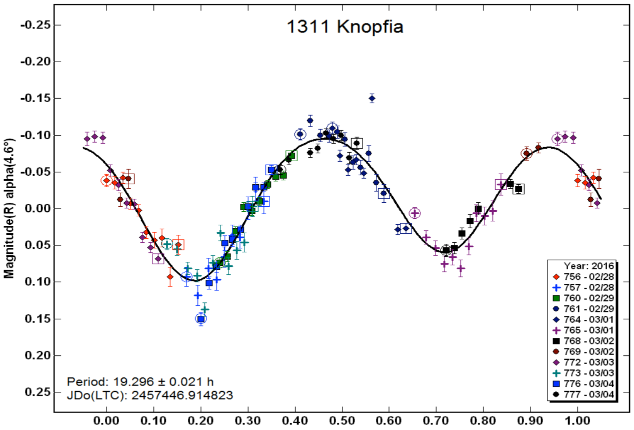
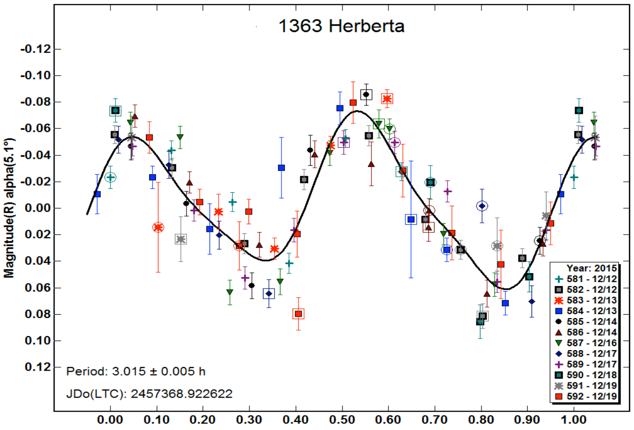
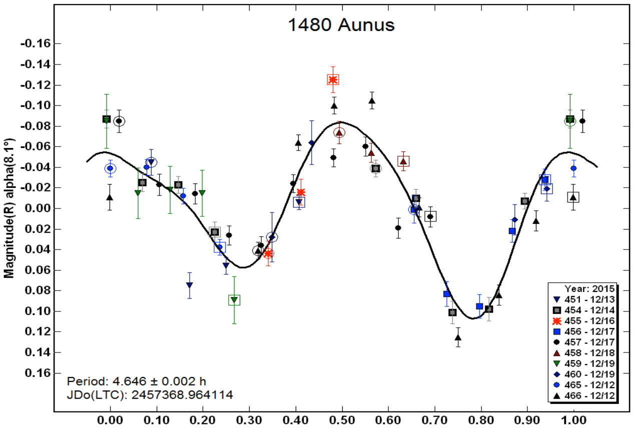


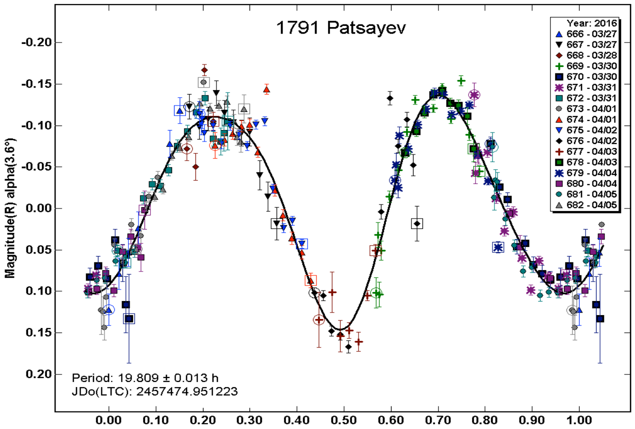


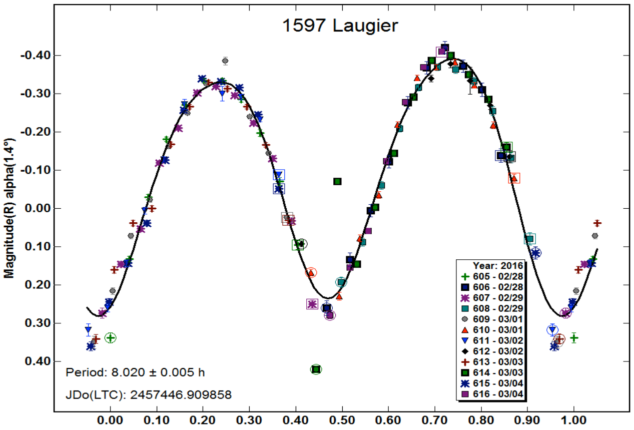


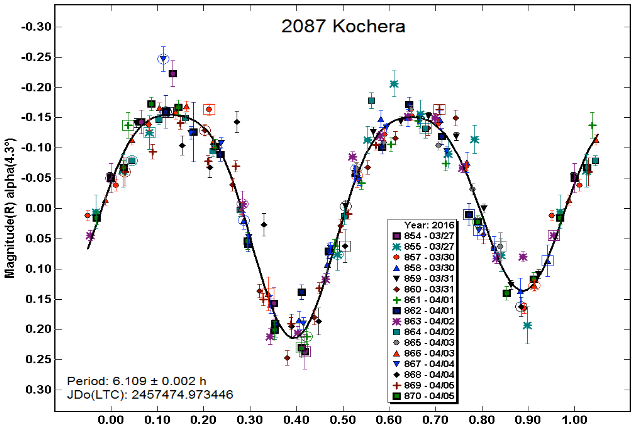
Number	Name	Dates (2016/MM/DD)	Period (h)	P.E. (h)	Amp (mag)	A. E. (mag)	Data Points	Exp (sec)
507	Laodica	04/6-7, 04/9-16	4.706	0.001	0.41	0.04	184	75
1311	Knopfia	02/28-29, 03/01-04	19.296	0.021	0.19	0.04	112	180
1363	Herberta	2015/12/12-19	3.015	0.005	0.12	0.02	86	210
1454	Kalevala	02/28-29, 03/01-04	-	-	0.37	0.02	96	120
1480	Aunus	2015/12/12-19	4.646	0.002	0.19	0.02	56	180
1597	Laugier	02/28-29, 03/01-04	8.020	0.005	0.68	0.04	124	180
1714	Sy	02/28-29, 03/01-04	-	-	0.03	0.03	143	180
1791	Patsayev	03/27-31, 04/1-5	19.809	0.013	0.28	0.03	202	150
1911	Schubart	04/6-7, 04/9-16	-	-	0.44	0.03	149	210
2087	Kochera	03/27-31, 04/1-5	6.109	0.002	0.37	0.04	165	210
2179	Platzeck	03/27-31, 04/1-5	5.995	0.002	0.24	0.04	137	180
2660	Wasserman	04/6-7, 04/9-16	-	-	0.08	0.08	109	210
2828	Iku-Turso	03/27-31, 04/1-5	-	-	0.60	0.02	159	210
2854	Rawson	02/05, 02/08-17	4.7755	0.0003	0.63	0.04	130	150
3228	Pire	02/05, 02/08-17	11.538	0.002	0.50	0.04	128	180
3606	Pohjola	2015/12/12-19	-	-	0.12	0.15	96	150
3669	Vertinskij	2015/12/12-19	-	-	0.86	0.04	93	210
3812	Lidaksum	02/05, 02/08-17	8.014	0.002	0.23	0.03	104	180
3829	Gunma	02/28-29, 03/01-04	4.720	0.002	0.22	0.05	142	120
3840	Mimistrobell	03/27-31, 04/1-5	-	-	0.05	0.03	141	150
4640	Hara	04/6-7, 04/9-16	3.534	0.002	0.18	0.05	128	210
7016	Conandoyle	02/05, 02/08-17	6.5427	0.0006	0.82	0.03	197	210
8045	Kamiyama	02/05, 02/08-17	-	-	0.07	0.02	147	180
12551	1998 QQ39	04/6-7, 04/9-16	11.202	0.002	0.95	0.05	139	210
13388	1999 AE6	2015/12/12-19	-	-	0.15	0.05	118	180

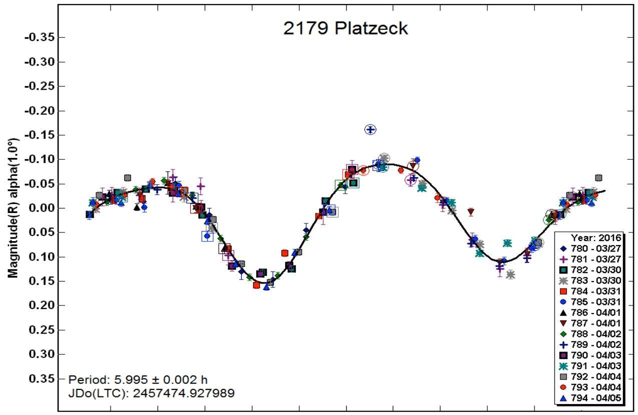
Table I. Observing dates and results for 25 asteroids.

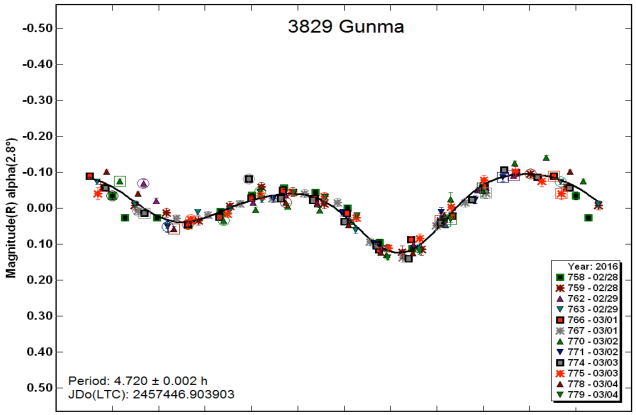


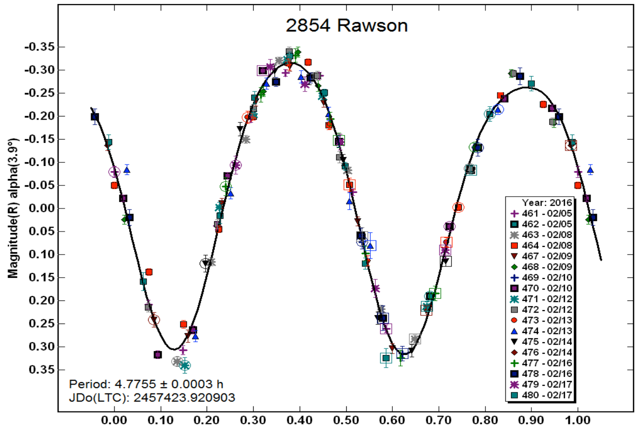


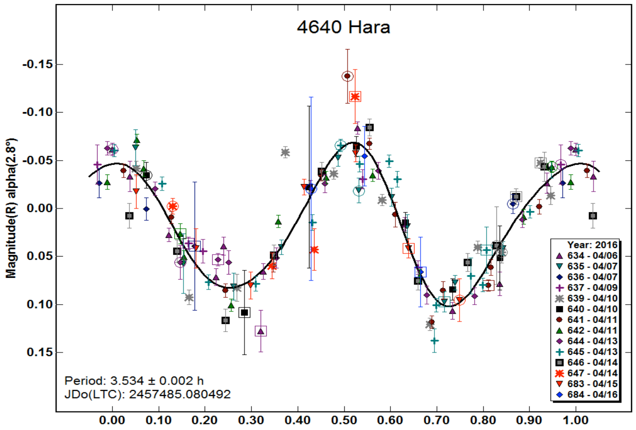


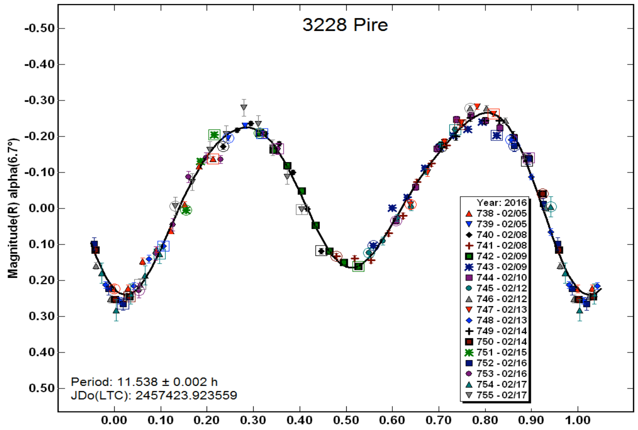


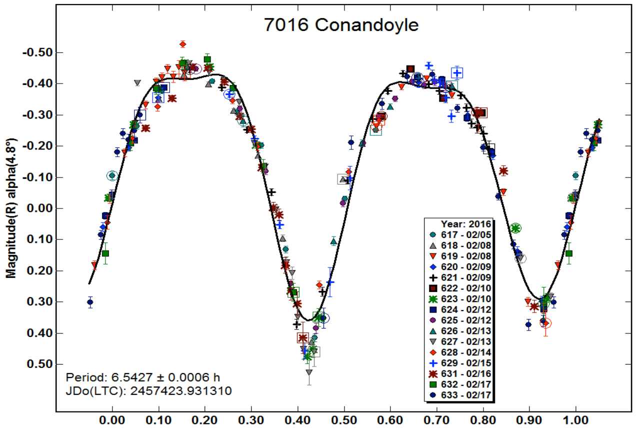

2179 Platzeck
Magnitude(R) alpha(1.0°)
-0.35 -0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
Year: 2016
780 - 03/27
781 - 03/27
782 - 03/30
783 - 03/30
784 - 03/31
785 - 03/31
786 - 04/01
787 - 04/01
788 - 04/02
789 - 04/02
790 - 04/03
791 - 04/03
792 - 04/04
793 - 04/04
794 - 04/05
Period: 5.995 ± 0.002 h
JDo(LTC): 2457474.927989
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

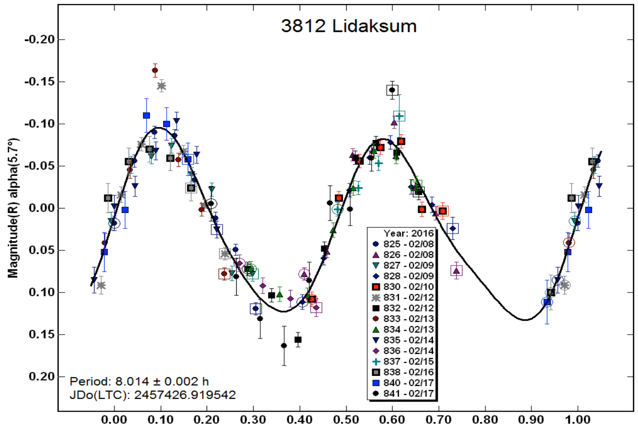

3829 Gunma
Magnitude(R) alpha(2.8°)
-0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50
Year: 2016
758 - 02/28
759 - 02/28
762 - 02/29
763 - 02/29
766 - 03/01
767 - 03/01
770 - 03/02
771 - 03/02
774 - 03/03
775 - 03/03
778 - 03/04
779 - 03/04
Period: 4.720 ± 0.002 h
JDo(LTC): 2457446.903903
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

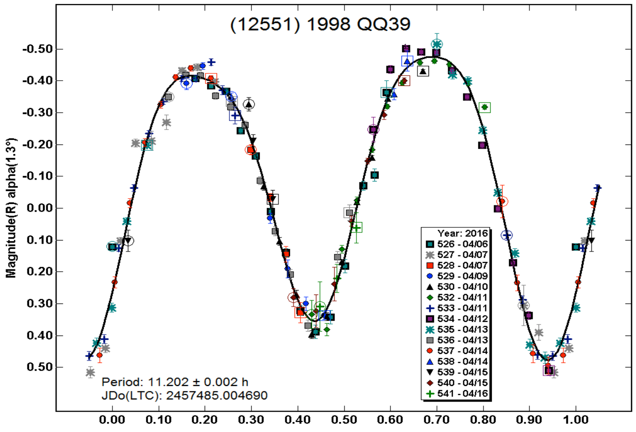

2854 Rawson
Magnitude(R) alpha(3.9°)
-0.35 -0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
Year: 2016
461 - 02/05
462 - 02/05
463 - 02/08
464 - 02/08
467 - 02/09
468 - 02/09
469 - 02/10
470 - 02/10
471 - 02/12
472 - 02/12
473 - 02/13
474 - 02/13
475 - 02/14
476 - 02/14
477 - 02/16
478 - 02/16
479 - 02/17
480 - 02/17
Period: 4.7755 ± 0.0003 h
JDo(LTC): 2457423.920903
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


4640 Hara
Magnitude(R) alpha(2.8°)
-0.15 -0.10 -0.05 0.00 0.05 0.10 0.15
Year: 2016
634 - 04/06
635 - 04/07
636 - 04/07
637 - 04/09
639 - 04/10
640 - 04/10
641 - 04/11
642 - 04/11
644 - 04/13
645 - 04/13
646 - 04/14
647 - 04/14
683 - 04/15
684 - 04/16
Period: 3.534 ± 0.002 h
JDo(LTC): 2457485.080492
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


3228 Pire
Magnitude(R) alpha(6.7°)
-0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50
Year: 2016
738 - 02/05
739 - 02/05
740 - 02/08
741 - 02/08
742 - 02/09
743 - 02/09
744 - 02/10
745 - 02/12
746 - 02/12
747 - 02/13
748 - 02/13
749 - 02/14
750 - 02/14
751 - 02/15
752 - 02/16
753 - 02/16
754 - 02/17
755 - 02/17
Period: 11.538 ± 0.002 h
JDo(LTC): 2457423.923559
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


7016 Conandoyle
Magnitude(R) alpha(4.8°)
-0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50
Year: 2016
617 - 02/05
618 - 02/08
619 - 02/08
620 - 02/09
621 - 02/09
622 - 02/10
623 - 02/10
624 - 02/12
625 - 02/12
626 - 02/13
627 - 02/13
628 - 02/14
629 - 02/15
631 - 02/16
632 - 02/17
633 - 02/17
Period: 6.5427 ± 0.0006 h
JDo(LTC): 2457423.931310
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


3812 Lidaksum
Magnitude(R) alpha(5.7°)
-0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20
Year: 2016
825 - 02/08
826 - 02/08
827 - 02/09
828 - 02/09
830 - 02/10
831 - 02/12
832 - 02/12
833 - 02/13
834 - 02/13
835 - 02/14
836 - 02/14
837 - 02/15
838 - 02/16
840 - 02/17
841 - 02/17
Period: 8.014 ± 0.002 h
JDo(LTC): 2457426.919542
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


(12551) 1998 QQ39
Magnitude(R) alpha(1.3°)
-0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 0.30 0.40 0.50
Year: 2016
526 - 04/06
527 - 04/07
528 - 04/07
529 - 04/09
530 - 04/10
532 - 04/11
533 - 04/11
534 - 04/12
535 - 04/13
536 - 04/13
537 - 04/14
538 - 04/14
539 - 04/15
540 - 04/15
541 - 04/16
Period: 11.202 ± 0.002 h
JDo(LTC): 2457485.004690
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

THE B-V AND V-R COLOR INDICES ON THE SURFACE OF NEA (214088) 2004 JN13

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(Received: 1 July 2016 Revised: 2016 August 16)

This paper presents the results of photometric observations with standard broad-band Bessel filters B, V, and R on near-Earth asteroid (214088) 2004 JN13. The analysis shows that the B-V and V-R color indices are fairly constant on the asteroid surface with mean values B-V = 0.83 ± 0.02 mag and V-R = 0.48 ± 0.03 mag, indicative of a relatively homogeneous surface color distribution. For a typical albedo, assuming these colors indicate an S-type asteroid, a mean diameter of 2.4 ± 0.5 km is inferred.

The asteroid (214088) 2004 JN13 was discovered by LINEAR at Socorro on 2004 May 15 and came close to the Earth (about 0.137 AU) on 2014 Nov. 18. Based on the orbital parameters of a = 2.8774 AU, e = 0.69728, and q = 0.871047 AU (JPL, 2016), it appears that 2004 JN13 belongs to the Apollo class of near-Earth asteroids (NEA). Its rotation period is about 6.342 hours (Warner *et al.*, 2009). This object was observed from OAVdA after the Earth flyby to find the B-V and V-R color indices as a function of rotation phase to see if there were any color variations on the asteroid's surface that may indicate possible compositional inhomogeneity or differential space weathering process, as for NEA (297274) 1996 SK (Lin *et al.*, 2014).

In this paper, I will first discuss the instruments and tools used for the observations and the data reduction. Then a comparison will be made between the magnitudes reported in Landolt's reference catalog and those of APASS catalog for the same stars. This will show that the magnitudes of APASS catalog have an acceptable uncertainty compared to standard stars and that an atmospheric-instrumental model capable of transforming instrumental magnitude in standard magnitudes can be used to find the asteroid's true magnitude. Finally, I will look at the color indices of the asteroid and results that may be inferred.

Instruments, Observations and Reduction Procedure

The asteroid (214088) 2004 JN13 was observed from OAVdA on 2014 Dec 16-17 from 19:00 UT to 02:30 UT, when it was moving away from the Earth but still bright, V ~ 13.9. The sky was clear and there were no passing clouds, so the transparency conditions were reasonably stable (see Fig. 1 and Fig. 2). The air mass values changed from 1.79 at the beginning of the observations, reached a minimum of 1.15, and increased to 1.64 at the end of observations. The images were captured with a modified 0.81-m *f*/7.9 Ritchey-Chrétien telescope and FLI-1001E CCD camera with an array of 1024×1024 pixels. The field-of-view was 13.1×13.1 arcmin while the plate scale was 1.54 arcsec/pixel in 2×2 binning mode.

Observations were performed alternately using broad-band Bessel B, V, and R filters with exposure times of 60 s for the B filter and 30 s for the others. The SNR of the target was greater than 100, which was ideal to obtain the color indices. The long observation run of 7.5 hours was divided into two sessions due to the proper motion of the asteroid, which was about 2.14 arcsec/min. This meant that different comparison stars were used for the first (18:55 to 23:45 UT) and second (23:50 to 02:30 UT) sessions (see Fig. 10). All images were calibrated with master-dark/bias and master-flat frames.

Reduction of the data, which consisted of the instrumental magnitudes of the target and comparison stars vs. the Julian day and air mass, and lightcurve analysis were done using *MPO Canopus* v10.7.1.3 (Warner, 2009), which makes use of differential aperture photometry and the Fourier period analysis algorithm developed by Harris (Harris *et al.*, 1989). The rotation period was found to be in good agreement with the known value (see Fig. 3-5).

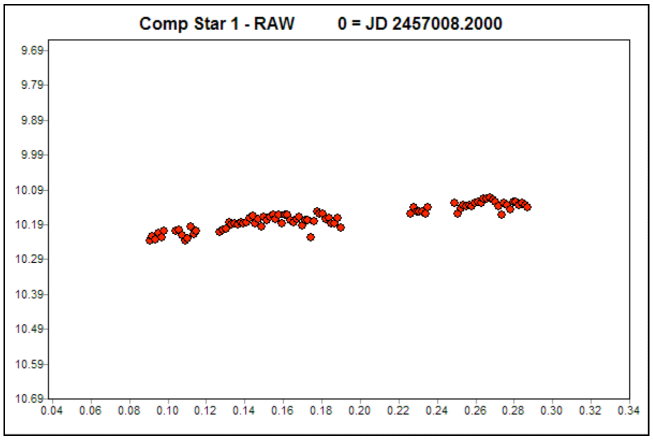

Figure 1. The raw magnitudes of the first comparison star for the first session shows no sudden or large attenuation indicating changing transparency. The gaps are when the asteroid was near background stars.

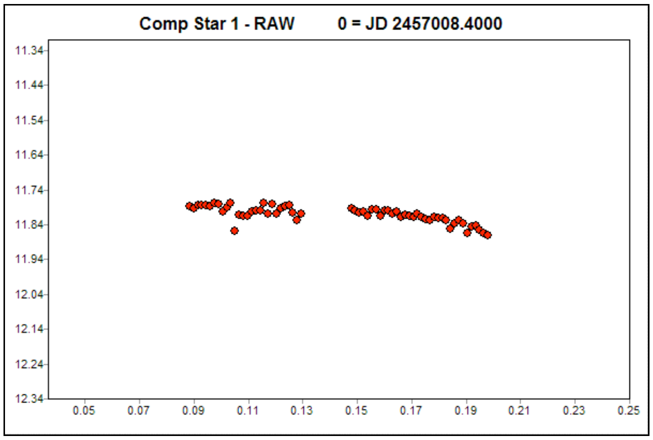

Figure 2. The raw magnitudes of the first comparison star for the second session also show no sudden attenuations. The gap is due to the asteroid being near a bright star.

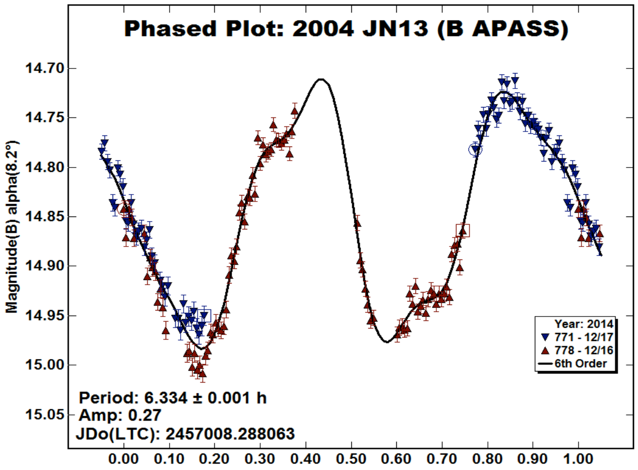

Figure 3. The phased lightcurve of 2004 JN13 taken with the B filter and reduced with B APASS magnitudes.

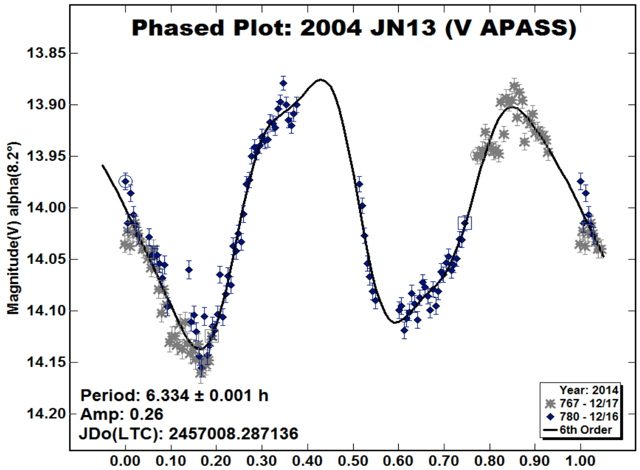

Figure 4. The phased lightcurve of 2004 JN13 taken with the V filter and reduced with V APASS magnitudes.

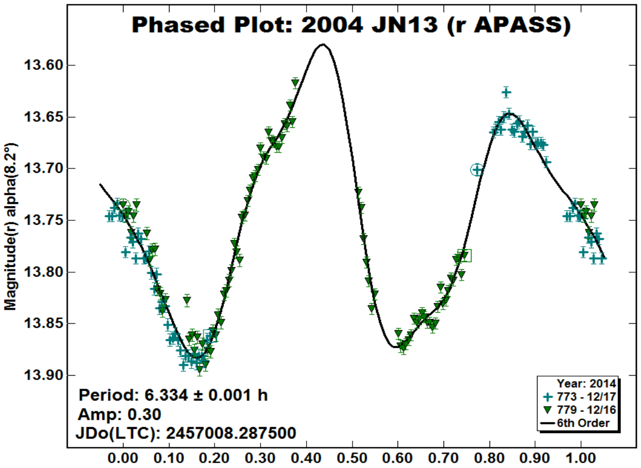

Figure 5. The phased lightcurve of 2004 JN13 taken with the R filter and reduced r' (SR) APASS magnitudes.

Landolt vs. APASS Star Catalog

In order to define the true magnitude of the asteroid in B, V, and R, comparison star magnitudes were taken from Release 9 of the AAVSO Photometric All-Sky Survey catalog (APASS; Henden *et al.*, 2009). This catalog contains photometry for 60 million objects over about 99% of the sky. The 5-band photometry is based on Johnson B and V and Sloan g' (SG), r' (SR), and i' (SI) filters. The catalog is a valid reference for stars over the range of V = 10-17 mag (Henden *et al.*, 2009). In this case however, stars with V > 15 were excluded because the photometric quality decreases significantly below this limit. The APASS catalog is not perfect, for example, Release 9 has known issues with blue magnitudes in the Northern Hemisphere and with red magnitudes in the Southern Hemisphere, and so it should be used with caution.

As seen in Fig. 6 and Fig. 7, for B and V between 11-15 mag, the RMS is about 0.04 mag when compared against Landolt's standard reference of 526 stars centered on the celestial equator (Landolt, 1992). So, for B and V

$$\begin{gathered} B_{Landolt} \equiv B_{APASS} \\ V_{Landolt} \equiv V_{APASS} \end{gathered} \tag{1}$$

Things are a bit different in the case of r´ (SR) filter. In this case, there is a systematic shift of about 0.21-0.22 mag (Fig. 8). The equation to transform the SR mag in APASS catalog to a Landolt R mag is

$$R = SR - 0.112 - 0.128 \cdot (B - V) \tag{2}$$

The RMS when using Eq. 2 is about 0.05 mag (Fig. 9).

In conclusion, if willing to accept a few hundredths of a mag decrease in accuracy and using Eq. 1 and 2, the stars from the APASS catalog in the same field as the asteroid can be used as references, provided that the night has constant atmospheric transparency conditions. Of course the APASS catalog is not a substitute of Landolt's fields in every situation; there may be cases in which a few hundredths of magnitude are important.

The Selection of Comparison Stars

The comparison stars were selected with the *MPO Canopus* Comp Star Selector (CSS) utility using the appropriate B, V, or SR magnitude from the APASS catalog. This way, it was possible to select five non-variable comparisons stars in the same field as the asteroid, each having an SNR > 100, for use in differential photometry (Fig. 10).

The comparison stars are not necessarily the same in all the filters used, although there is a common subset (see Table I). These are the stars that were used to calibrate the instrumental-atmospheric local model that will be described in the following section. This mathematical model is able to transform the instrumental mag of the target to exoatmospheric (true) B, V and SR magnitudes.

N	V	B	SR	RA	Dec	S
1	12.603	13.814	12.152	04:59:56.32	+16:46:17.3	1
2	13.144	14.480	12.633	05:00:02.57	+16:54:10.3	1
3	12.275	13.079	11.998	05:00:12.57	+17:07:26.4	2
4	12.930	13.752	12.640	04:59:29.97	+17:06:31.6	2
5	13.299	13.973	13.072	04:59:47.05	+17:07:40.0	2
6	14.507	15.282	14.246	05:00:04.60	+17:01:59.0	2

Table I. The subset of comparison stars common to all filters that were used for the calibration of the instrumental-atmospheric local model (J2000.0 coordinates). The mag values are from APASS catalog while column 'S' indicates the sessions number. These stars are identified by their number (N) in Fig. 10.

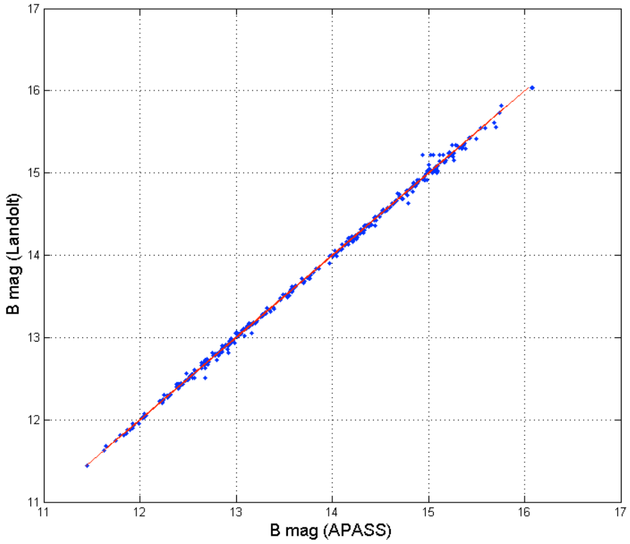

Figure 6. Landolt vs. APASS B magnitudes for the same stars. The red line is B_{Landolt} vs. B_{APASS}. The RMS is about 0.04 mag.

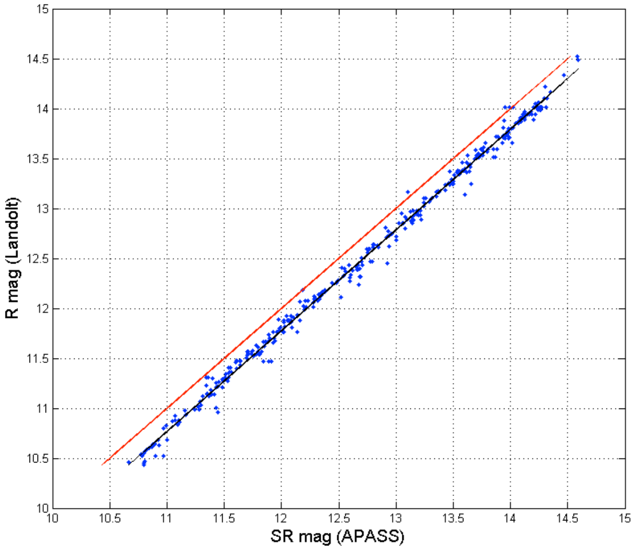

Figure 8. Landolt vs. APASS SR magnitudes for the same stars. The red line is R_{Landolt} vs. V_{APASS}. The RMS is about 0.04 mag. There is a systematic shift of about 0.21-0.22 mag. The RMS of the fitted black line is about 0.07 mag.

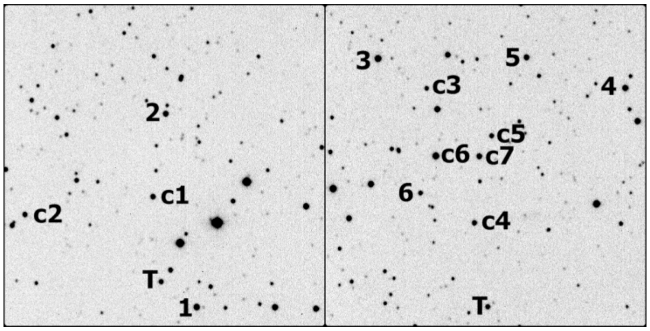

Figure 10. The fields for the first (left) and second (right) session showing the comparison stars in Table I along with 2004 JN13 (T) and the check stars (ci) listed in Table II. North is up, east is right.

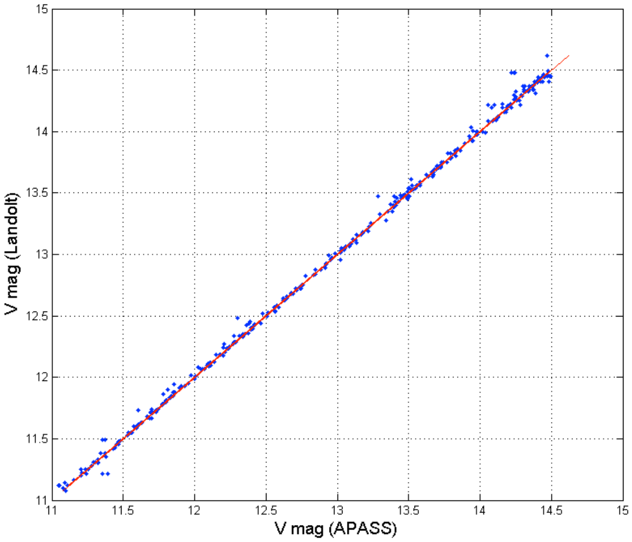

Figure 7. Landolt vs. APASS V magnitudes for the same stars. The red line is V_{Landolt} vs. V_{APASS}. The RMS is about 0.04 mag.

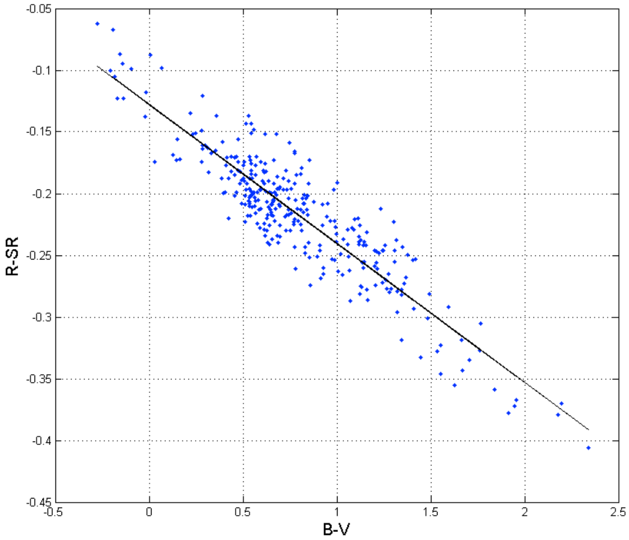

Figure 9. The R-SR mag vs. Landolt B-V. The RMS is about 0.05 mag.

The Instrumental-Atmospheric Local Model

In order to derive the true B, V, and R magnitude of the target, it is necessary to create a model that defines the zero point of the mag scale and corrects for atmospheric absorption and instrumental color shift compared to standard magnitudes. This model should be valid only for the stars of the two fields, so it will be "local." The adopted equations for the instrumental-atmospheric local model using B-V are the same for all-sky photometry, i.e. (Harris *et al.*, 1981):

$$\begin{cases} B - b = Zb - \left(k'_b + k''_b\left(B-V\right)\right)\cdot X + C_b\left(B-V\right) \\ V - v = Zv - \left(k'_v + k''_v\left(B-V\right)\right)\cdot X + C_v\left(B-V\right) \end{cases} \qquad (3)$$

The corresponding equations for V and SR are,

$$\begin{cases} SR - sr = Zsr - \left(k'_{sr} + k''_{sr}\left(V - SR\right)\right)\cdot X + C_{sr}\left(V - SR\right) \\ V - v = Zvr - \left(k'_{vr} + k''_{vr}\left(V - SR\right)\right)\cdot X + C_{vr}\left(V - SR\right) \end{cases} \quad (4)$$

In Eq. 3 and 4, B, V, and SR are taken from the APASS catalog. Z_b, Z_v, Z_{sr}, Z_{vr} are the zero point magnitudes; b,v, and sr are the instrumental magnitude in the three filters; k′ is the first-order atmospheric extinction coefficient for the given filter; k′′ is the second-order atmospheric extinction; X is the air mass, and C is the instrumental color-correction coefficient for the given color index.

In general, nonlinear regression can be used to find a model based on a set of data points. MATLAB by MathWorks (*http://www.mathworks.com*) was used for this step.

To get the unknown coefficients, images of the six comparison stars from Table I were taken over a range of air masses ranged from X = 1.15 to 1.79. Eq. 3 and 4 can be used as two overdetermined linear systems (i.e., when there are more equations than unknowns) and an ordinary least squares method can be used to find an approximate solution.

Table II shows the various parameters of the instrumental-atmospheric local model using MATLAB.

B		**V**		**SR**		**V**	
Zb	22.41	Zv	22.58	Zsr	22.80	Zvr	22.55
k_b'	0.195	k_v'	0.198	k_{sr}'	0.053	k_{vr}'	0.189
k_b''	0.0013	k_v''	-0.062	k_{sr}''	0.081	k_{vr}''	-0.146
C_b	0.065	C_v	-0.177	C_{sr}	0.196	C_{vr}	-0.415

Table II. The coefficients of the instrumental-atmospheric local model.

To check the results, the B, V, and SR magnitudes of a set of stars that were not used to compute the model (Table III) were computed and compared to the APASS values (Fig. 11 and 12).

I	V	B	SR	RA	Dec	S
c1	13.549	15.168	12.951	05:00:04.34	+16:50:45.3	1
c2	13.793	14.696	13.458	05:00:26.24	+16:49:51.9	1
c3	14.612	15.658	14.250	05:00:04.07	+17:06:16.9	2
c4	13.722	15.367	13.084	04:59:55.19	+17:00:49.5	2
c5	14.164	15.238	13.764	04:59:52.67	+17:04:24.8	2
c6	12.231	13.506	11.758	05:00:02.15	+17:03:31.4	2
c7	13.301	14.224	12.961	04:59:54.69	+17:03:33.6	2

Table III. The set of check stars shown in Fig. 10 used to test the quality of the instrumental-atmospheric local model (J2000.0 coordinates). The mag values are from APASS catalog while the 'S' column indicates the session number.

The Color Indices on the Asteroid's Surface

Now that the coefficients of the instrumental-atmospheric local model are known, it is possible to compute the (B-V) and (V-R) color indices for the target using its B, V, and R instrumental magnitudes. From Eq. (3) and Eq. (4) it follows that

$$\left(V - SR\right) = \frac{\left(v - sr\right) + X\cdot\left(k'_{sr} - k'_{vr}\right) + Zvr - Zsr}{1 - X\cdot\left(k''_{sr} - k''_{vr}\right) - \left(C_{vr} - C_{sr}\right)} \quad (5)$$

$$\left(B - V\right) = \frac{\left(b - v\right) + X\cdot\left(k'_{v} - k'_{b}\right) + Zb - Zv}{1 - X\cdot\left(k''_{v} - k''_{b}\right) - \left(C_{b} - C_{v}\right)} \quad (6)$$

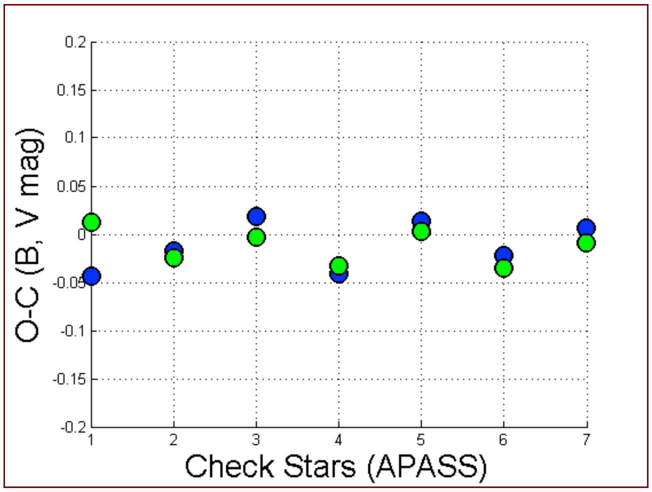

Figure 11. A graph showing the differences between the observed and the computed magnitudes for the check stars using the instrumental-atmospheric local model derived from data at air masses X = 1.19 and X = 1.79. Blue points are B and green points are V. The RMS in B is 0.026 mag; it is 0.018 mag in V.

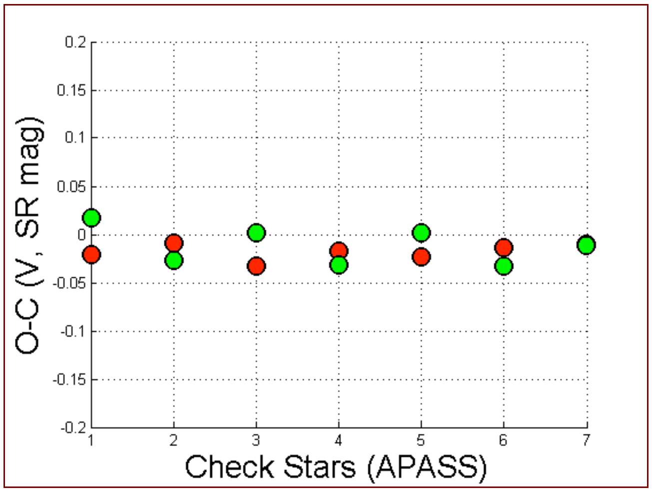

Figure 12. A graph showing the difference between the observed and the computed mag for the check stars using the derived instrumental-atmospheric model. Green points are V and red points are R. The RMS in R is 0.01 mag; it is 0.02 mag in V.

A correction is necessary to transform the color index V-SR to V-R. This can be found by subtracting Eq. 2 from the V mag,

$$\left(V - R\right) = \left(V - SR\right) + 0.112 + 0.128\cdot\left(B - V\right) \quad (7)$$

Due to the propagation of errors, the RMS in Eq. 7 is about $\sqrt{0.04^2 + 0.05^2}$, or 0.06 mag. Using the B, V, and R instrumental magnitudes of the target in Eq. 5-7, the (B-V) and (V-R) color indices can be found as a function of the rotation phase. The uncertainty in a single measure is found by adding all the uncertainties in quadrature. For (B-V), this gives 0.07 mag and 0.09 mag for V-R. The final result is shown in Fig. 13.

Each red or blue point in Fig. 13 is the average of several black points obtained directly from the atmospheric-instrumental local model. The error bars indicate the corresponding standard deviation. The bin is 0.15 of the rotational phase, so there are seven "mean" points. As can be seen, the data suggest that there are no significant changes in either color index over a rotation.

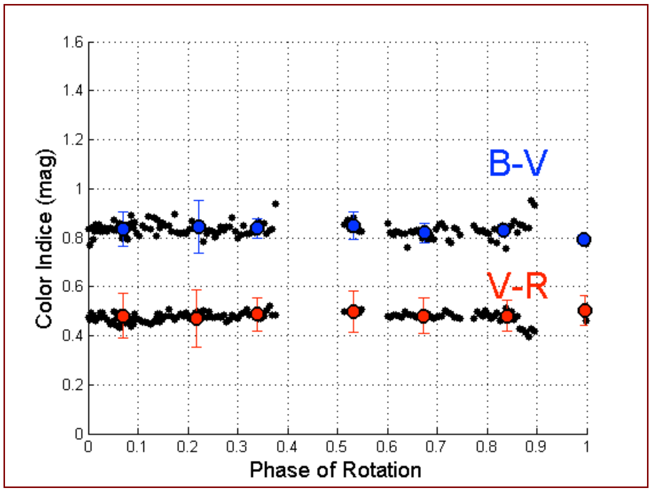

Figure 13. The mean (B-V) and (V-R) color indices of NEA (214088) 2004 JN13 vs. rotation phase. Black points are raw color indices. From rotation phase 0.0 to 0.2, the points are from both sessions. From 0.20 to 0.75, the points are from the second session only. From 0.75 to 1.0, they are from the first session only.

A Simpler Method for the Color Indices

A simplified method to achieve similar results follows. Looking at Eq. 5 and Eq. 6, the terms in the second member are all constants except for the difference between instrumental magnitudes, (v-sr) or (b-v), and the air mass, X. However, if the air mass changes little (from 1.15 to 1.64 in this case), Eq. 5 and 6 become

$$V - SR \cong a_1 + a_2 \cdot (v - sr) \qquad (8)$$

$$B - V \cong a_3 + a_4 \cdot (b - v) \qquad (9)$$

Where a_i (i = 1, 2, 3, 4) are all constants. Figures 14 and 15 shows the calibration plot obtained with the comparison stars listed in Table I. Note that for each true color index, there are several instrumental color indices, with only a small variation, due to the small variation in air mass. Note also that the range of color indices of the comparison stars is sufficiently extended to determine the slope. In other words, not just solar-color stars should be used for the calibration. Using the available data and Eq. 8 and 9 gives

$$V - SR \cong -0.32 + 0.75 \cdot (v - sr) \qquad (10)$$

$$B - V \cong -0.18 + 1.17 \cdot (b - v) \qquad (11)$$

The RMS of Eq. 10 is 0.014 mag, while for Eq. 11 the RMS is 0.025 mag. At this point we can use the previous equations to switch between the instrumental color indices of the target to the true ones, making sure to include Eq. 7. The result is shown in Fig. 16, which is nearly the same as Fig. 13. In this case the uncertainty for the single black dots is 0.06 mag for (B-V) and 0.09 mag for (V-R). The error bars in Fig. 16 are the standard deviation of the mean values (red and blue dots).

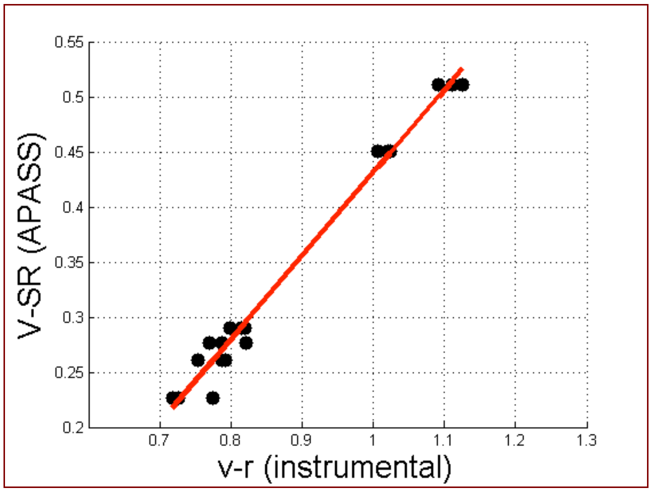

Figure 14. Plot of the catalog color index (V-SR) vs. the instrumental color index (v-r) for the comparison stars of Table I.

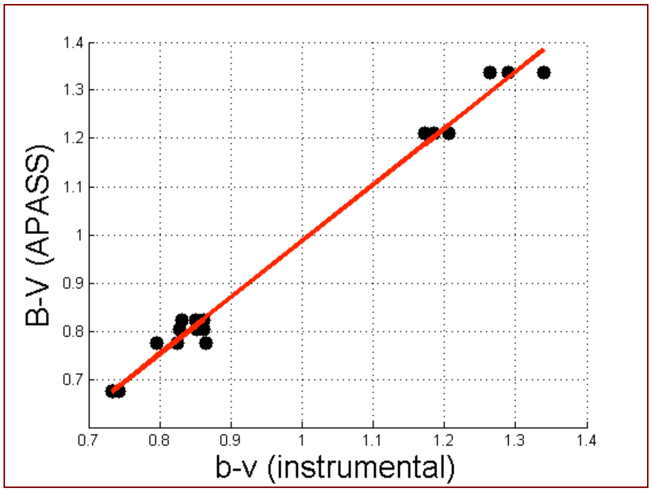

Figure 15. Plot of the catalog color index (B-V) vs. the instrumental color index (b-v) for the comparison stars of Table I.

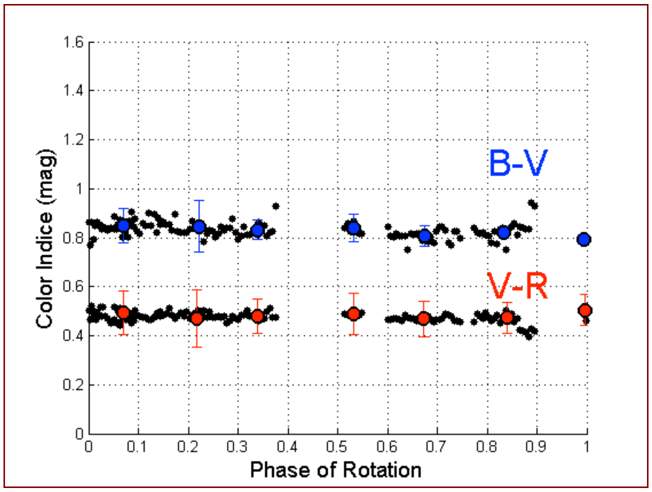

Figure 16. The color indices (B-V) and (V-R) of NEA (214088) 2004 JN13 vs. rotation phase using the simplified reduction method. This figure is very similar to Fig. 13.

The Optical Colors of NEAs and the Taxonomic Class of 2004 JN13

From Fig. 13 or 16, the mean color indices values for 2004 JN13 are (B-V) = 0.83 ± 0.02 mag and (V-R) = 0.48 ± 0.03 mag.

The uncertainties are the standard deviation of the mean, so lower by a factor $1/\sqrt{7}$ = 0.38 with respect to the mean standard deviation of the points (red or blue). To find the class of the asteroid we can make a comparison with the data available in the scientific literature, where our choice is to use Dandy *et al.* (2003). Our mean (B-V) and (V-R) values most closely match the tabulated values for S-type asteroids; while Q- and V-types are not ruled out. Given the percentages of NEAs with a known taxonomic class, 52% belong to the S-type, 20% belong to the Q-type while only 7% belong to the V-type (Binzel, 2002). So it is more probable than not that 2004 JN13 it's an S-type asteroid.

Assuming that 2004 JN13 is an S-type asteroid and using the available data, a rough estimate can be made of asteroid's effective diameter. The mean absolute V magnitude in the H-G system is given by Bowell *et al.* (1989):

$$H_o = m_{v_r}(\alpha) + 2.5\log_{10}\left[(1-G)\Phi_1(\alpha) + G\Phi_2(\alpha)\right] \qquad (12)$$

In Eq. 12, H_o is the absolute magnitude at 0° phase angle (usually given as just 'H'), m_{V_r} is the mean reduced magnitude and Φ_1 and Φ_2 are two functions of the phase angle α. For an S-type asteroid, in the H-G system, G = 0.24 ± 0.11 (Shevchenko and Lupishko, 1998).

Substituting the observed phase angle of 8.2° and mean V magnitude of 14.01 ± 0.03 mag gives H = 15.47 ± 0.38 mag, which is in good agreement with the JPL Small-Body Database value of 15.3. Assuming that the asteroid is an S-type and assuming the mean geometric albedo for the class of p_V = 0.20 ± 0.05, the effective diameter of 2004 JN13 will be (Harris, 1997)

$$D_e = \frac{1329}{\sqrt{p_v}} 10^{-0.2H_v} = 2.4 \pm 0.5\ \text{km} \qquad (13)$$

Conclusions

Asteroid (214088) 2004 JN13 was observed from OAVdA on 2014 Dec 16-17 for about 7.5 hours with B, V, and R filters on a night with relatively stable sky transparency. Using the stars from the APASS catalog as a reference, an instrumental-atmospheric local model was constructed. With this, it was possible to compute the color indices (B-V) and (V-R) as a function of the rotation phase. The color indices are constant within the uncertainties, indicating that the asteroid's surface is homogeneous within the measurement limits. The same results were achieved with a simplified data reduction method. The photometric data collected indicate that the asteroid is probably an S-type. Using a series of additional assumptions, the estimated effective diameter was found to be 2.4 ± 0.5 km.

Acknowledgements

This research has made use of the NASA's Astrophysics Data System and Planetary Data System, JPL's Small-Body Database Browser, and the VizieR catalogue access tool, CDS, Strasbourg, France. Research at the Astronomical Observatory of the Aosta Valley Autonomous Region was supported by the 2013 Shoemaker NEO Grant from The Planetary Society.

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THREE ASTEROIDS WITH CHANGING LIGHTCURVES: 124 ALKESTE, 465 ALEKTO, AND 569 MISA

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(Received: 2016 June 26)

Synodic rotation periods and amplitudes are found for 124 Alkeste: $P = 9.906 \pm 0.001$ h, $A = 0.18\text{-}0.29$ mag; 465 Alekto: $P = 10.936 \pm 0.001$ h, $A = 0.14\text{-}0.16$ mag; and 569 Misa: $P = 11.595 \pm 0.001$ h, $A = 0.09 \pm 0.01$ mag. Changes in the shapes of the lightcurves in an interval of 40 to 60 days are documented. For 124 Alkeste, V-R = 0.49 and $H = 8.155 \pm 0.018$, $G = 0.137 \pm 0.019$.

Main-belt asteroid lightcurves change slowly with changing phase angle because of shadowing by topographic features and, to a lesser extent, by changes in the phase angle bisector. Over an interval of a few days these changes are usually too small to notice and over even larger time intervals are frequently ignored. In this paper changes in the lightcurves of 124 Alkeste, 465 Alekto, and 569 Misa over an interval of about 40 to 60 days are documented.

Observations were made in 2016 at the Organ Mesa Observatory with a 0.35-meter Meade LX200 GPS Schmidt-Cassegrain (SCT) and SBIG STL-1001E CCD. Exposures were 60 seconds, unguided, with a clear filter. All measurements were calibrated to Cousins R magnitudes for solar-colored field stars. Photometric measurement and lightcurve construction were done with *MPO Canopus*. To reduce the number of points on the lightcurves and make them easier to read, data sets have been binned in groups of three with a maximum time difference of five minutes between points. In this paper, phase angles with negative values are pre-opposition and those with positive values are post-opposition.

<u>124 Alkeste</u>. Previously published rotation periods are by Behrend (2007), 9.908 h; Harris and Young (1983), 9.921 h; and Shevchenko *et al*. (2002), 9.907 h. New observations were made 2016 April 16 - June 17 and provide a good fit to a period of 9.906 ± 0.001 h, which is fully compatible with previous determinations.

A subset of observations covering April 12-16 (phase angles +0.8 degrees to +2.6 degrees) provides a good fit to 9.900 h and amplitude 0.18 mag (Fig 2). A second subset of observations covering April 24 - May 9 (phase angles +6.4 degrees to +12.8 degrees) provides a good fit to 9.905 h and amplitude 0.21 mag (Fig 3). A third subset of observations covering May 27 - June 17 (phase angles +18.8 degrees to +22.9) degrees provides a good fit to 9.908 h and amplitude 0.28 mag (Fig 4).

The May 27 observations at phase angle +18.8 degrees had a considerably smaller amplitude than the largely overlapping June 17 session at +22.9 degrees. A session from May 16 (not included in any of these subsets) had a shape intermediate between the shapes at larger and small phase angles. Because the shape of the lightcurve evolved steadily as the phase angle changed through the apparition rather than making an abrupt change, this behavior is as expected.

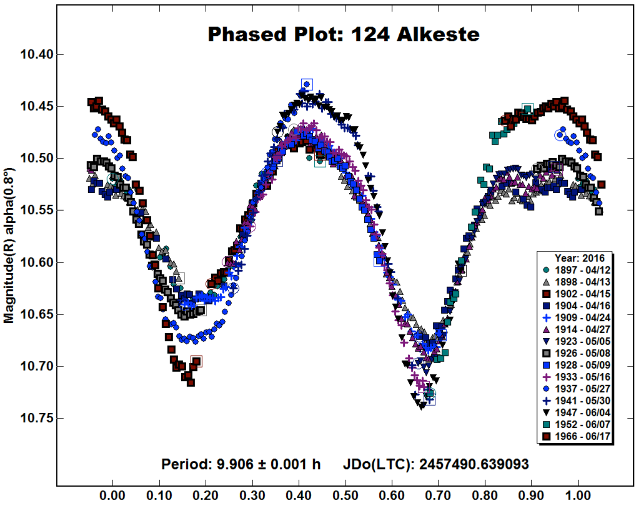

Figure 1. The lightcurve of 124 Alkeste including all sessions from 2016 Apr 12 - Jun 17.

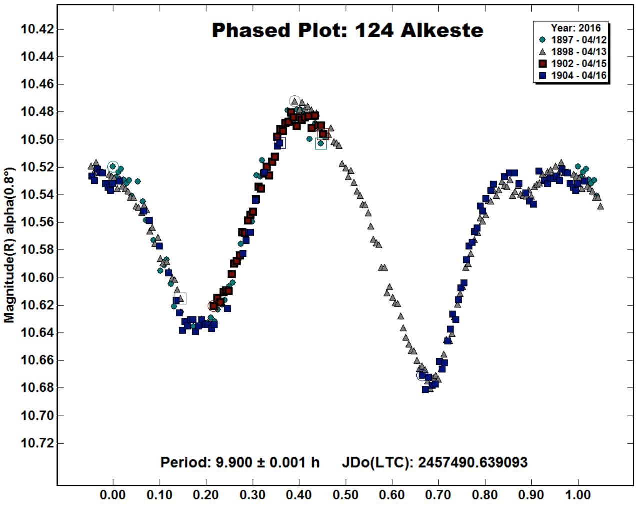

Figure 2. The lightcurve of 124 Alkeste form 2016 Apr 12-16, phase angles +0.8 to +2.6 degrees.

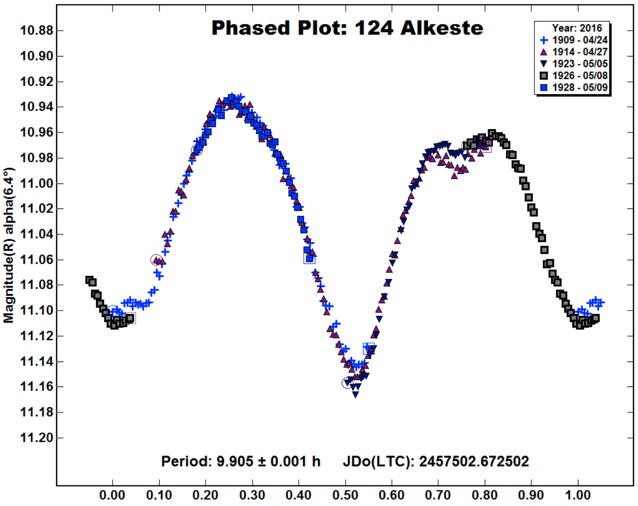

Figure 3. The lightcurve of 124 Alkeste from 2016 Apr 24 - May 9, phase angles +6.4 to +12.8 degrees.

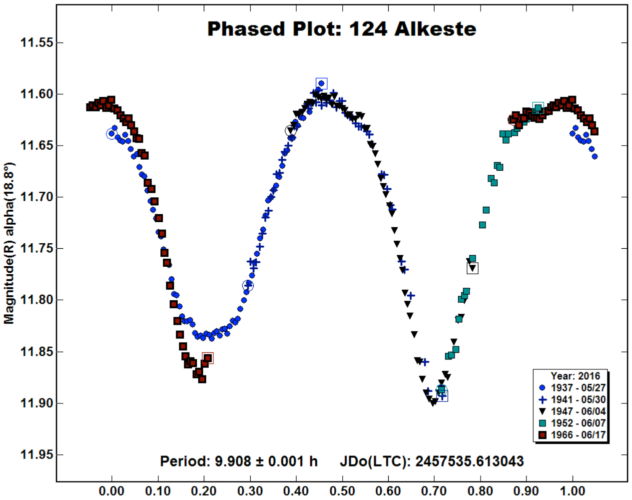

Figure 4. The lightcurve of 124 Alkeste from 2016 May 27 - June 17, phase angles +18.8 to +22.9 degrees.

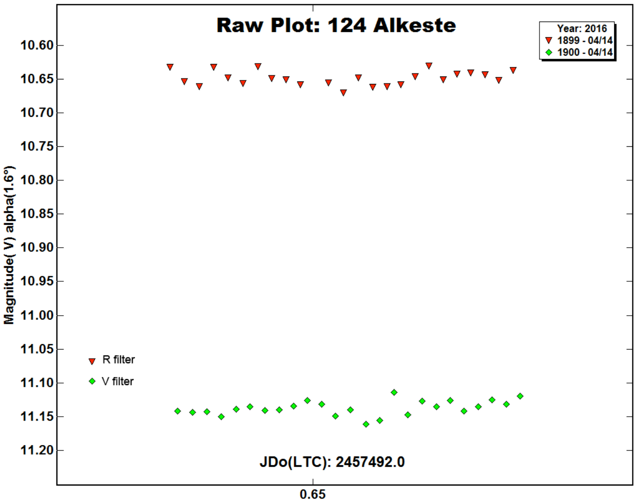

Figure 5. R and V filter observations of 124 Alkeste 2016 Apr 14.

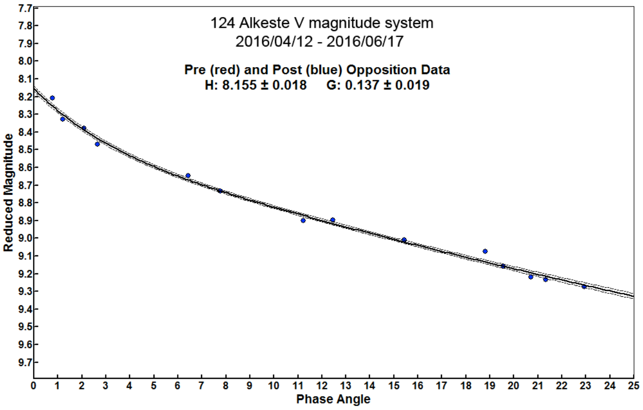

Figure 6. H-G plot for 124 Alkeste in the Johnson V magnitude band at mid-light.

Twenty-four images in both R and V filters were obtained alternately on April 14. The same solar-colored comparison stars with Sloan r´, J, and K magnitudes read from the CMC15 catalog (VizieR web site) were used to measure both image sets. For the R filter images, conversion to Cousins R magnitudes used R = r´ - 0.22 while conversion to Johnson V magnitudes used V = 0.9947r´ + 0.6278(J-K). Both conversion procedures are from Dymock and Miles (2009). The converted magnitudes for each color are shown together in Figure 5.

The R magnitude data points must be adjusted downward by 0.49 magnitudes to provide best fit to the V magnitude data points. Hence the standard photometric color index V-R is measured as 0.49. A raw plot of each session was drawn and the mid-time and R magnitude at mid-light (average of maximum+minimum magnitude) were read off the plot. Each measured R magnitude was converted to its corresponding V magnitude by adding 0.49. The H-G calculator function of *MPO Canopus* was used to produce the phase diagram for *H* and *G* and find *H* = 8.155 ± 0.018, *G* = 0.137 ± 0.019 (Fig. 6).

465 Alekto. Previous period determinations were by Pilcher (2013; 10.938 h, 0.12 mag) near ecliptic longitude 350 degrees and by Pilcher (2015, 10.936 h, 0.14 mag) near ecliptic longitude 110 degrees. New observations were made in 2016 Mar 20 - May 3 near ecliptic longitude 200 degrees. Using all the data gave a good fit to a period of 10.936 ± 0.001 h (Fig. 7). This is adopted as the synodic period for the 2016 apparition.

Note the change in the shape and depth of the deepest minimum near phase 0.20 when using the full data set. A subset of observations from March 20-28 (phase angles -12.6 to -9.7 degrees), provides full coverage of the lightcurve and a good fit to 10.940 h and amplitude of 0.16 mag (Fig. 8). Another subset of observations, Apr 10 - May 3 (phase angles -4.7 to a minimum of -3.2 to +8.0 degrees), also provides full coverage and a good fit to 10.936 h and amplitude 0.14 mag (Fig. 9).

A session on April 3 (not included in either of the two shorter interval lightcurves) has a shape intermediate between the shapes at large and small phase angles. Since the shape of the lightcurve evolves steadily throughout the apparition rather than making an abrupt change, this behavior is as expected.

Smaller changes in the shape of the lightcurves at other rotational phases can also be seen. The rotation period found in 2016 agrees very closely with periods found at very different ecliptic longitudes. The amplitudes are also all similar and all three data sets display three unequal maxima and minima per cycle. This suggests that all observations are fairly close to equatorial viewing aspect.

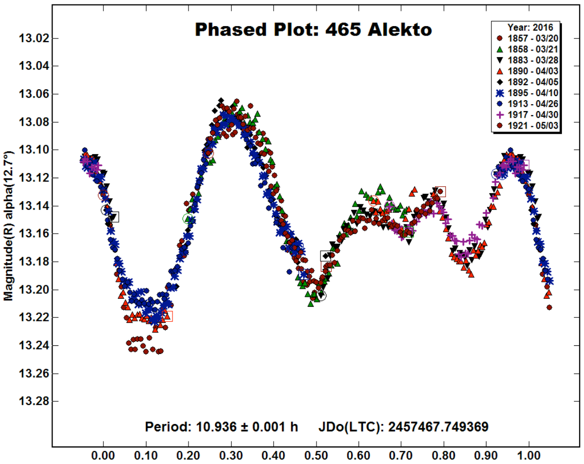

Figure 7. The lightcurve of 465 Alekto using all sessions from Mar 20 - May 3.

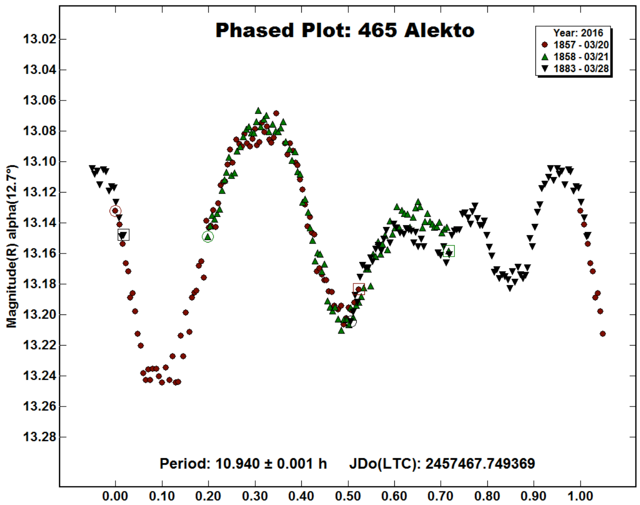

Figure 8. The lightcurve of 465 Alekto from Mar 20-28, phase angles -12.6 to -9.7 degrees.

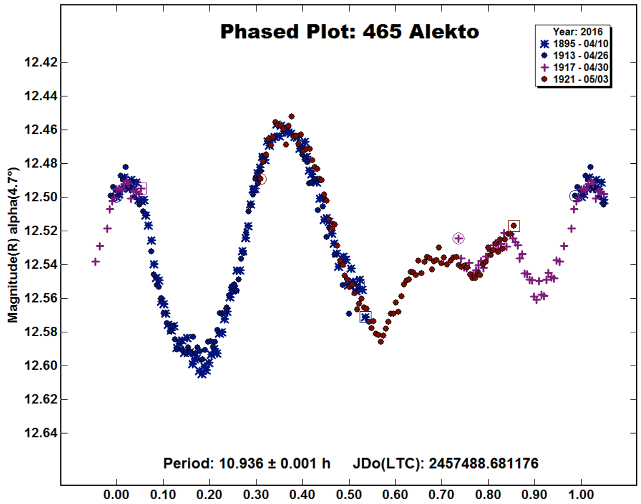

Figure 9. The lightcurve of 465 Alekto from Apr 10 - May 3, phase angles -4.7 to -3.2 to +8.0 degrees.

569 Misa. The only previously published rotation period is 13.52 h by Behrend (2002) based on a sparse data set. A new, denser data set was obtained in 2016 Mar 29 - May 7. A lightcurve using the complete data set of 11 sessions (Fig. 10) provides a good fit to 11.595 h and shows a considerable change in the wide maximum near rotational phase 0.9. The subset of five sessions from Mar 29 - Apr 11 (phase angles -9.3 to -4.2 degrees) provides a good fit to 11.597 h, 0.09 mag (Fig. 11).

The subset of three sessions from Apr 14-25 (phase angles -3.0 to +1.8 degrees) provides a good fit to 11.599 h and amplitude 0.07 mag. Here, the widest and highest maximum has become shallower at smaller phase angles (Fig. 12). The subset of three sessions Apr 29 - May 7 (phase angles +3.4 to +6.5 degrees) provides a good fit to 11.591 h and amplitude 0.09 mag. The widest and highest maximum has again become higher (Fig. 13).

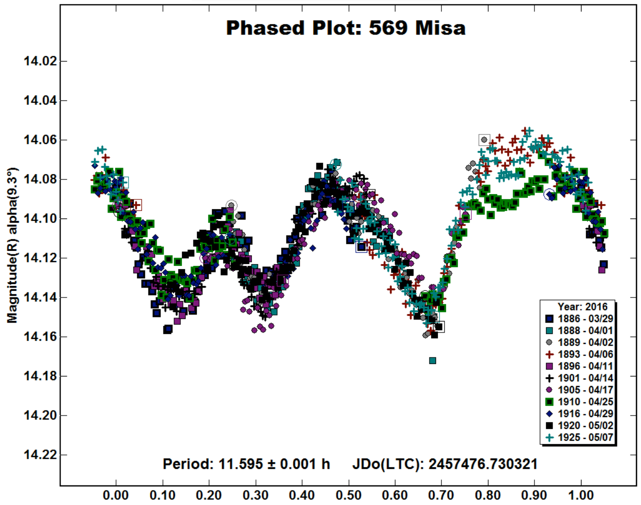

Figure 10. The lightcurve of 569 Misa including all sessions Mar 29 - May 7.

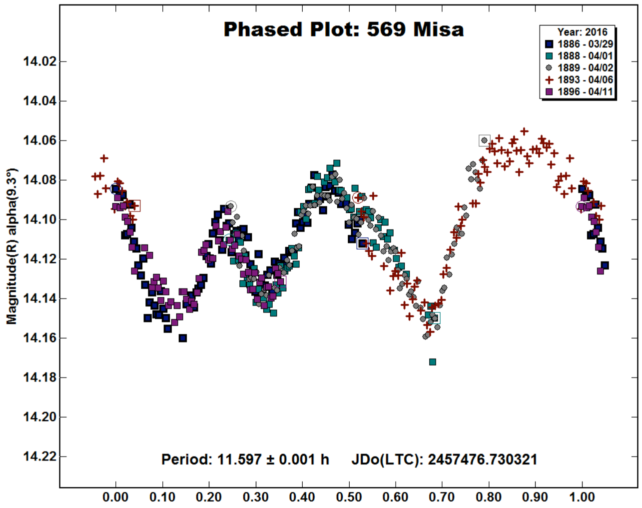

Figure 11. The lightcurve of 569 Misa from Mar 29 - Apr. 11, phase angles -9.3 to -4.2 degrees.

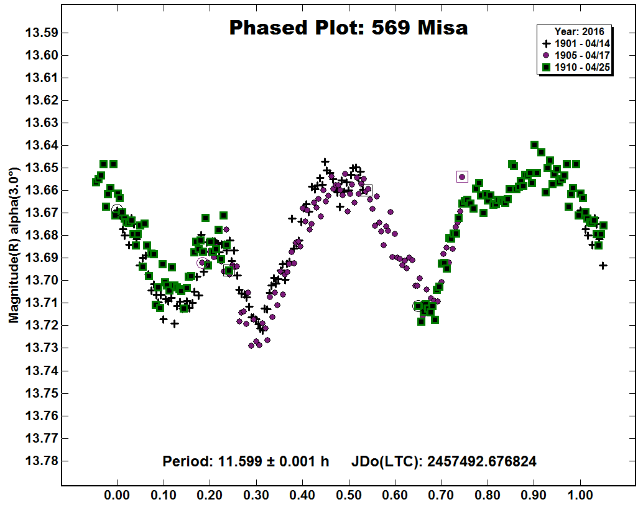

Figure 12. The lightcurve of 569 Misa from Apr 14-25, phase angles -3.0 to +1.8 degrees.

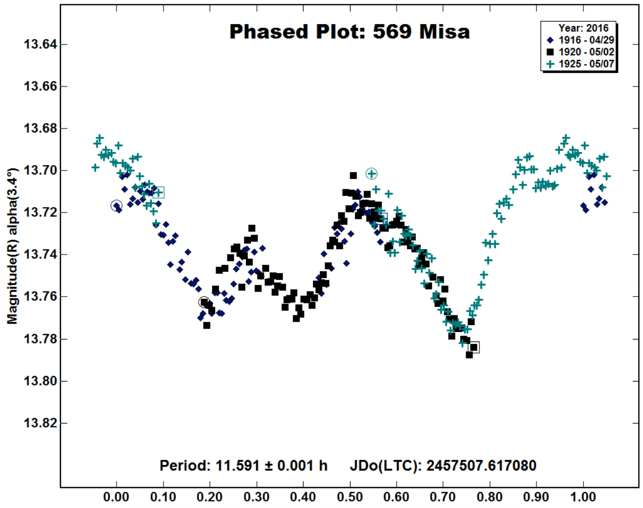

Figure 13. The lightcurve of 569 Misa from Apr 29 - May 7, phase angles +3.4 to +6.5 degrees.

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ROTATION PERIOD ANALYSIS FOR 3223 FORSIUS

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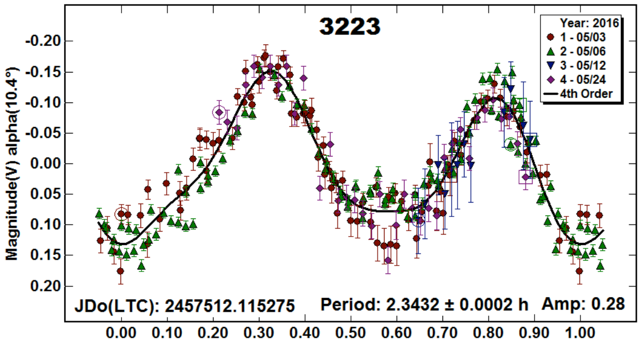
Analysis of photometric observations for the minor planet 3223 Forsius shows a synodic rotation period of *P* = 2.3432 ± 0.0002 h with an amplitude *A* = 0.28 mag.

Main-belt asteroid 3223 Forsius was discovered at Turku on 1942 Sep 7 by Y. Vaisala. Its orbit has a semi-major axis of 2.606 AU, eccentricity of 0.1439, and orbital period of 4.21 years (JPL, 2016). Previous works found a synodic rotation period *P* = 2.34307 ± 0.00002 h (Behrend, 2003), 2.343 ± 0.001 h (Koff, 2004), 2.3434 ± 0.0001 h (Behrend, 2005), and 2.34322 ± 0.00004 h (Behrend, 2013).

CCD photometric observations of 3223 Forsius were made at Lvye Observatory (IAU P34) on 2016 May 3 and 12 and at iTelescope Observatory (IAU Q62) on 2016 May 6 and 24. The instruments of Lvye Observatory are a Skywatcher 0.25-m *f*/4.4 Newtonian reflector telescope, SBIG ST-402ME CCD camera at –5°C, binned 2x2, and clear filter. The image scale is 3.22 arc seconds per pixel; exposure times were 120 s. The instruments of iTelescope Observatory are a Planewave 0.43-m corrected Dall-Kirkham telescope and FLI ProLine PL4710 CCD camera at –35°C, binned 2x2, and clear filter. The image scale is 1.83 arc seconds per pixel; exposures were 120 s. All images were dark, bias, and flat corrected using *MaxIm DL*.

Differential photometry and period analysis were made with *MPO Canopus*. A total of 242 data points were used for the analysis. The lightcurve shows a period *P* = 2.3432 ± 0.0002 h with an amplitude *A* = 0.28 mag. The period is in agreement with the earlier work.



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ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2016 APRIL-JULY

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Lightcurves for nine main-belt asteroids were obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 April to July. Of the group, four are known Hungaria binary asteroids: 1727 Mette, 2047 Smetana, 5899 Jedicke, and (18890) 2000 EV26. The Mars-crosser (54697) 2001 FA70 appears to be a newly-confirmed binary with $P_1 = 2.7075$ h and $P_{Orb} = 16.269$ h. A third period, $P_2 = 2.1239$ h, appears to be real. If so, it could be due to the asynchronous rotation of the satellite or a third body in the system.

CCD photometric observations of 9 main-belt asteroids were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 April to July. Table I lists 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
Squirt	0.30-m f/6.3 Schmidt-Cass	ML-1001E
Borealis	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
Eclipticalis	0.35-m f/9.1 Schmidt-Cass	ML-1001E
Australius	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Zephyr	0.50-m f/8.1 R-C	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.

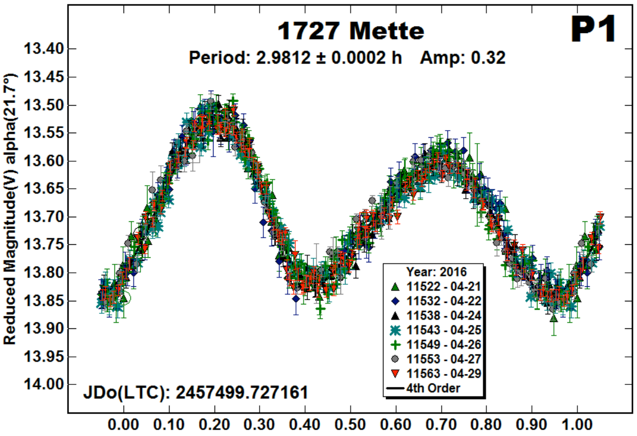
Measurements were made using *MPO Canopus*. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the APASS catalog (Henden et al., 2009). When there were insufficient stars, the MPOSC3 catalog was used. This catalog 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). The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag. There is a systematic offset between the two catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done using *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

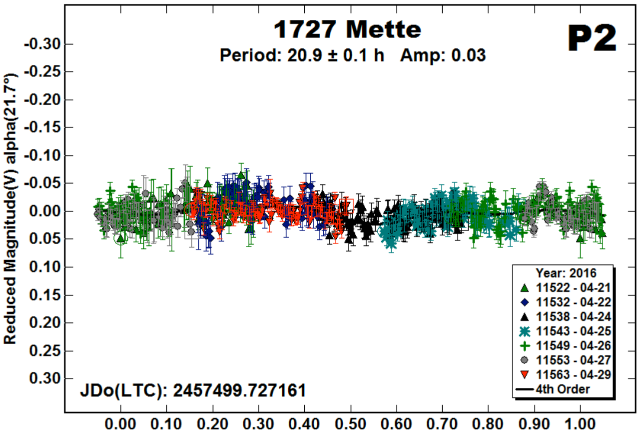
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances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

If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*. The value is meant only to be a quick guide.

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.

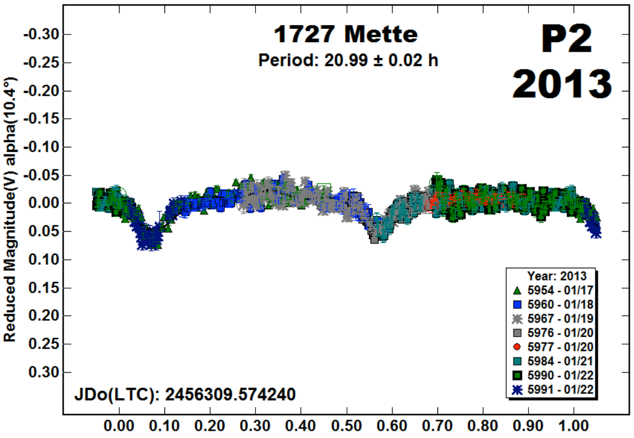
<ins>1727 Mette</ins>. This Hungaria asteroid was confirmed to be a binary by Warner *et al.* (2013c). The 2016 observations were made to help refine the primary and orbital periods as well as provide data for future modeling of the system. The 2016 results were $P_1 = 2.9812 \pm 0.0002$ h, $A_1 = 0.32 \pm 0.02$ mag, $P_{Orb} = 20.9 \pm 0.01$ h. The latter is just within the error bars of the previous result. The amplitude of the secondary lightcurve was only $A_{Orb} = 0.03$ mag. In the absence of the previous results, it would be very difficult to claim the existence of a satellite.





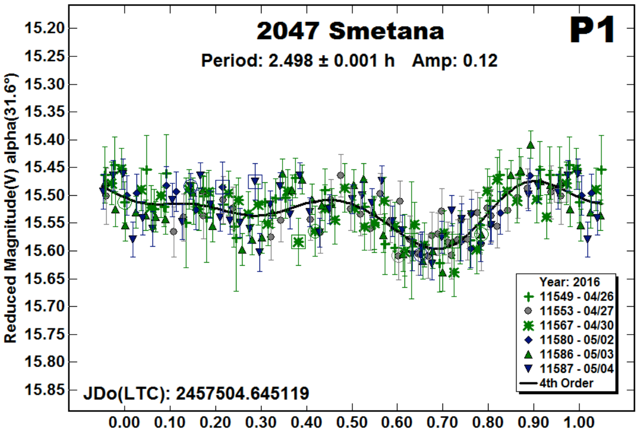
Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Group
1727	Mette	04/21-04/29	657	21.7,20.7	228	33	[P]2.9812	0.0002	0.32	0.02	H
2047	Smetana	04/26-05/04	200	29.3,32.2	159	19	2.498	0.001	0.12	0.02	H
2049	Grietje	05/27-06/03	355	17.2,18.8	242	26	8.91	0.005	0.12	0.02	H
5899	Jedicke	04/24-05/03	349	18.5,18.4,18.5	220	33	[P]2.751	0.001	0.11	0.02	H
6310	Jankonke	04/30-05/04	138	32.2,32.2	154	28	3.072	0.002	0.16	0.02	H
7660	1993 VM1	05/27-05/30	160	18.4,18.1	258	32	5.922	0.002	0.79	0.03	H
18890	2000 EV26	05/01-05/08	377	14.4,17.5	205	16	[P]3.815	0.002	0.09	0.01	H
54697	2001 FA70	06/17-07/02	992	19.2,23.1	261	22	[P]2.7075	0.0003	0.05	0.01	MC
78857	2003 QO70	06/17-06/21	123	25.7,26.2	256	34	3.38	0.002	0.42	0.03	H

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum, which is then the second of three values. If a single value is given, the phase angle did not change significantly and the average value is given. L_{PAB} and B_{PAB} are each the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range). The Group column gives the orbital group to which the asteroid belongs. The definitions and values are those used in the LCDB (Warner *et al.*, 2009). H = Hungaria; MC = Mars-crosser. Footnote: [P] indicates period of primary in binary system.

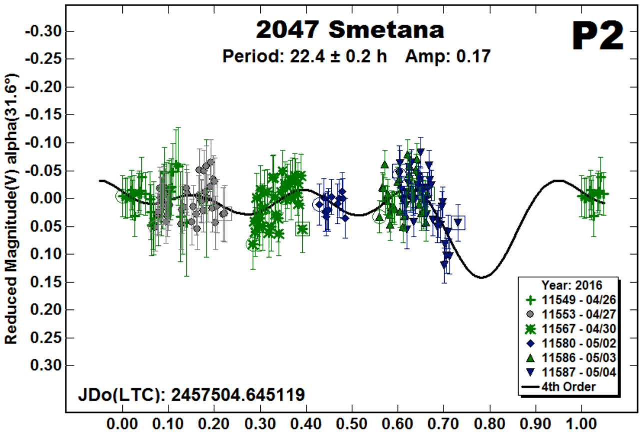


The difference between the two satellite lightcurves helps indicate the orientation of the satellite's orbit, which is presumably close to the equatorial plane of the primary. Data from past and future apparitions will be needed to model the system.

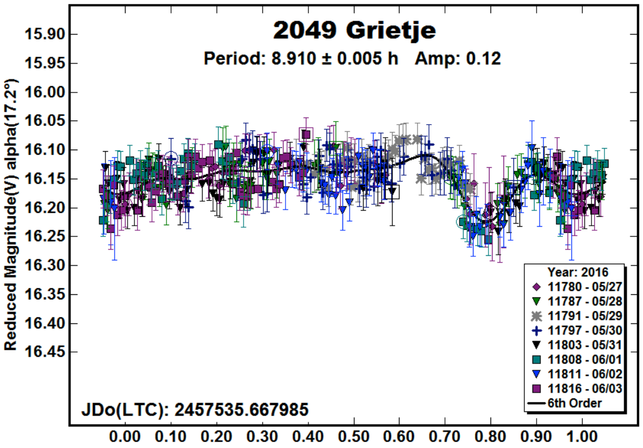
2047 Smetana. Warner *et al.* (2013b), using data obtained in 2012 November, reported this Hungaria to be a binary with the satellite having an effective diameter about 0.24 times that of the primary. The results of analysis from the 2016 data, P_1 = 2.498 ± 0.001 h, A_1 = 0.12 ± 0.01 mag, confirmed the period for the primary.



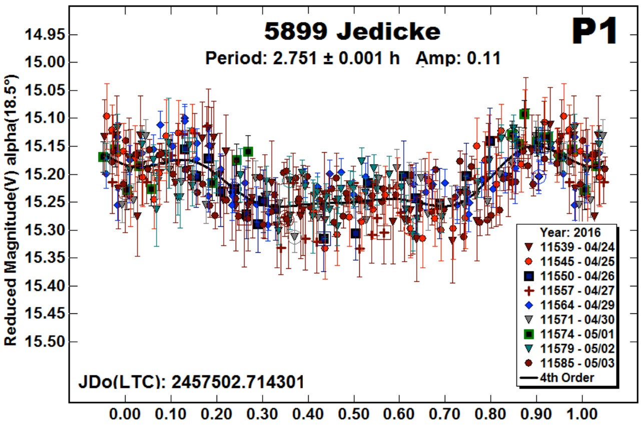
Due to an insufficient data set, the 2016 analysis had to force the orbital period to 22.4 h, or the approximate value found during from the discovery apparition. As with 1727 Mette above, the mutual events in 2016 were far less prominent than before and, in fact, cannot really be said to exist at all.

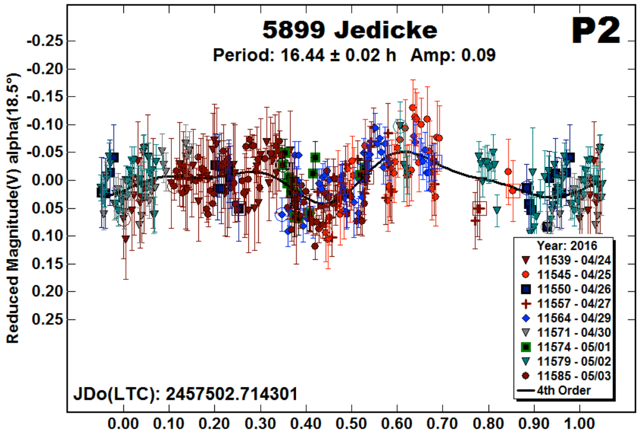


2049 Grietje. The only previously reported period in the LCDB for this Hungaria was about 12 hours (Wisniewski *et al.*, 1997) which was rated U = 1 (probably wrong). The 2016 observations at CS3-PDS led to P = 8.910 ± 0.005 h, A = 0.12 ± 0.01 mag. The unusual shape calls the period somewhat into question. However, an unusual shape, *i.e.*, not a typical bimodal lightcurve, is not uncommon for objects with amplitudes of the order of 0.1 mag or less, especially at low phase angles (Harris *et al.*, 2014). Follow-up at future apparitions is encouraged.



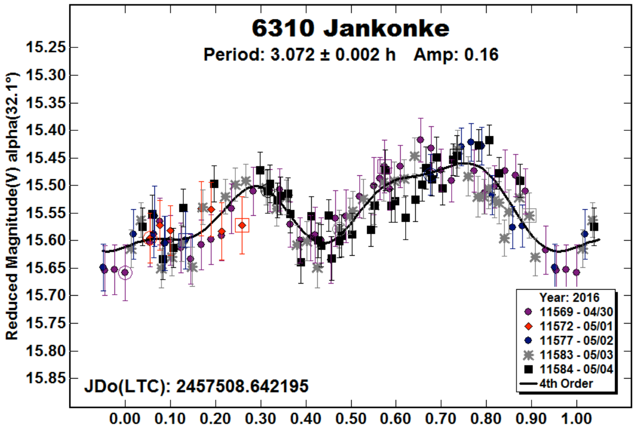
5899 Jedicke. Warner *et al.* (2010) found this Hungaria to be a binary. In a reversal of the usual circumstances, the mutual events in the secondary lightcurve were well-defined, leading to a satellite to primary effective diameter ratio of Ds/Dp ≥ 0.32. On the other hand, the amplitude of the primary was too low (0.04 mag) to find a reliable period.





The ambiguity was resolved with observations in 2013 (Warner, 2013d) with P_1 = 2.7481 h and the orbital period further refined to P_{Orb} = 16.722 h. Analysis of the 2016 data confirmed the revised primary period, finding P_1 = 2.751 ± 0.001 h and A_1 = 0.11 ± 0.01 mag. Due to insufficient data in 2016, the search for the orbital period had to be constrained to a small range about P_{Orb} = 16.7 h. The result of 16.44 h is well outside the error margin from the 2013 analysis, which is not surprising given the large gap in the coverage between orbital phases 0.7-0.9 and the relatively noisy data.

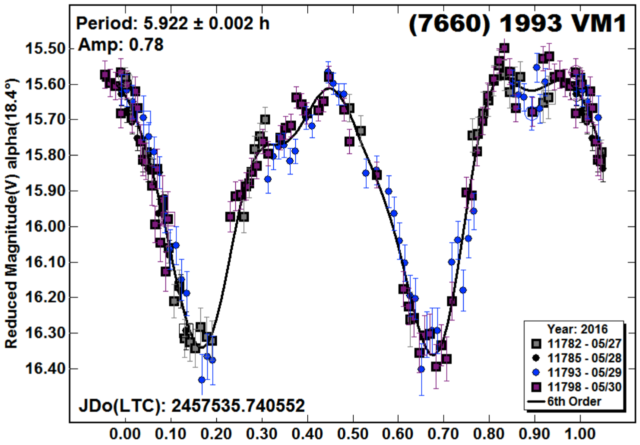
6310 Jankonke.



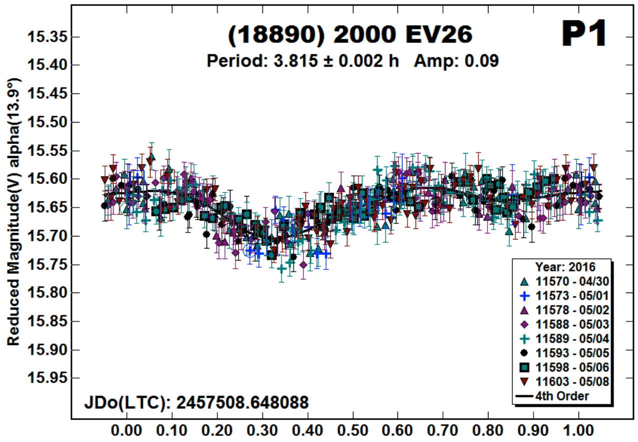
The rotation period for this Hungaria had been reported on several occasions, *e.g.*, Warner (2005, 3.042 h) and Behrend (2008, 3.0416 h), before Warner (2013a) found a significantly different period of 3.076 h. This alternate period was found again in 2015 (Warner, 2016) and following the analysis of the 2016 data.

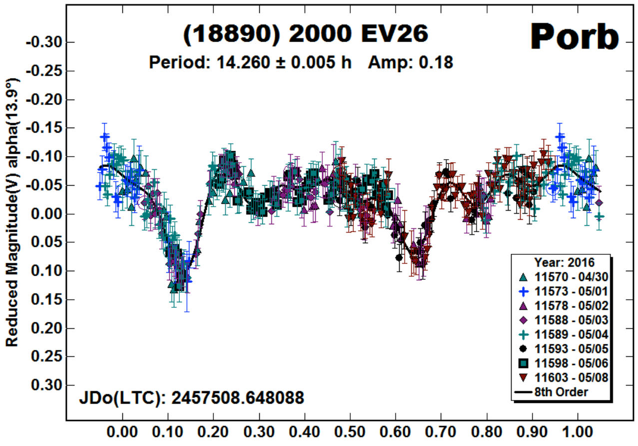
As before, attempts failed to get all the data sets to agree or at least reasonably fit a similar period. No plausible explanation can be found for the sudden 0.03 hour slowing that seems to have occurred between 2011 and 2012.

(7660) 1993 VM1. Previous results for this Hungaria, *e.g.*, Pravec *et al.* (2005, 5.916 h) and Warner (2015a, 5.917 h), are in agreement with the period found from analysis of the 2016 data.



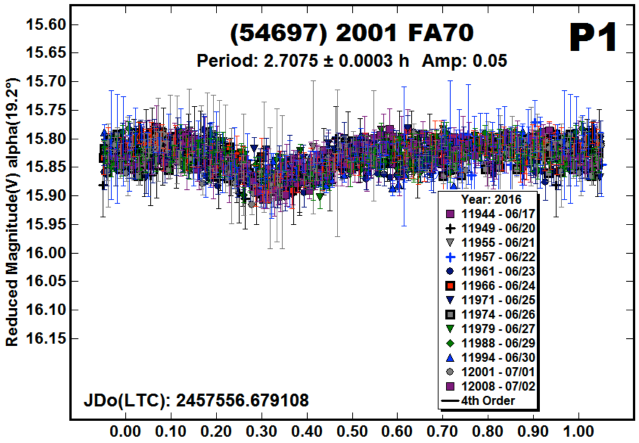
(18890) 2000 EV26.

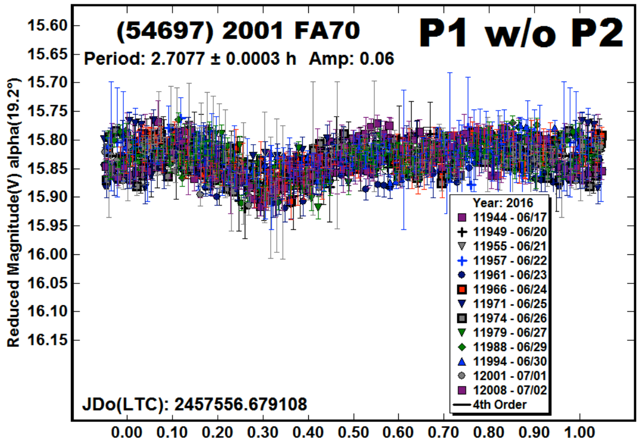


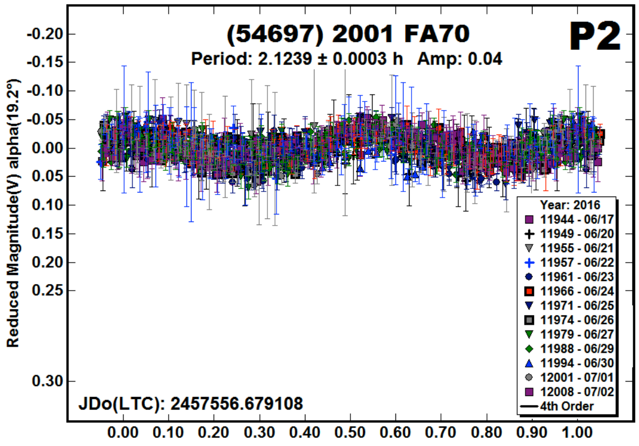


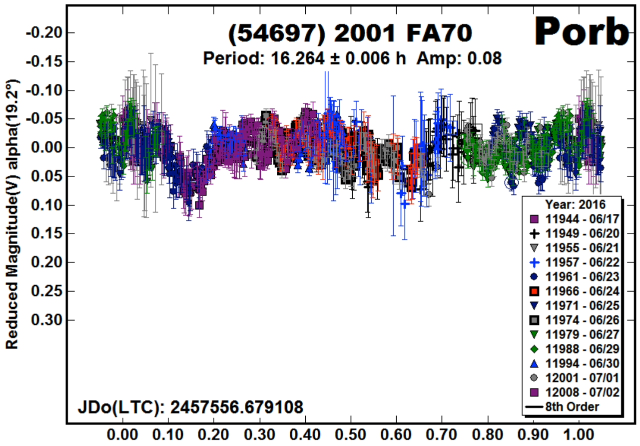
Warner (2015b) reported the discovery of a satellite for this Hungaria asteroid. The orbital period was 14.29 h and the estimated size ratio Ds/Dp ≥ 0.27. The 2016 results confirmed the existence of a satellite and the discovery values. The estimated size ratio from the 2016 data is Ds/Dp ≥ 0.31. The error bars for both results allow a value of 0.29, and so the two are in good agreement.

<u>(54697) 2001 FA70.</u> This Mars-crosser may be an interesting system. There seems little doubt that it is at least binary given the mutual events seen in the P_{Orb} plot. Using the shallower event, the estimated effective diameter ratio is Ds/Dp ≥ 0.19 ± 0.02. The mystery lies with what appears to be a third period (P_2= 2.1239 h, A_2= 0.04 mag).





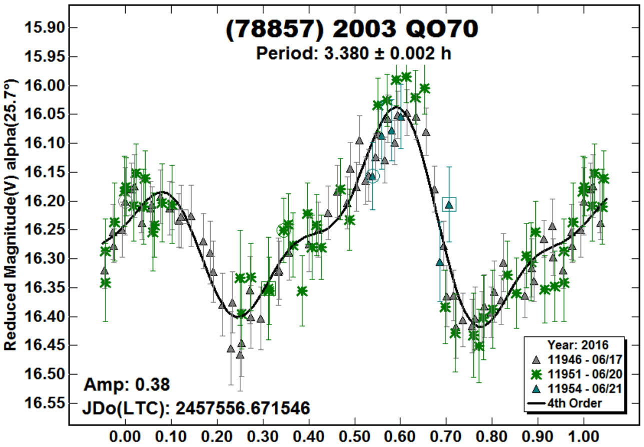




Without subtracting this period from the data during analysis, both the primary ("P1 w/o P2") and "POrb" plots have noticeably more scatter. P_1/P_2 = 1.274, which seems to indicate that one is not harmonically related to the other. If the two had a nearly integral ratio, then it would be possible, even likely, that the Fourier analysis had simply locked onto a multiple of the true value.

Assuming the second period has a physical cause, the two most likely conclusions are that the satellite is in asynchronous rotation and not locked to its orbital period, or that there is a third body in the system. A more extended high-quality data set will be required to help solve the mystery.

<u>(78857) 2003 QO70.</u> This Hungaria with an estimated size of 2.2 km offered one of the few bits of clarity. Three nights of observations each covered about a full cycle of the adopted period of 3.380 h. Despite the very small range of 0.65-0.70 where there are only one or two data points, the solution is considered secure.



Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. (*http://svo2.cab.inta-csic.es/vocats/cmc15/*).

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of

Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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ROTATION PERIOD DETERMINATIONS FOR 50 VIRGINIA, 58 CONCORDIA, 307 NIKE, AND 339 DOROTHEA

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(Received: 5 July)

Synodic rotation periods and amplitudes are found for 50 Virginia 14.320 ± 0.001 hours, amplitude 0.10 ± 0.01 magnitudes; 58 Concordia 9.895 ± 0.001 hours, 0.10 ± 0.01 magnitudes; 307 Nike 11.857 ± 0.001 hours, 0.20 ± 0.02 magnitudes; 339 Dorothea 5.9684 ± 0.0001 hours, 0.09 ± 0.01 magnitudes. Both 50 Virginia and 58 Concordia have irregular lightcurves.

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

50 Virginia. Historically, 50 Virginia has been a very difficult object with many different published rotation periods that are listed in the Asteroid Lightcurve Data Base (Warner, 2009). A period of 14.315 hours by Pilcher (2009) is the only period listed in that source as secure. New observations on 7 nights 2016 May 30 – July 3 provide a good fit to an irregular lightcurve with period 14.320 ± 0.001 hours, amplitude 0.10 ± 0.01 magnitudes (Figure 1). This is in good agreement with the secure 14.315 hour period previously found. Given the irregular shape of the lightcurve, the incorrect periods previously found can be explained as consequences of the full lightcurve being only partially sampled. Observers should be cautioned that except for amplitudes of 0.4 magnitudes or greater for which a bimodal lightcurve is the only feasible interpretation, a sufficient number of sessions to include full phase coverage for 3/2 and 2 times the suspected period are typically needed to obtain secure periods.

58 Concordia. Previous rotation period determinations have been made by Behrend (2006), 9.9 h; Behrend (2010), 9.905 h; Behrend (2011), 9.904 h; Gil-Hutton (1993), >16 h; Stephens (2006), 9.895 h; and Wang (2002), 9.89 h. New observations on 10 nights 2016 June 4 – July 5 provide a good fit to an irregular lightcurve with period 9.895 ± 0.001 hours, amplitude 0.10 ± 0.01 magnitudes

(Figure 2). This is in good agreement with several previous investigations.

<u>307 Nike.</u> Previous rotation period determinations have been made by Behrend (2005), 11.718 h; and by Lazar et al. (2001), 7.902 h. New observations on 7 nights 2016 Apr. 15 – May 28 provide a good fit to an unsymmetrical bimodal lightcurve with period 11.857 ± 0.001 hours, amplitude 0.20 ± 0.01 magnitudes (Figure 3). This is fairly close to the period by Behrend (2005) based on a much less dense lightcurve. Figure 4 presents a period spectrum between 7 and 17 hours and an attempt to plot a lightcurve to a period near 7.9 hours that shows a complete misfit, as evident in Figure 5. A plot phased to near 15.8 hours is not presented but also shows a complete misfit. The 7.902 hour period by Lazar et al. is now definitively ruled out.

<u>339 Dorothea.</u> Previous rotation period determinations have been made by Behrend (2002), 5.98 h; and Behrend (2005), 5.794 h. New observations on 7 nights 2016 Apr. 19 – June 21 provide a good fit to a lightcurve phased to 5.9684 ± 0.0001 hours with amplitude 0.09 ± 0.01 magnitudes (Figure 6). This is in good agreement with, and improves the accuracy of, previous period determinations.

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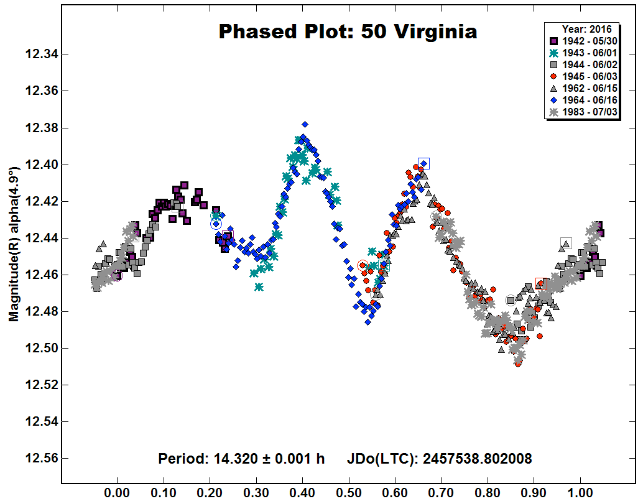

Figure 1: Lightcurve for asteroid 50 Virginia fit to a period of 14.320 ± 0.001 hours.

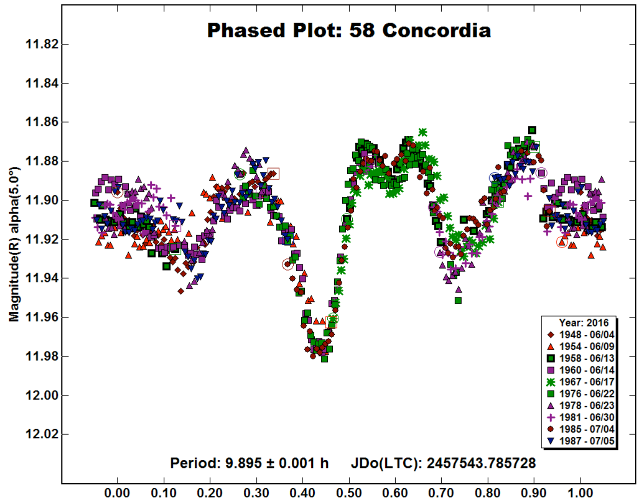

Figure 2: Lightcurve for asteroid 58 Concordia fit to a period 9.895 ± 0.001 hours.

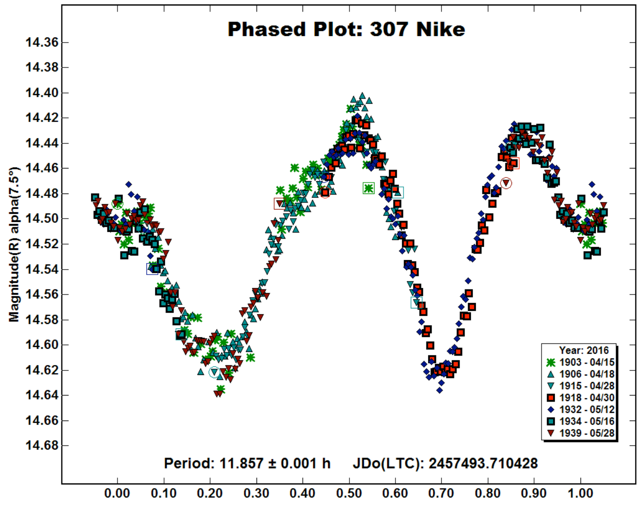

Figure 3: Lightcurve for asteroid 307 Nike fit to a period 11.857 ± 0.001 hours.

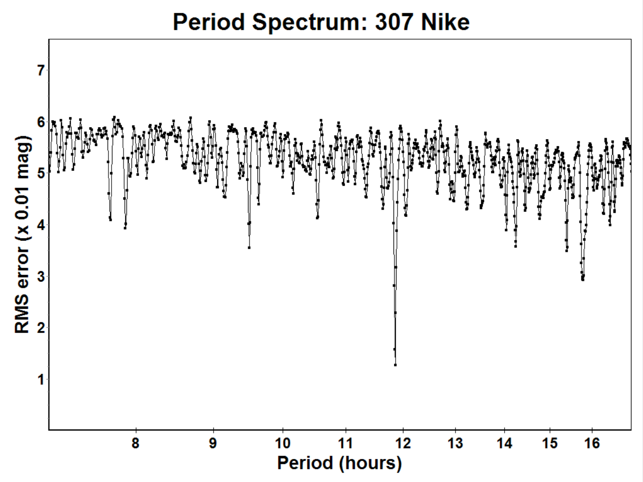

Figure 4: Period spectrum search for asteroid 307 Nike.

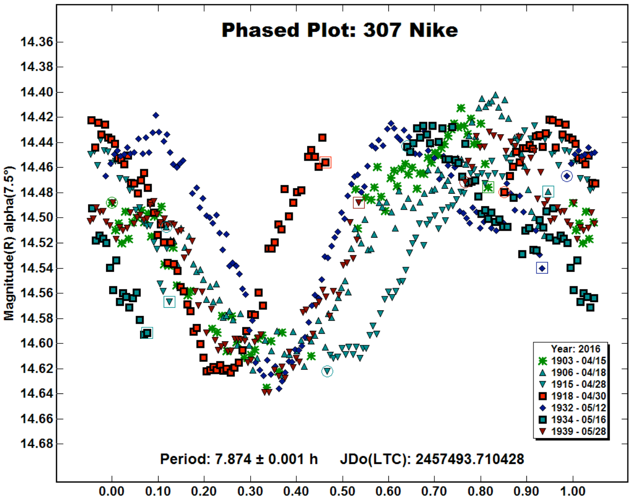

Figure 5: Attempted fit of 307 Nike measurements to a period of 7.9 hours, showing a misfit and ruling out this period.

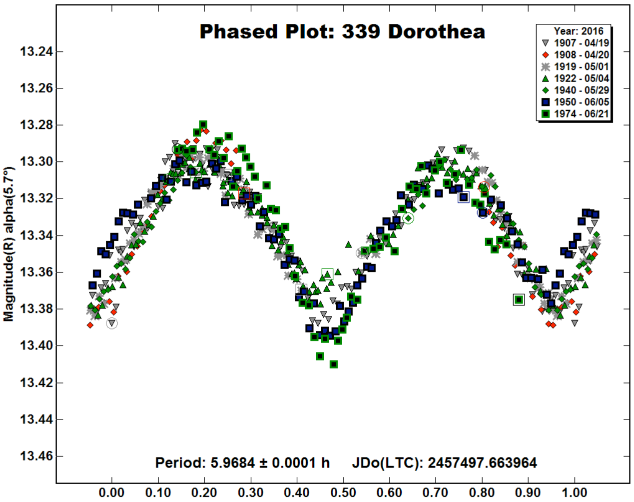

Figure 6: Lightcurve for asteroid 339 Dorothea fit to a period 5.9684 ± 0.0001 hours.

THREE ADDITIONAL CANDIDATES FOR THE GROUP OF VERY WIDE BINARY ASTEROIDS

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The very wide binary asteroids (VWBA) are a subgroup of binary asteroids that exhibit very long primary periods and, mostly, short secondary periods that are similar to those of the primary of “normal” small binary asteroids. It is unlikely that confirming mutual events will be seen by photometric observations, mostly because the orbital periods of the assumed satellites will be on the order of days. This paper introduces three additional candidates for this subgroup: (215442) 2002 MQ3, 2009 EC, and 2016 BU13. All three are considered to be among the more convincing examples that such systems exist.

CCD photometric observations of near-Earth (NEA) and main-belt asteroids (MBA) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 April to July. For details on the equipment and general processing and analysis procedures see Warner (2016). Three of the asteroids, all NEAs, were found to be suspected binaries that appear to belong to a subgroup that will be called the “very wide binary asteroids,” or VWBA for lack of a more appealing acronym.

Jacobson and Scheeres (2011) postulated that these systems might exist through a complex series of steps that involves fission, binary-YORP (BYORP), and tidal forces. BYORP is a thermal effect that acts on the primary and satellite of a binary system that can lead to the satellite’s orbit expanding to where it escapes from the primary or collapsing until the satellite and primary collide and possibly merge.

In the very wide binaries, the presumed primary has a large amplitude and very long period. In most cases, the period is in the hundreds of hours. The satellite, on the other hand, has a short period and low amplitude (P_2 = 2-4 hours, $A_2 < 0.2$ mag) that often resembles the attributes of the primary in a “normal” small binary asteroid system. Table I gives the primary and secondary periods and amplitudes for the 14 suspected members of this group.

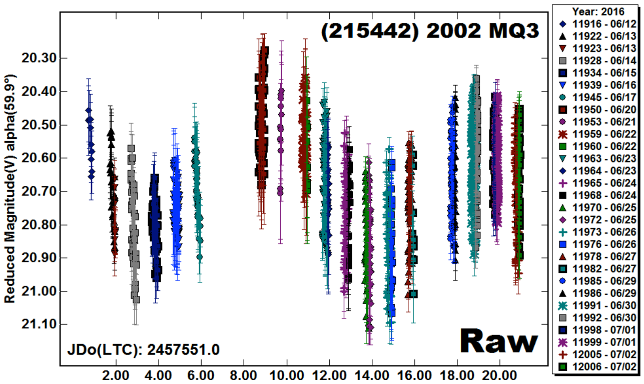
The primary (larger body) is assumed to have the long period and amplitude, otherwise the dilution of amplitude in the combined lightcurve would require that the smaller body be unreasonably elongated. According to Pravec *et al.* (2010), the limiting size ratio for binaries is about 0.6, or a difference of about 1.0 mag. For a secondary 1.0 mag fainter than the primary to produce a combined lightcurve amplitude of about 0.4 mag would require the secondary’s undiluted amplitude to be several magnitudes, or have near-infinite elongation, as well have a near-equatorial viewing aspect. Furthermore, for such a long period for the primary, the orbital period would be unlikely to synchronize to the spin period because the tidal locking force would be too weak (Alan Harris, private communications).

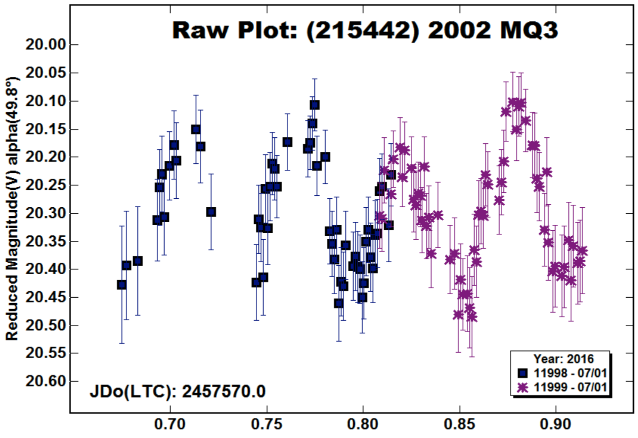
At the recent Binaries IV workshop in Prague, Czech Republic, (*http://www.boulder.swri.edu/binaries4-mtg/*) in 2016 June, some of the discussions concentrated on the long period primary. The general thought has been that after fission, the primary would usually spin up again. If the circumstances are right, it can also slow down. If the initial fission event created a satellite with almost but not quite enough energy to escape, this would lead to a very wide binary with a slowly-rotating primary body and a very long orbital period for the satellite. The very wide binaries appear to be evidence for this particular formation mechanism, but additional studies, theoretical and observational, are needed. For example, it's possible that the systems are not as rare as thought and that the systems found so far are where the primary has yet to spin up again.

In the plots below, the Y-axis gives the Johnson V "reduced magnitude." These are sky magnitudes converted to unity distances by applying –5*log (rΔ), with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the given phase angle, *e.g.*, alpha(6.5°), using G = 0.15, unless otherwise stated. The X-axis is the rotational phase, ranging from –0.05 to 1.05. If the plot includes an amplitude, *e.g.*, "Amp: 0.65", it is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*. The value is provided as a matter of convenience.

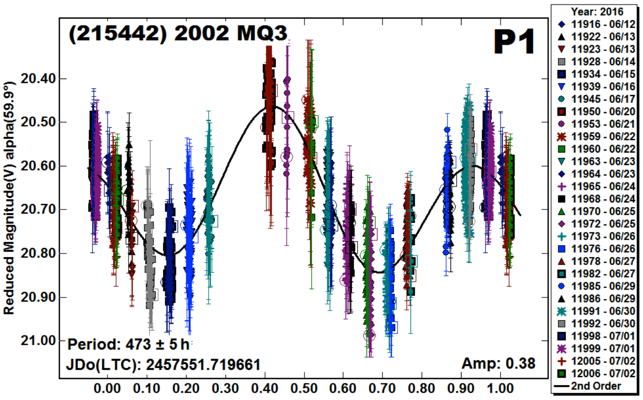
(215442) 2002 MQ3. This is probably the best candidate to-date for the VWBA group. Appropriately, it was first observed remotely from Prague during the Binaries IV workshop using telescopes at the Center for Solar System Studies in California.

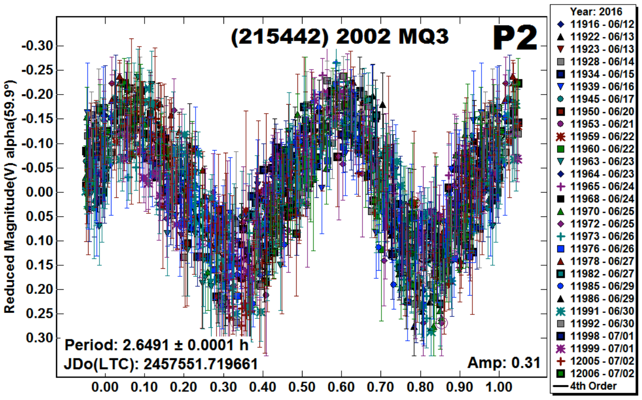
The "Raw" plot shows the data covering 2016 June 12 thru July 2. The long-period component of the lightcurve is easily seen. The raw plots of the individual nights (*e.g.*, July 1) clearly showed a short period component. Such obvious evidence for the secondary period is not usually seen.





When data from individual nights seem to be nearly flat with some minor amplitude "wiggles," the temptation is to attribute a slowly rising or falling trend from night-to-night to poor zero point calibrations in the photometry or an incorrect value for the phase slope parameter (G) used to account for changing phase angle and viewing geometry. If temptation wins, the individual sessions will be forced to align vertically by adjusting the zero points so that a single-period solution is found. If this temptation can be overcome and the data are left to fall where they may, a long period component may be revealed, as was the case for the three asteroids presented here.





For 2002 MQ3, the long-period component became apparent after a few nights. Initially, because of large gaps in the full-period lightcurve, a half-period solution using only second-order harmonics in the Fourier analysis was found as part of the dual-period search in *MPO Canopus*. With each night, the long period became more certain and the short-period solution stabilized at P_2 = 2.6491 ± 0.0001 h and A_2 = 0.31 ± 0.04 mag. Eventually, a full-period solution could be found (P_1 = 473 ± 5 h, A_1 = 0.38 ± 0.03 mag), although a second-order fit was still used to produce a smoother lightcurve.

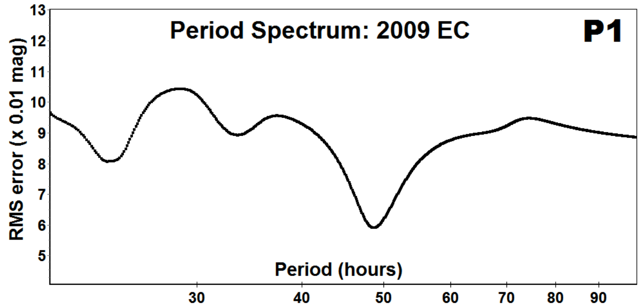
To get the final solution for P_1 required adjusting a few of the nightly zero points by up to 0.1 mag, which is the most usually expected when using the MPOSC3 catalog in *MPO Canopus* (see Warner, 2016). However, these were much smaller than required to get a single-period solution by forcing zero points such that the long-period component was arbitrarily removed.

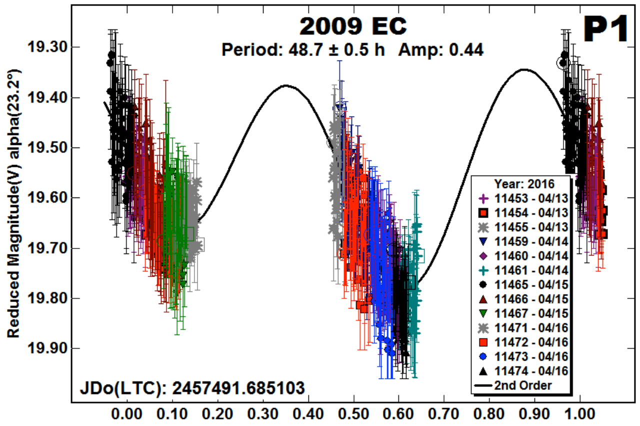
2009 EC. This is one of the unusual ("dark horse") candidates for the VWBA group, mostly because the long period is only 48.7 hours. Since this is almost commensurate with an Earth day, it was not possible to get complete coverage of P_1 from CS3 alone. The period spectrum shows that a half-period of about 24 hours could

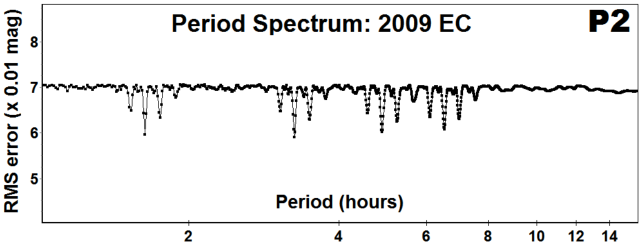
Num	Name	P_1	A_1	P_2	A_2	Ref
	2009 EC	48.6	0.44	3.261	0.13	*This paper*
	2014 PL51	205	0.43	5.384	0.09	Warner *et al.* (2015; *MPB* **42**, 31-34)
	2016 BU13	39.5	0.24	2.4499	0.11	*This paper*
1876	Napolitania	45.6	0.39	2.825	0.08	Warner (2016; *MPB* **43**, 57-65)
8026	Johnmckay	372	1.0	2.298	0.10	Warner (2011; *MPB* **38**, 33-36)
15778	1993 NH	113	0.61	3.320	0.04	Warner (2015; *MPB* **42**, 60-66)
19204	Joshuatree	480	0.25	21.25	0.08	Stephens et al. (2016; *MPB* **43**, 220-222)
23615	1996 FK12	368	0.23	3.646	0.09	Warner (2015; *MPB* **42**, 183-186)
67175	2000 BA19	275	0.25	2.716	0.07	Warner (2013; *MPB* **40**, 36-42)
119744	2001 YN42	625	0.52	7.24	0.07	Warner (2014; *MPB* **41**, 102-112)
190208	2006 AQ	182	0.25	2.621	0.08	Warner (2015; *MPB* **42**, 79-83)
215442	2002 MQ3	473	0.38	2.6491	0.31	*This paper*
218144	2002 RL66	587	0.32	2.49	0.04	Warner *et al.* (2010; *MPB* **37**, 109-111)
463380	2013 BY45	425	0.49	15.63	0.09	Warner (2016; *MPB* **43**, 240-250)

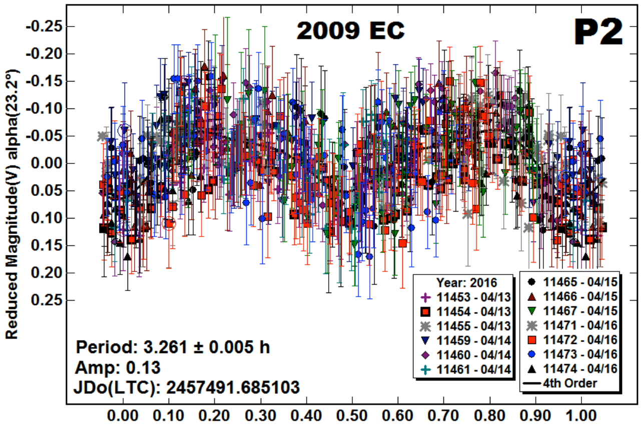
Table I. The very wide binary asteroid candidates. Periods are given in hours and amplitudes in magnitudes.

be reasonably eliminated. As with 2002 MQ3, the half-period solution based on a second-order fit was used for the initial stages of dual-period analysis. Otherwise, the Fourier model lightcurve had very large and physically impossible gyrations. Eventually a full-period, second-order fit was found and used in the final analysis to find the two periods.





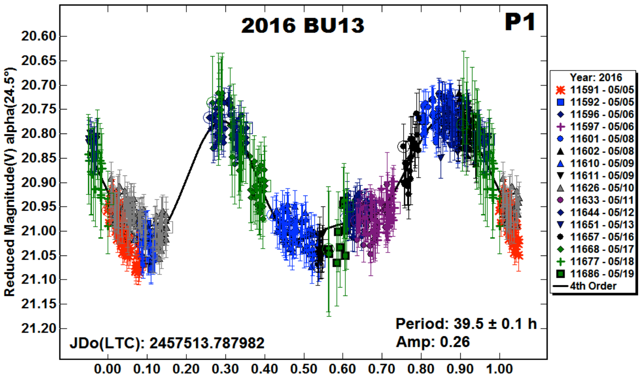


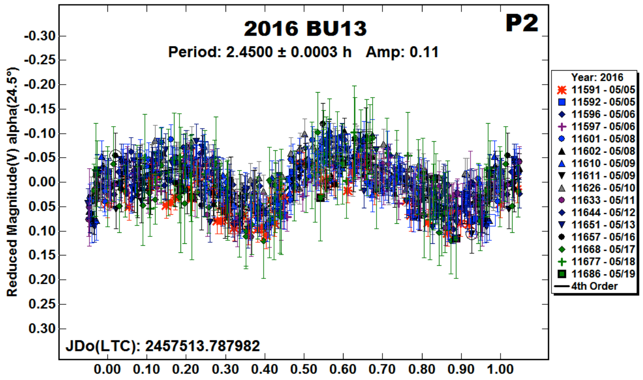


The period spectrum for P_2 shows a possible solution at about 3.2 hours as well as a half-period solution near 1.6 hours. The lack of a half-period solution near 2.5 hours and a trimodal lightcurve at a full-period near 5 hours helped confirm that $P_2 = 3.261$ h was most likely correct.

Despite the noisy data, the solution for both periods is considered sufficiently secure to list this NEA as another member of the very wide binary asteroid group.

2016 BU13. This is another unusual very wide binary asteroid candidate because the "short" primary period, *i.e.*, $P_1 \ll 100$ hours. The secondary period and amplitude (P_2, A_2), however, are in line with most of the other secondary members in the group.





After finding P_1 and P_2, a period search was done that subtracted both Fourier model curves. This was done to check that the result is a nearly flat line (no third period) or to spot obvious outliers. As with the other two candidates, there was no reasonable evidence for a third period.

Looking Back for Confirmation

Only two of the fourteen VWBA candidates have been observed at CS3 more than once. Duplication of results is an important element of good scientific method. The first object is 8026 Johnmckay. Observations in 2011 (Warner, 2011) found P_1 = 372 h based on a lightcurve with about 2/3 coverage of the full period. P_2 was 2.2980 h. In 2015 (Warner, 2015), a lightcurve with about 90% coverage but some large gaps fit P_1 = 363 h, or essentially the same result given the data sets and error bars. On the other hand, the P_2 lightcurve was almost flat and a period near the earlier one had to be forced. That gave P_2 = 2.2942 h but it would not have been accepted as a stand-alone solution, *i.e.*, without prior knowledge of the "correct" answer.

The other case was 19204 Joshuatree. Stephens and Warner (2016) found P_1 = 480 and P_2 = 21.25 h, the latter having small deviations from a bimodal lightcurve that made it a little suspect. These results prompted a second look at data from 2013 (Warner, 2013). There, the temptation to play with zero points had taken over and a single-period solution of 19.55 h was found. The original data were revised to use the original zero points. This led to a lightcurve covering only 25% of a lightcurve with a period of ~480 hours, but it had the approximately correct shape and amplitude. This emphasizes the need for having the patience to follow an asteroid long enough to assure a good solution and to trust the star catalogs – until there is good reason not to.

It will be important to do follow-up on all the known VWBA candidates and any others that may be found from here on. The design of the observing program at CS3 (and having up to nine telescopes) allows concentrating on these difficult targets, and they are difficult for a number of reasons. However, doing so in the past few years, looking carefully but with a healthy skepticism – not every long-period asteroid is binary, has allowed finding what may the first known members of a somewhat rare and highly interesting group of binary asteroids that will occupy the theorists for some time to come.

Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. (*http://svo2.cab.inta-csic.es/vocats/cmc15/).*

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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LIGHTCURVE ANALYSIS FOR ASTEROIDS 895 HELIO AND 1108 DEMETER

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Photometric observations of asteroids 895 Helio and 1108 Demeter were conducted on six nights in 2016 June from Tempe, AZ. Synodic rotation periods are 9.391 ± 0.008 h for 895 Helio and 9.846 ± 0.008 h for 1108 Demeter.

CCD photometric observations of main-belt asteroids 895 Helio and 1108 Demeter were carried out at the Command Module Observatory (MPC V02) in Tempe. Images were taken using a 0.32-m *f*/6.7 modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a Cousins R filter. Exposure time for all images was 180 s. The image scale after 2x2 binning was 1.76 arcsec/pixel.

Images were calibrated using bias, dark, and flat frames. Flats were acquired using an electroluminescent panel. Data analysis and period determination were accomplished using *MPO Canopus*. The asteroid and four or five comparison stars were measured with apertures of 9 or 11 pixels diameter, adopting Cousins R magnitudes for the comparison stars from the *MPO Canopus* internal catalogue. Despite high signal-to-noise, the nightly RMS scatter on the comparisons was only about 0.01 mag due to the urban location, some clouds, and bright moonlight during the observation interval.

For both asteroids, sets of three images were averaged to improve the quality of the lightcurve fit. The lightcurves are both fourth-order Fourier fits plotted at the same vertical scale and give observed magnitudes close to the Cousins R zero-point.

The asteroid lightcurve database (LCDB; Warner *et al*., 2009) was consulted to locate historical lightcurve results.

895 Helio is an outer main-belt asteroid with moderately high inclination. The rotation period for 895 Helio has been determined several times. Danforth (1994) first reported a period of 9.67 ± 0.2 h while Woo *et al.* (2001) found a much different period of 27.792 h. The most recent analysis by Behrend (2005) shows a period of 9.3959 ± 0.0004 h.

A total of 214 data points taken on six nights in 2016 June were used in this study, resulting in a period of 9.391 ± 0.008 h. This confirms Behrend's result within our mutual errors. The amplitude is 0.18 ± 0.01 mag.

1108 Demeter. Two LCDB entries were found for the rotation period of 1108 Demeter, a member of the Phoceea group. Stephens (2002) gives a period of 9.70 ± 0.01 h, agreeing with the period derived by Behrend (2001) of 9.701 ± 0.002 h.

Using 261 data points acquired on six nights in 2016 June, the rotation period of 1106 Demeter of 9.846 ± 0.008 h was calculated, which differs somewhat from previous determinations. There is no minimum in the periodigram of our data at 9.7 hours. The amplitude is 0.12 ± 0.01 mag.

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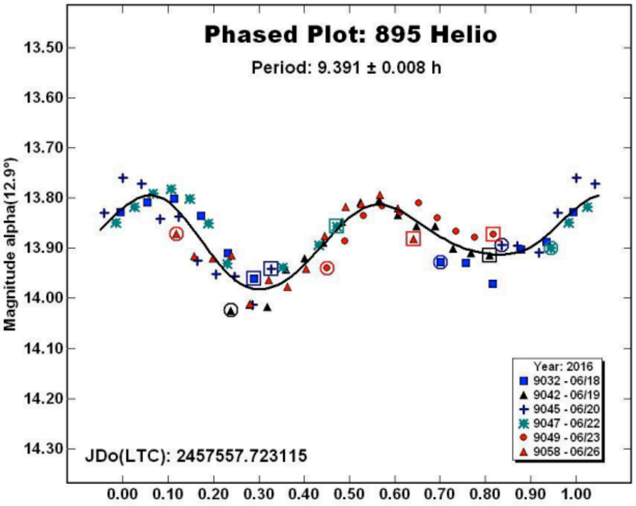
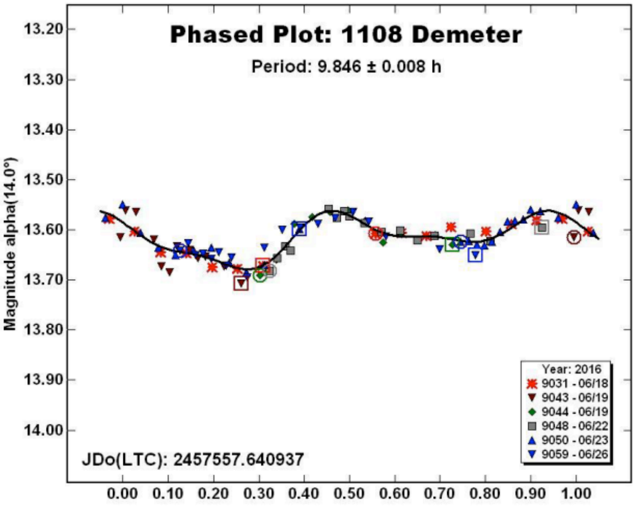
Warner, B.D., Harris, A.W., Pravec, P. (2009). "The asteroid lightcurve database." *Icarus* **202**, 134-146. Updated 2016 Feb. *http://www.minorplanet.info/lightcurvedatabase.html*

Woo H.S., Kim, S.L., Chun, M.Y., Park, M.G. (2001). "CCD Photometry of Two Asteroids (895) Helio and (165) Loreley." *Small Telescope Astronomy on Global Scales, ASP Conference Series Vol. 246, IAU Colloquium 183*, 251.





NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT CS3-PALMER DIVIDE STATION: 2016 APRIL-JULY

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(Received: 7 July 2016)

Lightcurves for 31 near-Earth asteroids (NEAs), obtained at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 April-July, were analyzed for rotation period and signs of satellites or tumbling.

CCD photometric observations of 31 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies-Palmer Divide Station (CS3-PDS) from 2016 January-April. Table I lists 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
Squirt	0.30-m f/6.3 Schmidt-Cass	ML-1001E
Borealis	0.35-m f/9.1 Schmidt-Cass	FLI-1001E
Eclipticalis	0.35-m f/9.1 Schmidt-Cass	ML-1001E
Australius	0.35-m f/9.1 Schmidt-Cass	STL-1001E
Zephyr	0.50-m f/8.1 R-C	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. If necessary, an elliptical aperture with the long axis parallel to the asteroid's path was used.

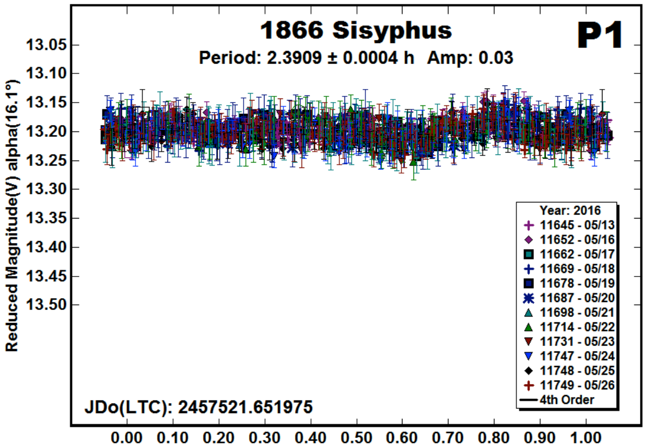
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the APASS catalog (Henden *et al*., 2009). When there were insufficient stars, the MPOSC3 catalog was used. This catalog is based on the 2MASS catalog (*http://www.ipac.caltech.edu/2mass*) with magnitudes converted from J-K to BVRI using formulae developed by Warner (2007). The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion reach 0.1 mag and more. There is a systematic offset between the two catalogs so, whenever possible, the same catalog is used throughout the observations for a given asteroid. Period analysis is also done with *MPO Canopus*, which implements the FALC algorithm developed by Harris (Harris *et al.,* 1989).

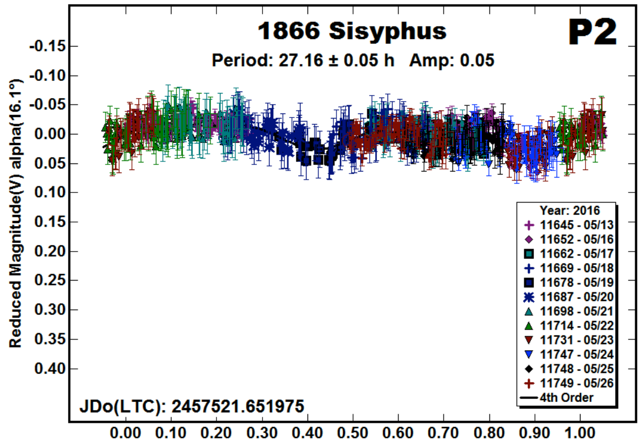
In the plots below, the "Reduced Magnitude" is Johnson V as indicated in the Y-axis title. These are values that have been converted from sky magnitudes to unity distance by applying –5*log (rΔ) to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The magnitudes were normalized to the given phase angle, *e.g.*, alpha(6.5°), using $G = 0.15$, unless otherwise stated. The X-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 a specific asteroid. 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, readers are strongly encouraged to check against the original references listed in the LCDB.

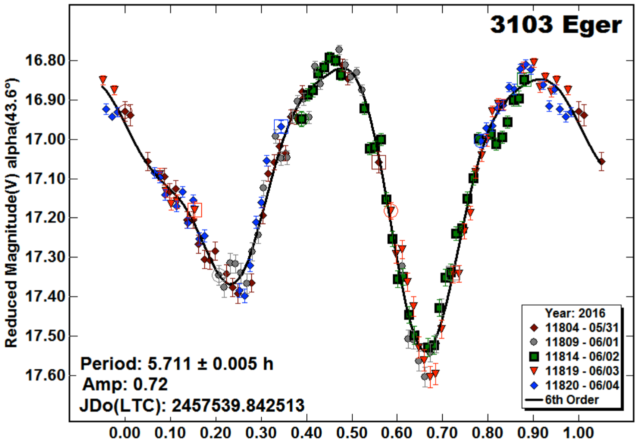
If the plot includes an amplitude, *e.g.*, "Amp: 0.65", this is the amplitude of the Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*. The value is provided as a matter of convenience.

1866 Sisyphus. Stephens *et al.* (2011) reported this NEA as a suspected binary with an orbital period for the tidally-locked satellite of 25.25 hours. On a web page dated in 2013, (Benner *et al.* (2013) reviewed radar data taken in 1985 and classified the system as binary. The 2016 observations from CS3-PDS add additional weight to the conclusion that the system is binary. The orbital period, $P_{Orb} = 27.16 \pm 0.05$ h, is longer than that reported by Stephens *et al.* (25.25 h), but their data set was noisy and the lightcurve had some gaps. The PDS lightcurve does not show obvious mutual events (occultations and/or eclipses) but does have the signature shape of an elongated satellite that is tidally-locked to its orbital period. Given the combined evidence in hand, Sisyphus should be considered a confirmed binary asteroid.

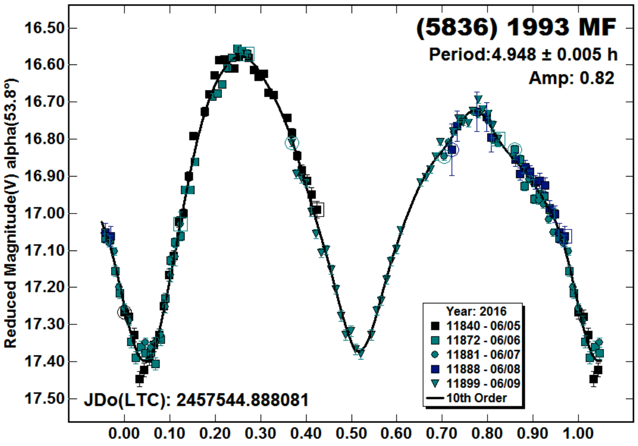




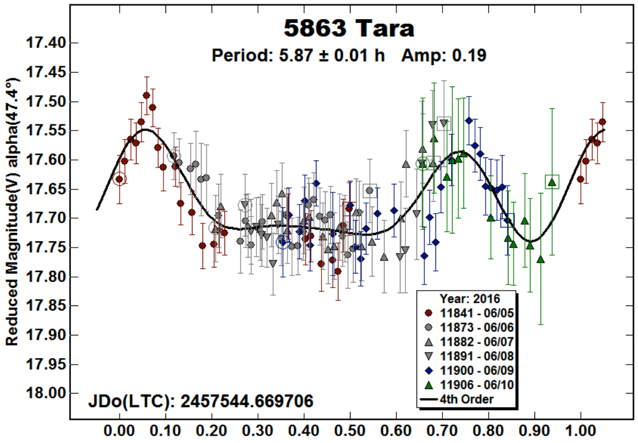
3103 Eger. The period for Eger has been reported on several occasions: Wisniewski (1991, 5.709 h) and Warner (2014, 5.715 h). The period found from the analysis of the 2016 data is in good agreement with those earlier results.



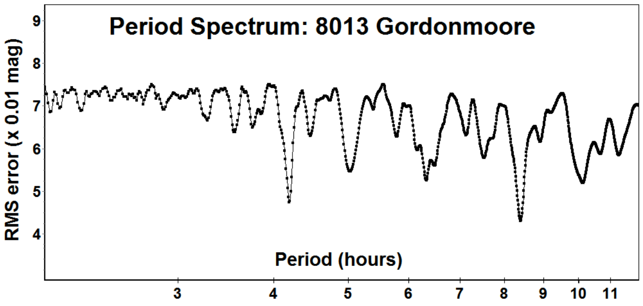
(5836) 1993 MF. The period found from the 2016 data agrees with earlier results, *e.g.*, Mottola *et al.*, (1995, 4.959 h).

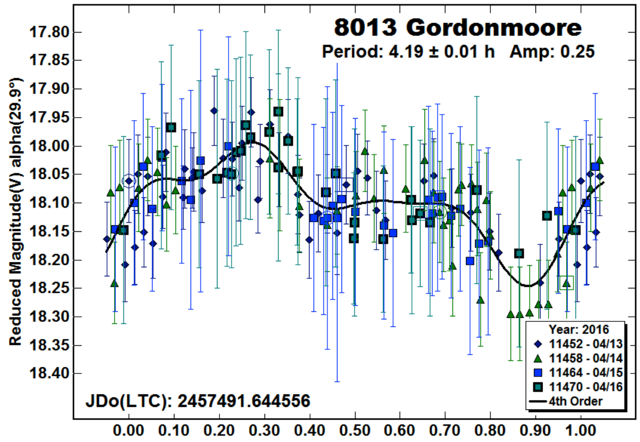


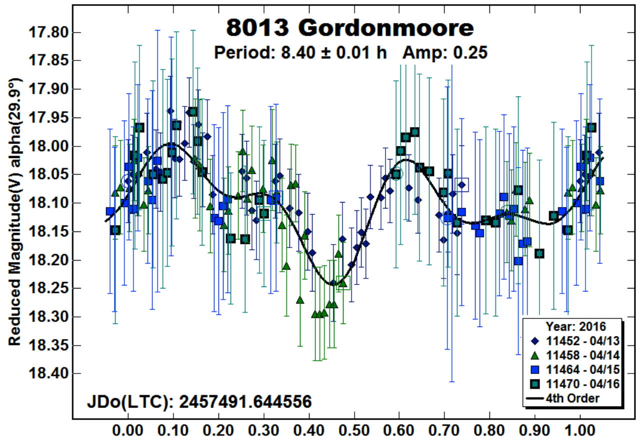
5863 Tara. The 2016 June observations were in follow-up to those in 2016 March (Warner, 2016b). In the three month period, the amplitude increased by 0.02 mag while the phase angle increased from 10° to 48°. The synodic periods were essentially the same given that the June data did not allow a higher quality result.



8013 Gordonmoore. The only previous entry with a period in the LCDB was from Hoffmann (1991), who reported 6 hours (U = 1; probably wrong). The 2016 PDS data led to two possible solutions: 4.19 ± 0.01 h or 8.40 ± 0.01 h. Given the low SNR of the data, the two solutions have about an equal chance of being correct. Observations of higher quality will be needed to resolve the ambiguity.

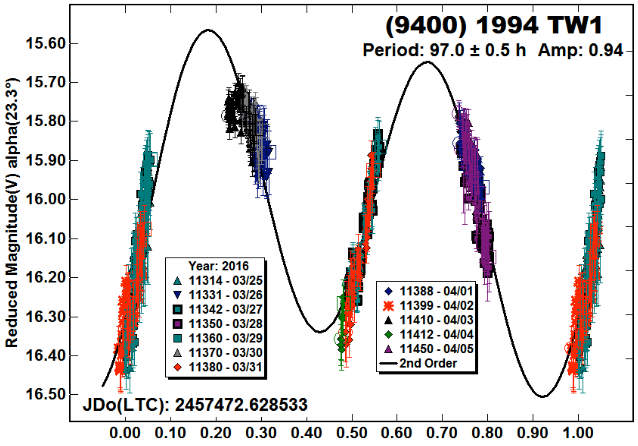




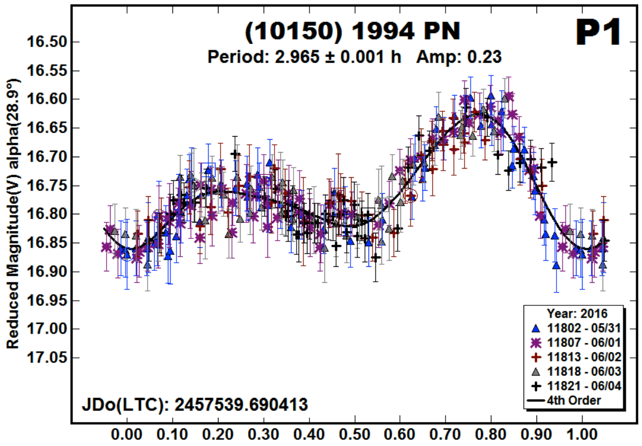


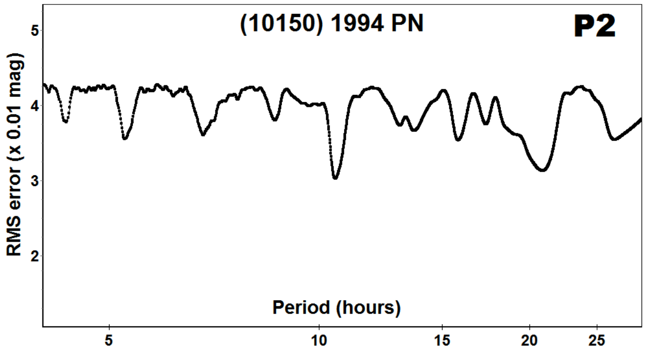
(9400) 1994 TW1. This NEA is a suspected tumbler, *i.e.*, an asteroid in non-principal axis rotation (NPAR). See Pravec *et al.* (2005, 2014) for a thorough discussion of these objects. While the data from 2016 appear to fit the Fourier model fairly well, there are slight deviations and the slopes of at least two of the individual sessions seem too steep. A similar result was found based on data obtained in 2015 (Warner, 2016a) when a period of 82.8 h and amplitude of 0.80 mag were reported.

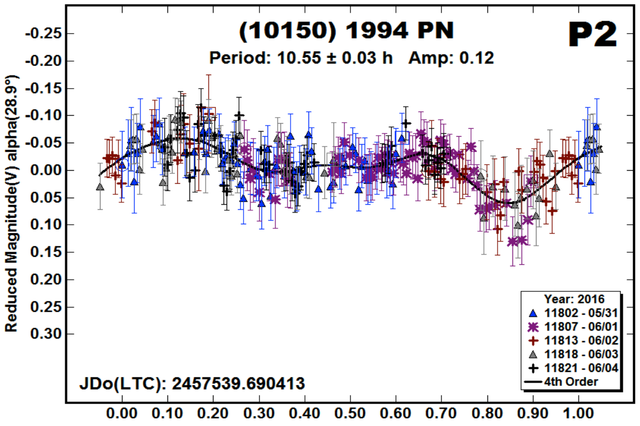
Tumbling is not unexpected for this 3 km NEA. The shorter rule of thumb found by Pravec *et al.* (2014) for the asteroid to dampen from NPAR to single axis rotation (PAR) is more than the age of the Solar System.



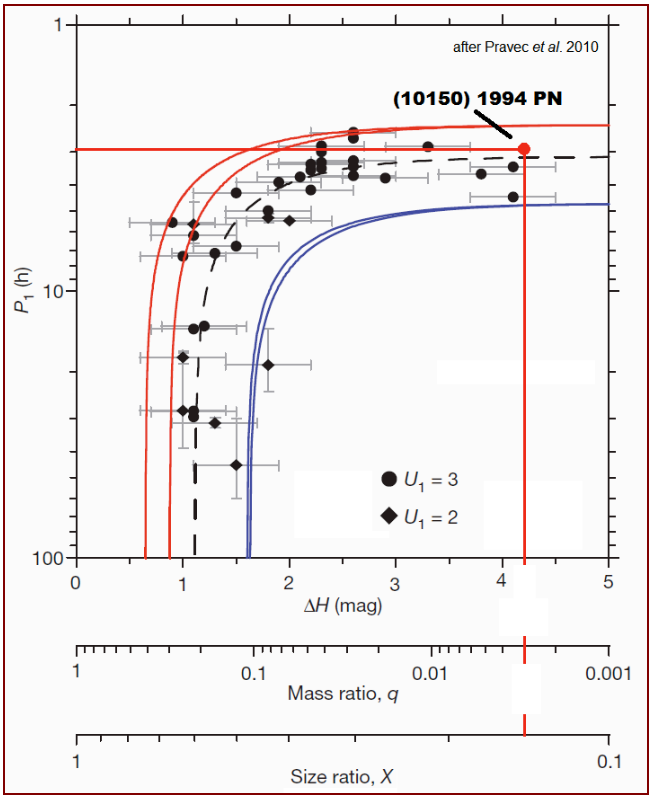
(10150) 1994 PN. This 2.6 km NEA may be a newly discovered binary. The proposed primary period of 2.965 h is within the range of those found for most small binary systems.





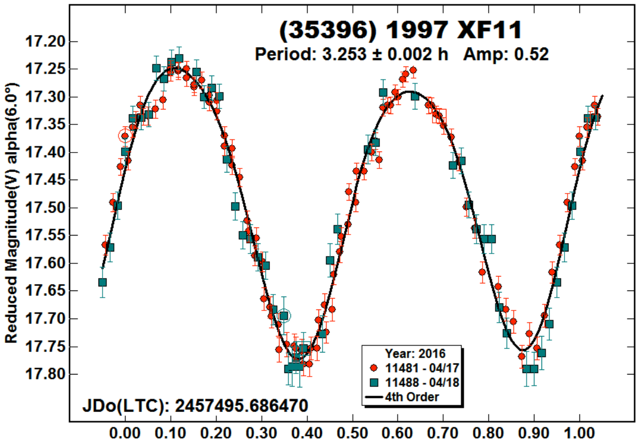


The secondary lightcurve appears to be showing signs of a tidally-locked satellite with mutual events. Assuming that this is the case and the shallower of the two events is ~ 0.02 mag deep, this gives an effective satellite-to-primary diameter ratio of Ds/Dp ≥ 0.13. Based on work by Pravec *et al.* (2010), this system fits within expected bounds.

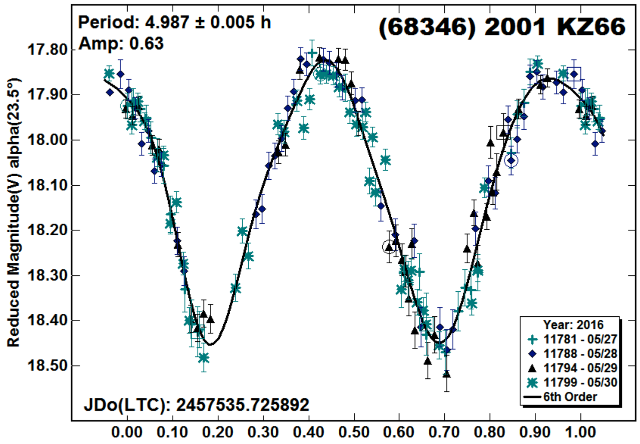


The evidence for a satellite is *far* from conclusive. Future observations are strongly encouraged.

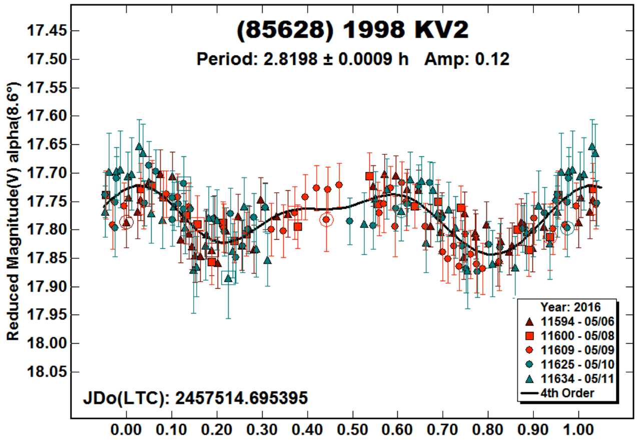
(35396) 1997 XF11. Previous results for 1997 XF11 include Slivan *et al.* (2003, 3.2566 h), Behrend (2002, 3.25765 h), and Pravec *et al.* (2002w, 3.2563 h). All groups observed the asteroid in 2002 November and reported an overall amplitude range of 0.71 to 0.93 mag. The period found from the 2016 PDS data agrees with those earlier results.



(68346) 2001 KZ66. Based on radar observations, Benner *et al.* (2006) reported a rotation period of 2.7 for this NEA. The PDS data lead to a more likely period of 4.987 h. This is based on the large amplitude and relatively low phase angle, both of which essentially require a bimodal lightcurve (Harris *et al.*, 2014).



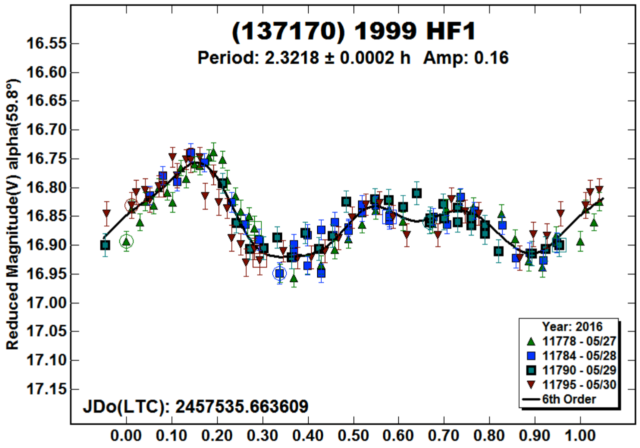
(85628) 1998 KV2. Warner (2014) reported a period of 2.819 h. Follow-up observations in 2016 February and March (Warner, 2016b) along with those from May give the same period. As shown in the table below, the 2016 amplitudes generally followed the accepted behavior of decreasing amplitude with decreasing phase angle (Zappala *et al.*, 1990). The low quality of the February lightcurve along with shadowing effects at the high phase angle may account for why the amplitude was not larger.



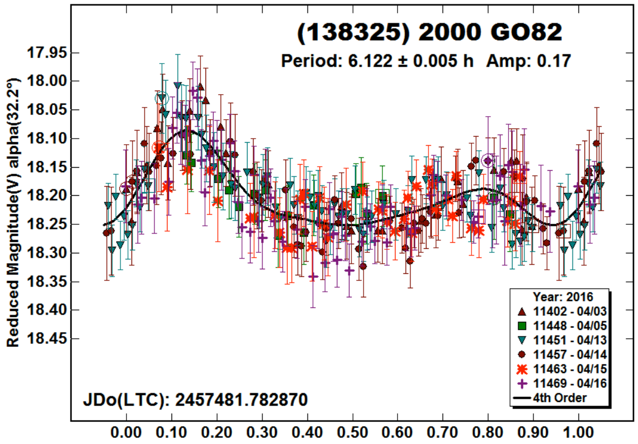
Mid-Date	Phase	Amp
Feb 11	56.5	0.16
Mar 15	43.8	0.18
May 09	8.6	0.12

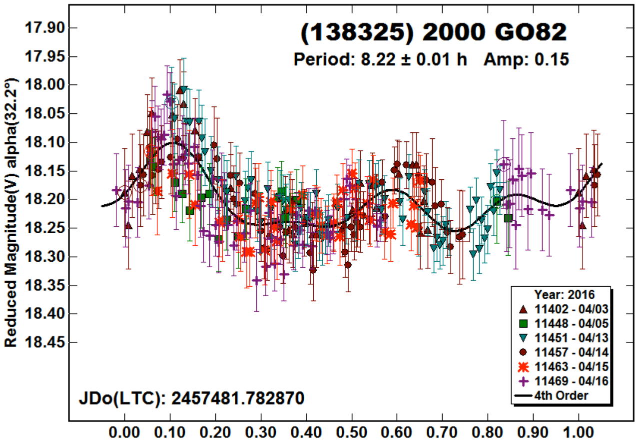
(137170) 1999 HF1. This is a known binary (Pravec *et al.*, 2006) with an orbital period of 14.03 h. The estimated effective diameter ratio is Ds/Dp ≥ 0.24. Marchis *et al.* (2012) confirmed the discovery, finding an orbital period of 14.04 h and Ds/Dp ≥ 0.23.

The 2016 PDS observations were at almost the same phase angle bisector longitude and latitude as for the 2002 observations by Pravec *et al.* (2006). Even so, there were no obvious signs of the satellite in the PDS data. It would have seemed probable that some signs of mutual events or at least a secondary period would have been seen. The reason why not may lie in the fact that the observing runs were only about 3 hours. Given that, it's possible that the narrow observing windows were timed "just so" and were all in-between the times of the mutual events.

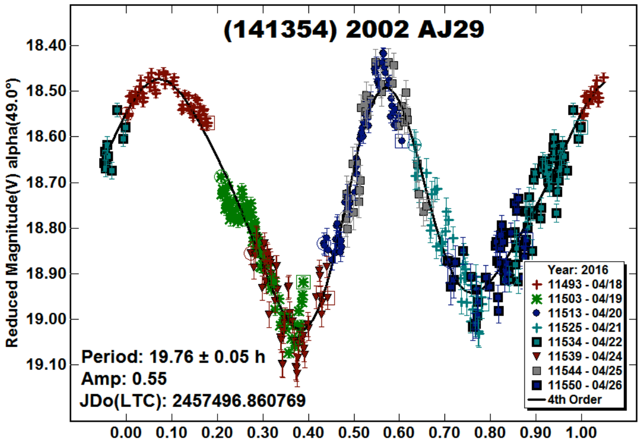


(138325) 2000 GO82. These appear to be the first reported results for this NEA. Unfortunately, they are ambiguous since the data fit nearly as well to periods of 6.122 h and 8.22 h. The two differ by almost exactly one rotation over 24 hours. The asymmetry of the solution for 6 hours makes it questionable, but the fit at 8 hours may be one of a *fit by exclusion*, which is where the Fourier analysis finds a minimum RMS by also minimizing the number of overlapping (in rotation phase) data points.

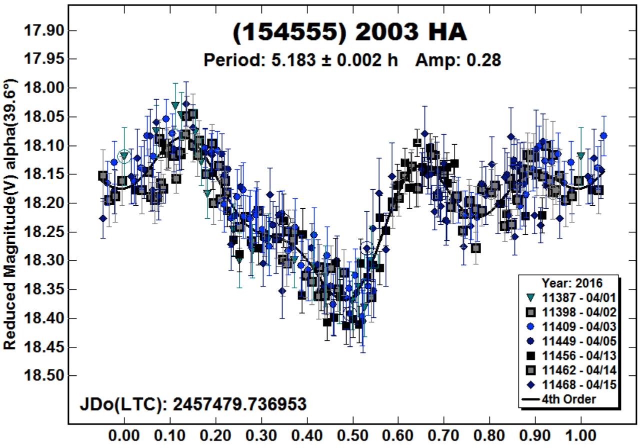


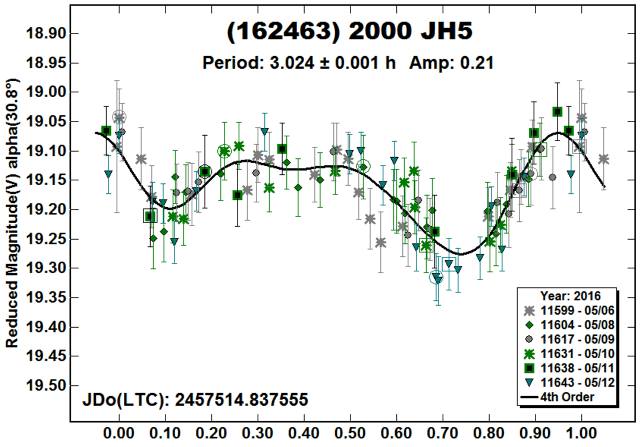


<u>(141354) 2002 AJ29</u>. Despite the gaps in the lightcurve and noisy data, the solution of *P* = 19.76 h seems fairly secure for this 1 km NEA. No previous results were found in the LCDB.



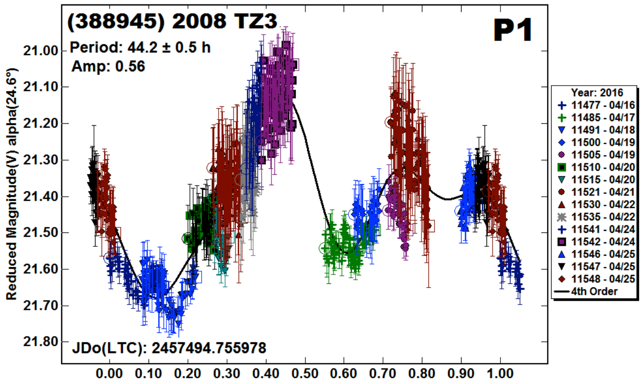
<u>(154555) 2003 HA and (162463) 2000 JH5</u>. There were no previous results in the LCDB for these two NEAs.

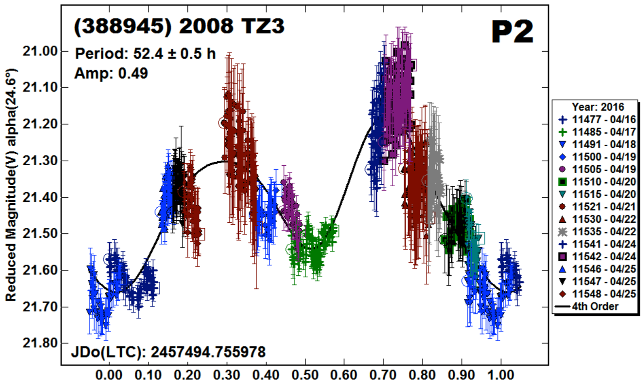




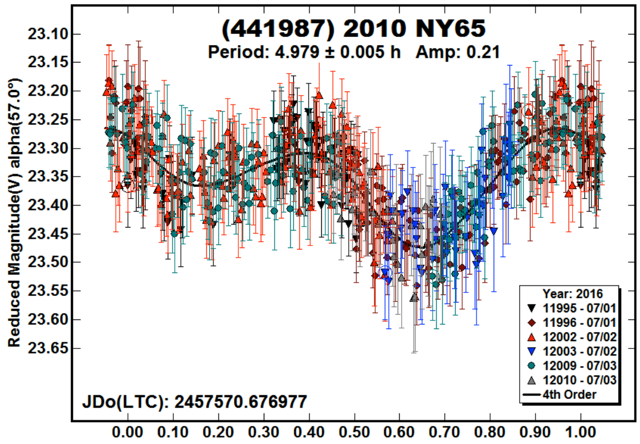
<u>(388945) 2008 TZ3</u>. The observations of this NEA were made partly in support of planned radar observations. Unfortunately, the those were cancelled due to maintenance. The asteroid does remain on the Goldstone schedule for 2018 and 2020.

From all appearances, the asteroid is tumbling. The two periods reported here are best single period fits. They could be integral multiples of the true periods of rotation or precession. The plots use "P1" and "P2" for clarity; they do not necessarily respectively represent a solution for rotation and precession,

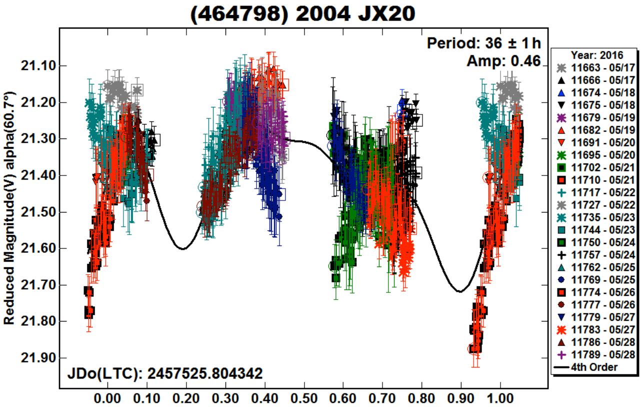




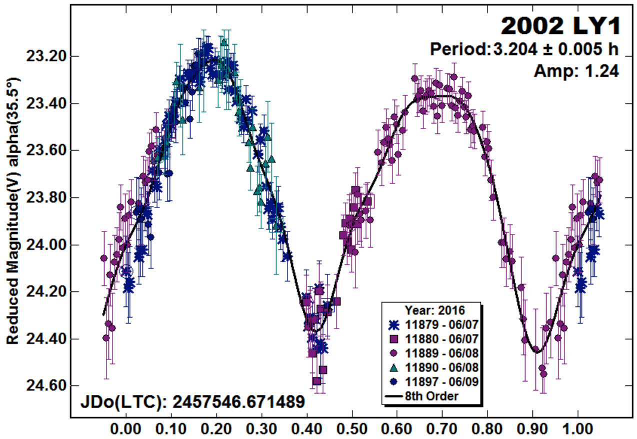
<u>(441987) 2010 NY65</u>. Radar observations in 2014 and 2015 (*http://echo.jpl.nasa.gov/asteroids/2010NY65/2010NY65_planning.2016.html*) gave an upper limit for the rotation period of 6.4 hours. The data from three nights in 2016 July, although having a somewhat low SNR, produce a reliable solution of 4.979 h, which is not too far removed from the radar estimate.



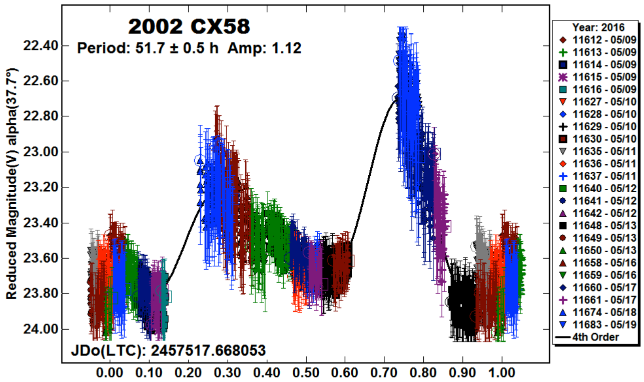
<u>(464798) 2004 JX20</u>. This NEA appears to be another tumbler. However, it was not possible to find even a probable rotation period due to the complexity of the data set and that many solutions were nearly commensurate with an Earth day (Petr Pravec, private communications). Data from at least a second station well-removed in longitude may have allowed finding a solution, or at least removing some ambiguities. Given the high phase angle, and tumbling aside, the lightcurve may have been rapidly evolving, complicating period analysis even further.



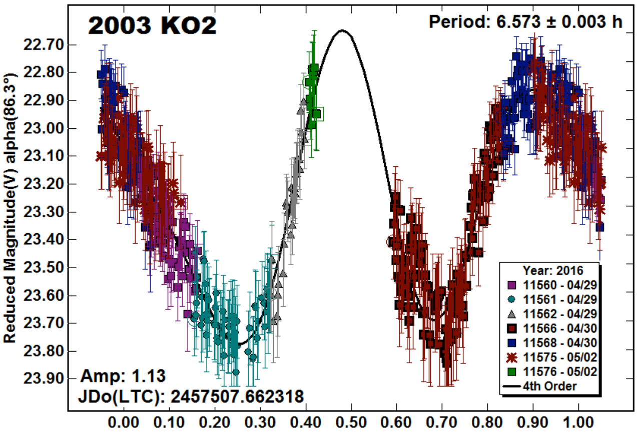
<u>2002 LY1</u>. The period spectrum showed several possible solutions, but a search around the potential half-periods clearly favored a full period of 3.204 h. Supporting this is that with so large an amplitude, only a nearly symmetrical bimodal solution is physically possible (Alan Harris, private communications).



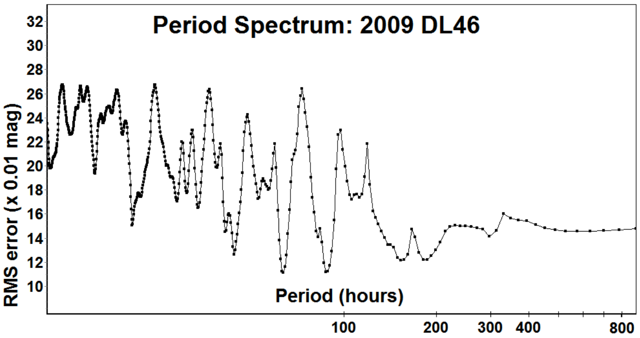
<u>2002 CX58</u>. Radar observations (*http://www.naic.edu/~pradar/asteroids/2002CX58/2002CX58.2016May09.p0175Hz.cw.gif*) show a narrow Doppler frequency spread, indicating slow rotation. The lightcurve data support this, leading to a period of 51.7 h. Here again, the reported period is the most dominant one in a single period search. It's likely that the asteroid is tumbling.

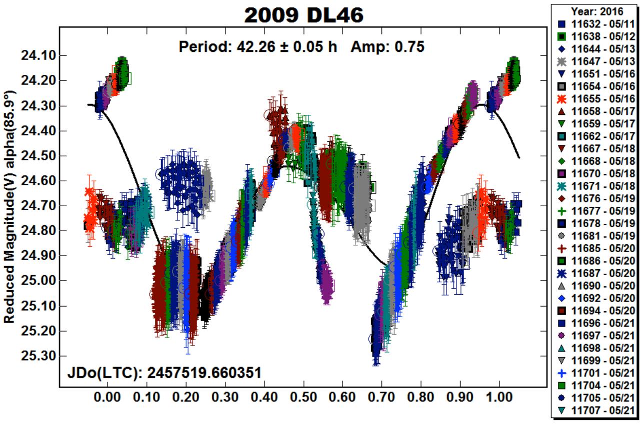


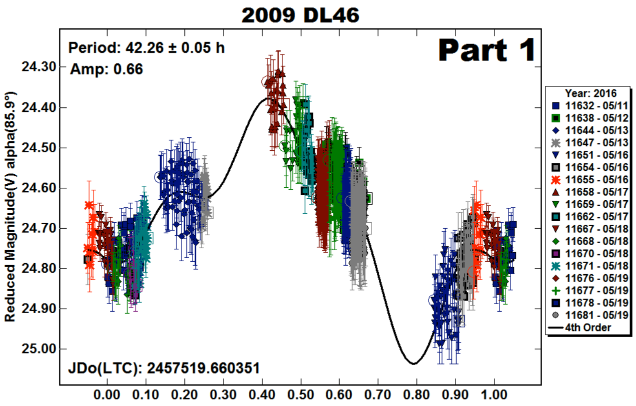
<u>2003 KO2</u>. Planned observations of this potentially hazardous asteroid (PHA) were another victim of maintenance at the Goldstone facility. Despite the gaps in the lightcurve, based on the individual nights, the solution is considered reasonably secure. The asteroid returns for a somewhat favorable apparition in 2021 May, when it will reach V ~ 17.8.

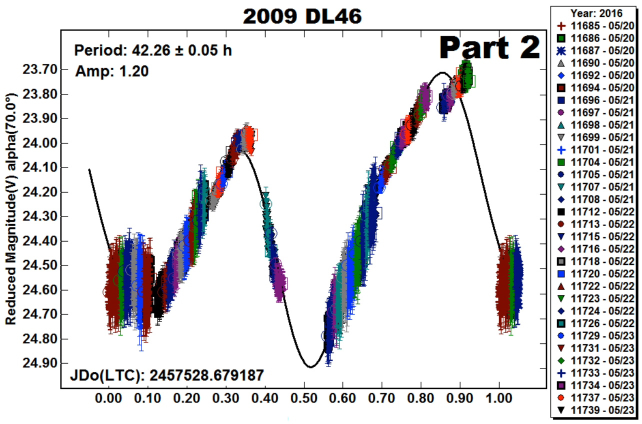


<u>2009 DL46</u>. There seems little doubt that this asteroid is in a tumbling state. It's the dominant period that is in doubt. The PDS data support one of about 42 hours. The period spectrum favors about 65 hours, but that produces a three-peaked solution and so the solution near 2/3 of that, or about 44 hours, was adopted.



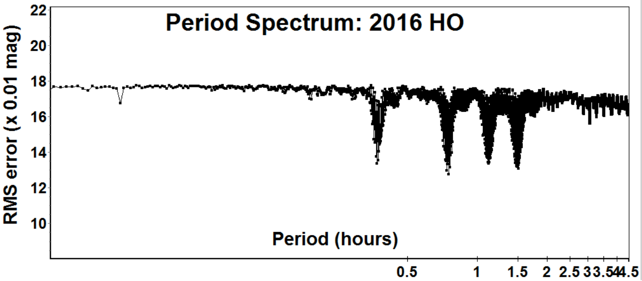


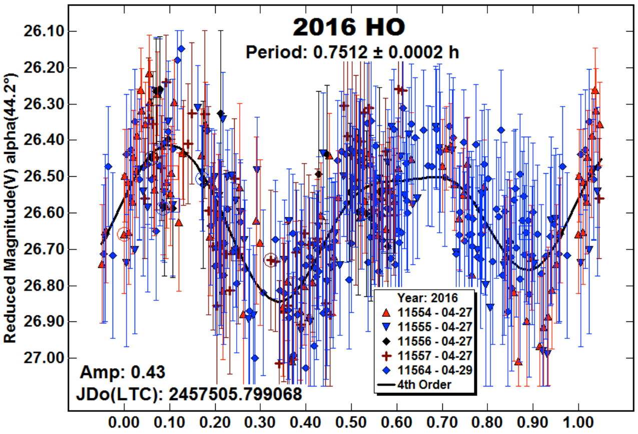




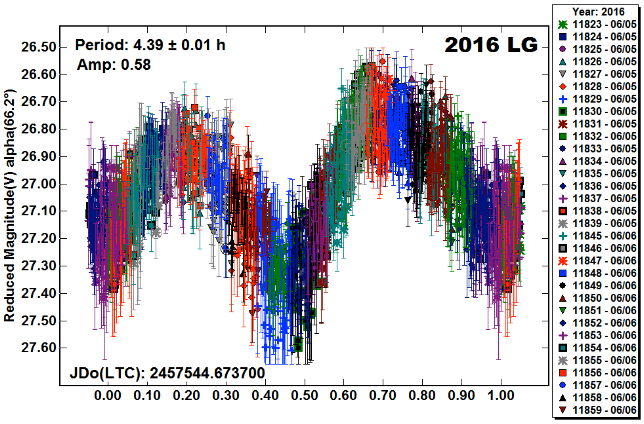
The "Part 1" and "Part 2" plots separate the overall data set into two blocks, one ranging from May 11-19 (phase angle 86-75°) and the other from May 20-23 (phase angle 71-50°). These would seem reasonable approximations but radar data (Ellen Howell, private communications) gave a preliminary indication of a period around 400 hours. Further analysis and future observations may resolve the mystery. Unfortunately for photometry observers, the next apparition a V < 20 is not until 2046 June.

2016 HO. The low SNR of the data made analysis of this NEA difficult. The adopted solution is based on, rightly or wrongly, a bimodal solution, which gives a period of 0.7512 ± 0.0002 h (45.07 minutes). The estimated diameter is only 20 meters, so a super-fast rotation period is not unusual.

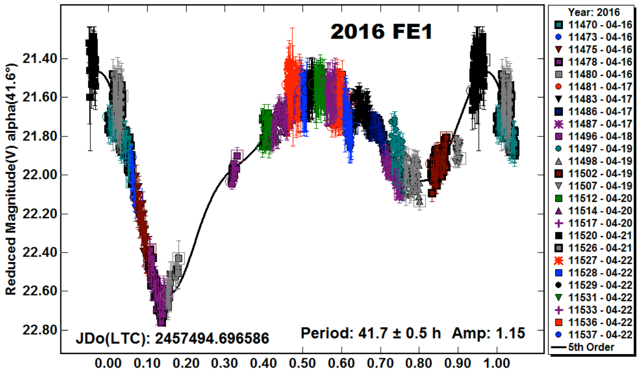




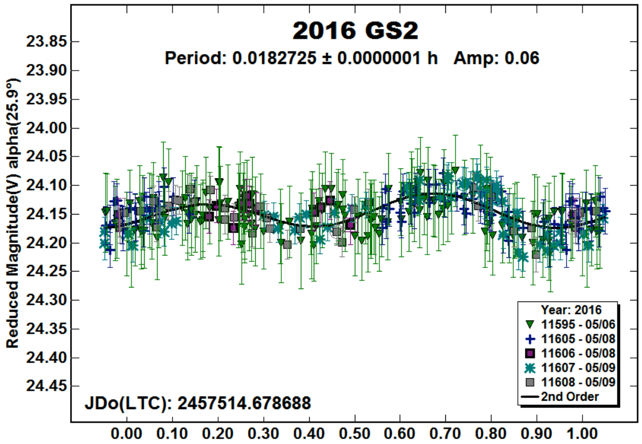
2016 LG. Noisy data (low SNR) can still provide a secure solution, if the data set has a large number of data points and the amplitude of the lightcurve is at least that of the error bars. Such was the case for this NEA with an estimated size of only 26 meters. Maybe somewhat unusual is the period of 4.39 h. Many objects of such small size are either super-fast rotators and/or tumbling.

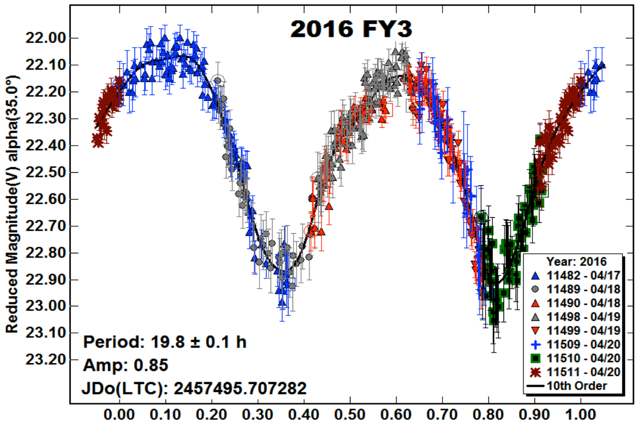


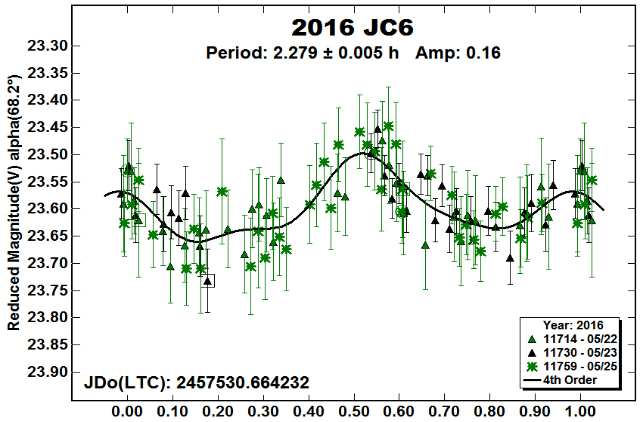
2016 FE1. Using either of the rules of thumb given by Pravec *et al.* (2005, 2014) for the time it takes an asteroid to dampen from a tumbling state to single axis rotation, this asteroid might be expected to be in a tumbling state. The PDS data seem to bear this out with some sessions having a slope opposite to the Fourier model curve and the unusual shape. However, tumbling is not a certainty. It is possible that the unusual shape is due to shadowing effects at higher phase angles, but low-level tumbling seems more likely.

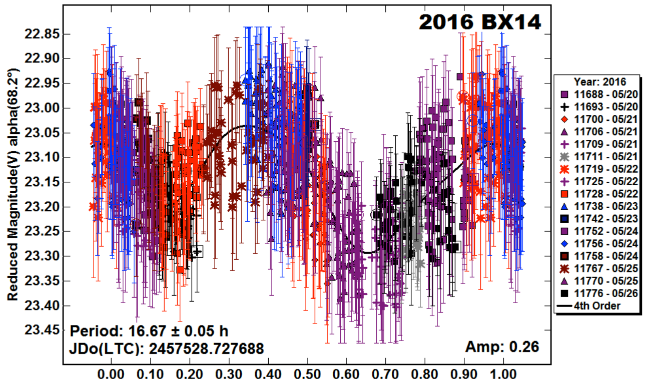


2016 GS2, 2016 FY3, 2016 JC6, and 2016 BX14. There were no previous entries in the LCDB for these four NEAs. 2016 GS2 has an estimated diameter of only 75 meters. Radar observations (*http://echo.jpl.nasa.gov/asteroids/2009DL46/2009DL46_planning .html*) support the super-fast rotation period. No results from radar observations for the other three asteroids were found. A solution, although not fully secure, for 2016 BX14 was possible because the amplitude was at least equal to the error bars.

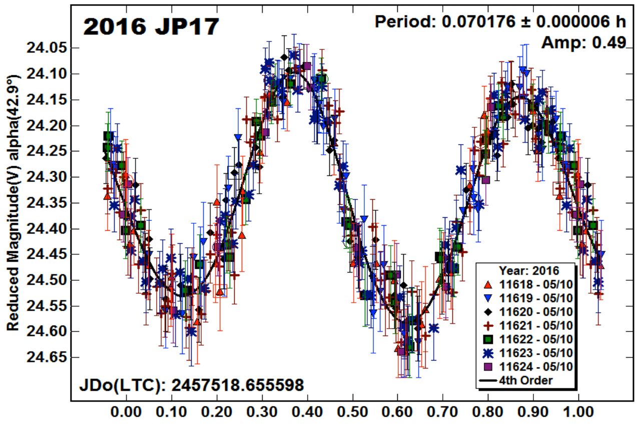








<u>2016 JP17</u>. This 70 meter NEA is another super-fast rotator, the period being only 4.21 min. The large amplitude makes the solution secure.



Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. (*http://svo2.cab.inta-csic.es/vocats/cmc15/).*

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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Number	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Grp
1866	Sisyphus	05/13-05/26	782	16.1,19.4	211	26	2.3909	0.0004	0.03	0.01	NEA
3103	Eger	05/31-06/04	158	43.6,44.0	298	20	5.711	0.005	0.76	0.03	NEA
5836	1993 MF	06/05-06/09	157	53.8,55.4	307	10	4.948	0.005	0.82	0.03	NEA
5863	Tara	06/05-06/10	125	47.4,48.9	193	21	5.87	0.01	0.19	0.03	NEA
8013	Gordonmoore	04/13-04/16	139	30.0,31.7	171	13	8.4	0.01	0.25	0.03	NEA
9400	1994 TW1	03/25-04/05	657	23.3,25.0	156	16	97.1	0.5	1.04	0.05	NEA
10150	1994 PN	05/31-06/04	254	28.9,29.0	264	44	2.965	0.001	0.23	0.02	NEA
35396	1997 XF11	04/17-04/18	136	6.0,7.3	203	-1	3.253	0.002	0.52	0.02	NEA
68346	2001 KZ66	05/27-05/30	151	23.5,24.2	258	20	4.987	0.005	0.63	0.03	NEA
85628	1998 KV2	05/06-05/11	177	8.6,9.2	225	8	2.82	0.001	0.12	0.02	NEA
137170	1999 HF1	05/27-05/30	137	59.7,15.7,58.9	133	22	2.3218	0.0002	0.17	0.01	NEA
138325	2000 GO82	04/03-04/16	280	32.1,40.5	221	32	6.122	0.005	0.17	0.02	NEA
141354	2002 AJ29	04/18-04/26	389	49.0,31.7	249	11	19.76	0.05	0.55	0.03	NEA
154555	2003 HA	04/01-04/15	287	39.6,44.4	202	43	5.183	0.002	0.28	0.02	NEA
162463	2000 JH5	05/06-05/12	95	30.9,26.1	250	17	3.024	0.001	0.21	0.02	NEA
388945	2008 TZ3	04/16-04/25	775	24.6,23.8	217	13	44.2	0.5	0.56	0.05	NEA
441987	2010 NY65	07/01-07/03	511	56.6,51.9	259	21	4.979	0.005	0.21	0.03	NEA
464798	2004 JX20	05/17-05/28	1333	60.8,49.2	243	34	36	1	0.38	0.05	NEA
	2002 LY1	06/07-06/09	235	36.3,48.7	235	4	3.204	0.005	1.24	0.05	NEA
	2002 CX58	05/09-05/19	1926	37.2,17.5	236	15	51.7	0.5	1.12	0.1	NEA
	2003 KO2	04/29-05/03	778	85.7,74.8	177	6	6.48	0.01	1.28	0.05	NEA
	2009 DL46	05/11-05/26	3320	85.4,24.3	210	17	42.26	0.05	1.08	0.05	NEA
	2016 HO	04/27-04/29	371	44.7,53.2	241	11	0.7512	0.0002	0.43	0.05	NEA
	2016 LG	06/05-06/06	1757	63.7,54.4	234	21	4.39	0.01	0.58	0.05	NEA
	2016 FE1	04/16-04/20	1825	41.4,27.7	213	20	41.7	0.5	1.15	0.05	NEA
	2016 GS2	05/06-05/09	287	26.5,31.4	219	14	0.0182725	1.0E-7	0.06	0.01	NEA
	2016 FY3	04/17-04/20	471	35.0,35.4	215	19	19.8	0.1	0.85	0.04	NEA
	2016 JC6	05/22-05/25	100	68.5,73.8	204	3	2.279	0.005	0.16	0.02	NEA
	2016 BU13	05/06-05/19	773	24.2,23.8,24.8	240	13	39.54	0.1	0.26	0.03	NEA
	2016 BX14	05/20-05/26	841	68.0,51.2	260	28	16.67	0.05	0.25	0.05	NEA
	2016 JP17	05/10-05/10	287	41.1,41.1	222	20	0.070176	6.0E-6	0.49	0.03	NEA

Table III. Observing circumstances. ^{T}Dominant period of a tumbler. ^{P}Period of the primary in a binary system. Pts is the number of data points used in the analysis. 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, respectively the average phase angle bisector longitude and latitude, unless two values are given (first/last date in range). Grp is the orbital group of the asteroid. See Warner *et al.* (LCDB; 2009; *Icarus* **202**, 134-146.).

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ROTATION PERIOD DETERMINATION OF FOUR MAIN-BELT ASTEROIDS

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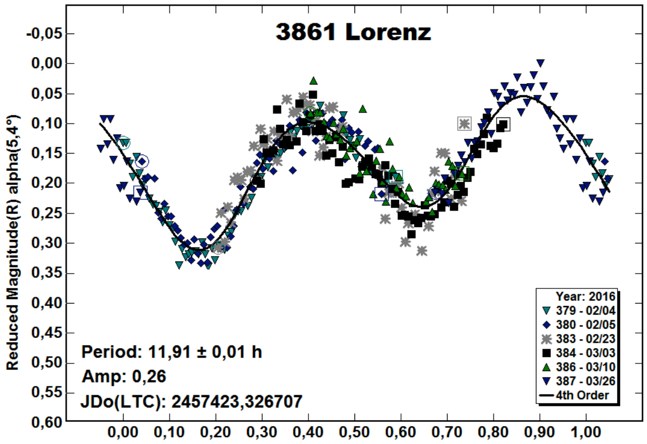
(Received: 2016 Jul 10)

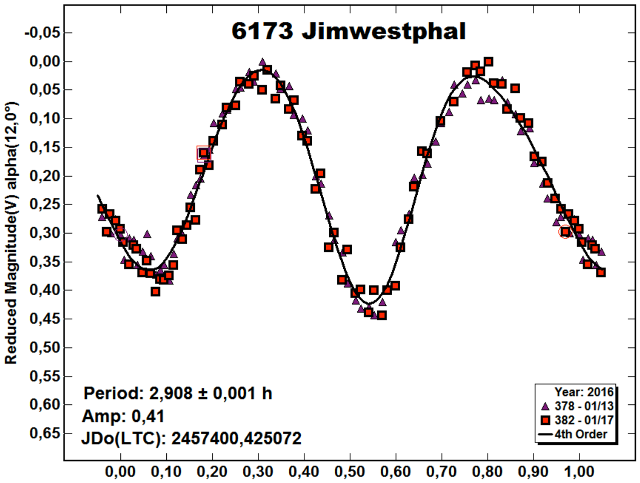
Observations of four main-belt asteroids (MBA) revealed the following rotation periods and lightcurve amplitudes: 3861 Lorenz, *P* = 11.91 ± 0.01 h, *A* = 0.28 mag; 6173 Jimwestphal *P* = 2.908 ± 0.001 h, *A* = 0.41 mag; 10259 Osipovyurij, *P* = 6.356 ± 0.001 h, *A* = 0.30 mag; 29470 Higgs, *P* = 36.31 ± 0.01 h, *A* = 0.48 mag.

During the first six months of 2016, the Bigmuskie Observatory measured the rotation period of four asteroids. They were all chosen because, at the time, there were no periods reported in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009). The observations were made with a Marcon 0.30-meter *f*/8 Ritchey-Chretién and SBIG ST-9 CCD camera with a pixel array of 512x512x20 microns. This combination gave a field-of-view of 15x15 arcmin and image scale of 1.72 arcsec/pixel. Exposures were 300 sec for all targets. For 3861 Lorenz, an Astrodon R filter was used while; no filter was used for the other targets. *MPO Canopus* v10.7.1.3 (Warner, 2012) was used for image calibration and photometrical measurements. The Comp Star Selector utility in *MPO Canopus* was used to find from three to five solar-color comparison stars for differential photometry. Magnitudes are from the MPOSC3 catalog supplied with *MPO Canopus* (see Warner, 2007).

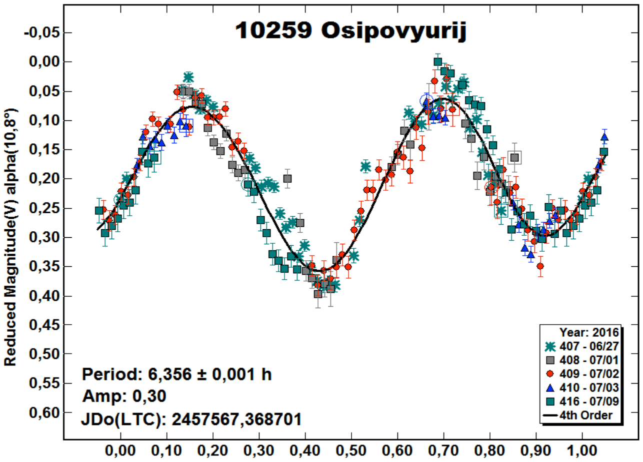
<u>3861 Lorenz.</u> With a period almost commensurate with an Earth day, it was necessary to follow the target for almost two months to complete the curve. This is the only target measured through an R filter. The lightcurve has a period of *P* = 11.91 ± 0.01 h and an amplitude of *A* = 0.26 mag.



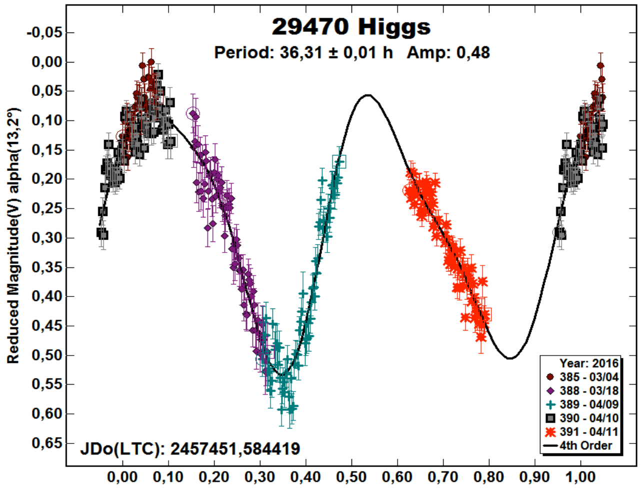
<u>6173 Jimwestphal.</u> This target shows a classical bimodal and symmetrical curve with a short period and large amplitude. This made it possible to reach a secure result in only two nights. The resultant lightcurve has a period of *P* = 2.908 ± 0.001 h and an amplitude *A* = 0.41 mag.



<u>10259 Osipvyurij.</u> This target had a period commensurate with the Earth's rotation as well being in very crowded fields. These made it difficult to find a secure period. After five sessions, the period was found to be *P* = 6.356 ± 0.001 h with an amplitude of *A* = 0.30 mag.



<u>29470 Higgs.</u> Because of a long period of bad weather, the lightcurve for this target is incomplete. Even so, the period is believed to be reasonably correct. The period, close to a 3:2 ratio with an Earth day, is *P* = 36.31 ± 0.01 h with an amplitude of *A* = 0.48 mag.



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THE ROTATION PERIOD OF 2408 ASTAPOVICH

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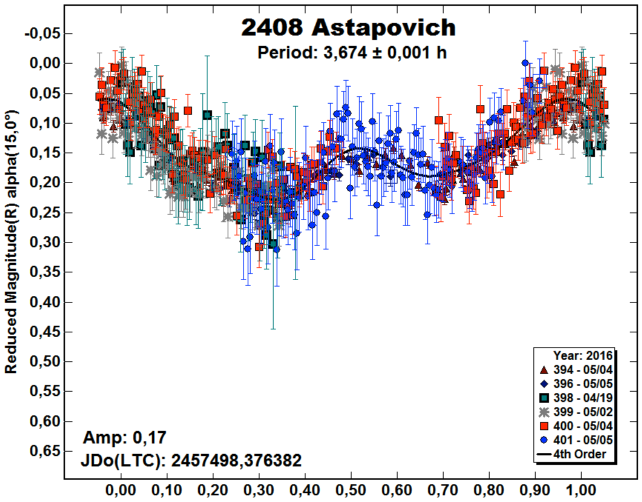
Analysis of observations of the main-belt asteroid 2408 Astapovich led to a synodic rotation period of 3.674 ± 0.001 h and lightcurve amplitude of 0.17 mag.

Asteroid 2408 Astapovich, a main-belt asteroid of about 20 km diameter, was independently observed by the authors in 2016 April and May. We decided to observe this target because no previous observations was reported in the in the CALL website (Warner, 2016). We became aware of each other's observations and decided to merge our results into a single data set.

Ferrero used a Marcon 0.30-meter *f*/8 R-C with an SBIG ST-9 CCD camera and Astrodon R filter. The unguided exposures were 240 sec. Luna observed with a Marcon 0.30-meter *f*/10 SCT reduced to *f*/5.2, an SBIG ST-7 CCD camera, and Shuler R filter Exposures were 60 sec. We each performed photometric reductions with *MPO Canopus* (Warner, 2012), using the Comp Star Selector utility to select up to five solar-color stars.

Ferrero observed the asteroid on May 4-5 (sessions 394/396). Thanks to an SNR of about 100, the scatter in the curve is very low. Unfortunately, the observations during the second night were interrupted by clouds, but it was possible to find a period of 3.675 ± 0.004 h with an amplitude of 0.15 mag. Luna observed the asteroid on April 19 and May 2, 4, and 5 (sessions 398-401). Using only his data led to a period of 3.674 ± 0.001 h and an amplitude of 0.18 mag. The combined data set gives 3.674 ± 0.001 h with an amplitude of 0.17 mag.



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ASTEROID 4962 VECHERKA: A HIGH-AMPLITUDE SLOW ROTATOR

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We present nine nights of photometric observations of the main-belt asteroid 4962 Vecherka. Its amplitude during our observations was not less than 1.08 ± 0.02 mag. We estimated its synodic rotation period at 14 ± 2 d (336 ± 48 h), meaning that 4962 Vecherka is probably among a rare class of slowly rotating, high-amplitude asteroids. A much longer observational campaign is required to calculate the period of rotation with a satisfactory accuracy.

Asteroid 4962 Vecherka was discovered in 1973 by Tamara Smirnova. It is a main-belt asteroid with an orbital period of 4.21 years and eccentricity of 0.146. There was no information about the rotation period or amplitude of the object's lightcurve in the

Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009) as of 2016 July.

Observations

Photometric observations of 4962 Vecherka were conducted during nine clear nights in the period 2015 Aug 5-16 within the 2015 Beli Brezi Summer School of Astronomy and Astrophysics (approximate coordinates 41°34′N 25°10′E). To acquire the images, we used a 0.25-m *f*/4.8 Skywatcher Newtonian on an EQ6 mount and an SBIG ST-1603ME CCD camera. This setup provided an image scale of 1.54 arcsec/pix and a 39x26 arcmin field-of-view (FOV). All exposures were 180 s and unfiltered. During our observations, 4962 Vecherka had an extremely low sky motion of as little as 5 arcsec/h on Aug 5 according to MPC's Minor Planet and Comet Ephemeris Service. This allowed us to use the same reference stars in the photometry process for more than three consecutive nights.

Data Processing and Analysis

Data reduction and aperture photometry were done using IRAF (*Image Reduction and Analysis Facility*). We reduced the raw frames by dark-frame subtraction and flat-field division. The median stellar profile FWHM was 4″. This should be attributed to slight defocusing or pixel undersampling rather than bad atmospheric seeing. We used aperture radii in the 6″-8″ range. We used one reference and one check star for each separate night to obtain a lightcurve in relative magnitudes. To obtain reduced magnitudes, the raw data were corrected by –5*log(rΔ), where r and Δ are, respectively, the Sun-asteroid and Earth-asteroid distances in AU. The resulting data showed that the amplitude in 2015 August was at least 1.08 ± 0.02 mag. The error is based on the dispersion of the data points near the registered extrema on Aug 10 and Aug 12. They are not true extrema since the derivative does not reach zero.

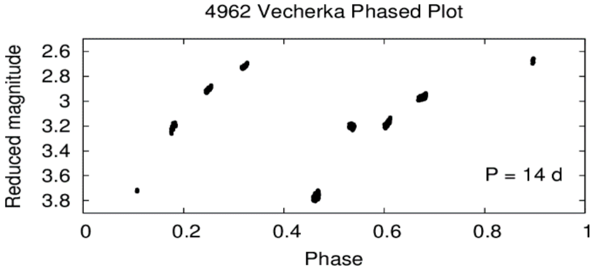

Figure 1. A lightcurve of 4962 Vecherka, phased at *P* = 14 d (336 h). The data on nights from Aug 7 to 15 come consecutively at phases 0.1 – 0.8, while Aug 5 is at phase 0.9.

The data are insufficient to determine the rotation period but we can attempt to estimate it. The first derivative of the lightcurve was calculated for 7 of the 9 observational nights by linear function fitting. The lightcurve was steepest on Aug 8 when |dm/dt| = 0.49 mag/d and the median value |dm/dt| = 0.22 mag/d. It is not steep enough to allow a rotation period lower than 5 d (120 h).

The lightcurve is dominated by two sections of continuous brightness increase, which overlap approximately when phased at *P* = 6.3 d (151.2 h). However, their shapes are quite different and this would require eclipses by a companion satellite to explain the deep minima. Moreover, this yields a phase interval between two consecutive extrema of at least 0.5, therefore such a period does not support a bimodal lightcurve.

If we assume that the increase between Aug 8 and Aug 10 (phases 0.17 – 0.34 on Fig. 1) occurs during a phase interval shorter than 0.25, we obtain *P* > 9 d (216 h). An upper limit is difficult to set, but the phase difference between the two deep minima becomes less than 0.4 for *P* > 20 d (480 h). A period analysis was attempted via the Phase Dispersion Minimization technique. The *IRAF* task *pdm* was used to generate a Theta-statistic plot (Stellingwerf 1978). It is in accordance with the discussion above.

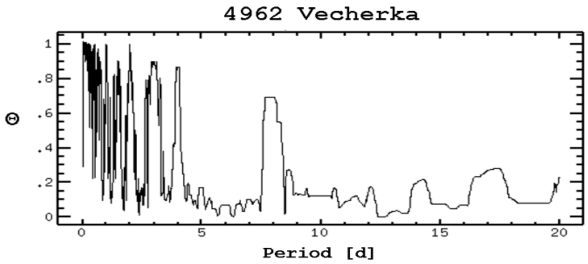

Fig. 2. A plot of the Θ-statistic of 4962 Vecherka in the 0 – 20 d period range.

Conclusion

We suggest *P* = 14 ± 2 d (336 ± 48 h) based on the smoothness of the phased curve. A shorter period would require two more inflection points before the second maximum (Fig. 1). Any period would require the existence of either a local minimum in the bimodal curve or eclipses by a companion. Whether 4962 Vecherka is a binary asteroid remains an open question. In case there are eclipses, its amplitude due to rotation could have been as low as 0.6 mag.

Asteroid 4962 Vecherka probably belongs to a small class of objects with *P* > 10 d and *A* > 1 mag. Currently 18 of those are listed in the Asteroid Lightcurve Database (LCDB; Warner *et al.*, 2009). A more extensive observational effort is required to explore this interesting object. We encourage the organization of a long observational campaign. The coming oppositions are in 2017 January (~16.5 mag, δ = –2°), 2018 April (~16.2 mag, δ = –10°), and 2019 August (~15.4 mag, δ = +8°).

Acknowledgements

All observations were conducted within the 2015 Beli Brezi Summer School of Astronomy and Astrophysics using equipment provided by the Kardzhali Astronomical Observatory and the University of Sofia.

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LIGHTCURVES OF JOVIAN TROJAN ASTEROIDS FROM THE CENTER FOR SOLAR SYSTEM STUDIES: L4 GREEK CAMP AND SPIES

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Jovian Trojan asteroids larger than ~ 30 km were studied from the Center for Solar System Studies (CS3, MPC U81). Lightcurves for 30 Trojan asteroids in the L4 (Greek) cloud were between May and June 2016. These were mostly from the L4 "Greek" cloud, but several were L5 "Trojan" cloud lightcurves not previously published.

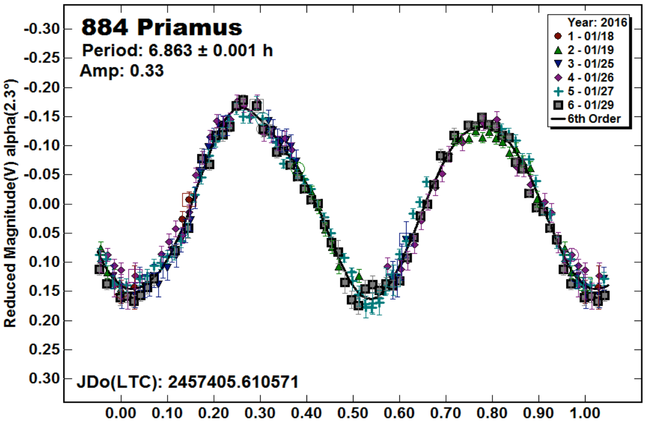
For three years, CS3 has been conducting a study of Jovian Trojan asteroids. As part of this study, data are being accumulated for family rotational and future shape model studies. It is anticipated that for most Jovian Trojans, up to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed since reliable sparse data probably do not exist for Trojan asteroids at 5 AU and a low albedo. To date, CS3 has obtained three or more dense lightcurves for several dozen Jovian Trojans.

With the exception of the 2015 observations of (11395) 1998 XN77 and the 2016 observations of 5012 Eurymedon, all images were made with a 0.4-m or a 0.35-m SCT using an 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. The 2015 observations of (11395) 1998 XN77 were made with the 0.9-m SMARTS telescope at CTIO (Cerro Tololo Inter-American Observation, MPC 807). The observations of 5012 Eurymedon were obtained with the 4-m Blanco telescope and the Dark Energy Camera at CTIO.

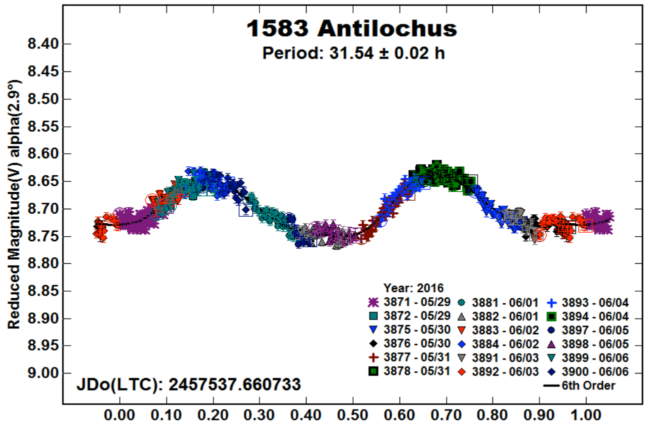
Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al.*, 1989). Night-to-night calibration of the data (generally < ±0.05 mag) was done using field stars converted 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.

In the lightcurve plots, the "Reduced Magnitude" is Johnson R corrected to a unity distance by applying –5*log(rΔ) to the measured sky magnitudes with r and Δ being respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$.

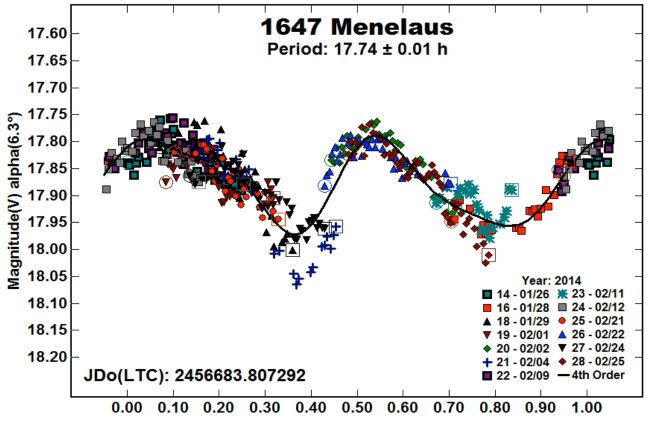
<u>884 Priamus</u>. Mottola *et al.* (2011) observed this Trojan in 1995 and again in 2002, reporting periods of 6.866 h and 6.894 h, respectively. We observed it in 2010 (French *et al.*, 2011) and 2015 (Stephens *et al.*, 2015), finding periods of 6.8605 h and 6.854 h. The results from the observations in 2016 agree with those previous findings.



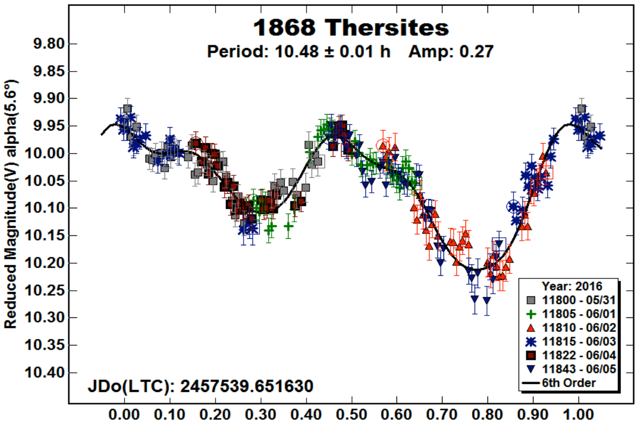
<u>1583 Antilochus</u>. We observed this Trojan in 2009 (Stephens, 2010), finding a rotation period of 31.52 h. Our results from 2016 agree with the 2009 period.



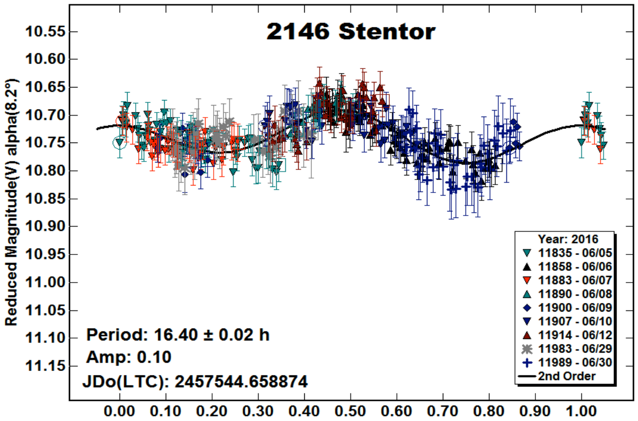
<u>1647 Menelaus</u>. Using sparse photometry from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a period of 17.7390 h. Our period of 17.74 h agrees with that result.

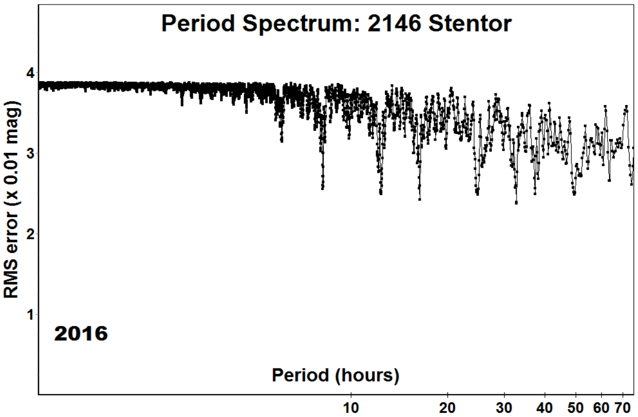


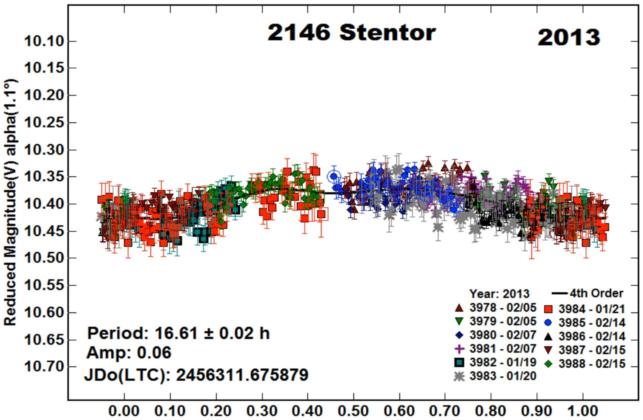
1868 Thersites. Mottola *et al*. (2011) studied this Trojan in 1994, reporting a period of 10.416 h. The result from 2016 of 10.48 h is in good agreement with the Mottola finding.

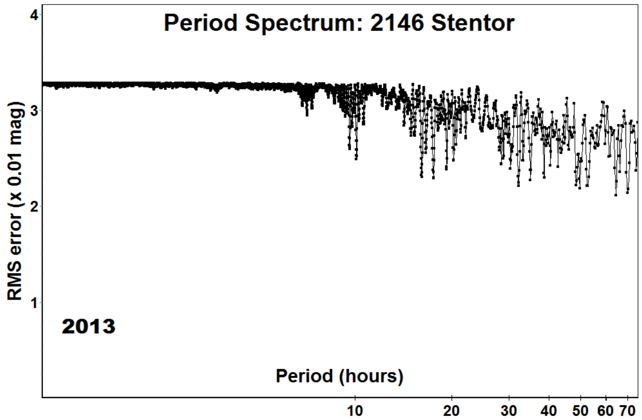


2146 Stentor. We observed Stentor in 2013 (French *et al*., 2013) finding a period of 35.14 h with an amplitude of 0.08 magnitudes. This produced a bimodal lightcurve. However, as mentioned in the 2013 analysis, with an amplitude under 0.1 magnitudes, it is possible that a lightcurve could have only a single extremum, or three or more extrema (Harris *et al* 2014). The data obtained in 2016 resulted in a bimodal lightcurve at about a 1:2 alias of the 2013 period and amplitude of 0.1 mag. We were able to make the 2013 data fit a single modal lightcurve with a period of 16.61 h. Given the bimodal features present in the 2016 data, we now prefer the 16.40 h period. This is another example of the need to reobserve low amplitude asteroids at several oppositions.

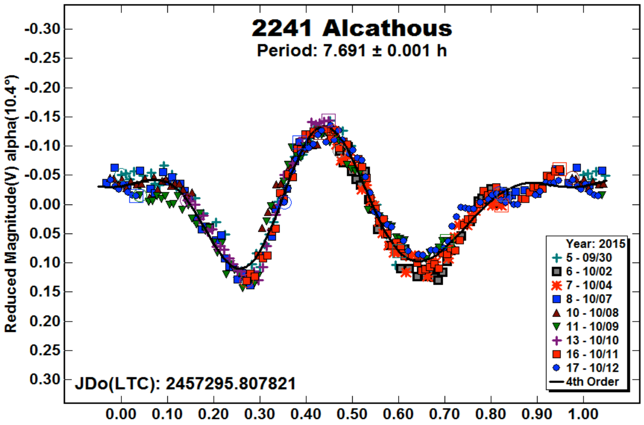




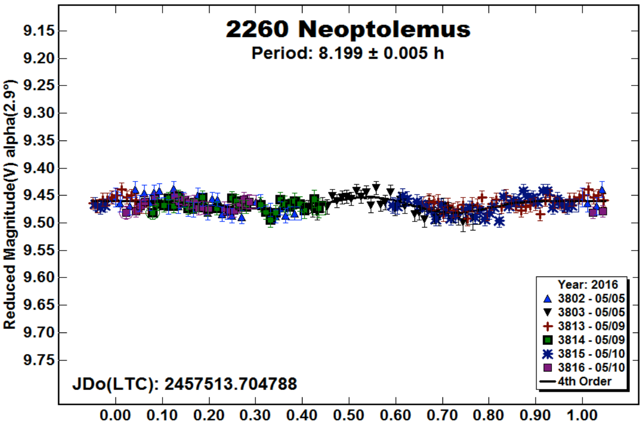




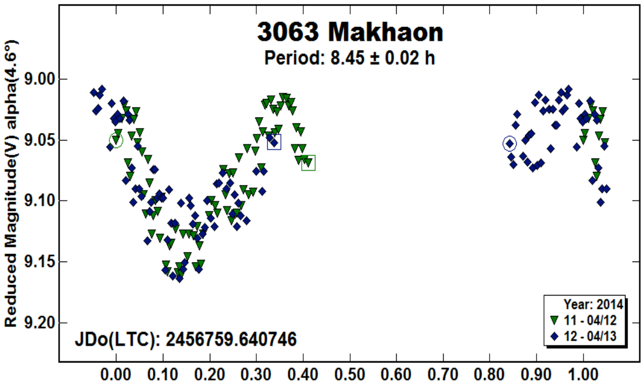
2241 Alcathous. We observed Alcathous three times before (French *et al.,* 2011b, Stephens *et al.,* 2014; 2015), finding rotation periods of 7.695 h, 7.690 h, and 7.689 h. Mottola *et al.* (2011) found a similar period of 7.687 h. The result we found at this year's opposition is in good agreement with those previous findings.



2260 Neoptolemus. Mottola *et al.* (2011) observed this Trojan in 1995 and again in 2002, reporting a period of 8.180 h. Our observations in 2016 result in a flat, almost featureless lightcurve with an amplitude of about 0.05 mag. The observations by themselves would not be sufficient to derive the rotation period with any confidence. However, the rotation period derived in 2016 is consistent with the Mottola results and perhaps useful for shape modeling.

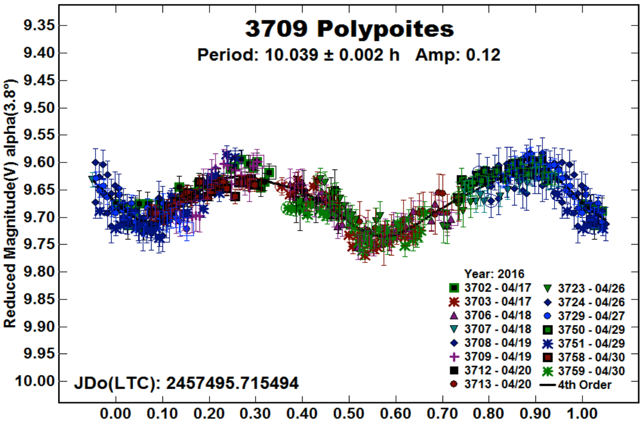


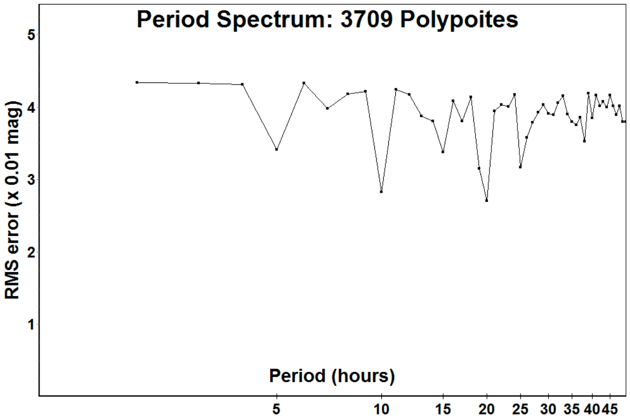
3063 Makhaon. We observed this Trojan in 2010 (French *et al.*, 2011) finding a period of 8.64 h. Binzel (1992) reported a period of 17.3 h based upon two consecutive nights of observations. This appears to be an alias of our 8.64 ± 0.01 h period. Mottola *et al.* (2011) observed this Trojan in 1994 and again in 2009, reporting periods of 8.648 h and 8.6354 h, respectively. Our previously unreported observations from 2014 covered only half the phased lightcurve on two nights, but the period is consistent with previous results.

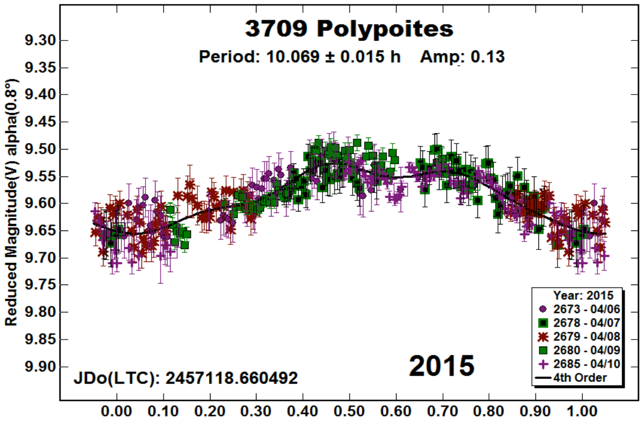


3709 Polypoites. This Trojan illustrates the need to reobserve asteroids, sometimes multiple times. In 2010 we observed Polypoites on two nights, obtaining what appeared to be a very reasonable, if asymmetric, lightcurve with a 5.71 h period (French *et al.*, 2011). However, with an amplitude of about 0.12 magnitudes, it is possible that it could have only a single extremum, or three or more extrema (Harris *et al.,* 2014). In 2015 our lightcurve had a slightly larger amplitude and a dramatically different appearance, which is inconsistent with a 5.71 h period. The phased lightcurve was still asymmetric and likely dominated by surface features. It has a rotation period 2.5 times that of the 2010 result. We rephased the 2010 data, producing a lightcurve that has almost no overlap for the two nights and rejecting the 5.71 h period in favor of the 14.19 h period.

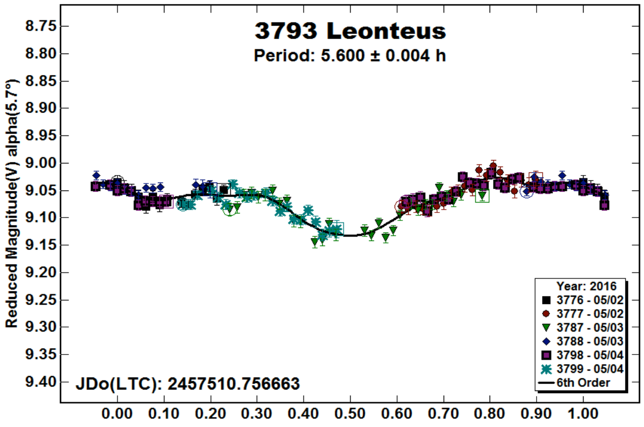
In 2016 the data favored a 10.039 h period with bimodal lightcurve and amplitude of only 0.12 mag. The period spectrum shows the 14.2 hour period to be a weak alias and the lightcurve has several inconsistences. We were able to rephase the 2015 data to a monomodal lightcurve with an amplitude of 0.13 mag. Based on the 2015 and 2016 data, we now favor the 10.039 h period.



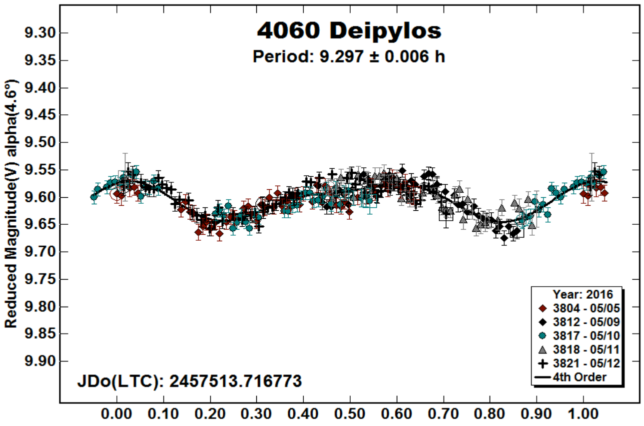


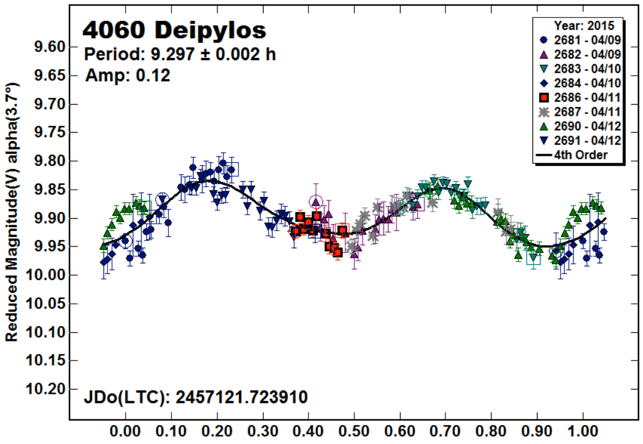


3793 Leonteus. Leonteus is another example where a low amplitude lightcurve can produce alias results when forced to a bimodal solution. We observed this Trojan in 2009 and 2015, showing asymmetric lightcurves reporting a period of 5.62 h and a small amplitude of 0.05 mag. Mottola *et al.* (2011) reported a period of 5.6225 h from observations obtained in 1994 and 1997. The largest amplitude in the Mottola observations was 0.24 magnitudes, which suggested that our 2009 observations were nearly pole on. Our observations in 2016 still show an asymmetric lightcurve with a period of 5.60 h but a larger amplitude of 0.11 mag.

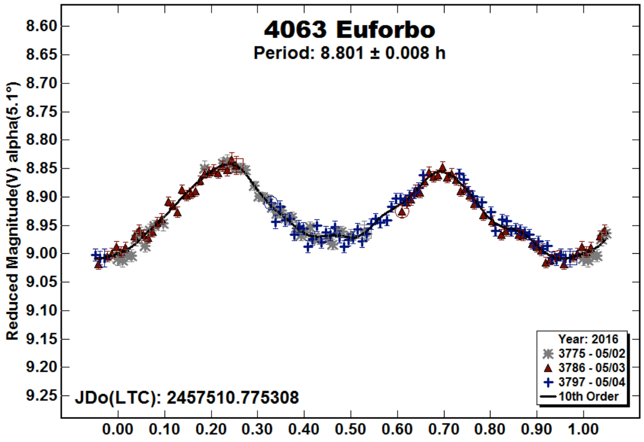


4060 Deipylos. Using sparse photometry from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a period of 11.4905 h for Deipylos. That period appears to be a 5:4 alias of the period of 9.19 h that we found in 2015 (Stephens *et al.,* 2016), when the asteroid was observed over four consecutive nights. We observed Deipylos again in 2016 for five nights spanning a week. Analysis found a slightly different rotation period of 9.297 h. By making slight zero point adjustments to the 2015 data, we were able to phase the lightcurve to a reasonable match to the 2016 period, which we now adopt as the correct period.

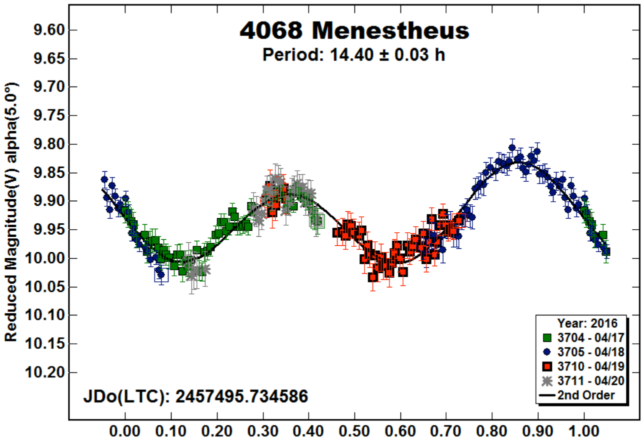




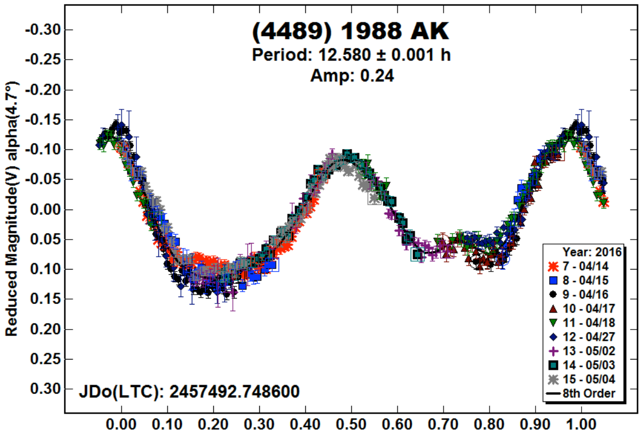
4063 Erforbo. This Trojan has been well observed over the years. Brinsfield (2011), Mottola *et al.* (2011), and Waszczak *et al.,* (2015) each reported periods near 8.84 h, which were in agreement with our findings. In 2015, we again found a period of 8.84 h (Stephens *et al*., 2016). The period of 8.801 h we found in 2016 is in good agreement with the earlier results.



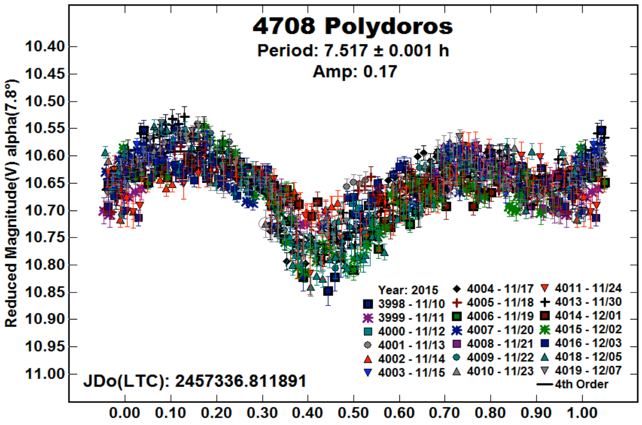
4068 Menestheus. We studied this asteroid on two previous occasions: French *et al.* (2011) and Stephens *et al.* (2016), finding a period of 14.341 h and 14.45 h. The result this year of 14.40 h is in good agreement with those findings.

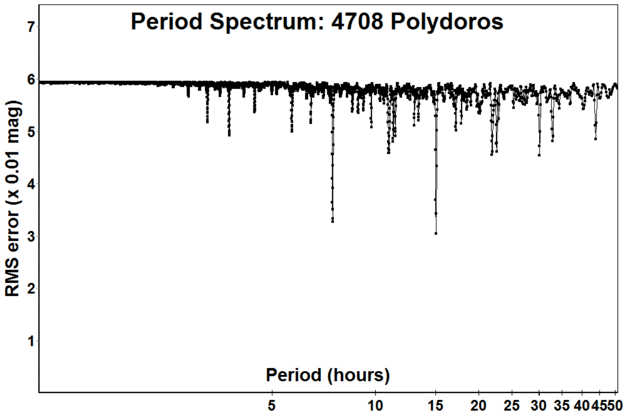


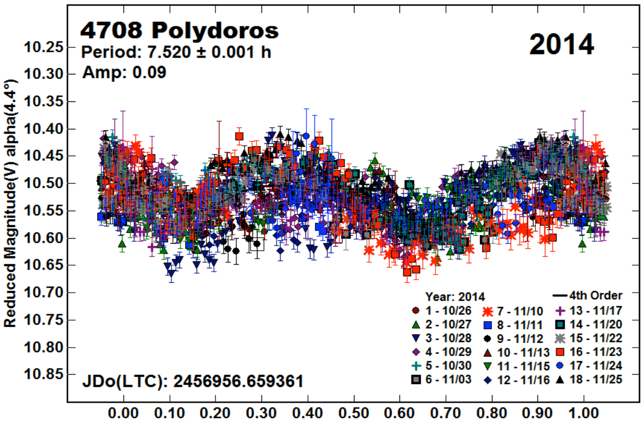
(4489) 1988 AK. Mottola *et al.* (2011) observed this Trojan in 1995, finding a period of 16.25 h. We observed it in 2009 and 2010 (French *et al.,* 2011) and 2015 (Stephens *et al.,* 2016). Each time we found a period near 12.58 h. The period from based on the 2016 agrees with our previous results.



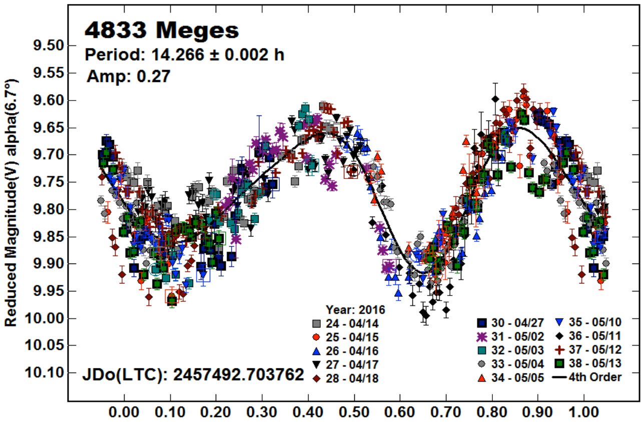
4708 Polydoros. We previously observed this Trojan in 2011 (French *et al*., 2012) and 2014 (Stephens *et al*., 2015), finding periods of 20.03 h and 20.24 h, respectively. We obtained a much denser dataset in 2016. Analysis of the new data favored 7.517 h and 15.037 h, with an alias around 23 h. We adopted the 7.517 h solution because it produces a bimodal lightcurve. The 15.037 h solution creates a lightcurve with four extrema, and although possible with a lightcurve with a 0.21 mag. amplitude, the 7.517 h solution is more likely. We rephased the 2014 lightcurve to 7.520 h with a result of an asymmetric bimodal lightcurve with an amplitude of 0.09 mag. We also rephased the 2011 data, forcing a monomodal fit to 7.52 h on the assumption that the ending data on Aug 3 were the result of observational errors.



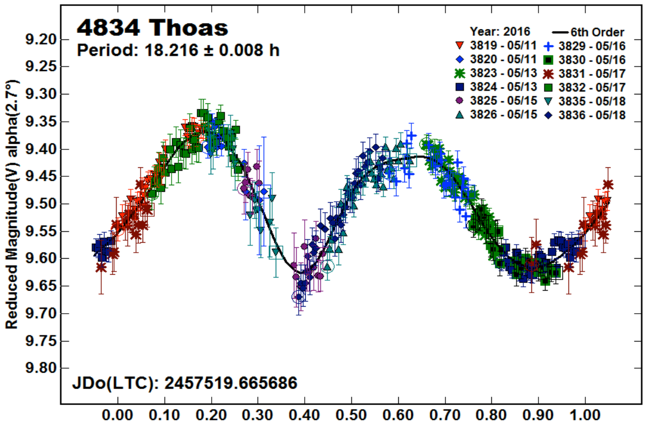




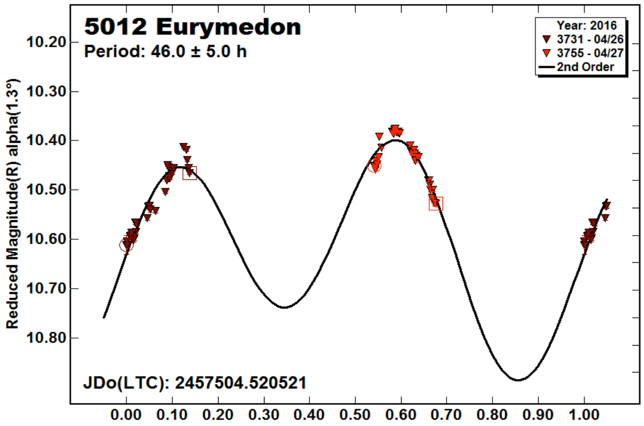
4833 Meges. Mottola *et al.* (2011) observed Meges in 1995, finding a period of 14.250 h. Our period derived from the 2016 data is in good agreement.



4834 Thoas. Mottola *et al.* (2011) observed Thoas in 1996, finding a period of 18.22 h. We observed it in 2010 (French *et al.*, 2011), finding a period of 18.192 h, and again in 2015 (Stephens *et al.*, 2016) when we found a period of 18.14 h. Our period of 18.216 h based on the 2016 data is in good agreement with those results.

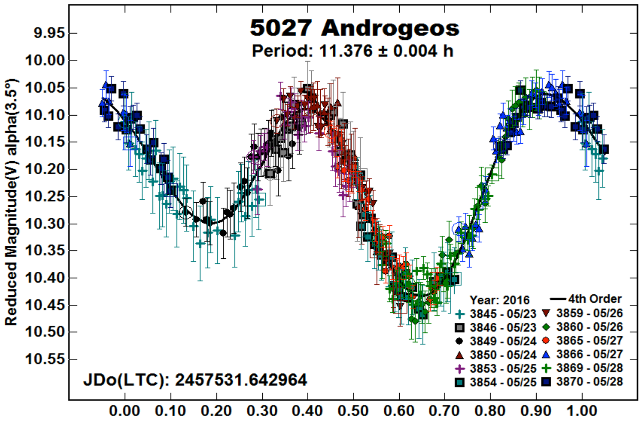


5012 Eurymedon. There were no previously reported rotation periods in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) for this Trojan, which was observed with the 4-m Blanco Telescope at CTIO as part of a survey of small ($D < 30$ km) Jovian Trojan asteroids.

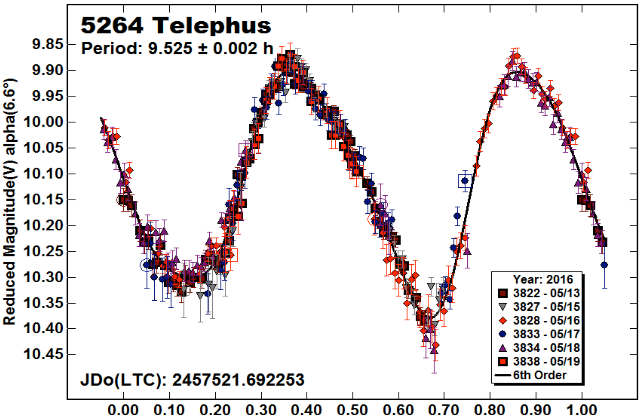


The WISE/NEOWISE program (Grav *et al.*, 2012) estimates the size of Eurymedon to be 36 km, so it was excluded from the small Trojan survey. For our observing run in 2016, the Trojan L4 cloud could be observed for only two nights which is insufficient to determine a rotation period exceeding 20 hours. However, based on the maxima and slopes of the lightcurve segments that were observed, we estimate that the period is probably near 46 h.

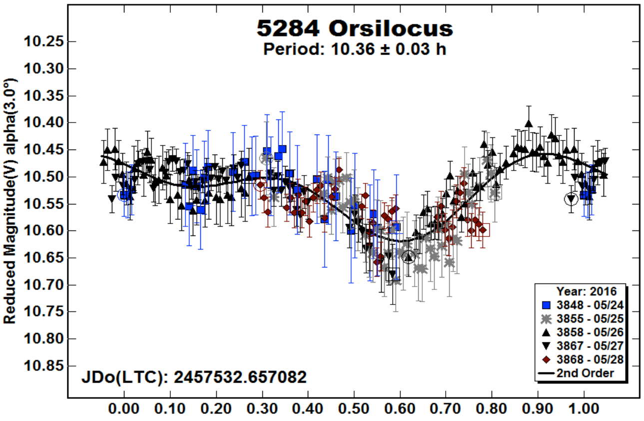
5027 Androgeos. Mottola *et al*. (2011) observed Androgeos in 1992, finding a period of 11.355 h. We observed it in 2015 (Stephens *et al*., 2016), finding a period of 11.301 h. The period of 11.376 h found from the 2016 data agrees with those prior results.



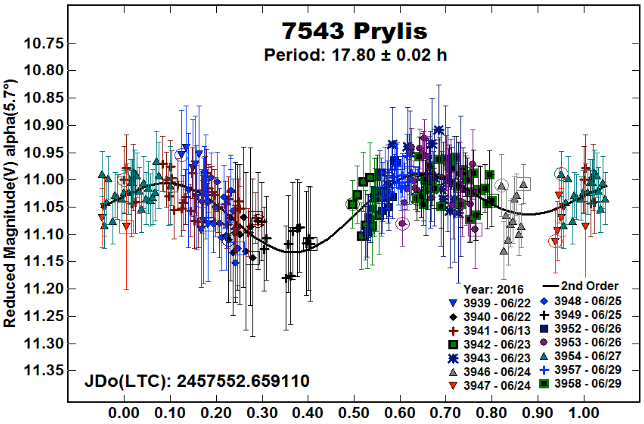
5264 Telephus. Telephus was observed by Mottola *et al*. (2011) in 1994, who reported a period of 9.518 h. We found a period of 9.540 h in 2015 (Stephens *et al*., 2016). The 2016 result of 9.525 h agrees with those previous findings.



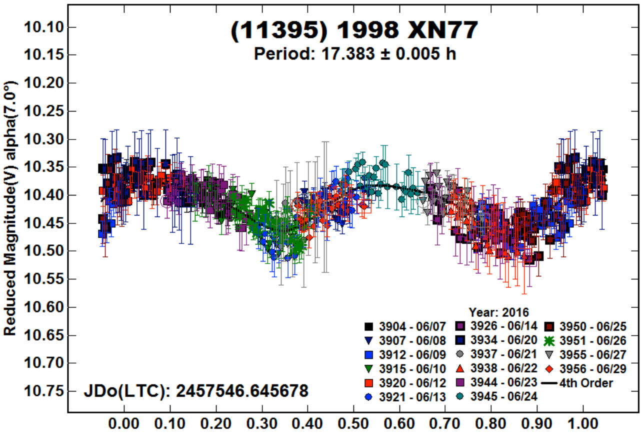
5284 Orsilocus. We studied Orsilocus in 2013 (French *et al*., 2013) and 2015 (Stephens *et al*., 2016), finding periods of 10.31 h and 10.28 h, respectively. The period of 10.36 h found from the 2016 data agrees with those findings.

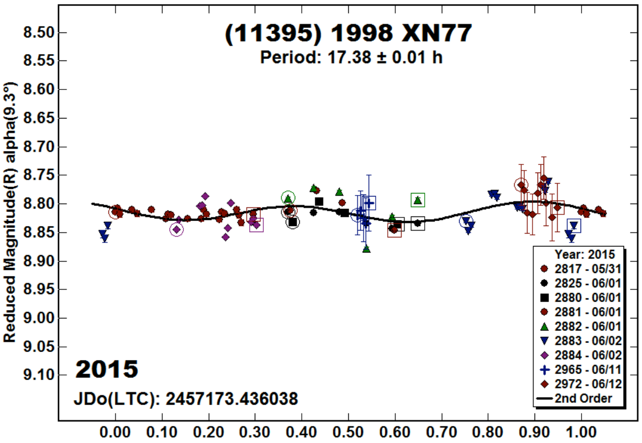


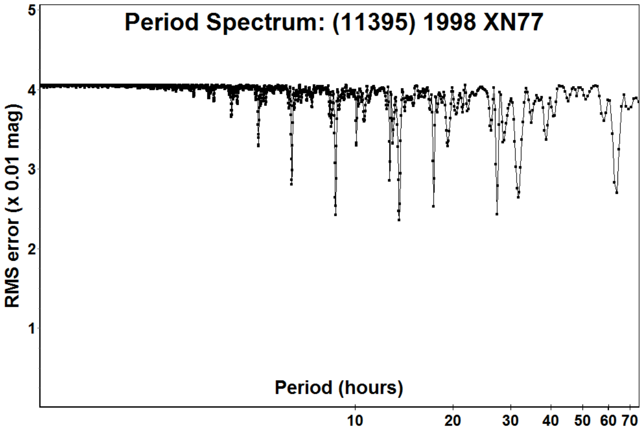
7543 Prylis. This Trojan did not have a previously reported rotation period in the LCDB (Warner *et al*., 2009).



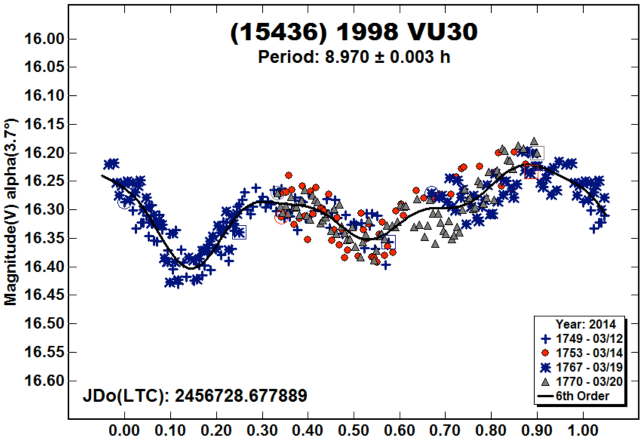
(11395) 1998 XN77. Mottola *et al*. (2011) observed this Trojan in 2009 and 2010, finding periods of 13.70 h and 13.696 h, respectively. We first observed the asteroid in 2015 using the 0.9-m SMARTS telescope at CTIO and then in a follow-up session using the 0.35-m telescope at CS3 (Stephens *et al*., 2016), finding a period of 17.89 h. We observed it again in 2016 from CS3, obtaining a much denser data set, and found a period of 17.383 h. Determining a rotation period proved difficult because of the low amplitude and strong aliases. We were able to rephase the 2015 data to this period, but because of the low amplitude, many rotation periods were possible.



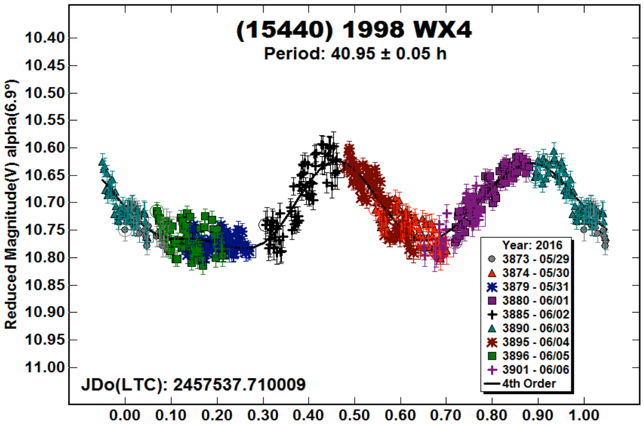




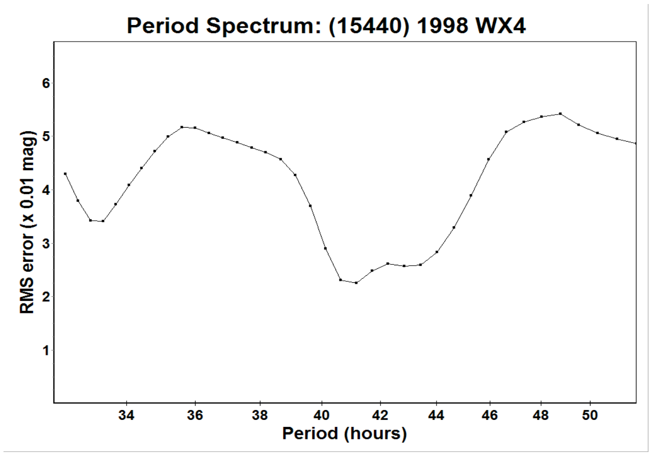
(15436) 1998 VU30. We observed this Trojan in 2013 (French *et al*., 2013) finding a rotational period of 8.97 h. The period we found in 2016 is identical to that result.

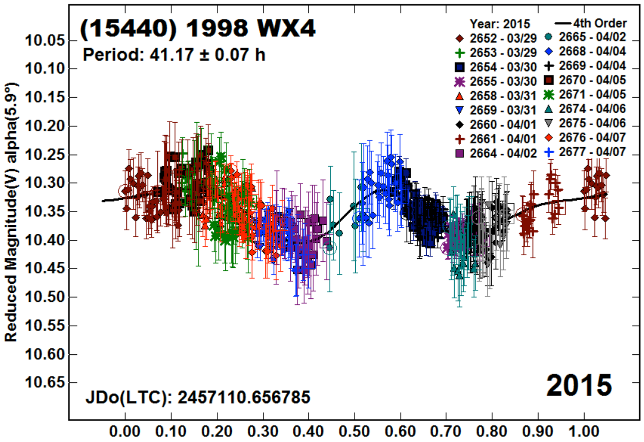


(15440) 1998 WX4. We observed this Trojan in 2013 (French *et al*., 2013) and 2014 (Stephens *et al*., 2014). In both cases, the raw lightcurves spanning multiple nights were featureless. We observed it again in 2015 (Stephens *et al*., 2016) and found a rotation period of 43.08 h and an amplitude of 0.11 magnitudes based on an asymmetric bimodal shape. However, with such a low amplitude, it is possible that a lightcurve could have only a single extremum, or three or more extrema (Harris *et al.*, 2014).

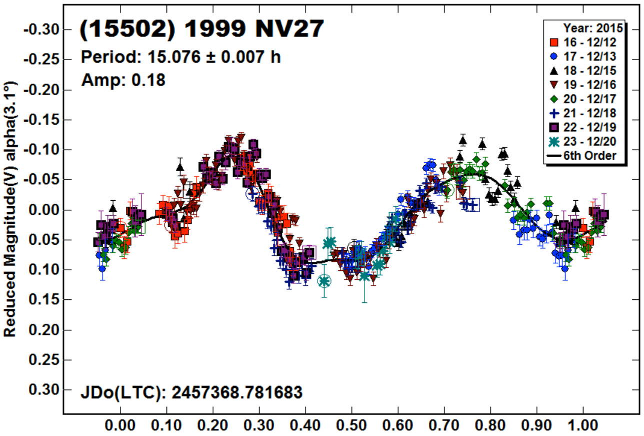


We observed (15440) 1998 WX4 again in 2016, this time finding a rotation period of 40.95 h with an amplitude of 0.16 mag. The data were much cleaner in 2016. We attempted to reconcile the differences between the 2015 and 2016 results. We rephased the 2015 results after making slight zero point adjustments and were able to find a period of 41.17 h, which is close to the 2016 result considering the formal error of ± 0.07 h. A period spectrum of the 2016 data shows a slight dip for the 43 h solution. Given the quality of the 2016 data, we are adopting 40.95 h as the rotation period.

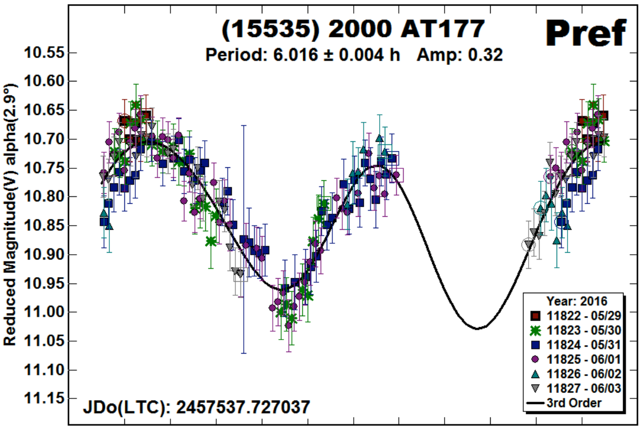


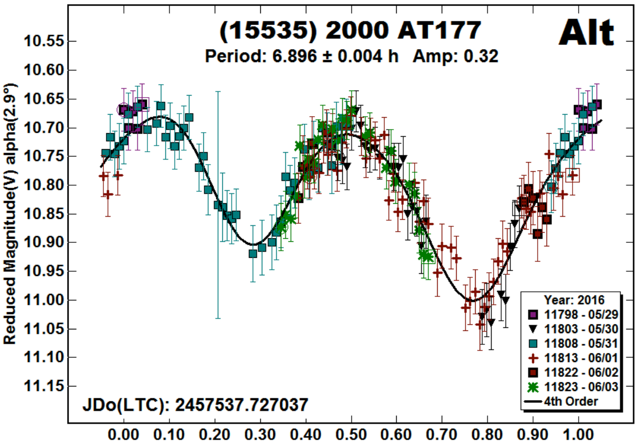


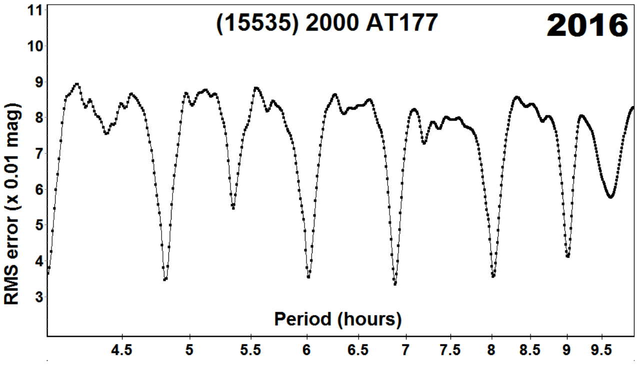
(15502) 1999 NV27. We observed this Trojan three times in the past: in 2012 (French *et al*., 2013), in 2013 Stephens *et al*., 2014), and in 2014 (Stephens *et al*., 2015). Each time we found periods near 15.1 h. This results from 2016 are in good agreement with those previous findings.



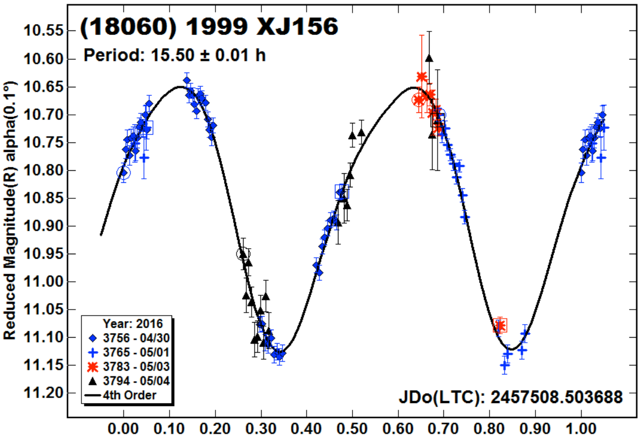
(15535) 2000 AT177. We observed this Trojan in 2013 (French *et a.,* 2013), finding a rotational period of 6.01 h. Analysis of the 2016 observations led to aliases at 6.016 h and 6.896 h. The shorter solution covered only three quarters of the lightcurve. To break the tie, we reanalyzed the 2013 data, which did not show a strong alias near 6.9 h. Therefore we are adopting the 6.016 h solution as the most likely.



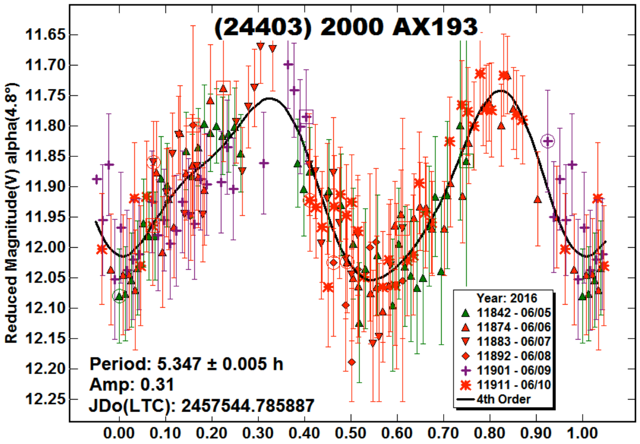




(18060) 1999 XJ156. This Trojan is a member of the Eurybates family. We observed it with the 0.9-m SMARTS telescope at CTIO. Using sparse photometry from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a period of 15.4542 h. Our denser dataset was used to find a period of 15.50 h, which is in good agreement with the Wazczak *et al.* results.



(24403) 2000 AX193. We could not find a previously reported rotation period in the LCDB (Warner *et al.*, 2009).



Acknowledgements

This research was supported by National Science Foundation grant AST-1212115. The purchase of two FLI-1001E CCD cameras was made possible by a 2013 and 2015 Gene Shoemaker NEO Grants from the Planetary Society.

French and Stephens were visiting astronomers at Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatory, operated by the Association of Universities for Research in Astronomy, under contract with the NSF.

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Numbe	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Gr
884	Priamus	01/18-01/29	234	2.2,4.0	105	3	6.863	0.001	0.33	0.02	L5
1583	Antilochus	05/29-06/06	533	2.9,3.7	244	14	31.54	0.02	0.11	0.02	L4
1647	Menelaus	[1]01/26-02/25	437	6.3,1.4	157	-6	17.74	0.01	0.17	0.03	L4
1868	Thersites	05/31-06/05	213	5.6,6.3	220	8	10.48	0.01	0.27	0.02	L4
2146	Stentor	06/05-06/30	335	8.2,9.5	226	42	16.40	0.02	0.1	0.01	L4
2241	Alcathous	[2]09/30-10/12	427	10.4,9.7	78	5	7.691	0.001	0.24	0.02	L4
2260	Neoptolemus	05/05-05/10	188	2.9,2.4	234	11	8.199	0.005	0.03	0.01	L4
3063	Makhaon	[1]04/12-04/13	607	4.6,6.4	185	-13	8.45	0.02	0.15	0.01	L4
3709	Polypoites	04/17-04/30	403	3.8,2.6	222	12	10.039	0.002	0.12	0.02	L4
3793	Leonteus	05/03-05/04	135	5.6,5.5	248	17	5.600	0.004	0.11	0.02	L4
4060	Deipylos	05/09-05/12	264	4.1,3.8	242	17	9.297	0.006	0.07	0.02	L4
4063	Euforbo	05/02-05/04	155	5.1,4.8	245	16	8.801	0.008	0.17	0.01	L4
4068	Menestheus	04/17-04/20	205	5.0,4.5	227	14	14.40	0.03	0.18	0.03	L4
4489	1988 AK	04/14-05/04	444	4.7,3.9	218	19	12.58	0.001	0.24	0.02	L4
4833	Meges	04/14-05/13	537	6.6,6.1,6.3	221	34	14.266	0.002	0.27	0.03	L4
4708	Polydoros	[2]11/10-12/07	850	7.9, 3.3	88	3	7.517	0.001	0.17	0.02	L4
4834	Thoas	05/11-05/18	316	2.7,3.0	230	14	18.216	0.008	0.26	0.02	L4
5012	Eurymedon	[4]04/26-04/27	69	1.3,1.1	223	-1	46	5	0.3	0.07	L4
5027	Androgeos	05/23-05/28	337	1.3,0.0,1.1	233	+15	11.376	0.004	0.37	0.02	L4
5264	Telephus	05/13-05/19	305	6.6,6.2	250	31	9.525	0.002	0.48	0.02	L4
5284	Orsilocus	05/24-05/28	233	3.0,3.2	242	18	10.36	0.03	0.16	0.02	L4
7543	Prylis	06/13-06/29	245	4.3,6.7	244	12	17.80	0.02	0.14	0.0	L4
11395	1998 XN77	[2,3]05/31-	94	9.3,10.2	194	-7	17.383	0.01	0.03	0.02	L4
11395	1998 XN77	06/07-06/29	477	7.0,9.7	222	6	17.383	0.005	0.1	0.01	L4
15436	1998 VU30	[1]03/12-03/20	316	3.7,4.0	172	-18	8.970	0.003	0.18	0.02	L4
15440	1998 WX4	05/29-06/06	477	6.9,7.5	227	30	40.95	0.05	0.16	0.02	L4
15502	1999 NV27	[2]12/12-12/20	334	3.1,2.7	86	13	15.076	0.007	0.18	0.02	L5
15535	2000 AT177	05/29-06/03	160	2.9,3.0	249	15	6.016	0.004	0.32	0.03	L4
18060	1999 XJ156	[3]04/30-05/04	92	0.1,0.8	220	-1	15.50	0.01	0.48	0.03	L4
24403	2000 AX193	06/05-06/10	176	4.8,4.9	254	24	5.347	0.005	0.31	0.03	L4

Table 1. Observing circumstances. [1,2]Observations in 2014, 2015. [3]Observations made with 0.9-m SMARTS Telescope at CTIO. [4]Observations made with 4-m Blanco Telescope at CTIO. Pts is the number of data points used in the analysis. The phase angle (α) is given at the start and end of each date range, unless it reaches a minimum, which is then the second of the three values. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude. Grp is the Trojan family, L4 (Greeks) and L5 (Trojans).

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EIGHTEEN ASTEROIDS LIGHTCURVES AT ASTEROIDES OBSERVERS (OBAS) - MPPD: 2016 MARCH - MAY

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(Received: 2016 Jun 14)

We report on the analysis of photometric observations of 18 main-belt asteroids (MBA) done by Asteroides Observers (OBAS). This work is part of the Minor Planet Photometric Database program initiated by a group of Spanish amateur astronomers. We have managed to obtain a number of accurate and complete lightcurves as well as some additional incomplete lightcurves to help analysis at future oppositions.

In this paper we publish the result of 18 asteroids analyzed under the Minor Planet Photometric Database project (*http://www.minorplanet.es*). This database is focused on collecting lightcurves of main-belt asteroids using photometric techniques and shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

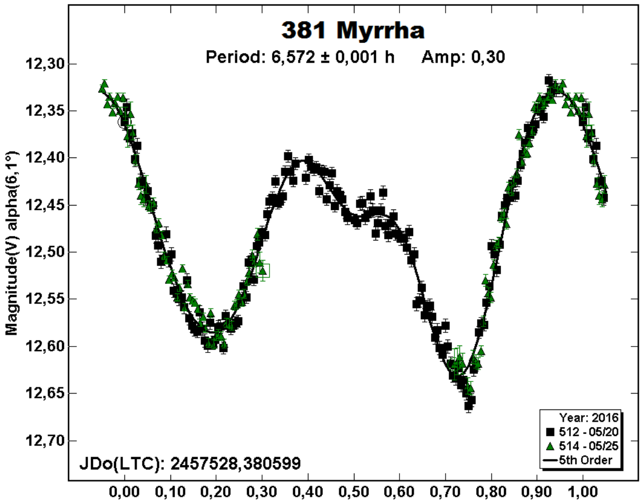
Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	QHY6
Vallbona	0.25 SCT	SBIG ST7-XME
TRZ	0.20 R-C	QHY8
Elche	0.25 DK	SBIG ST8-XME
Oropesa	0.20 SCT	Atik 16I
Bétera	0.23 SCT	Atik 314L+
Serra Observatory	0.25 NW	Atik 414L+

Table I. List of instruments used for the observations. SCT is Schmidt-Cassegrain. R-C is Ritchey-Chrétien. DK is Dall-Kirkham. NW is Newton.

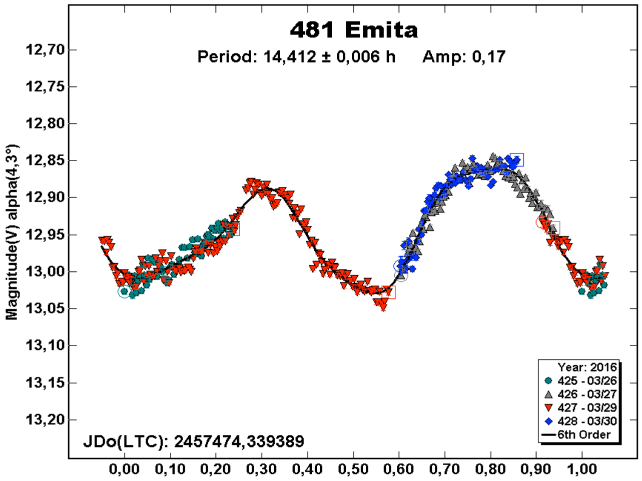
Table I shows the equipment at the observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website at *http://www.minorplanet.info/call.html*, paying special attention to keeping the asteroid's magnitude within reach of the telescopes being used. We tried to observe asteroids at a phase angle of less than 14°, but this was not always possible. Table II lists the individual results along with the range of dates for the observations and the number of nights that observations were made.

Images were measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. See Aznar *et al.* (2016) for details about the techniques used in this project.

381 Myrrha. The OBAS group observed this asteroid during two nights in 2016 May. Our analysis determined a period of 6.572 ± 0.001 h. This is consistent with the period reported by several observers, *e.g.*, Behrend (2015), who found a period of 6.57229 h and amplitude of 0.35 mag.

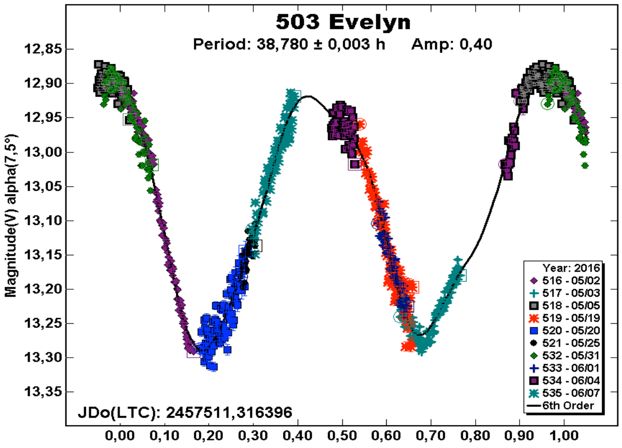


481 Emita. The OBAS group observed this asteroid during four nights in 2016 March. We obtained a rotation period of 14.412 ± 0.006 h and amplitude of 0.17 mag. This result is consistent the period of 14.35 h found by Denchev *et al.* (2000), but it differs from the 15.1 h reported by Behrend (2007).

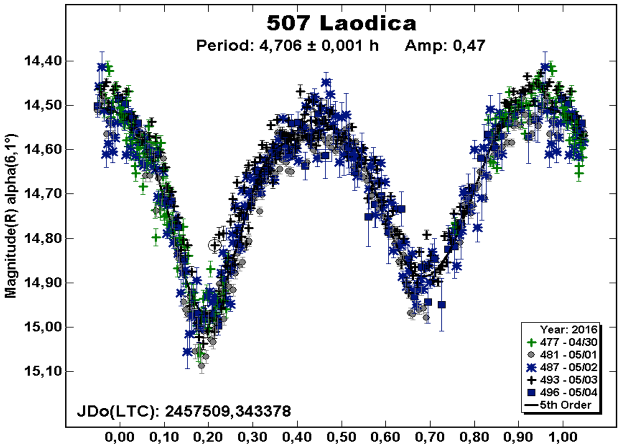


503 Evelyn. Previous results include Kamel (1999; 38.7 h, 0.5 mag), Fauerbach (2007, 38.7 h, 0.30 mag), and Behrend (2014,

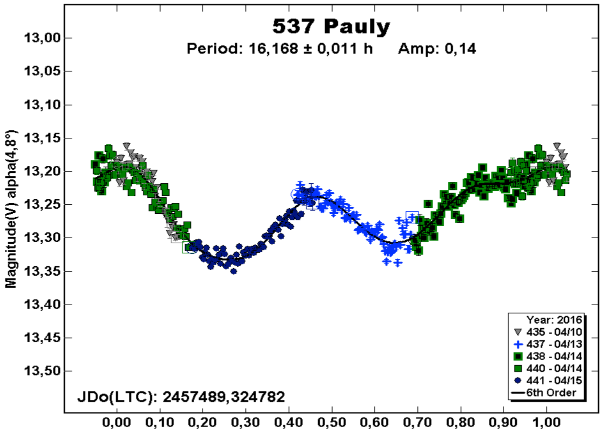
38.728 h, 0.30 mag). Based on observations from six nights, we found a period of 38.794 ± 0.009 h and amplitude of 0.40 mag.



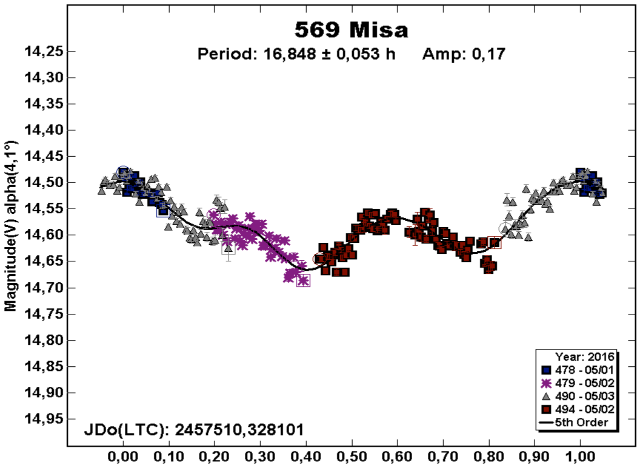
507 Laodica. Behrend (2001) found a period of 4.539 h and amplitude of 0.24 mag. Robinson (2002) found a period of 4.705 h with an amplitude of 0.22 mag. Warner (2011) found a period of 6.737 hours with an amplitude of 0.29 mag. Our analysis of data from five nights found a rotation period of 4.706 ± 0.001 h with an amplitude of 0.47 mag, which is consistent with Robinson.



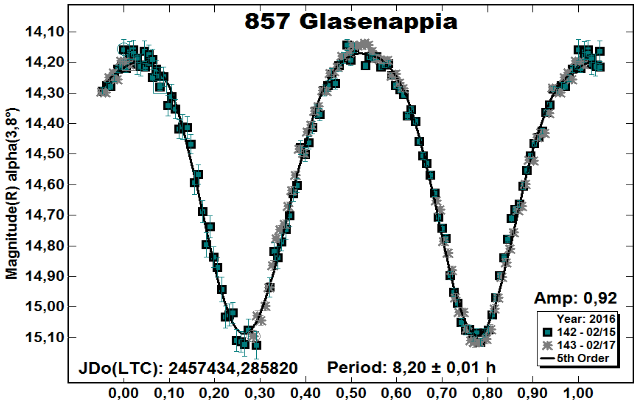
537 Pauly. The OBAS group observed this asteroid on five nights in 2016 April to get the complete lightcurve. We found a rotation period of 16.168 ± 0.011 h and amplitude of 0.14 magnitudes. This is consistent with the results from Barucci *et al.* (1992), who found a period 16.252 h and amplitude of 0.18 mag.



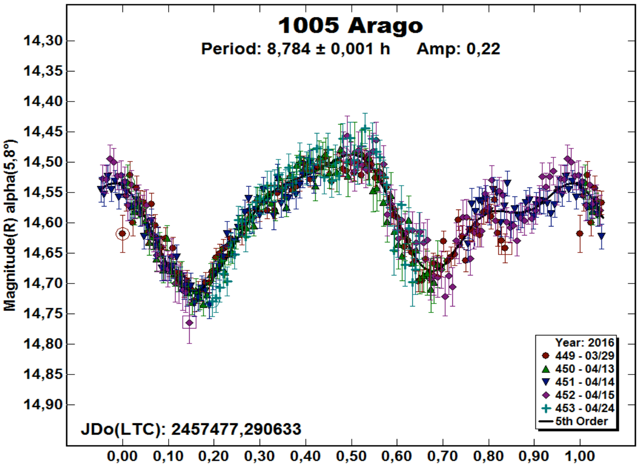
569 Misa. The OBAS group found a rotation period of 16.842 ± 0.053 h and amplitude of 0.17 mag based on observations on four nights. This result is different from the period of 13.52 h and amplitude of 0.25 mag reported by Behrend (2002).



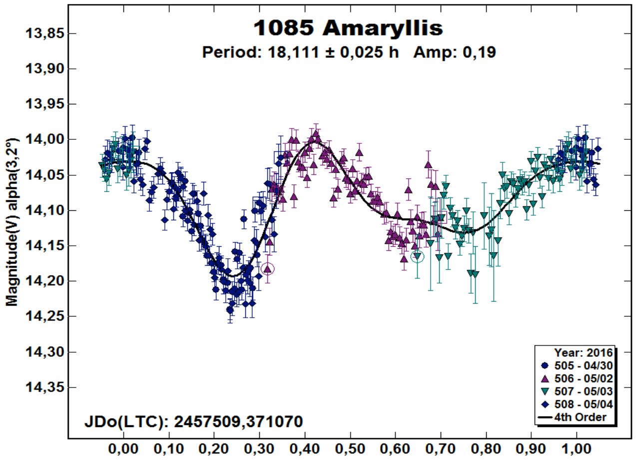
857 Glasenappia. Analysis of our data from three nights gives a rotation period of 8.20 ± 0.01 h and amplitude of 0.92 mag. The period agrees with the 8.20 h found by Behrend (2006), who reported an amplitude of 0.75 mag.



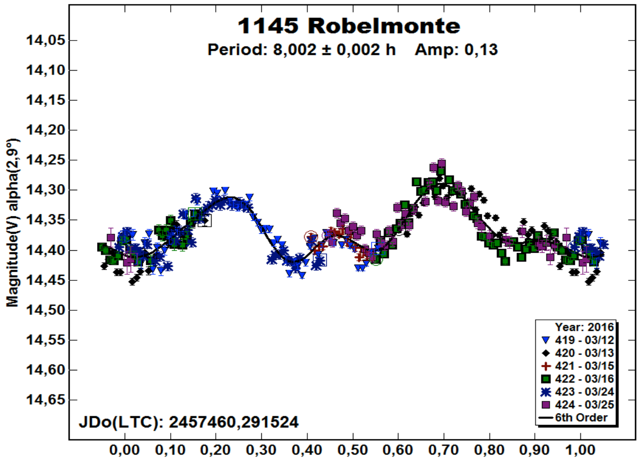
1005 Arago. Pozzoli (2002) found a period of 8.7819 h and amplitude of 0.22 mag. We found a rotation period of 8.784 ± 0.001 h and amplitude is 0.22 mag, which is identical to the earlier results.



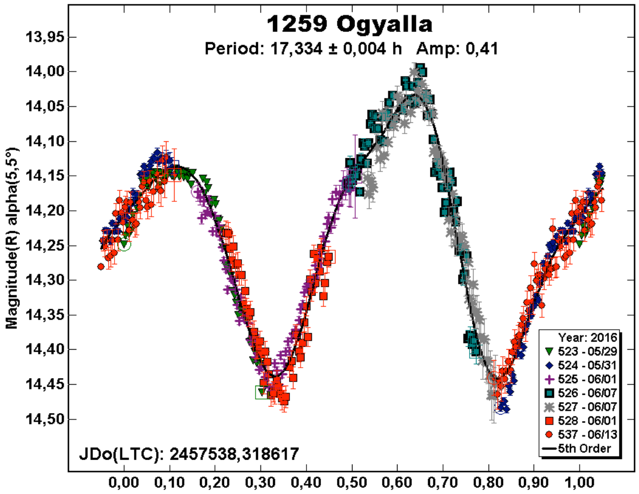
1085 Amaryllis. Using data from four nights, we found a rotation period of 18.111 ± 0.025 h. The lightcurve amplitude was 0.19 mag. This result is very similar to the one obtained by Behrend (2009) with a period of 18.2 h and amplitude of 0.20 mag.



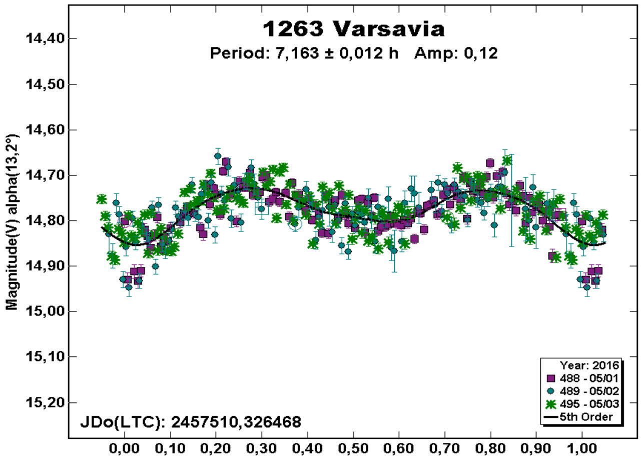
1145 Robelmonte. The OBAS group observed this asteroid on six nights in 2016 March. We found a period of 8.002 ± 0.002 h and amplitude of 0.13 mag. This differs from other results except those from Waszczak *et al.* (2015), who found a period of 7.582 ± 0.027 h and amplitude of 0.13 mag.



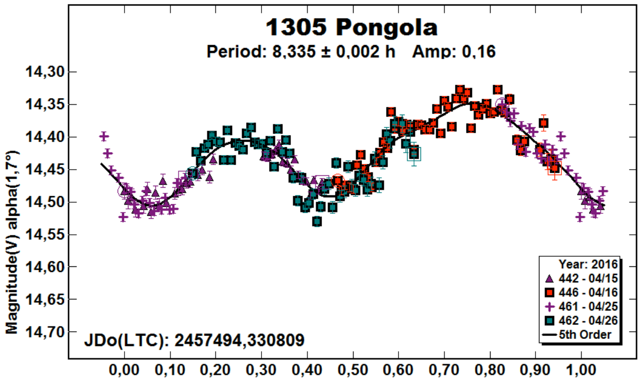
1259 Ogyalla.



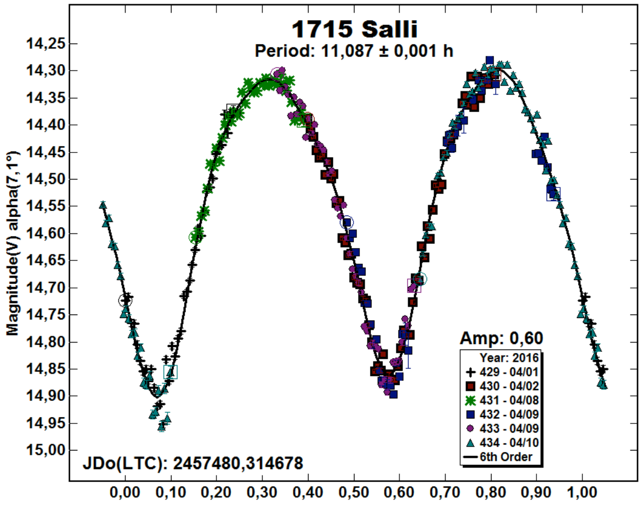
1263 Varsavia. Using data from three nights, we found a period of 7.163 ± 0.012 h and amplitude of 0.12 mag. This agrees with Warner and Stephens (2011; 7.163 h) and Wazczak *et al.* (2015; 7.165 h).



1305 Pongola. The OBAS group observed this asteroid on four nights in 2016 April. We obtained a rotation period of 8.335 ± 0.002 h and amplitude of 0.16 mag. Waszczak *et al.* (2015) found 8.0586 h and 0.17 mag.



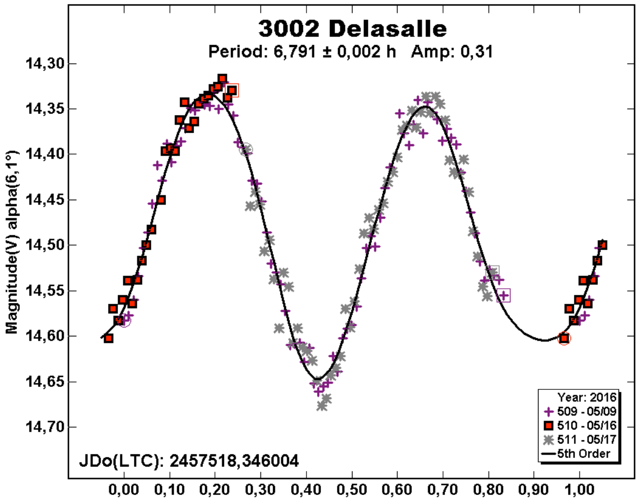
1715 Salli.



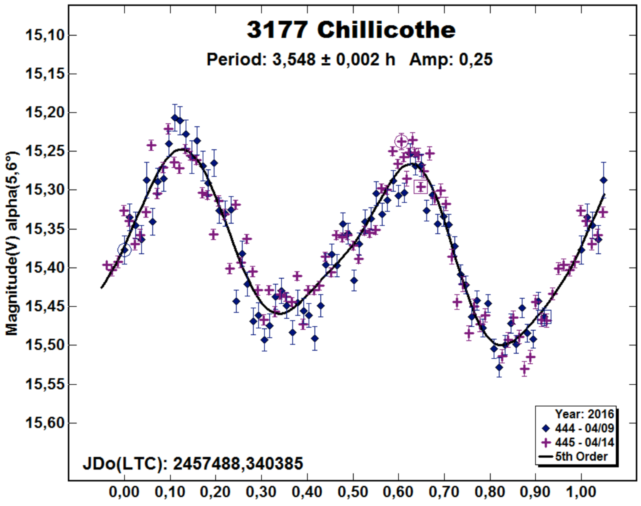
Waszczak *et al.* (2015) found a period of 11.1667 h and amplitude of 0.22 mag. We observed the asteroid on six nights during 2016

April. Our analysis determined a rotation period of 11.087 ± 0.001 h and amplitude 0.60 mag.

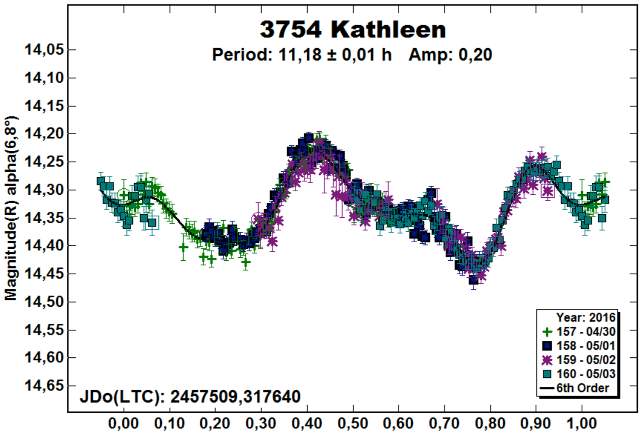
3002 Delasalle. Our analysis found a period of 6.791 ± 0.002 h and amplitude of 0.31 mag based on observations on three nights in 2016 May. The period differs a little from previous results, e.g., Waszczak *et al.* (2015; 6.5335 h, 0.39 mag)



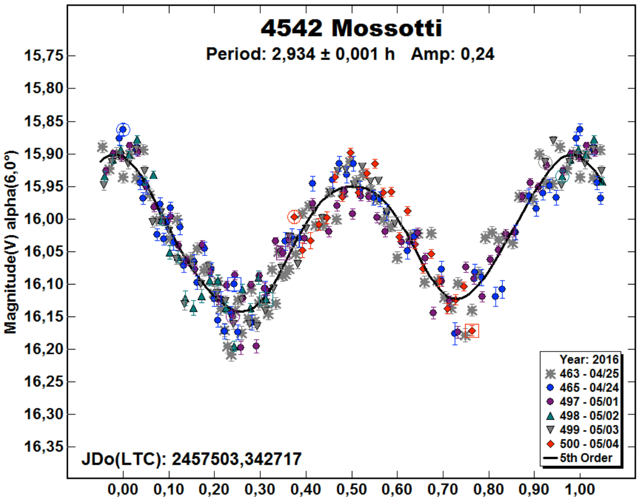
3177 Chillicothe. We observed this asteroid on two nights in 2016 April. Our analysis found a period of 3.548 ± 0.002 h and amplitude of 0.25 mag.



3754 Kathleen. This asteroid was discovered in 1931 by Clyde Tombaugh. The OBAS group observed it on four nights in 2016 April-May. We obtained a rotation period of 11.18 ± 0.01 h and amplitude of 0.29 mag. Torno *et al.* (2008) found a period of 11.2 h and amplitude of 0.13 mag. Behrend reported on the asteroid two times: 2004 (11.16 h) and 2005 (11.17 h).



4542 Mossotti. This asteroid was discovered in 1989 at Osservatorio San Vittore. The OBAS group observed it on six nights in 2016 April-May. We determined a rotation period of 2.934 ± 0.001 h and amplitude of 0.24 mag. The period is in good agreement with the 2.947 h found by Carb *et al.* (2009).



Acknowledgements

We would like to express our gratitude to Brian Warner for supporting the CALL web site and his suggestions made to the OBAS group.

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http://obswww.unige.ch/~behrend/page_cou.html

Number	Name	Date Range yy/mm/dd	Nights	Period (h)	Error (h)	Amp
381	Myrrha	2016/05/20 – 2016/05/25	2	6.572	0.001	0.30
481	Emita	2016/03/26 – 2016/03/30	4	14.412	0.006	0.17
503	Evelyn	2016/05/02 – 2016/05/25	6	38.780	0.003	0.40
507	Laodica	2016/04/30 – 2016/05/04	5	4.706	0.001	0.47
537	Pauly	2016/04/10 – 2016/04/15	5	16.168	0.011	0.14
569	Misa	2016/05/01 – 2016/05/03	4	16.848	0.053	0.17
857	Glasenappia	2016/02/15 – 2016/02/17	2	8.20	0.01	0.92
1005	Arago	2016/03/29 – 2016/04/24	5	8.784	0.001	0.22
1085	Amaryllis	2016/04/30 – 2016/05/04	4	18.111	0.025	0.19
1145	Robelmonte	2016/03/12 – 2016/03/25	6	8.002	0.002	0.13
1259	Ogyalla	2016/05/29 – 2016/06/13	7	17.334	0.004	0.41
1263	Varsavia	2016/05/01 – 2016/05/03	3	7.163	0.012	0.12
1305	Pongola	2016/04/15 – 2016/04/26	4	8.335	0.002	0.16
1715	Salli	2016/04/01 – 2016/04/10	6	11.087	0.001	0.60
3002	Delasalle	2016/05/09 – 2016/05/17	3	6.791	0.002	0.31
3177	Chillicothe	2016/04/09 – 2016/04/14	2	3.548	0.002	0.25
3754	Kathleen	2016/04/30 – 2016/05/03	4	11.18	0.01	0.20
4542	Mossotti	2016/04/25 – 2016/05/04	6	2.934	0.001	0.24

Table II. Dates of observation, number of nights, and derived periods/amplitudes.

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Pozzoli, V. (2002). Posting on CALL web site. *http://www.minorplanet.info/call.html*

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

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

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Waszczak, A., Chang, C.-K., Ofek, E.O., Laher, R., Masci, F., Levitan, D., Surace, J., Cheng, Y.-C., Ip, W.-H., Kinoshita, D., Helou, G., Prince, T.A., Kulkarni, S. (2015). "Asteroid Light Curves from the Palomar Transient Factory Survey: Rotation Periods and Phase Functions from Sparse Photometry." *Astron. J.* **150**, A75.

ASTEROIDS OBSERVED FROM CS3: 2016 APRIL - JUNE

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(Received: 11 July 2016)

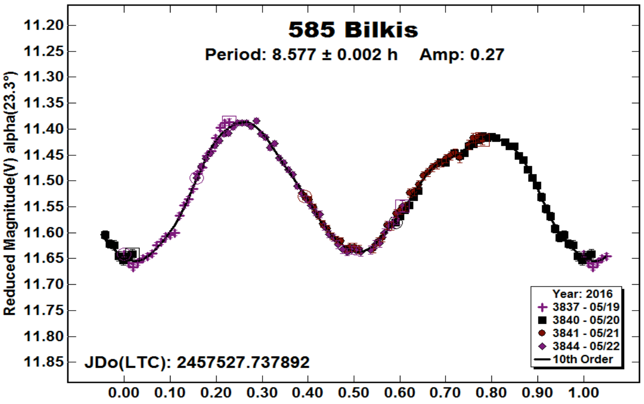
CCD photometric observations of seven asteroids were obtained from the Center for Solar System Studies from 2016 April to June.

The Center for Solar System Studies "Trojan Station" (CS3, MPC U81) has two telescopes which are normally used in program asteroid family studies. During bright moon times, those targets are usually too dim to continue observations, so brighter targets are selected to keep the telescopes operating.

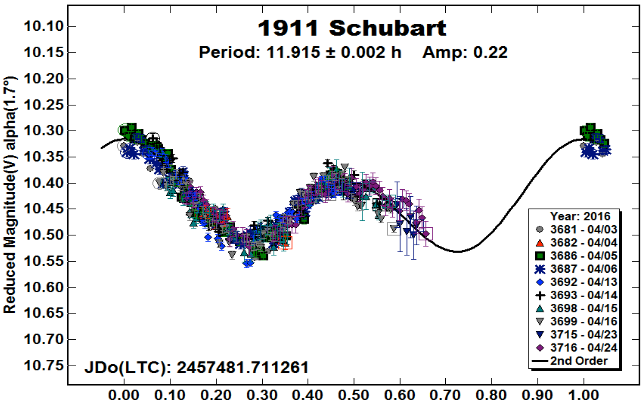
All images were made with a 0.4-m or a 0.35-m SCT using an FLI ML-Proline 1001E or FLI ML-Microline 1001E CCD camera. Images were unbinned with no filter and had master flats and darks applied. Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris *et al*., 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 2007a). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color.

In the lightcurve plots, the "Reduced Magnitude" is Johnson R corrected to a unity distance by applying $-5*\log(r\Delta)$ to the measured sky magnitudes with r and Δ being respectively, the Sun-asteroid and the Earth-asteroid distances in AU. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$.

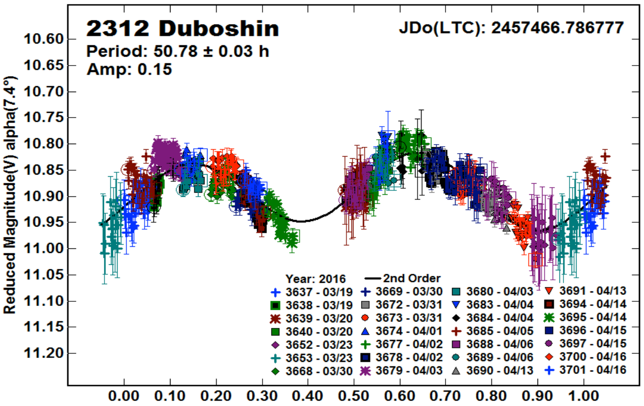
585 Bilkis. This Vestoid has been observed several times in the past. Behrend (2016) reports periods of 8.58 h, 8.5751 h, and 8.582 h. Robinson observed it in 2001 (Robinson *et al.*, 2002) initially reporting a period of 6.442 h. Warner (2011) later reanalyzed the dataset adjusting the reported period to 8.5742 h. The results from the observations in 2016 agree with those previous findings.



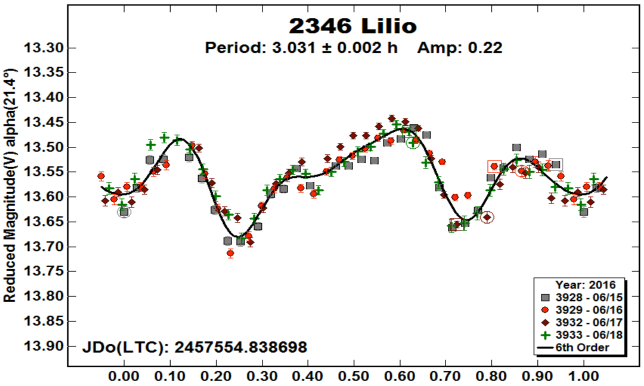
1911 Schubart. There were no previously reported rotation periods in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009), which is not surprising for a rotational period so close to 12 h. It will take a coordinated effort from observatories well separated in longitude to obtain a complete lightcurve for this Hilda.



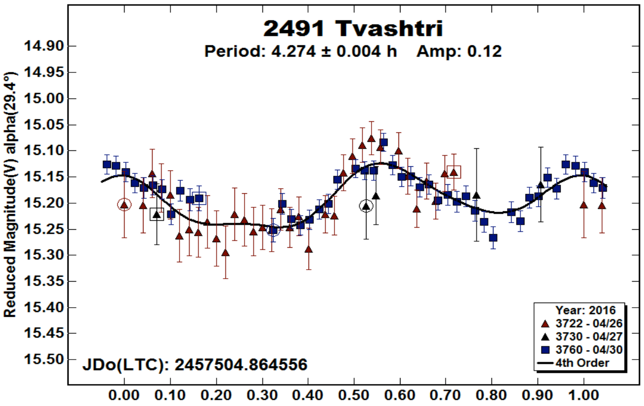
2312 Duboshin. Dahlgren *et al.* (1998) could not determine a period but reported this Hilda to be a slow rotator. Our observations show it to be slowly rotating, and close enough to double the Earth's rotation as to make getting a complete lightcurve difficult.



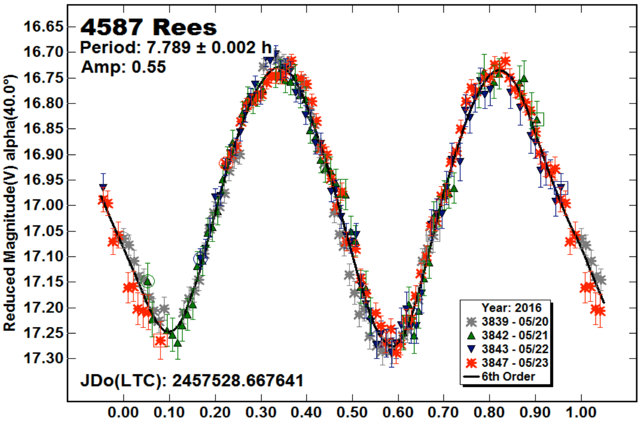
2346 Lilio. Behrend (2016) reports observations of this Vestoid in 2003, 2005, and 2007 reporting periods of 3.03 h, 3.0288.h, and 3.05 h respectively. Warner (2006) observed Lilio in 2005 reporting a period of 3.029 h. The result from 2016 of 3.031 h is in good agreement with those previous findings.



2491 Tvashtri. This Hungaria has been observed three times in the past by Warner (2008, 2013 and 2015) each time finding a period near 4.1 h. The period found this year is slightly longer and will be used as part of Warner's Hungaria pole position study.



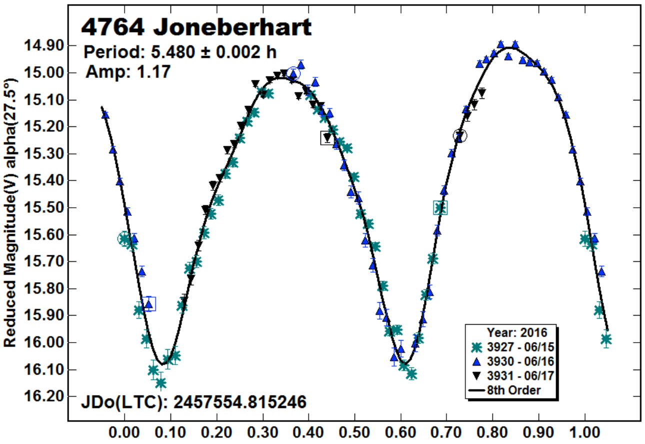
4587 Rees. Using sparse photometry from the Palomar Transient Factory, Waszczak *et al.* (2015) reported a period of 11.4905 h for this Mars Crosser which appears to be a 1.5:1 alias of other's results. Rees was also observed as a target of the Photometric Survey for Asynchronous Binary Asteroids (Parvec 2012) which found a rotational period of 7.7886 h. The result we found at this year's opposition is in good agreement with those previous findings.



Numbe	Name	2016 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period	P.E.	Amp	A.E.	Gr
585	Bilkis	05/19-05/22	144	23.3,23.9	190	3	8.577	0.002	0.27	0.01	V
1911	Schubart	04/03-04/24	430	1.7,0.9,4.6	199	-2	11.915	0.002	0.22	0.02	HI
2312	Duboshin	03/19-04/16	659	7.4,1.3	211	3	50.78	0.03	0.15	0.02	HI
2346	Lilio	06/15-06/18	131	21.5,20.6	304	6	3.031	0.002	0.22	0.02	V
2491	Tvashtri	04/26-04/30	80	29.4,28.8	270	23	4.274	0.004	0.12	0.02	H
4587	Rees	05/20-05/23	248	40.0,41.4	209	32	7.879	0.01	0.55	0.02	MC
4764	Joneberhart	06/15-06/17	108	27.5,26.9	306	13	5.48	0.002	1.17	0.02	H

Table 1. Observing circumstances. Pts is the number of data points used in the analysis. The phase angle (α) is given at the start and end of each date range, unless it reaches a minimum, which is then the second of the three values. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude. Gr is the family.

4764 Joneberhart. This is another Hungaria observed as part of Warner's Hungaria pole position study. We observed it three times in the past (Warner 2007 and 2010, Stephens 2014) each time finding periods near 5.48 h. Hanus *et al.* (2016) used the previously acquired data to construct a shape model using a synodic period of 5.48411 h and the best fitting pole positions of λ_1 219 and β_1 -36.



Acknowledgements

This research was supported by NASA grant NNX13AP56G. The purchase of a FLI-1001E CCD cameras was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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LIGHTCURVES AND ROTATION PERIODS FOR 14 ASTEROIDS

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(Received: 2016 Jul 15)

CCD photometric observations of 14 asteroids were made between 2015 May and 2016 May. A review of the results of data analysis is presented.

This review summarizes the lightcurve and rotation period results for 14 main-belt (MBA), Mars-crossing, and near-Earth (NEA) asteroids obtained from CCD photometry carried out at Sopot Astronomical Observatory (SAO) between 2015 May to 2016 May. Some of the asteroids were selected from the Potential Lightcurve Targets list of the CALL website maintained by Warner (2016) while the others were implemented within the Photometric Survey for Asynchronous Binary Asteroids (BinAstPhot Survey) under the guidance of Petr Pravec of the Astronomical Institute of the Czech Academy of Sciences.

The observations were made with a 0.35-m *f*/6.3 Schmidt-Cassegrain (SCT) and an SBIG ST-8XME CCD camera. The exposures were unguided and no filters were employed. The camera was operated in a 2x2 binning mode, which produced an image scale of 1.66 arcsec/pixel. Prior to measurements, all images were corrected using dark and flat-field frames.

Photometric reduction, lightcurve construction, and period analysis were conducted using *MPO Canopus* (Warner, 2015a). Differential photometry using up to five comparison stars of near solar color (0.5 ≤ B-V ≤ 0.9) was performed using the Comp Star Selector (CSS) utility. This helped ensure a satisfactory quality level of night-to-night zero point calibrations and correlation of the measurements within the standard magnitude framework. To calibrate field comparison stars, the Johnson V magnitudes from the AAVSO Photometric All-Sky Survey catalog (APASS; Henden *et al.,* 2009), Data Release 9 were used. In some instances, small zero point adjustments were necessary in order to achieve the best match between individual data sets in terms of minimum RMS residual of a Fourier fit.

<u>512 Taurinensis</u>. Several rotation period results were previously reported on this Mars-crosser: 5.582 h (Lagerkvist, 1982); 5.585 h (Harris, 1992); 5.59 h (Piironen, 1998), and 5.583 h (Behrend, 2005). The observations taken at the SAO from 2016 May 23-28 led to a bimodal lightcurve with a period of 5.5804 ± 0.0006 h and amplitude of 0.44 mag, which is in good agreement with the previous period results.

<u>1271 Isergina</u>. Prior to the observations conducted at the SAO, no records on rotation period determinations for this asteroid were found. The data gathered over 11 nights from 2015 December to 2016 February reveal a very likely bimodal solution of 7.59932 ± 0.00009 h with a lightcurve amplitude of 0.24 mag.

Some deviations and shallow "dips" seen in some individual data sets could possibly indicate that the asteroid is binary. A thorough analysis of the SAO data conducted by Petr Pravec refutes such a possibility (Petr Pravec, private communication) and suggests, most likely, systematic problems.

<u>1320 Impala</u>. There are three previously known period determinations for this main-belt asteroid: 6.174 h (Behrend, 2001); 6.167 (Warner, 2006), and 6.169 h (Behrend, 2006). The photometric data obtained at the SAO over five nights from 2016 March to April show a rotation period of *P* = 6.1713 ± 0.0003 h, which is fairly consistent with the other results. The bimodal lightcurve has an amplitude of 0.48 mag.

<u>2408 Astapovich</u>. No previous rotation period determinations were found for this asteroid. SAO data collected over four nights in May 2016. The most likely period solution, based on a minimum RMS fit in the Fourier analysis and a bimodal lightcurve, is 3.6749 ± 0.0005 h, which has a peak-to-peak amplitude of 0.16 mag.

<u>2904 Millman</u>. This was another target with no record of previous rotation period determinations. The SAO data gathered from 2015 December 22 to 2016 February 15 led to a bimodal lightcurve showing a period of 12.6603 ± 0.0005 h. The lightcurve amplitude was 0.26 mag.

<u>4145 Maximova</u>. There were previously reported periods found for this target prior to the photometric observations conducted exclusively at the SAO within the framework of BinAstPhotSurvey. The observations were made over eight nights in 2015 August. A bimodal lightcurve with an amplitude of 0.92 mag established by the author using *MPO Canopus* software shows a period of 19.875 ± 0.005 h, which is slightly different from a value derived independently from the same data set by Pravec (19.872 ± 0.004 h). These values are fully consistent with the recently published result by Klinglesmith (2016) of 19.875 ± 0.002 h.

<u>4919 Vishnevskaya</u>. This was another target that was observed within the BinAstPhot Survey. In this case as well, no results for a period were previously known. A period of 3.629 ± 0.002 h and amplitude of 0.09 mag were found from the SAO observations that were carried out over four nights in 2015 August. Using the same data set, Pravec (2015) independently found a slightly different value of 3.634 ± 0.003 h for the period and characterized it as insecure (uncertainty flag U = 2) due to an insufficient amount of data. Unfortunately, it wasn't possible to get additional data during that apparition.

<u>6556 Arcimboldo</u>. Higgins (2006) published a period of 2.5158 h. The data obtained at SAO within the BinAstPhot Survey in 2015 November led to a bimodal period very close to that of Higgins: 2.5166 ± 0.0003 h. The amplitude of the lightcurve is 0.24 mag. Pravec (2015) independently found a value of 2.5165 ± 0.0002 h from the same SAO data set.

<u>9414 Masamimurakami</u>. This was another BinAstPhot Survey target with no previous period determination. The period analysis, based on four data sets obtained at SAO from 2016 March 30 through April 5, yielded a secure bimodal period solution of 15.575 ± 0.004 h. The lightcurve amplitude was 0.24 mag.

<u>(16233) 2000 FA12</u>. This main-belt asteroid was observed at SAO over two consecutive nights in 2015 December as a potential binary target within the BinAstPhot Survey program. The asteroid was also observed within the same survey during the 2006 and 2012 apparitions, when periods of 3.1811 ± 0.0002 h (Pravec, 2006) and 3.1809 ± 0.0003 h (Pravec, 2012) were found. The most recent period of 3.181 ± 0.003 h derived from the SAO photometry is consistent with the previous results.

(39810) 1997 WQ35. This was a BinAstPhot Survey main-belt target that was observed during the 2009 apparition, when a period of 2.7737 ± 0.0003 h was found (Pravec, 2009). The resulting bimodal lightcurve obtained from the 2016 SAO data shows a period of 2.774 ± 0.002 h, which is fully consistent with the previous result.

(93768) 2000 WN22. This is a Mars-crossing asteroid that was observed within BinAstPhot Survey program in 2009, when a period of 2.6821 h was found (Pravec, 2009). A search found two previously reported periods: 2.6814 h (Stephens, 2009) and 2.679 h (Vander Haagen, 2009). The observations within BinAstPhot Survey obtained exclusively at SAO over three nights in 2016 March show a most likely bimodal solution with a period of 2.679 ± 0.001 h, which is consistent with the previous results. The amplitude of the 2016 lightcurve was 0.21 mag.

(153652) 2001 TC103. No previous rotation period determinations were found for this MBA. The observations conducted over three nights in 2016 May at SAO yielded a bimodal lightcurve phased to a period of 3.0681 ± 0.0004 h.

(436775) 2012 LC1. There were no known reports on rotation period determinations for this large ($D > 1$ km) NEA at the time the observations were carried out at SAO (2015 May) as part of the BinAstPhot Survey. The photometric observations taken during three consecutive nights led to a bimodal lightcurve phased to 5.687 ± 0.003 h and relatively large amplitude of 0.36 mag. Warner (2015b) later published his results for this NEA (5.687 h) based on observations carried out in 2015. His period is identical to that found by the author. The independent analysis of the SAO data conducted by Petr Pravec found a value of 5.686 ± 0.002 h (Pravec, 2015).

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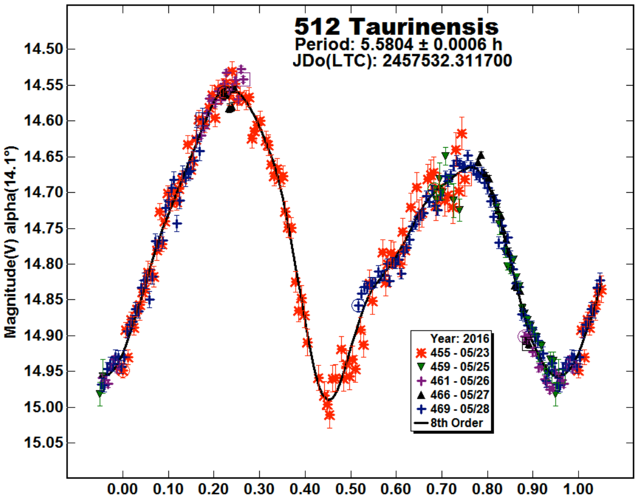
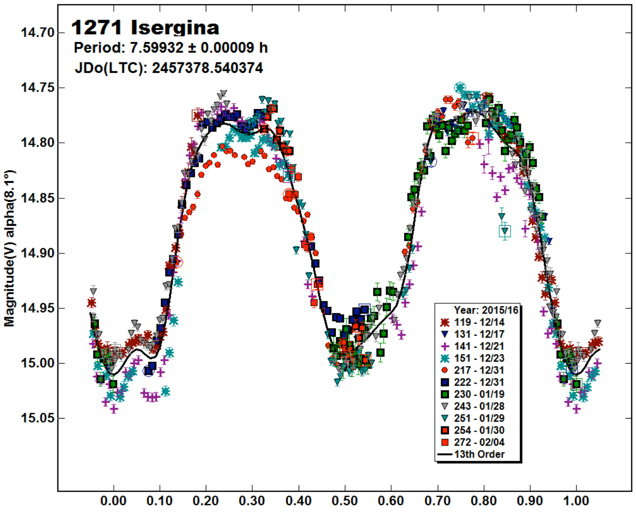
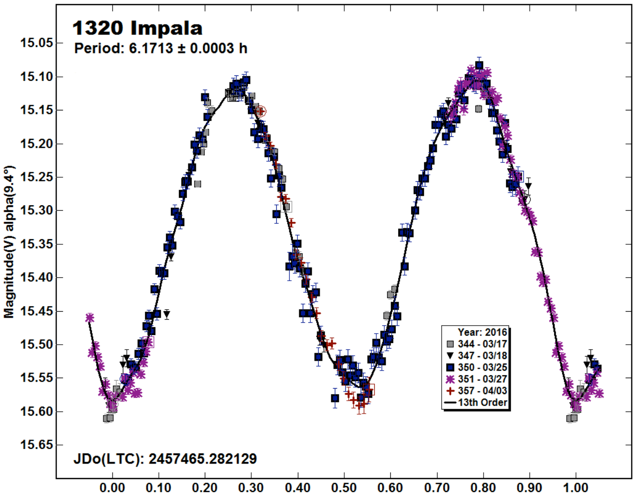
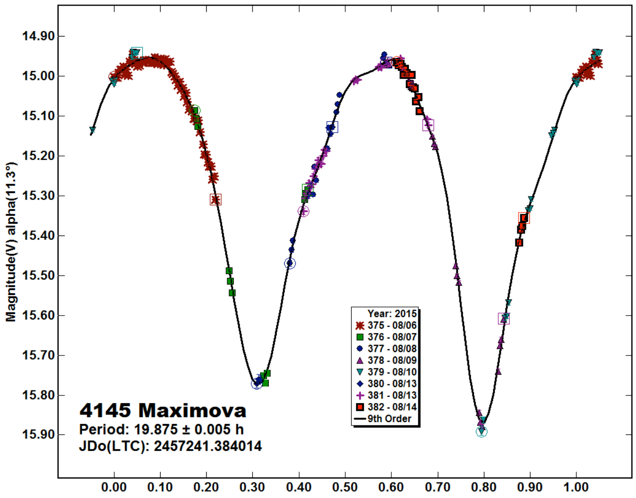
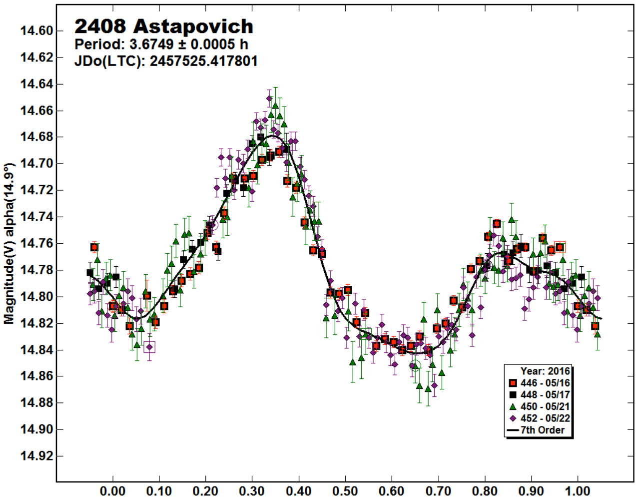
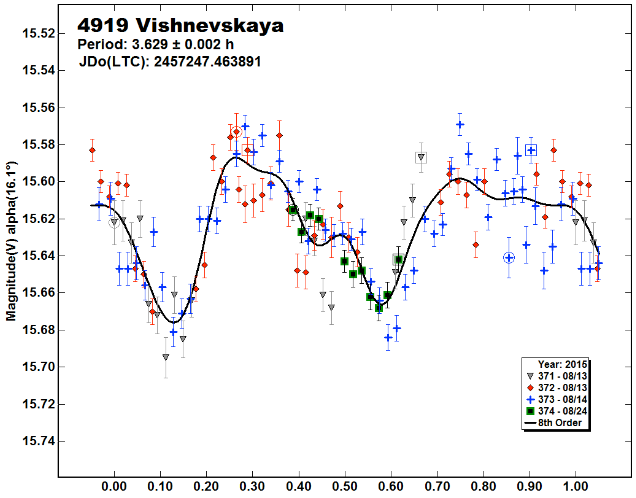


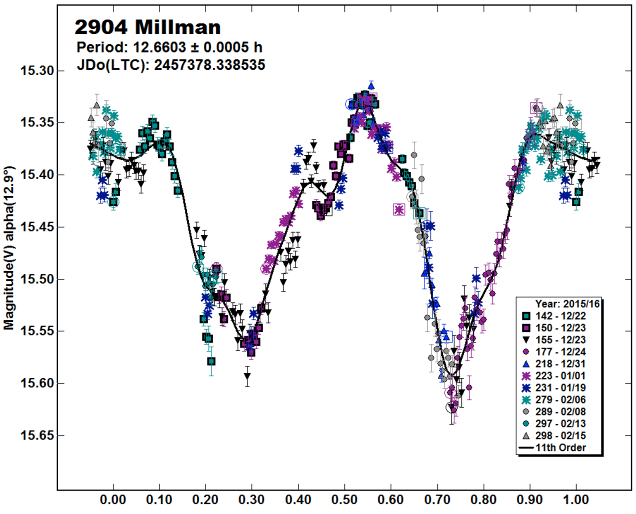


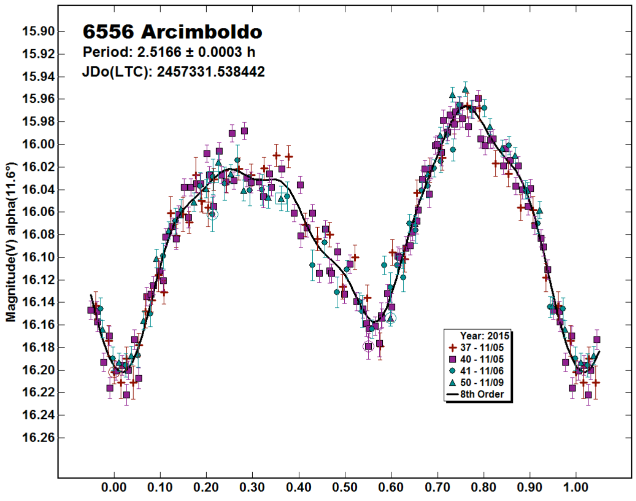

1320 Impala
Period: 6.1713 ± 0.0003 h
JDo(LTC): 2457465.282129
Magnitude(V) alpha(9.4°)
Year: 2016
344 - 03/17
347 - 03/18
350 - 03/25
351 - 03/27
357 - 04/03
13th Order
15.05
15.10
15.15
15.20
15.25
15.30
15.35
15.40
15.45
15.50
15.55
15.60
15.65
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

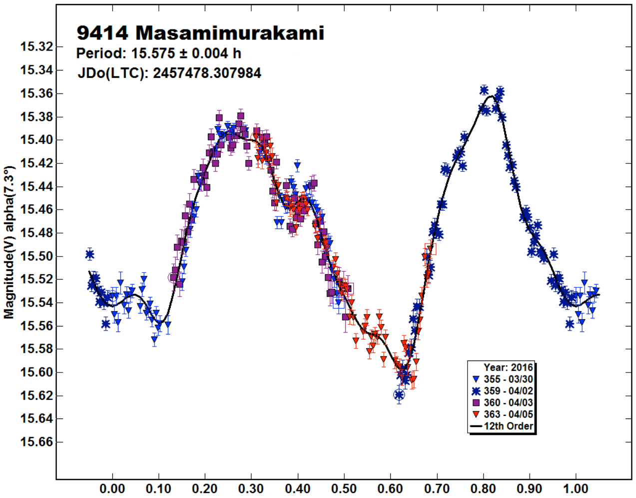

4145 Maximova
Period: 19.875 ± 0.005 h
JDo(LTC): 2457241.384014
Magnitude(V) alpha(11.3°)
Year: 2015
375 - 08/06
376 - 08/07
377 - 08/08
378 - 08/09
379 - 08/10
380 - 08/13
381 - 08/13
382 - 08/14
9th Order
14.90
15.00
15.10
15.20
15.30
15.40
15.50
15.60
15.70
15.80
15.90
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

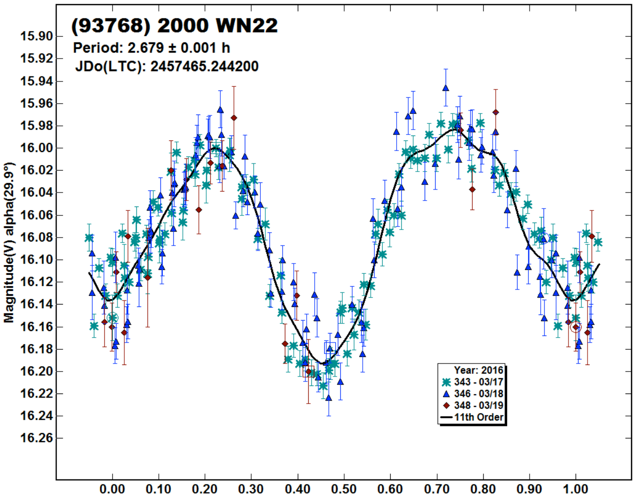

2408 Astapovich
Period: 3.6749 ± 0.0005 h
JDo(LTC): 2457525.417801
Magnitude(V) alpha(14.9°)
Year: 2016
446 - 05/16
448 - 05/17
450 - 05/21
452 - 05/22
7th Order
14.60
14.62
14.64
14.66
14.68
14.70
14.72
14.74
14.76
14.78
14.80
14.82
14.84
14.86
14.88
14.90
14.92
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

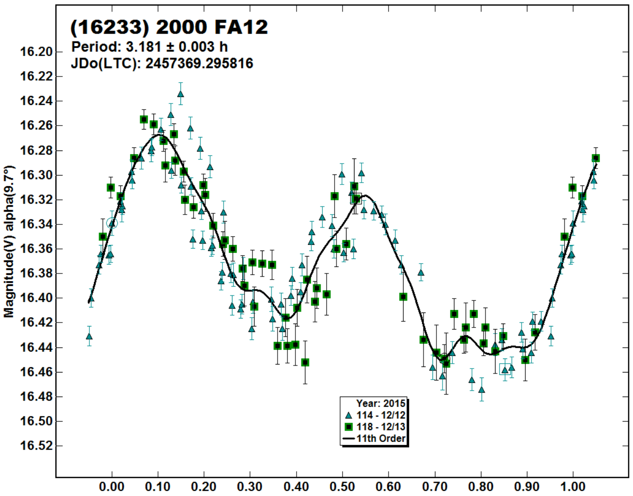

4919 Vishnevskaya
Period: 3.629 ± 0.002 h
JDo(LTC): 2457247.463891
Magnitude(V) alpha(16.1°)
Year: 2015
371 - 08/13
372 - 08/13
373 - 08/14
374 - 08/24
8th Order
15.52
15.54
15.56
15.58
15.60
15.62
15.64
15.66
15.68
15.70
15.72
15.74
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

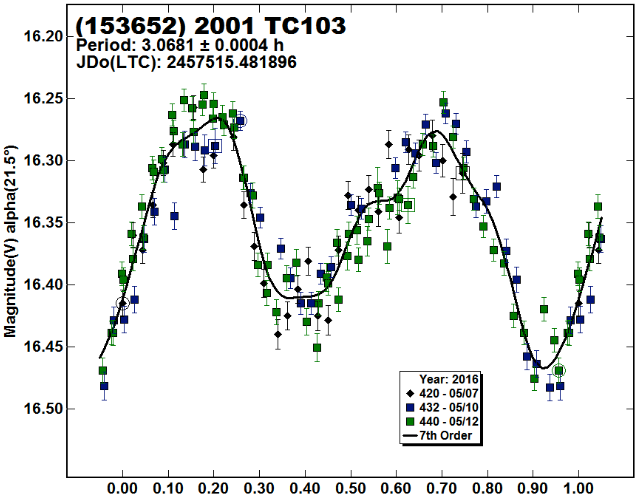

2904 Millman
Period: 12.6603 ± 0.0005 h
JDo(LTC): 2457378.338535
Magnitude(V) alpha(12.9°)
Year: 2015/16
142 - 12/22
150 - 12/23
155 - 12/23
177 - 12/24
218 - 12/31
223 - 01/01
231 - 01/19
279 - 02/06
289 - 02/08
297 - 02/13
298 - 02/15
11th Order
15.30
15.35
15.40
15.45
15.50
15.55
15.60
15.65
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

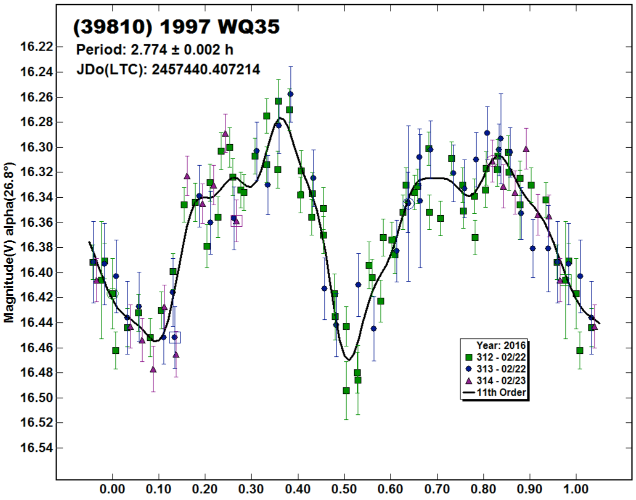

6556 Arcimboldo
Period: 2.5166 ± 0.0003 h
JDo(LTC): 2457331.538442
Magnitude(V) alpha(11.6°)
Year: 2015
37 - 11/05
40 - 11/05
41 - 11/06
50 - 11/09
8th Order
15.90
15.92
15.94
15.96
15.98
16.00
16.02
16.04
16.06
16.08
16.10
16.12
16.14
16.16
16.18
16.20
16.22
16.24
16.26
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

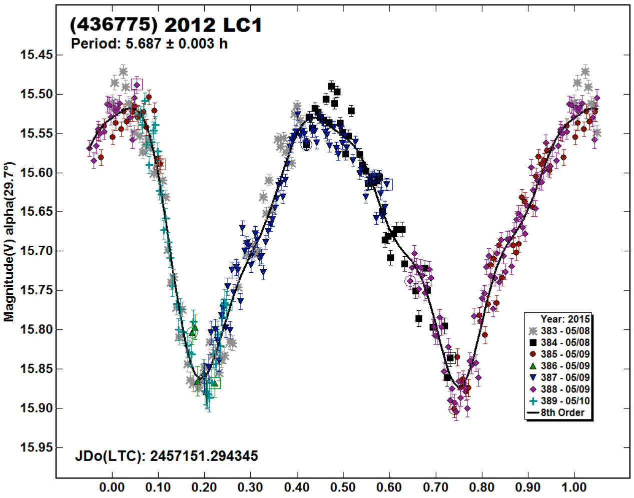

9414 Masamimurakami
Period: 15.575 ± 0.004 h
JDo(LTC): 2457478.307984
Magnitude(V) alpha(7.3°)
15.32 15.34 15.36 15.38 15.40 15.42 15.44 15.46 15.48 15.50 15.52 15.54 15.56 15.58 15.60 15.62 15.64 15.66
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2016
355 - 03/30
359 - 04/02
360 - 04/03
363 - 04/05
12th Order


(93768) 2000 WN22
Period: 2.679 ± 0.001 h
JDo(LTC): 2457465.244200
Magnitude(V) alpha(29.9°)
15.90 15.92 15.94 15.96 15.98 16.00 16.02 16.04 16.06 16.08 16.10 16.12 16.14 16.16 16.18 16.20 16.22 16.24 16.26
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2016
343 - 03/17
346 - 03/18
348 - 03/19
11th Order


(16233) 2000 FA12
Period: 3.181 ± 0.003 h
JDo(LTC): 2457369.295816
Magnitude(V) alpha(9.7°)
16.20 16.22 16.24 16.26 16.28 16.30 16.32 16.34 16.36 16.38 16.40 16.42 16.44 16.46 16.48 16.50 16.52
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2015
114 - 12/12
118 - 12/13
11th Order


(153652) 2001 TC103
Period: 3.0681 ± 0.0004 h
JDo(LTC): 2457515.481896
Magnitude(V) alpha(21.5°)
16.20 16.25 16.30 16.35 16.40 16.45 16.50
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2016
420 - 05/07
432 - 05/10
440 - 05/12
7th Order


(39810) 1997 WQ35
Period: 2.774 ± 0.002 h
JDo(LTC): 2457440.407214
Magnitude(V) alpha(26.8°)
16.22 16.24 16.26 16.28 16.30 16.32 16.34 16.36 16.38 16.40 16.42 16.44 16.46 16.48 16.50 16.52 16.54
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2016
312 - 02/22
313 - 02/22
314 - 02/23
11th Order


(436775) 2012 LC1
Period: 5.687 ± 0.003 h
JDo(LTC): 2457151.294345
Magnitude(V) alpha(29.7°)
15.45 15.50 15.55 15.60 15.65 15.70 15.75 15.80 15.85 15.90 15.95
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
Year: 2015
383 - 05/08
384 - 05/08
385 - 05/09
386 - 05/09
387 - 05/09
388 - 05/09
389 - 05/10
8th Order

LIGHTCURVE ANALYSIS OF NEA (154244) 2002 KL6: A POTENTIAL NEW BINARY ASTEROID

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(Received: 12 July 2016)

Analysis of CCD photometric observations of near-Earth asteroid (154244) 2002 KL6 indicate that it may be a binary system. The presumed primary has a synodic rotation period of 4.60869 ± 0.00005 h and lightcurve amplitude of 0.65 ± 0.03 mag. The presumed satellite has an orbital period of 24.05 ± 0.02 h and maximum lightcurve amplitude of 0.07 mag. The secondary lightcurve showed no mutual events and seems to indicate that the satellite's rotation is tidally locked to its orbital period.

CCD photometric observations of the near-Earth asteroid (154244) 2002 KL6 were conducted from 2016 June 10-27. Table I gives the telescope size and dates of observations for each of the observers.

Obs	Telescope	2016 June
Warner	0.30-m	10-17, 20-22, 27
Benishek	0.35-m	15, 22, 23
Ferrero	0.30-m	23, 26
Skiff	0.70-m	14-15

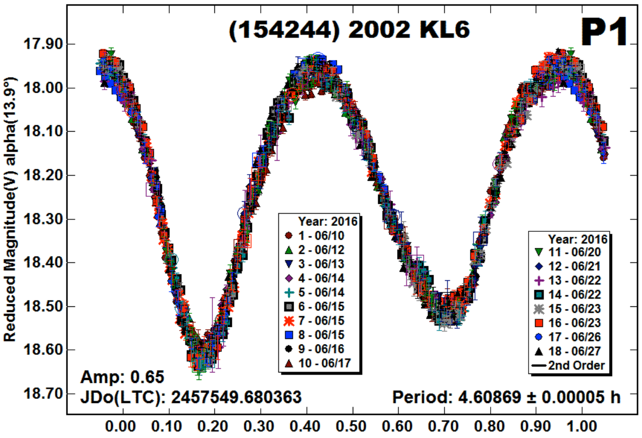
Table I. List of telescopes used and dates of observations for each observer.

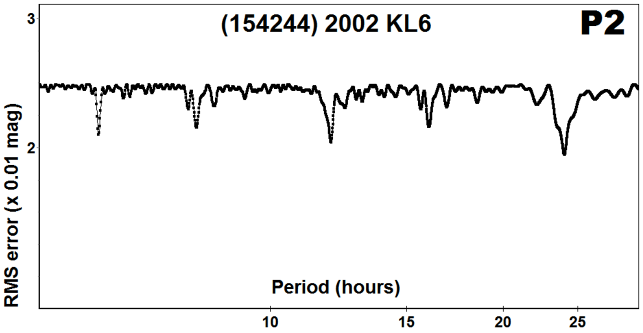
Each observer used *MPO Canopus* to process the raw images with dark and flat field frames and then to perform differential photometry. Up to five solar colored comparison stars were used each night to help minimize errors due to color differences between the asteroid and comparison stars. Warner, Benishek, and Ferrero used V magnitudes from the MPOSC3 catalog supplied with *MPO Canopus*. This catalog 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). The nightly zero points for both catalogs have been found to be generally consistent to about ± 0.05 mag or better, but on occasion are as large as 0.1 mag.

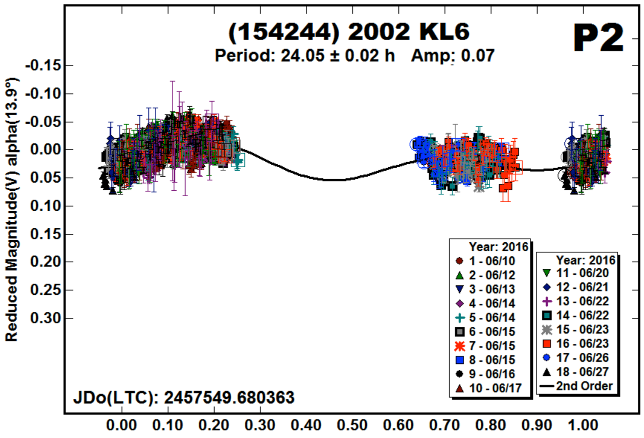
Skiff used Sloan r´ magnitudes from the CMC-15 catalog. Merging his data with those from the other observers required a small zero point offset to minimize the RMS error in the Fourier analysis. Fortunately, the large amplitude of the primary lightcurve made matching all the data sets a relatively easy and precise task.

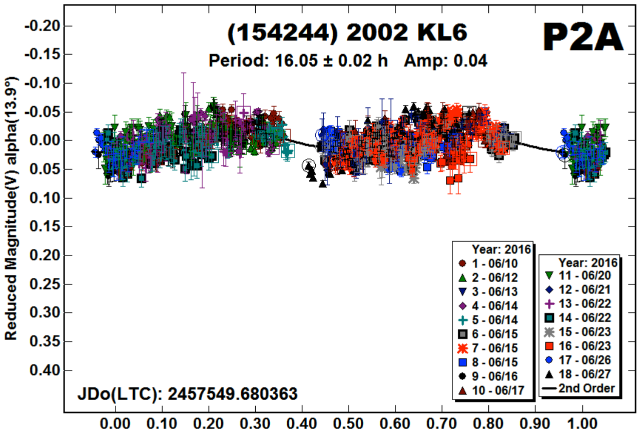
Period analysis was done by Warner using *MPO Canopus*, which incorporates the FALC Fourier analysis algorithm developed by Harris (Harris *et al.*, 1989). Even with zero point adjustments, a single period solution did not seem to give the best possible fit. The dual period feature in *MPO Canopus* was used first to find a likely dominant period. To search for a second period, the Fourier curve of the dominant period was subtracted from the dataset before the search began.

The period spectrum favored a solution at 24.05 ± 0.02 h and amplitude of 0.07 mag. This solution was confirmed by searching about the half period, which produced a monomodal solution with much smaller gaps in the coverage. However, an alternate solution of 16.05 ± 0.02 h cannot be formally excluded.









Previous results in the asteroid lightcurve database (LCDB; Warner et al., 2009) agree with the period for the presumed primary: Galad *et al.* (2010; 4.6063 h) and Koehn *et al.* (2014, 4.6081 h). Neither reported indications of a satellite. It's worth noting that the observations in 2016 were at phase angle bisector longitudes (see Harris *et al.*, 1984) roughly 90° from the earlier observations and that the lightcurve in 2016 had the lowest amplitude by 0.2-0.5 mag. This may indicate that the viewing geometry in 2016 was "just so" and allowed seeing signs of a satellite.

Since there were no obvious mutual events (occultations and/or eclipses) seen in the secondary lightcurve and the amplitude of the bimodal solution is so small, it is not appropriate to claim that the asteroid is a binary, only that it is a suspected binary.

Given the presumed orbital period, a single station has little or no hope of confirming the existence of a satellite and so a well-organized campaign with observers at widely-separated longitudes will be required at future apparitions to determine the true nature of the asteroid. Unfortunately, the next time the asteroid will again be V < 14 mag is not until 2023 August.

Acknowledgements

Funding for PDS observations, analysis, and publication was provided by NASA grant NNX13AP56G. Work on the asteroid lightcurve database (LCDB) was also funded in part by National Science Foundation grant AST-1507535. This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund. (*http://svo2.cab.inta-csic.es/vocats/cmc15/*).

This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. (*http://www.ipac.caltech.edu/2mass/*)

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SYNODIC ROTATION PERIOD OF 2656 EVENKIA

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(Received: 2016 Jul 15)

The asteroid 2656 Evenkia was observed between 2016 March 20 and April 30. A synodic period of rotation of $P = 7.0870 \pm 0.0002$ h and amplitude of $A = 0.68$ mag was found.

The asteroid 2656 Evenkia appeared on the *Lightcurve Opportunities* list (Warner *et al.*, 2016) where it was listed with a period of 7.0836 h and U = 2. Opposition for 2656 Evenkia occurred 2016 March 17.1. A search of the asteroid lightcurve database (LCDB; Warner *et al.,* 2009; updated 2016 Feb 14) found only one entry for this asteroid: Waszczak *et al.* (2015), who reported the period mentioned above.

Instruments. Observer KL used a 0.20-m Newtonian telescope fitted with a coma corrector that gave an effective focal length of 890 mm. The camera was an Atik 383L+ with a Kodak KAF-8300 chip and pixel size of 5.4x5.4 µm. Observer LH used a 0.28-m Schmidt-Cassegrain (SCT) with a 0.8x reducer and an Atik 428EX with a 1932x1452 array of 4.54x4.54 µm pixels. Both observers KL and LH used timekeeping software *Dimension 4* (2015). Observer JJ used a 0.36-m SCT with a 0.65 reducer giving an effective focal length of 2430 mm. The camera was a Moravian G2-1600 with a 1536x1024 array of 9.0x9.0 µm pixels.

Timekeeping was done with a GPS device. Observer FRL used an ACF12@f/10 and SBIG ST8 XME camera.

All telescopes were on German equatorial mounts and needed flipping near the meridian.

Calibration. All images were calibrated with master darks and flats corresponding to different filters and binning configurations. For calibration JJ used *AIP4WIN* v.2.40 (Berry and Burnell, 2005). KL used *IRIS* 5.59 software (Buil, 2011) to calibrate images by LH and KL.

Photometry. The calibrated images were analyzed by KL using *MPO Canopus 10.7.1.3* (Warner, 2011). The Comp Star Selector utility of *MPO Canopus* was used to select up to five comparison stars of near solar-color for the differential photometry.

Analysis. The first three sessions showed lightcurves with an amplitude of about 0.6 magnitudes and a half-period near 3.5 h when assuming a bimodal lightcurve. The individual lightcurves were unable to cover the entire full-period. After session 9 (April 9), a period of circa 7.08 h had the lowest RMS in the period spectrum that covered a range of 3 to 18 h. The periods with the second and third lowest RMS corresponded to the half- and double-periods, respectively. This period is in concurrence with the period first reported by Waszczak *et al.* (2015).

A lightcurve phase coverage diagram was created with Excel® spreadsheet (Fig. 1). The diagram illustrates the missing overlap of the lightcurves at rotation phase 0.4 and marginal overlap at 0.75 before session 11 on April 11, which is why observations were continued.

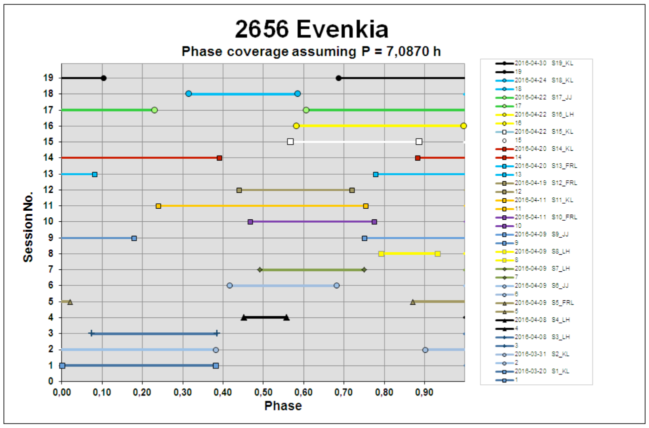

Figure 1. The diagram shows all sessions stacked vertically and, for each session, a colored bar connects the times of first and last observation folded in phase space to the reported period. Phase is measured relative to session 1.

With session 11 (April 11), the gap at phase 0.4 was covered and session 17 (April 22) covered the curve again near 0.75 phase. Using sessions 1-11 yielded a period of P = 7.087 ± 0.002 h and amplitude of 0.70 mag when using six harmonic terms. The RMS fit was 0.03 mag. Using the order-search of *MPO Canopus* v10.7.1.3. (Warner, 2013), the best RMS fit occurred at nine harmonic terms, but with less than a 10% improvement over the fit with six terms. The three phased plots (Fig. 3-5) are presented with sixth-order fits. When searching in the interval between 3.4 and 15.4 h, the four lowest RMS values in the period spectrum are all connected to the 7.087 h period (see Fig. 2).

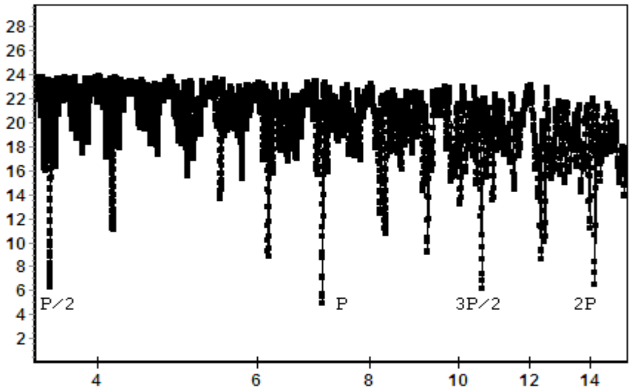

Figure 2. Period spectrum of a search between 3.4 and 15.4 h of the full data set. The four significant minima are identified and annotated.

The observations continued since the overlap at phase 0.75 in Figure 3 still was a bit thin. Sessions 12 through 19 (Fig. 4) give full phase coverage and yield an independent determination of the period. The exact values of P and amplitude are not as precise as formally stated in the figure because of sensitivity to of zero point adjustments for some of the more noisy lightcurves.

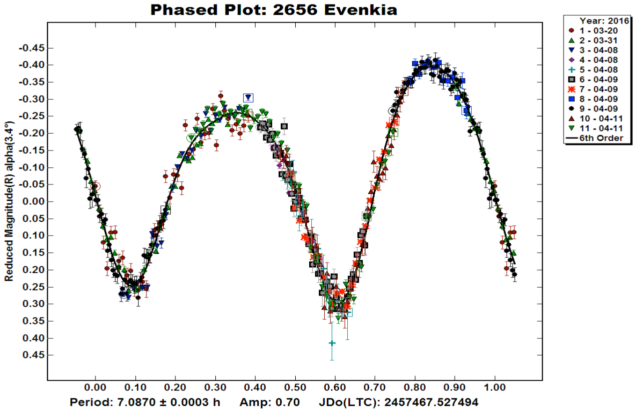

Figure 3. The phased plot of lightcurves from sessions 1-11 of 2656 Evenkia with a period of P = 7.087 h. Using the slider bar in the period search tool of *MPO Canopus,* the 2% error of ± 0.002 h was found to be more realistic. The amplitude of the Fourier fit is *A* = 0.70 mag.

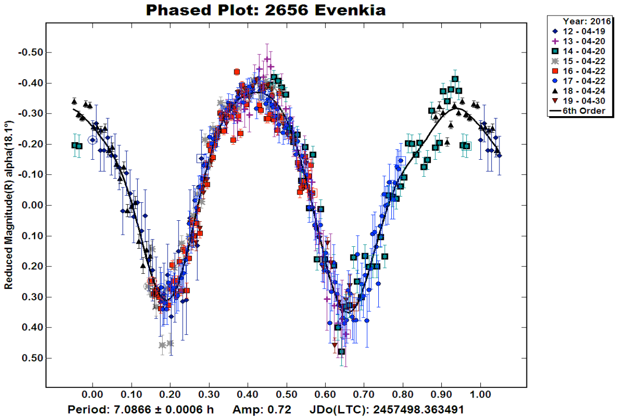

Figure 4. Phased plot with sessions 12-19 of 2656 Evenkia. The purpose of the figure is to demonstrate an independent solution for the period of *P* = 7.087 h. The formal error of the period and amplitude of this plot are unreliable due to some noisy lightcurves.

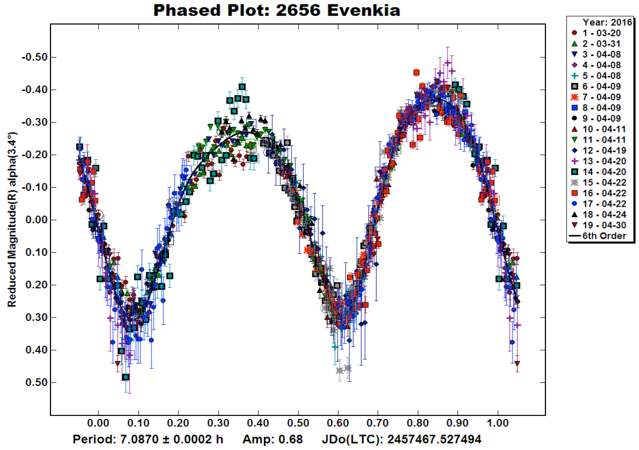

Figure 5. The phased lightcurve for 2656 Evenkia using the full data set.

Combining all sessions required zero point adjustments (DeltaComp in *MPO Canopus*) to minimize the RMS to 0.047 mag since the amplitude of the lightcurves changed slightly with increasing phase angle. We report a synodic period for 2656 Evenkia of P = 7.0870 ± 0.0002 h (3σ error) with an amplitude of A = 0.68 mag.

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THE BINARY NATURE OF THE ASTEROID 2242 BALATON

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(Received: 2016 Jul 15)

Initial observations of 2242 Balaton indicated a rotation period of about 2.8 hours with some attenuation events. Further observations and analysis showed that 2242 is a binary asteroid with a primary period of 2.7979 ± 0.0001 h and amplitude of 0.18 mag; the orbital period of the secondary is 12.96 ± 0.01 h. Mutual events that are 0.03 to 0.08 magnitude deep indicate a lower limit on the secondary-to-primary mean-diameter ratio of 0.25. From sparse photometric data we also derived H = 13.31 ± 0.05, G = 0.22 ± 0.04.

2242 Balaton (1936 TG) is a main-belt asteroid discovered at Konkoly (Budapest) on 1936 October 13 by G. Kulin. It is named for the largest lake in Hungary following a suggestion by F. Pilcher (MPC 21605). It orbits with a semi-major axis of about 2.208 AU, eccentricity 0.117, and a period of 3.28 years. According to Small-Body Database Browser (JPL, 2015) and MPC Database (MPC, 2015), its absolute magnitude is 13.2. The WISE survey used a value of H = 13.80 ± 0.15 to find a diameter of 6.129 ± 0.113 km and albedo of p_V = 0.142 ± 0.017 (Masiero *et al.*, 2011). Using photometric sparse data from Catalina Sky Survey (MPC 703; CSS, 2015), we derived H = 13.31 ± 0.05 and G = 0.22 ± 0.04 (Fig. 1), which is close to those in the JPL Small-Body Database Browser and MPC database.

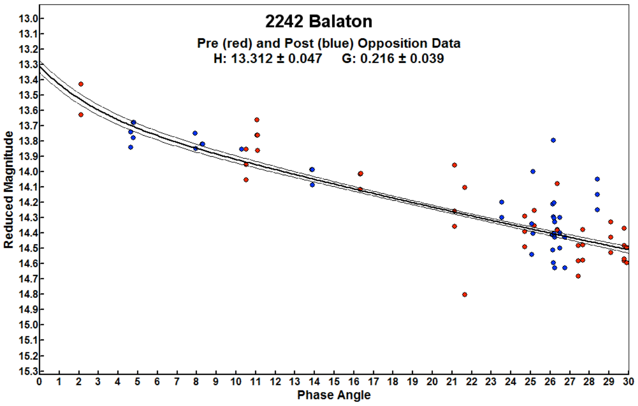

Figure 1. H-G plot for 2242 Balaton from Catalina Sky Survey (MPC 703) photometric sparse data.

We decided to observe 2242 Balaton since it listed in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009).

The asteroid was observed on 11 nights from 2015 Dec 27 through 2016 Jan 16. Starting with the initial sessions, conducted at the Astronomical Observatory of the University of Siena (DSFTA, 2016), we noticed some anomalous attenuations in the lightcurves that made us suspect they were due to eclipse/occultation events. Preliminary data were sent to Lorenzo Franco and Petr Pravec, who involved three other observatories in the campaign to confirm the binary hypothesis for 2242 Balaton. Table I lists all the observers and equipment used.

Observers	Telescope	CCD
Bacci (104)	0.60-m f/4.0 SCT	Apogee Alta
Klinglesmith (719)	0.35-m f/11 SCT 0.35-m f/11 SCT	SBIG STL-1001E SBIG ST-10XME
Marchini (K54)	0.30-m f/5.6 MCT	SBIG STL-6303E (bin 2x2)
Pray	0.50-m f/4.0 RT	SBIG ST-10XME

Table I. Observers and equipment. SCT: Schmidt-Cassegrain; MCT: Maksutov-Cassegrain; RT: Reflector.

All images were calibrated with bias, flat, and dark frames. Data processing, including reduction to R band, and period analysis were performed using *MPO Canopus* (BDW Publishing, 2012). Differential photometry measurements were performed using the Comp Star Selector (CSS) procedure in *MPO Canopus* that allows selecting of up to five comparison stars of near-solar color. Additional adjustments of the magnitude zero-points for the particular data sets were required in order to achieve the minimum RMS value from the Fourier analysis.

A total of 707 data points were collected. Over the interval of about 20 days, the phase angle ranged from 5.1 to 16.2 degrees after the opposition. Using the single period solution from *MPO Canopus*, we obtained a period of 2.7979 ± 0.001 h and amplitude of about 0.20 mag (Fig. 2).

Looking at the phased plot obtained with the single period solution, the data from some sessions did not fit well. Using instead the iterative dual-period solution from *MPO Canopus*, we obtained a better result, with a primary period of $P_1 = 2.7979 \pm 0.0001$ h and amplitude of 0.18 mag (Fig. 3) along with a secondary period of $P_{Orb} = 12.96 \pm 0.01$ h (Fig. 4). The mutual eclipse/occultation events have amplitudes of 0.03 to 0.08 mag. The lower value gives a lower limit on the secondary-to-primary mean-diameter ratio of Ds/Dp ≥ 0.25.

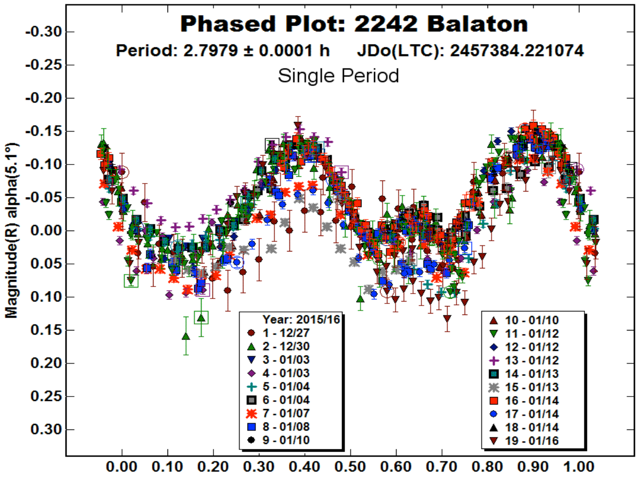

Figure 2. The single-period solution using data from 19 sessions. Note that some sessions show attenuation events in the lightcurve.

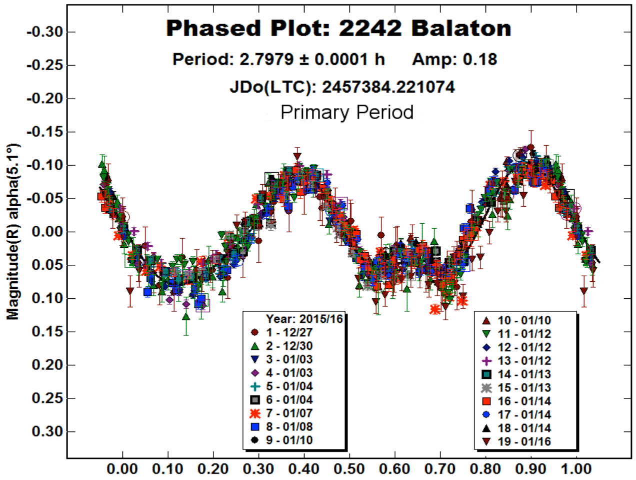

Figure 3. Using the dual-period search within MPO Canopus after subtracting out the secondary period, we obtain the primary period.

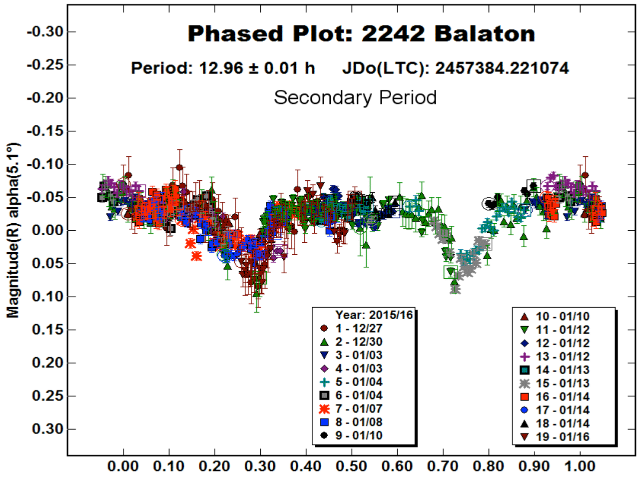

Figure 4. Using the dual-period search within MPO Canopus after subtracting out the primary period, we obtain the secondary period where the eclipse/occultation events are evident.

A parallel, independent analysis was performed by Petr Pravec, who confirmed these results, so the authors announced the discovery through the CBET 4243 (Marchini *et al.*, 2016), published on 2016 Jan 23.

Acknowledgements

The Etscorn Campus Observatory operations are supported by the Research and Economic Development Office of New Mexico Institute of Mining and Technology (NMIMT).

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LIGHTCURVE AND ROTATION PERIOD DETERMINATION FOR 5318 DIENTZENHOFER AND 9083 RAMBOEHM

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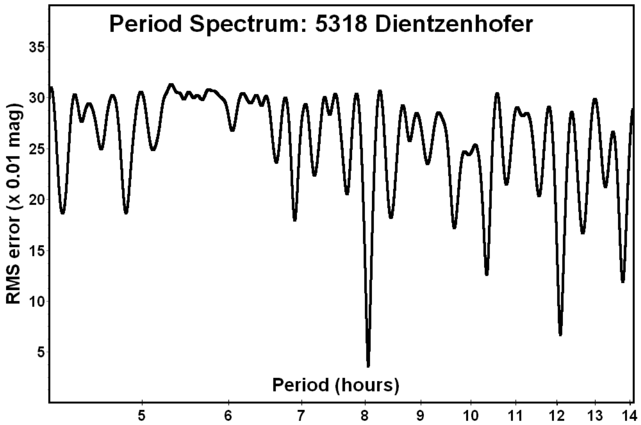
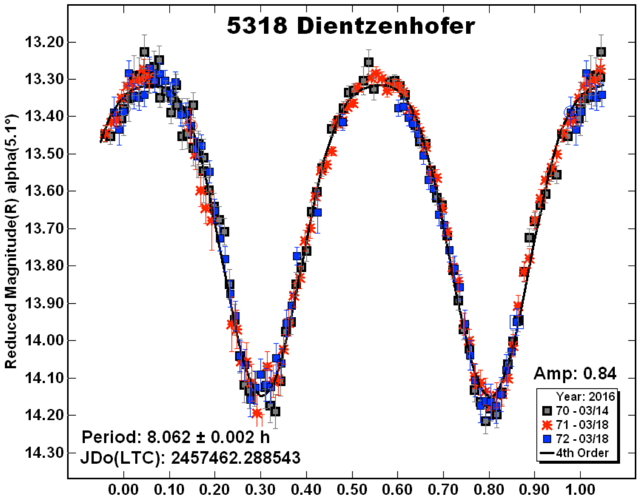
(Received: 2016 Jul 15)

Photometric observations of the main-belt asteroids 5318 Dientzenhofer and 9083 Ramboehm were made in 2016 March and 2015 December, respectively. Analysis of the data found a bimodal lightcurve with a synodic rotation period of 8.062 ± 0.002 h for 5318 Dientzenhofer. A trimodal lightcurve with synodic period of 10.199 ± 0.004 h for 9083 Ramboehm was found to be the most likely solution.

5318 Dientzenhofer is a main-belt asteroid that was discovered on 1985 April 21 by Antonin Mrkos (JPL, 2016). It's a typical main-belt asteroid in an orbit with a semi-major axis of about 2.29 AU, eccentricity 0.13, and orbital period of about 3.47 years. The absolute magnitude is H = 13.5 (JPL, 2016). Using H = 13.3, the WISE survey (Mainzer *et al.*, 2011) found a diameter of D = 6.27 km and albedo of p_V = 0.2152. Bus and Binzel (2002a; 2002b) found the asteroid to be type taxonomic type Sk.

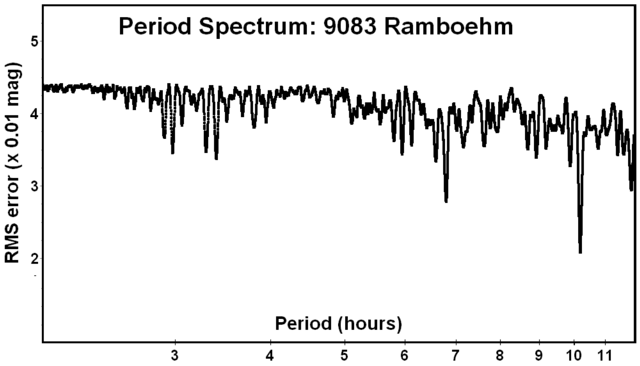
Observations were made on three nights from 2016 March 14-18, with a total of 230 useful data points collected during that time. The phase angle ranged from 5.5° to 3.8° before opposition. At the Astronomical Observatory of the University of Siena, data were obtained with 0.30-m *f*/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E CCD camera, and clear filter; the pixel scale was 2.26 arcsec in binning 2x2. Exposures were 300 seconds.

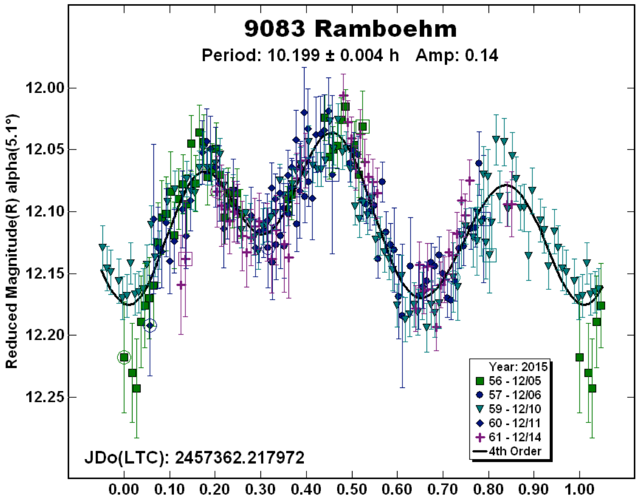




The period analysis yielded several possible solutions with similar RMS values that clearly stand out in the period spectrum. We concluded that the most likely value of the synodic period for 5318 Dientzenhofer is associated with a bimodal lightcurve phased to 8.062 ± 0.002 hours with an amplitude of 0.84 ± 0.02 mag.

9083 Ramboehm is a main-belt asteroid discovered on 1994 November 28 by David Levy and Carolyn Shoemaker. It’s a typical main-belt asteroid in an orbit with a semi-major axis of about 2.57 AU, eccentricity 0.16, and orbital period of about 4.13 years. The absolute magnitude is $H = 12.4$ (JPL, 2016). Using the same value, Mainzer *et al*. (2012) found $D = 8.74$ km, $p_V = 0.2536$.





Observations were made on five nights from 2015 December 5-14, with a total of 271 useful data points collected. The phase angle ranged from 1.9° to 4.7° after opposition. Data were obtained at the Astronomical Observatory of the University of Siena with the same equipment as used for 5318 Dientzenhofer, with exposure times of 300 seconds.

The period analysis strongly favored a solution near 10 hours. We concluded that the most likely value of the synodic period for 9083 Ramboehm is associated with a trimodal lightcurve phased to 10.199 ± 0.004 hours with an amplitude of 0.16 ± 0.03 mag.

Acknowledgments

Image acquisition and analysis of 5318 Dientzenhofer at the Astronomical Observatory of the University of Siena were performed by some high school students involved in interesting guidance vocational projects about astronomy: Marina Bastiani (Liceo Bandini, Siena); Agnese Calvani, Federico Cigalotti, Elena Cortesi, Federico Martinelli, Bernardo Parrini, Michele Valenti, Pietro Vitale (Liceo Galilei, Siena); Federico Benincasa, Alessandro Brizzi, Lorenzo Cozzani, Davide D'Onofrio, Roberto Fontana, Antonio Grassia, Sophia Gullo, Francesco Mattera, Demetra Paghi (Liceo Sarrocchi, Siena); Giovanni La Rosa (Liceo Volta, Colle Val d’Elsa).

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PARAMETERS OF ROTATION AND SHAPES OF MAIN-BELT ASTEROIDS FROM APT OBSERVATORY GROUP: SECOND QUARTER 2016

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Received: (2016 Jul 15)

Using observations made during the second quarter of 2016, the rotation periods and the semi-axis a/b ratio of the projected shape for six main-belt asteroids were determined: 238 Hypatia, 1603 Neva, 1859 Kovalevskaya, 4170 Semmelweis, 3002 Delasalle, and (31013) 1996 DR.

For about the last four decades, photometric analysis of main-belt asteroids has been growing steadily. As of mid-2016, rotation periods for more than five thousand asteroids are reported in the asteroid lightcurve database (LCDB; Warner *et al.*, 2009).

In the LCDB, the quality of almost all lightcurve period solutions is indicated with a quality code (U). The U values range from 0 to 3, with U = 0 indicating that the reported period has been found to be wrong while U = 3 indicates a secure solution without any ambiguities. Some asteroids have no quality code assigned, which means that a valid estimate of the period and amplitude could not be made from the available data.

For this work, I selected asteroids with U = 2 to 3 as well as one other that was not in the LCDB at the time. Even if an asteroid has a U = 3 rating, it can still be useful to observe it. For example, the lightcurve amplitude may be different because it will be observed at a different phase angle or viewing aspect as defined by the phase angle bisector (PAB; see Harris *et al.*, 1984). The changes over several apparitions are important when trying to generate a three-dimensional model of the asteroid.

Observations

All observations were conducted from APT Observatory Group. During the last 10 years, APT has contributed relative astrometry of double stars as well astrometry and photometry of minor planets. It has published a number of papers in some of Spain's leading scientific journals.

Observatory	**Scope (meters)**	**CCD + Accessories**
OIA Obs. Isaac Aznar	0.35 SCT	SBIG STL-1001E + AO
POP Punto Obser. Puçol	0.25 SCT	SBIG ST-9XE + AO

Table I. Equipment used for imaging.

The APT Observatory Group is made up of two observatories. The first is the Isaac Aznar Observatory, located at 1270 meters in Centro Astronómico del Alto Turia, Aras de los Olmos, Valencia, Spain. This observatory is equipped with a 0.35-m telescope, a STL-1001E CCD camera, and adaptive optics (AO) system; the image scale is 1.44 arcsec/pixel. The skies are very dark (22.1 magnitudes/arcsec^2) and have very good seeing. The second site is the POP-Punto de Observación de Puçol, Puçol, Spain. This is an urban observatory equipped with a 0.25-m telescope, SBIG ST-9 CCD camera, and AO system.

All images were obtained in 1x1 binning mode and were taken without any photometric filter. Exposures were chosen so that SNR would keep data dispersion to a minimum. Bias frames and twilight sky flat-field were taken to calibrate the images.

Data Reduction

MPO Canopus was used to reduce the images. This program incorporates the Fourier analysis for lightcurves (FALC) algorithm developed by Harris (Harris *et al.*, 1989). A star subtraction technique in *MPO Canopus* (StarBGone) was used when needed to remove the effect of stars located along the asteroid's path. The subtraction is most effective when the SNR of the star is equal to or less than asteroid SNR. (Aznar, 2013).

When analyzing the rotation period for the six asteroids, a period spectrum covering a wide range of potential solutions was used to determine the most likely period. The Fourier analysis used fourth-order or less fits to make sure that the amplitude of the Fourier model lightcurve would not go far beyond the amplitude of the asteroid lightcurve.

Number	Name	Class	p_V	H
238	Hypatia	C	0.428	8.18
1603	Neva	C	0.0594	10.9
1859	Kovalevskaya	C	0.057	10.7
3002	Delasalle	S	0.24	12.6
4170	Semmelweis	S	0.14	11.6
31013	1996 DR	-	0.15*	14.0

Table II. Asteroid classification, albedo, and absolute magnitude. *Assumed. (LCDB, 2016 February).

The lightcurve of an asteroid can provide information about its shape, especially when the asteroid is near opposition. If the lightcurve is double-peaked (bimodal) and has an amplitude of at least 0.2-0.3 mag, then the asteroid very likely is an elongated body. It is very important to select an appropriate harmonic order to avoid finding the wrong result as the analysis tries to follow the noise in the data.

Assume that the lightcurve has a large enough amplitude. Also assume that the asteroid is approximately a triaxial body where a > b > c and that the asteroid is spinning about the c axis (Harris and Lupishko, 1989). If these assumptions are true, then it is possible to determine a *minimum* a/b axis ratio. The first step is to calibrate the lightcurve amplitude A(α) to its amplitude at zero phase angle A(0) using the formula from Zappala *et al.* (1990):

$$A(0) = A(\alpha) / (1 + m \cdot \alpha) \quad (1)$$

where α is the phase angle and m is the slope that correlates the amplitude to the phase angle.

After finding the amplitude at zero phase angle, it was possible to find the *minimum* a/b ratio for each of the six asteroids using the formula from Zappala *et al.* (1990):

$$\Delta m = 2.5 \log(a/b), \text{ or} \qquad (2a)$$

$$a/b = 10^{(\Delta m/2.5)} \qquad (2b)$$

where Δm is the peak-to-peak lightcurve amplitude.

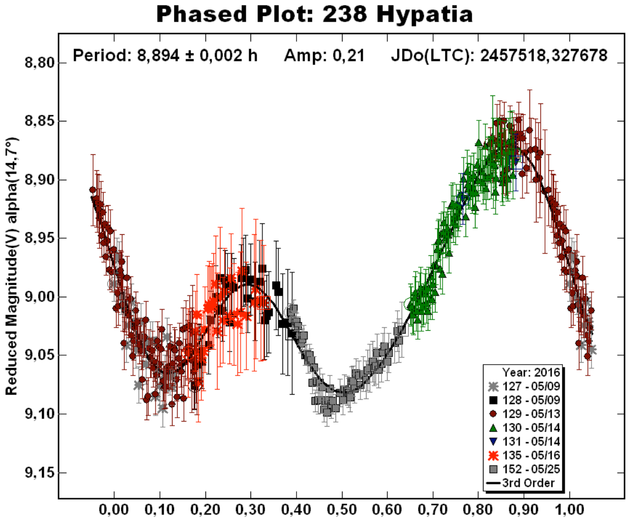
These formulae assume that the view of the asteroid is exactly equatorial. If the asteroid's spin axis is tilted towards the Earth, then the a/b ratio is a *minimum* since, when one of the asteroid's poles is pointed exactly towards Earth, the amplitude of the lightcurve is considerably less, sometimes approaching 0.0 mag. See Binzel and Sauter (1992) for the complete formula.

Num	Name	Size	Period (h)	a/b
238	Hypatia	148.48	8.894 ± 0.002	1.172
1603	Neva	36.03	6.430 ± 0.015	1.252
1859	Kovalevskaya	34.40	11.114 ± 0.010	1.272
3002	Delasalle	7.47	6.537 ± 0.010	1.310
4170	Semmelweis	17.0	5.31 ± 0.01	1.563
31013	1996 DR	5.44*	10.52 ± 0.092	1.167

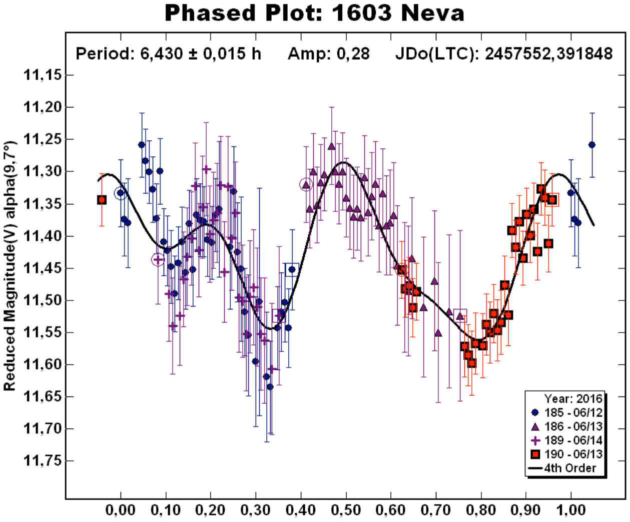
Table III. Physical properties of six asteroids. *Assuming *H* from Solar System Dynamics (JPL, 2016) and *G* = 0.15 (LCDB).

238 Hypatia. This is a 146 km (Mainzer *et al.*, 2011) outer main-belt asteroid was discovered in 1884 by Viktor Knorre in Berlin. Bus and Binzel (2002a; 200b) classified Hypatia as type C. The absolute magnitude is *H* = 8.18 (MPC, 2016). Mainzer *et al.* (2011) found an albedo of p_V = 0.044. The LCDB rates the period U = 3. Even though the period is well known, it is still useful to get new data in order to evaluate changes in the lightcurve shape and amplitude with different phase angle bisector values (Harris *et al*, 1984).

The rotation period for Hypatia has been reported by several observers, *e.g.*, Behrend (2011), who reported a period of 8.8749 h and maximum amplitude of 0.12 mag when the phase angle bisector (PAB) values were L_{PAB} = 181° and B_{PAB} = –0.2° while the phase was about 4°. In 2016, a similar synodic rotation period of 8.894 ± 0.002 h was found along with an amplitude of 0.21 mag. The PAB values were L_{PAB} = 185°, B_{PAB} = +2° and the phase angle was about 15°. Since the PAB values were similar, the difference in amplitude was probably due almost entirely to the difference in phase angles. Using Eq. 2b, the asteroid's shape projected onto the sky had an a/b ratio of 1.213;

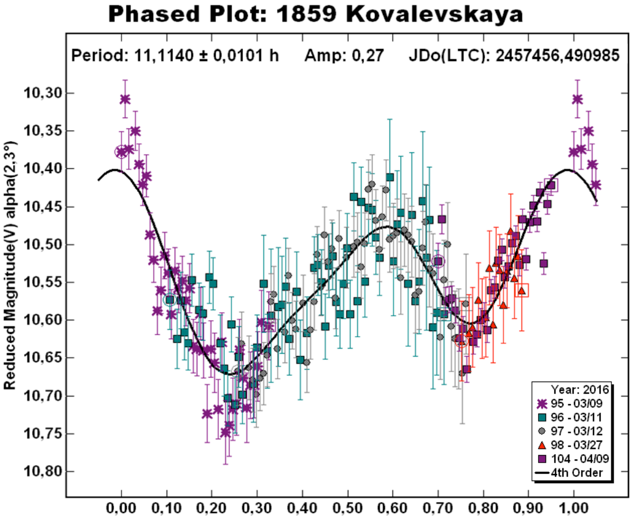


1603 Neva. Discovered in 1926 by Grigori Neúimin, the orbit of this is located at the outer region of the main-belt. This is a C-type asteroid (Bus and Binzel, 2002a; 2002b). Mainzer *et al.* (2011) give a diameter of 36 km based *H* = 10.9 and p_V = 0.0423. The only reported rotation period is from Behrend (2004), who found *P* = 6.4249 h and amplitude of 0.22 mag (U = 2; LCDB). Analysis of the data from 2016 found a period of 6.430 ± 0.015 h with an unusual lightcurve shape that has three maximums and three minimums. The maximum lightcurve amplitude is 0.28 magnitudes. The projected shape has a/b = 1.294.



1859 Kovalevskaya. This is a C-type asteroid located in the outer main-belt that was discovered in 1974 by Russian astronomer Lyudmila Zhuravleva. The class is assumed based on the albedo p_V = 0.0427 found by Mainzer *et al.* (2011) using *H* = 10.6 They gave an estimated size of 46.02 km.

Waszczak *et al.* (2015) found *P* = 11.1084 h and *A* = 0.13 mag using data obtained in 2013. The data from the 2016 campaign show a bimodal lightcurve (two minimums and two maximums) with a period of 11.1140 ± 0.0101 h and amplitude of 0.27 mag. The calculated a/b ratio is 1.282.

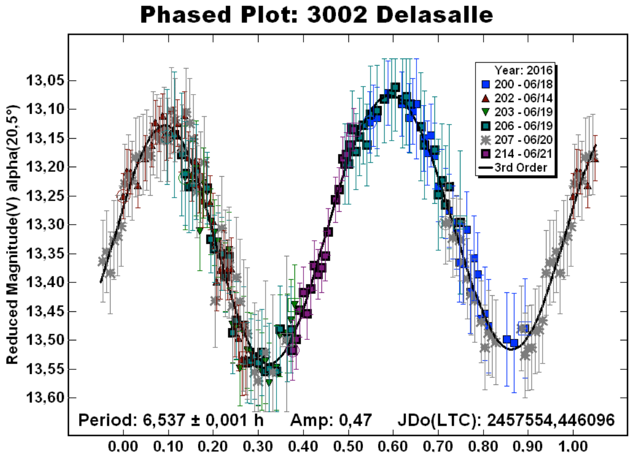


3002 Delasalle. This is a Flora group member that is assumed to be of type S based on it being a part of that group. The asteroid was discovered in 1982 by Henry Debenogne. Waszczak *et al.* (2015) found H_R = 12.35. If a V-R color index is not available, the LCDB assumes V-R = 0.45. This gives *H* = 12.80. Masiero *et al.* (2012) used *H* = 12.5 to find p_V = 0.452 and *D* = 6.3 km.

A rotation period of about 6.53 hours was reported by Waszczak *et al.* (2015, *A* = 0.39 mag), Pravec *et al.* (2016w, A = 0.34 mag), and

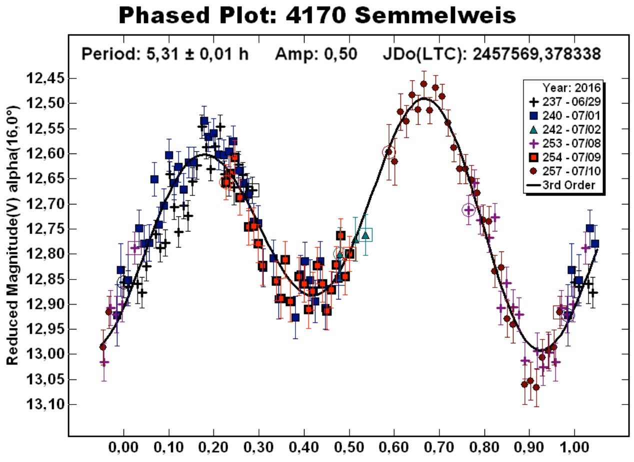
Behrend (2016, A = 0.35 mag). The Pravec *et al.* and Behrend results are rated U = 3 in the LCDB.

This asteroid was observed by APT during the 2016 opposition. We found a rotation period of P = 6.537 ±0.001 h, which is consistent with the previous results. The amplitude was 0.47 mag, or a little larger than previous results. The 2016 data were obtained when the phase angle was about 20 degrees, about the same as Waszczak *et al.* but much larger than with the other two results at phases angles <10 degrees. This clearly shows the amplitude-phase relationship. The projected shape has a/b = 1.542.



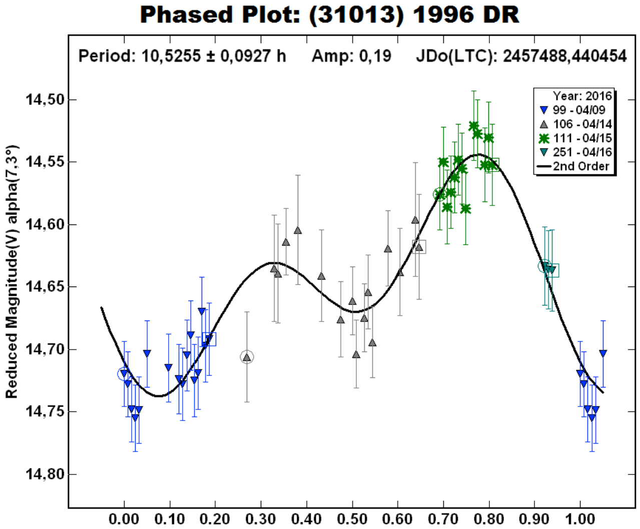
4170 Semmelweis is a member of the Eos group and was discovered in 1980 by Vavrova at Klet. The assumed taxonomic class is S based on the group membership. Mainzer *et al.* (2011) found D = 17.0 km and p_V = 0.1683 using H = 11.4. Waszczak *et al*. (2015) found a period of 5.3051 h.

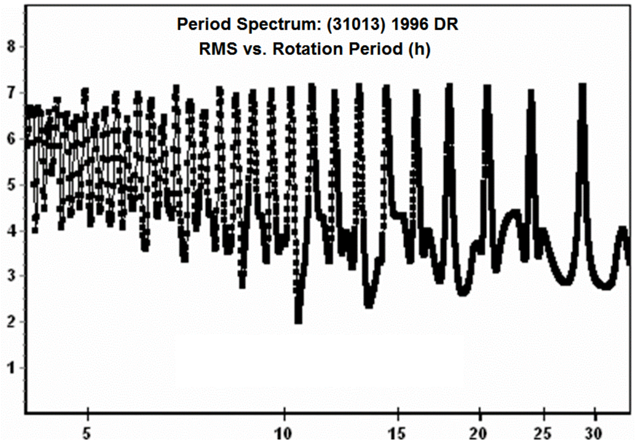
Our analysis of the data from 2016 found a rotation period of 5.31 ± 0.01 h. The lightcurve shows a bimodal shape with an amplitude of 0.50 mag. This amplitude is higher than the two amplitudes reported by Waszczak *et al.* (0.36 and 0.48 mag) using data from 2012 August and September, respectively. The PAB values for our observations were about L_{PAB} = 237° and B_{PAB} = 12°. It appears that the main reason for the changes in amplitude from 2012 to 2016 was due to differences in L_{PAB}. The calculation a/b ratio is 1.585.



(31013) 1996 DR. This asteroid was discovered in 1996 by Takao Kobayashi at Oizumi (Japan). The MPC (2016) gives H = 14.1. The LCBD gives an assumed taxonomic type of S and p_V = 0.20 based on the inner main-belt location. The estimated diameter in the LCDB is 4.5 km.

Pravec *et al.* (2016w) reported a period of about 280 h with an amplitude of 0.5 mag. The analysis made in this campaign reveals a bimodal lightcurve with an amplitude of 0.20 mag with a period of 10.52 ± 0.092 h but the period spectrum shows that there are other solutions possible. Since there are such different results, observations in the future should be made. The estimated a/b ratio is 1.191.





Acknowledgments

We would like to express our gratitude to Brian Warner for supporting LCDB as main database for study of asteroids.

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LIGHTCURVE AND ROTATION PERIOD OF MAIN-BELT ASTEROID 10259 OSIPORVYURIJ

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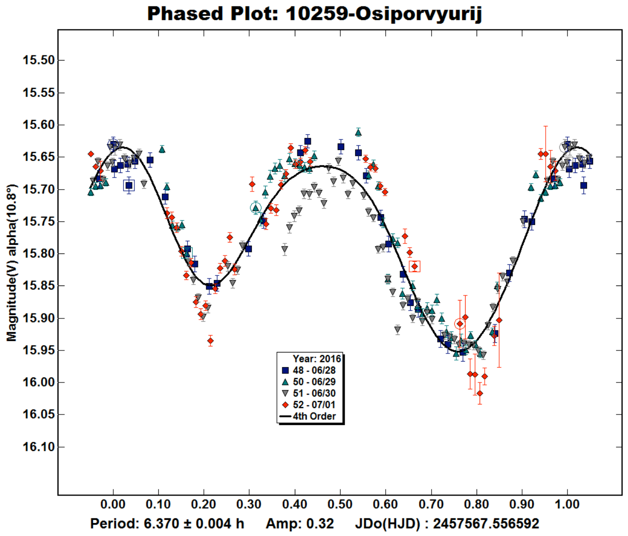
(Received: 2016 Jul 15)

CCD photometric observations of main-belt asteroid 10259 Osiporvyurij were made over four nights in 2016 June and July. Fourier analysis rendered a synodic rotation period of 6.370 ± 0.004 h.

The purpose of this research was to find the synodic rotation period of main-belt asteroid 10259 Osiporvyurij. The Asteroid Lightcurve Database (LCDB; Warner *et al*., 2009) did not show any previously reported results for this object. This asteroid was chosen for its magnitude and opposition near the time of the observation.

Images were taken throughout four consecutive nights from 2016 June 28 to July 1. The first set of observations was carried out using a 0.3-m *f*/8 Maksutov-Cassegrain robotic telescope and (FLI) PL-16803 CCD camera located at Las Campanas Remote Observatory (Chile; Hoot 2015, 2016; Long *et al*., 2016). A luminance filter was used for the 360-s exposures. The other three observations were performed with a 0.4-m *f*/8 Meade robotic telescope and ATIK-383L CCD camera located at the Center for Solar System Studies in Landers, CA (USA; Hoot 2016; Stephens, 2016). A clear filter was used for the exposures of 240 s.

The images were acquired with *Maxim DL v5.24*. All image processing and photometry, as well as Fourier analysis of the data, was done with *MPO Canopus*. The lightcurve shows a synodic rotation period of P = 6.370 ± 0.004 h and an amplitude of A = 0.32 mag.



Acknowledgements

This research has been possible thanks to the CUREA Undergraduate Observational Program in Astrophysics at Mount Wilson Observatory and its staff volunteers.

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TARGET ASTEROIDS! OBSERVING CAMPAIGNS FOR OCTOBER THROUGH DECEMBER 2016

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(Received: 15 July)

Asteroid campaigns to be conducted by the *Target Asteroids!* program during the October-December 2016 quarter are described. 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 and (162173) Ryugu, targets of the OSIRIS-REx and Hayabusa-2 sample return missions.

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 and (162173) Ryugu, the target asteroids of the NASA OSIRIS-REx and JAXA Hayabusa-2 sample return missions respectively. Most target asteroids are near-Earth asteroids (NEA) though observations of relevant Main Belt asteroids (MBA) are also 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 (2000). 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).

Current Campaigns

Target Asteroids! continues to conduct a number of dedicated campaigns on select NEAs and analog carbonaceous MBAs during the quarter. These campaigns have a primary goal of conducting photometric measurements over a large range of phase angles.

Target Asteroids! objects brighter than V = 17.0 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 spacecraft accessible asteroids that are between V magnitude ~17.0 and ~20.0 during the quarter (contained in the table below).

Asteroid Number	Name	Peak V Mag	Time of Peak Brightness
(136635)	1994 VA1	19.7	late Dec
(141018)	2001 WC47	19.2	late Dec
(163249)	2002 GT	18.4	late Nov
(173664)	2001 JU2	18.6	early Oct
(187040)	2005 JS108	18.6	early Dec
(311925)	2007 BF72	19.8	early Oct
(382758)	2003 GY	19.5	late Oct
	2012 WK4	19.8	late Nov

The campaign targets are split up into two sections: carbonaceous MBAs that are analogous to Bennu and Ryugu; and NEAs analogous to the Bennu and Ryugu or provide an opportunity to fill some of the gaps in our knowledge of these spacecraft targets (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

Analog Carbonaceous Main Belt Asteroid Campaigns

(24) Themis (a=3.14 AU, e=0.13, i=0.8°, H = 7.1)

The target asteroids of the OSIRIS-REx and Hayabusa-2 missions originated in the inner part of the Main Belt (between 2.0 and 2.55 AU) on low inclination orbits. Though not an inner Main Belt object, *Target Asteroids!* is continuing a campaign on (24) Themis as it is a carbonaceous asteroid and analog of Bennu and Ryugu.

Themis is a large ~200 km carbonaceous Main Belt asteroid and ranks in the top 30 largest Main Belt asteroids. IR observations have detected evidence of water ice and organics on its surface (Campins et al. 2010, Rivkin and Emery 2010). Themis is also the parent of the Themis asteroid family. Some members of the Themis family have exhibited cometary activity confirming the presence of ices. It reached a minimum phase angle of 0.3 and peak brightness of V = 11.9 back on August 16. It has a rotation period of 8.4 hours with a small amplitude of ~0.15 magnitudes.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	21 19	-16 32	2.81	3.53	12.8	13	129
10/11	21 18	-16 33	2.93	3.53	12.9	14	119
10/21	21 19	-16 25	3.07	3.52	13.1	16	109
10/31	21 22	-16 09	3.21	3.52	13.2	16	100
11/10	21 26	-15 45	3.35	3.52	13.3	16	91

Near-Earth Asteroid Campaign Targets

(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 making it an easily observable analog 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 (Ansdell et al. 2014).

This year, Phaethon peaks in brightness at V = 15.1 in early October. Observable phase angles range from a high of ~120° (in early September) to a minimum of 32° when it becomes fainter than V = 17.0 in mid-November. Phaethon will be even easier for observation in late 2017 when it peaks at V = 10.7.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	13 58	+82 51	0.40	1.06	15.2	71	87
10/11	21 30	+71 31	0.44	1.21	15.2	52	108
10/21	22 12	+54 27	0.53	1.34	15.5	40	120
10/31	22 30	+42 18	0.66	1.47	16.0	35	123
11/10	22 44	+34 04	0.82	1.58	16.5	33	121
11/20	22 57	+28 22	1.00	1.68	17.1	32	115
11/30	23 10	+24 49	1.19	1.77	17.6	32	109
12/10	23 23	+22 21	1.38	1.85	18.0	31	102

(154244) 2002 KL6 (a=2.31 AU, e=0.55, i=3.2°, H = 17.4)
2002 KL6 is a Q or Sq type asteroid with a rotation period of 4.6 h and large amplitude of >1 magnitude (Galad et al. 2010, Koehn et al. 2014). It has been bright for a few months now and peaked in brightness back in July at V = 13.7. The phase angle reaches a local minimum on October 17 at 1°. Color photometry over a large range of phase angles will determine if it experiences phase angle dependent color changes.

DATE	RA	DEC	Δ	r	V	PH	Elong
10/01	01 38	+15 41	0.29	1.28	16.2	17	159
10/11	01 30	+12 37	0.35	1.34	16.3	6	172
10/21	01 24	+10 15	0.42	1.41	16.7	3	175
10/31	01 20	+08 39	0.51	1.49	17.6	11	164
11/10	01 20	+07 45	0.61	1.56	18.3	16	154

(433953) 1997 XR2 (a=1.08 AU, e=0.20, i=7.2°, H = 20.8)
Little is known of this near-Earth asteroid. It becomes brighter than V = 18 on November 10. The phase angle decreases from 100° on November 10 to 7° in early December. Peak brightness is V = 15.9 in late November. Photometry of all types is encouraged to determine this object's taxonomy, rotation period and phase angles.

DATE	RA	DEC	Δ	r	V	PH	Elong
11/10	12 39	+53 54	0.06	0.98	18.1	100	77
11/15	10 32	+57 46	0.05	1.00	17.1	81	97
11/20	08 07	+51 29	0.05	1.01	16.3	58	120
11/25	06 36	+38 30	0.05	1.03	15.9	37	143
11/30	05 48	+26 40	0.06	1.05	16.0	18	160
12/05	05 20	+18 12	0.08	1.06	16.0	8	171
12/10	05 02	+12 35	0.10	1.08	16.5	10	170
12/15	04 51	+08 55	0.12	1.10	17.2	15	163
12/20	04 44	+06 34	0.14	1.11	17.8	21	157
12/25	04 40	+05 07	0.16	1.13	18.3	25	151

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2016 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 2016 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; Warner *et al.*, 2009) 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 ≤ 18.5 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 2.5 million observations for more than 11500 objects.

Now that many backyard astronomers and small colleges have access to larger telescopes, we have expanded the photometry opportunities and spin axis lists to include asteroids reaching V = 15.5 or brighter.

In both of those lists, a line in *italics text* indicates a near-Earth asteroid (NEA). In the spin axis list, a line in **bold text** indicates a particularly favorable apparition. To keep the number of objects manageable, the opportunities list includes only those objects reaching a particularly favorable apparition, meaning they could all be set in bold text.

Lightcurve/Photometry Opportunities

Objects with U = 3– or 3 are excluded from this list since they will likely appear in the list below for shape and spin axis modeling. Those asteroids rated 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.

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
1135	Colchis	10 01.8	13.2	+6	23.47	0.45	2
2805	Kalle	10 01.8	15.1	-4			
23260	2000 YA34	10 03.7	15.0	+10	8.8	0.04	1
8984	Derevyanko	10 03.8	15.1	+5			
11386	1998 TA18	10 05.4	14.7	+19			
2420	Ciurlionis	10 06.6	14.8	+10	12.84	0.48	2
2463	Sterpin	10 08.2	14.7	+0	13.44	0.25-0.30	2
1374	Isora	10 08.6	14.0	+19	36.699	0.12	2+
341	California	10 09.1	11.9	+4	317.	0.02-0.75	2+
4369	Seifert	10 09.6	14.0	+28	30.3	0.28	2
16806	1997 SB34	10 10.6	15.1	+4			
19469	1998 HV45	10 10.8	15.4	+14			
2774	Tenojoki	10 11.1	15.2	+19	11.2	0.30	2+
2016	Heinemann	10 12.8	14.9	+8			
3970	Herran	10 12.9	14.7	+7	8.09	0.31-0.36	2+
9566	Rykhlova	10 13.3	15.3	+13	8.8	0.56-0.95	2
25960	2001 FQ20	10 13.5	15.4	+10			
58143	1983 VD7	10 13.5	14.2	+1			
10421	Dalmatin	10 14.0	15.4	+9			
5521	Morpurgo	10 14.1	14.9	-10	6.1913	0.89	2
2541	Edebono	10 14.3	15.4	+4			
2646	Abetti	10 14.3	14.9	+15			
1913	Sekanina	10 14.4	14.9	+9	13.97	0.31	2+
3843	OISCA	10 15.0	15.3	+8	19.078	0.28	2
6911	Nancygreen	10 16.6	15.0	+13	59.1	0.10-0.52	2
15075	1999 BF15	10 17.1	15.2	+9	16.	0.14	2
2885	Palva	10 18.1	15.0	+13			
5823	Oryo	10 18.2	15.4	+22	2.801	0.31-0.42	2
2909	Hoshi-no-ie	10 21.2	14.8	-4		0.23	
1751	Herget	10 21.4	14.7	+18			
957	Camelia	10 22.9	13.8	+20	150.	0.30	1+
4092	Tyr	10 27.4	15.0	+18			
4871	Riverside	10 28.1	15.2	+17			
2810	Lev Tolstoj	10 29.9	15.3	+5			
4164	Shilov	10 30.1	14.6	+14	18.35	0.24-0.30	1
6729	Emiko	11 02.1	14.9	+24			
22141	2000 VH36	11 02.4	15.3	+18			
2550	Houssay	11 02.5	15.2	+1			
4488	Tokitada	11 03.3	14.8	+15			
24643	MacCready	11 05.6	15.3	+12	4.507	0.11	2
707	Steina	11 05.9	13.9	+23	414.	0.1-1.0	2+
5112	Kusaji	11 06.4	15.2	+12			
3981	Stodola	11 07.8	15.3	+14	102.6566	0.08	1
3203	Huth	11 11.1	15.0	+18			
703	Noemi	11 12.7	13.7	+16			
5997	Dirac	11 13.1	15.0	+19			
1840	Hus	11 14.3	15.3	+19	4.78	0.85	2
7008	Pavlov	11 14.3	15.4	+15			
932	Hooveria	11 19.9	12.5	+30	39.1	0.20-0.22	2+
9182	1991 NB4	11 20.4	15.5	+24	5.416	0.40	2+

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
7774	1992 UU2	11 21.6	14.8	+17	3.87	0.54	2
645	Agrippina	11 22.2	13.8	+29	32.6	0.11-0.18	2
13512	1989 TH1	11 22.8	15.1	+36			
2024	McLaughlin	11 23.7	14.9	+19			
6626	Mattgenge	11 25.9	15.5	+22	107.0814	0.48	2
2707	Ueferji	11 27.0	15.2	+20	5.2862	0.16	2
20789	Hughgrant	11 27.0	14.7	+21			
82256	2001 KM8	11 27.0	15.2	+24			
3019	Kulin	11 28.2	15.3	+18			
958	Asplinda	11 29.7	15.3	+29	25.3	0.57	2
4936	Butakov	11 29.8	15.5	+10	13.828	0.14	2
814	Tauris	12 01.0	11.7	+9	35.8	0.18-0.20	2
12736	1991 VC3	12 02.0	15.4	+24			
2848	ASP	12 04.5	15.0	+24	40.1143	0.39	2
7001	Noether	12 05.8	15.4	+9	9.581	0.65	2
24814	1994 VW1	12 05.9	15.2	-8	4.533	0.05	2
4742	Caliumi	12 07.8	14.9	+12			
20231	1997 YK	12 07.8	15.2	+31	178.	0.22-0.70	2
326683	2002 WP#	12 08.0	14.8	+21			
6610	Burwitz	12 13.2	14.7	+29	3.014	0.22	2
4293	Masumi	12 13.6	14.4	+30		0.1	
3550	Link	12 14.1	14.6	+24	12.3706	0.21	2
41074	1999 VL40	12 14.3	15.4	+26			
3134	Kostinsky	12 15.5	14.7	+22	14.7	0.33-0.40	2
9718	Gerbefremov	12 15.9	15.5	+23	6.2494	0.17	2
2005	Hencke	12 16.1	14.8	+33	10.186	0.08	2
764	Gedania	12 17.9	13.5	+21	24.9751	0.09-0.35	2
2984	Chaucer	12 25.7	15.2	+25			
5323	Fogh	12 26.0	15.4	+27	15.5486	0.61	2
2068	Dangreen	12 28.0	14.1	+23		0.04	
2102	Tantalus#	12 29.7	13.9	-14	2.384	0.08-0.12	2+
7019	Tagayuichan	12 29.8	15.1	+22	39.7954	0.49	2

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." Use the on-line query form for the LCDB

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

to get more details about a specific asteroid.

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 must 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 difficult. Refer to Harris *et al.* (1989; *Icarus* **81**, 365-374) 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.

The International Astronomical Union (IAU) has adopted a new system, H-G_{12}, introduced by Muinonen *et al.* (2010; *Icarus* **209**, 542-555). However it will be some years before it becomes the general standard and, furthermore, it is still in need of refinement. That can be done mostly through having more data for more asteroids, but only if there are data at very low and moderate phase angles. Therefore, we strongly encourage observers to obtain data for these objects not only at very low phase angles, but to follow them well before and/or after opposition, *i.e.*, out to phase angles of 15-30 degrees.

Num	Name	Date	α	V	Dec	Period	Amp	U
620	Drakonia	10 01.1	0.98	13.4	+05	5.487	0.52-0.65	3
108	Hecuba	10 05.8	0.68	12.8	+07	14.256	0.05-0.2	3
428	Monachia	10 07.0	0.45	13.2	+05	3.634	0.25-0.34	3
954	Li	10 12.1	0.37	13.6	+06	7.207	0.11-0.25	3
518	Halawe	10 15.6	0.25	13.1	+09	14.310	0.50-0.55	3
91	Aegina	10 16.7	0.35	11.6	+10	6.025	0.12-0.27	3
57	Mnemosyne	10 18.8	0.97	10.7	+07	12.463	0.12-0.14	3
551	Ortrud	10 19.8	0.14	12.9	+10	13.05	0.09-0.18	2
396	Aeolia	10 22.0	0.89	13.8	+13	22.2	0.30	2-
345	Tercidina	10 22.7	0.46	11.0	+12	12.371	0.11-0.23	3
496	Gryphia	10 23.7	0.23	13.6	+11	18.0	0.05	1
448	Natalie	10 25.8	0.60	13.9	+11	8.065	0.32	3
1353	Maartje	10 30.2	0.43	13.7	+13	22.98	0.40	2
1219	Britta	11 02.7	0.26	13.2	+15	5.575	0.48-0.75	3
1419	Danzig	11 05.1	0.90	13.0	+14	8.120	0.81-0.92	3
849	Ara	11 09.9	0.12	12.6	+17	4.116	0.14-0.53	3
644	Cosima	11 10.6	0.74	13.5	+16	7.556	0.16-0.28	3
703	Noemi	11 12.7	0.78	13.7	+16			
822	Lalage	11 13.4	0.32	13.8	+18	3.345	0.47-0.67	3
2044	Wirt	11 15.1	0.51	13.7	+18	3.690	0.12-0.26	3
178	Belisana	11 15.8	0.15	12.4	+19	12.323	0.08-0.18	3
311	Claudia	11 16.1	0.76	13.8	+17	7.532	0.16-0.89	3
1243	Pamela	11 23.4	0.48	13.9	+22	26.017	0.42-0.71	2
1089	Tama	11 25.9	0.53	13.1	+20	16.44	0.08-0.41	3
468	Lina	11 26.2	0.19	13.4	+21	16.33	0.10-0.18	3
1137	Raissa	11 27.2	0.74	13.2	+19	142.79	0.11-0.56	3-
1177	Gonnessia	12 03.1	0.13	13.8	+23	30.51	0.10-0.25	3-
1687	Glarona	12 03.1	0.60	13.5	+21	6.3	0.75	3
818	Kapteynia	12 06.4	0.51	13.3	+24	16.35	0.09-0.12	3
223	Rosa	12 07.7	0.50	13.3	+24	20.283	0.06-0.13	3
803	Picka	12 07.8	0.32	13.8	+22	5.074	0.12-0.47	3
764	Gedania	12 17.9	0.65	13.5	+21	24.975	0.09-0.35	2
461	Saskia	12 20.9	0.78	13.9	+21	7.348	0.25-0.36	3
180	Garumna	12 23.3	0.43	12.9	+24	23.866	0.42-0.6	3
323	Brucia	12 29.6	0.40	11.2	+24	9.463	0.19-0.36	3
424	Gratia	12 31.0	0.05	12.4	+23	19.47	0.32	3-

Shape/Spin Modeling Opportunities

Those doing work for modeling should contact Josef Ďurech at the email address above. If looking to add lightcurves for objects with existing models, visit the Database of Asteroid Models from Inversion Techniques (DAMIT) web site

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

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.

Included in the list below are objects that:

1. Are rated U = 3– or 3 in the LCDB
2. Do not have reported pole in the LCDB Summary table
3. Have at least three entries in the Details table of the LCDB where the lightcurve is rated U ≥ 2.

The caveat for condition #3 is that no check was made to see if the lightcurves are from the same apparition or if the phase angle bisector longitudes differ significantly from the upcoming apparition. The last check is often not possible because the LCDB does not list the approximate date of observations for all details records. Including that information is an on-going project.

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
3443	Leetsungdao	10 01.9	14.6	+2	3.44	0.23-0.33	3
5427	Jensmartin	10 04.7	15.4	+23	5.81	0.44-0.64	3
1044	Teutonia	10 05.2	13.9	+0	3.153	0.20-0.32	3
428	Monachia	10 07.0	13.2	+5	3.6338	0.25-0.34	3
793	Arizona	10 08.7	13.5	-3	7.399	0.16-0.25	3
197	Arete	10 09.4	12.3	-6	6.6084	0.10-0.16	3
2080	Jihlava	10 10.0	14.7	+6	2.7088	0.15-0.27	3-
781	Kartvelia	10 11.9	14.3	-14	19.04	0.16-0.28	3-
954	Li	10 12.0	13.6	+6	7.207	0.11-0.25	3
840	Zenobia	10 13.8	14.6	+21	5.565	0.08-0.28	3

		Brightest			LCDB Data		
Num	Name	Date	Mag	Dec	Period	Amp	U
2961	Katsurahama	10 14.4	14.7	+11	2.936	0.20-0.30	3
91	Aegina	10 16.7	11.6	+10	6.025	0.12-0.27	3
737	Arequipa	10 17.9	11.4	+3	7.0259	0.10-0.27	3
251	Sophia	10 20.8	14.0	-1	20.216	0.30-0.61	3
5404	Uemura	10 22.1	15.0	+16	3.449	0.10-0.13	3
308	Polyxo	10 23.6	11.8	+9	12.029	0.08-0.15	3-
1321	Majuba	10 25.4	14.4	+26	5.207	0.24-0.35	3
3416	Dorrit	10 25.8	14.5	+28	2.574	0.21-0.27	3
444	Gyptis	10 26.1	10.7	+8	6.214	0.11-0.18	3
772	Tanete	10 28.2	13.2	-8	17.258	0.07-0.18	3
1304	Arosa	10 28.5	14.4	-6	7.7478	0.13-0.38	3
2951	Perepadin	10 29.9	14.5	+18	4.781	0.54-0.60	3
5836	1993 MF#	11 01.2	15.3	+22	4.9543	0.53-0.82	3
657	Gunlod	11 07.0	14.9	+30	15.6652	0.19-0.20	3
3073	Kursk	11 07.3	15.1	+13	3.4468	0.20-0.21	3
822	Lalage	11 13.4	13.7	+18	3.345	0.47-0.67	3
790	Pretoria	11 13.5	13.2	+28	10.37	0.05-0.18	3
301	Bavaria	11 13.7	14.2	+11	12.253	0.25-0.31	3
194	Prokne	11 13.8	11.4	-8	15.679	0.05-0.27	3
2044	Wirt	11 15.2	13.7	+18	3.6898	0.12-0.26	3
4031	Mueller	11 15.5	14.9	+54	2.942	0.14-0.19	3
100	Hekate	11 17.3	12.1	+11	27.066	0.11-0.23	3
1406	Komppa	11 18.3	14.8	+39	3.508	0.16-0.20	3
604	Tekmessa	11 20.0	12.6	+25	5.5596	0.49-0.52	3
76818	2000 RG79	11 20.7	15.3	+50	3.1664	0.14-0.15	3
2486	Metsahovi	11 22.0	14.9	+33	4.4518	0.04-0.13	3
806	Gyldenia	11 22.4	14.6	+26	16.852	0.10-0.27	3
5143	Heracles	11 23.3	12.4	+73	2.7063	0.05-0.20	3
1563	Noel	11 23.9	14.7	+22	3.5495	0.14-0.18	3
175	Andromache	11 25.0	12.2	+24	8.324	0.21-0.30	3
468	Lina	11 26.2	13.4	+21	16.33	0.10-0.18	3
1146	Biarmia	11 27.3	15.1	+9	5.47	0.20-0.32	3
2763	Jeans	11 29.9	14.8	+27	7.805	0.13-0.18	3
303	Josephina	12 01.7	12.9	+32	12.497	0.12-0.15	3
232	Russia	12 05.1	14.1	+13	21.905	0.14-0.31	3
102	Miriam	12 10.7	12.2	+16	23.613	0.04-0.14	3
1139	Atami	12 11.3	13.0	-5	27.446	0.19-0.45	3
1777	Gehrels	12 13.1	14.8	+28	2.8355	0.21-0.27	3
461	Saskia	12 20.9	13.9	+21	7.348	0.25-0.36	3
3533	Toyota	12 21.4	14.7	+14	2.9807	0.16-0.20	3
890	Waltraut	12 22.5	15.4	+9	12.581	0.32-0.36	3
273	Atropos	12 23.2	14.5	-5	23.924	0.52-0.65	3
1694	Kaiser	12 25.0	14.3	+43	13.02	0.14-0.32	3
255	Oppavia	12 26.4	14.1	+38	19.499	0.14-0.16	3
323	Brucia	12 29.5	11.2	+24	9.463	0.19-0.36	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 (through Dr. Benner's email listed above) if you get data. The team may not always be observing the target but 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” 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.

About YORP Acceleration

Many, if not all, of the targets in this section are near-Earth asteroids. These objects are particularly sensitive to YORP acceleration. YORP (Yarkovsky–O'Keefe–Radzievskii–Paddack) is the asymmetric thermal re-radiation of sunlight that can cause an asteroid’s rotation period to increase or decrease. High precision lightcurves at multiple apparitions can be used to model the asteroid’s *sidereal* rotation period and see if it’s changing.

It usually takes four apparitions to have sufficient data to determine if the asteroid is rotating under the influence of YORP, so while obtaining a lightcurve at the current apparition may not result in immediately seeing a change, the data are still critical in reaching a final determination. This is why observing asteroids that already have well-known periods can still be a valuable use of telescope time. It is even more so when considering BYORP (binary-YORP) among binary asteroids where that effect has stabilized the spin so that acceleration of the primary body is not the same as if it would be if there were no satellite.

Name	Grp	Period	App	Last	Bin	R SNR
2002 QF15	NEA	29-120	2	2006	-	**394 A**
2003 TL4	NEA	27.2	1	2003	-	**6 G**
Ra-Shalom	NEA	19.79	4	2003	-	**24 G**
Heracles	NEA	2.706	4	2012	-	**48 G**
Cacus	NEA	3.76	4	2009	-	**25 A**
2009 MS	NEA	-	-	-	-	**204 G**
2011 DU	NEA	-	-	-	-	**75 G**
2016 LX48	NEA	-	-	-	-	**4 G**
Toutatis	NEA	176	6	2013	-	**3000 G**
2003 YT1	NEA	2.343	2	2006	Y	**5200 G**
2002 NW16	NEA	-	-	-	-	**1 G**
1998 XB	NEA	500.	1	2005	-	**335 G**
1999 YR14	NEA	-	-	-	-	**<1 G**
1997 XR2	NEA	-	-	-	-	**36 G**
2006 XD2	NEA	3.70	1	2006	-	**35 G**
2008 UL90	NEA	-	-	-	-	**382 G**
Tantalus	NEA	2.384	2	2014	?	**10 G**
Eger	NEA	5.751	6	2014	N	**7 A**

Table I. Summary of radar-optical opportunities in 2016 Oct-Dec. Data from the asteroid lightcurve database (Warner *et al.,* 2009; *Icarus* **202**, 134-146).

To help focus efforts in YORP detection, Table I gives a quick summary of this quarter's radar-optical targets. The Grp column gives the family or group for the asteroid. The period is in hours and, in the case of binary, for the primary. The App columns gives the number of different apparitions at which a lightcurve period was reported while the Last column gives the year for the last reported period. The Bin column is 'Y' if the asteroid has one or more satellites (a '?' indicates a suspected binary). The last column indicates the estimated radar SNR using the tool at

http://www.naic.edu/~eriverav/scripts/radarscript.php

The estimate in Table I is based on using the Arecibo (A) or Goldstone (G) radar. Goldstone is the default if a close approach is outside the declination range of Arecibo. The estimate uses the current MPCORB absolute magnitude (*H*), a period of 3.0 hours if it's not known, and the approximate minimum Earth distance during the three-month period covered by this paper.

If the SNR value is in bold text, the object was found on the radar planning pages listed above. Otherwise, the search tool at

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

was used to find known NEAs that were V < 18.0 during the quarter. An object was placed on the list only if the estimated radar SNR > 10. This would produce a very marginal signal, not enough for imaging, but might allow improving orbital parameters

(68950) 2002 QF15 (Oct, *H* = 16.4)
Be prepared to follow this asteroid for several days, maybe organize an observing campaign involving observers at different longitudes. The reported period on this NEA ranges from 29 h (Pravec *et al.*, 2003) to 120 h (Ostro *et al.*, 2003). Keep in mind that the high phase angles may cause the lightcurve not to be exactly as expected because of deep shadowing effects.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	20 22.5	+63 11	0.40	1.17	16.8	55.4	105	103	+0.00	+15
10/04	20 12.4	+61 54	0.39	1.16	16.7	56.7	104	95	+0.09	+15
10/07	20 03.4	+60 23	0.37	1.14	16.6	58.2	104	85	+0.31	+15
10/10	19 55.5	+58 40	0.35	1.13	16.5	59.8	103	76	+0.60	+15
10/13	19 48.6	+56 42	0.33	1.11	16.4	61.7	101	74	+0.88	+15
10/16	19 42.7	+54 30	0.31	1.10	16.3	63.7	100	83	-1.00	+15
10/19	19 37.5	+52 01	0.30	1.08	16.3	66.1	98	100	-0.87	+14
10/22	19 33.0	+49 13	0.28	1.06	16.2	68.8	96	113	-0.57	+14
10/25	19 29.1	+46 03	0.26	1.04	16.1	71.9	94	113	-0.26	+13
10/28	19 25.6	+42 27	0.24	1.03	16.0	75.4	91	101	-0.06	+12

(413260) 2003 TL4 (Oct, *H* = 19.4)
The period of this NEA is 27.2 h (Pravec *et al*., 2003) who reported an amplitude of > 1.0 mag. The ephemeris cuts off on Oct 19 because the phase soon exceeds 90°. At such phase angles, it can be very difficult to get data from night-to-night to match because the lightcurve amplitude and/or shape may be evolving rapidly.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	04 23.0	+61 13	0.16	1.06	17.8	64.3	108	107	+0.00	+8
10/03	04 24.9	+62 09	0.15	1.06	17.6	64.0	108	122	+0.04	+9
10/05	04 26.8	+63 13	0.13	1.05	17.4	63.9	109	131	+0.15	+10
10/07	04 28.5	+64 25	0.12	1.05	17.2	63.8	110	133	+0.31	+11
10/09	04 30.2	+65 50	0.11	1.04	17.0	63.9	110	126	+0.50	+12
10/11	04 31.9	+67 31	0.10	1.04	16.8	64.2	111	113	+0.70	+13
10/13	04 33.6	+69 35	0.09	1.03	16.5	64.8	111	97	+0.88	+15
10/15	04 35.7	+72 11	0.08	1.03	16.3	65.9	110	80	+0.98	+16
10/17	04 38.6	+75 36	0.07	1.02	16.0	67.6	109	68	-0.98	+19
10/19	04 44.5	+80 15	0.06	1.01	15.7	70.3	107	64	-0.87	+22

2100 Ra-Shalom (Oct-Nov, *H* = 16.0)
This is a good candidate for YORP evolution. Several models have already been done, but a longer base line will allow a more careful look at the sidereal period's evolution over time. The period is well established at about 19.79 h. Based on radar observations (Shepard et al., 2008), the estimated size for the NEA is 2.3 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	03 07.7	-26 16	0.16	1.12	14.0	42.0	132	135	+0.00	-60
10/06	03 04.9	-39 06	0.15	1.10	14.0	47.9	126	120	+0.23	-60
10/11	02 58.1	-52 29	0.15	1.07	14.2	56.9	116	79	+0.70	-55
10/16	02 43.9	-65 00	0.16	1.05	14.6	67.1	105	72	-1.00	-48
10/21	02 10.6	-75 39	0.17	1.02	15.0	77.0	94	102	-0.68	-40
10/26	00 19.6	-83 34	0.18	0.99	15.5	86.0	83	103	-0.18	-33
10/31	19 08.4	-84 22	0.20	0.96	15.9	94.1	74	76	+0.00	-27
11/05	17 06.5	-79 20	0.22	0.92	16.4	101.4	66	62	+0.25	-22
11/10	16 28.4	-74 01	0.25	0.89	16.9	108.3	58	88	+0.74	-17
11/15	16 09.5	-68 53	0.27	0.85	17.4	114.9	51	127	-0.99	-13

5143 Heracles (Oct-Nov, Binary, *H* = 13.9)
Pilcher et al. (2012) did an extensive campaign on this NEA and found a synodic period of about 2.7063 h. Their excellent work showed how the lightcurve evolved in amplitude and synodic period as the phase angle and phase angle bisector changed. Using radar observations, Taylor et al. (2012) found a satellite with an effective diameter 0.17x that of the primary. The orbital period was estimated to be about 16 h. The size ratio will make it difficult to detect mutual events assuming, the viewing geometry allows. High-quality data will be required and, given the estimated orbital period, a campaign involving at least two widely-separated observers is in order.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	04 37.9	+37 22	1.02	1.70	16.5	32.6	114	115	+0.00	-6
10/06	04 44.8	+38 37	0.93	1.64	16.2	32.8	117	158	+0.23	-5
10/11	04 51.9	+40 02	0.83	1.59	15.9	33.0	120	122	+0.70	-3
10/16	04 59.3	+41 38	0.74	1.53	15.6	33.2	123	59	-1.00	-1
10/21	05 07.2	+43 32	0.65	1.47	15.2	33.5	125	31	-0.68	+2
10/26	05 16.0	+45 48	0.57	1.41	14.8	34.0	127	82	-0.18	+4
10/31	05 26.4	+48 38	0.48	1.35	14.4	34.9	129	130	+0.00	+7
11/05	05 40.0	+52 16	0.41	1.29	14.0	36.5	129	143	+0.25	+11
11/10	06 00.9	+57 09	0.33	1.22	13.5	39.6	128	101	+0.74	+16
11/15	06 41.4	+63 55	0.26	1.15	13.0	45.5	124	55	-0.99	+23

161989 Cacus (Oct-Nov, *H* = 16.6)
The period is 3.7538 h, but that was determined more than a decade ago (Pravec *et al*., 2003). The minimum reported amplitude is *A* = 0.8 mag, indicating a highly-elongated shape. High phase angles may make for unusual lightcurves. Even large amplitudes at such phase angles don't necessarily assure a bimodal lightcurve. More than once, a monomodal lightcurve proved correct after confirming data from radar were obtained.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	19 05.7	-41 15	0.31	1.07	17.2	68.6	95	93	+0.00	-20
10/06	19 41.7	-44 58	0.34	1.09	17.4	65.9	96	48	+0.23	-27
10/11	20 15.7	-47 20	0.38	1.11	17.6	63.7	96	33	+0.70	-34
10/16	20 47.2	-48 40	0.42	1.12	17.8	61.7	96	82	-1.00	-39
10/21	21 15.7	-49 14	0.46	1.14	18.0	60.1	96	135	-0.68	-43
10/26	21 41.5	-49 13	0.50	1.16	18.1	58.6	96	135	-0.18	-48
10/31	22 04.7	-48 47	0.54	1.17	18.3	57.3	95	94	+0.00	-51
11/05	22 25.7	-48 01	0.58	1.19	18.4	56.1	95	52	+0.25	-55
11/10	22 44.8	-47 00	0.63	1.21	18.6	55.0	94	42	+0.74	-58
11/15	23 02.3	-45 48	0.67	1.22	18.7	54.0	93	91	-0.99	-61

(369264) 2009 MS (Oct-Nov, *H* = 16.3)
The period for this NEA is unknown. Here again, high phase angles will require careful period analysis.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	10 22.4	+85 11	1.00	1.41	18.8	45.4	89	88	+0.00	+31
10/06	11 05.3	+84 01	0.93	1.36	18.6	47.2	90	106	+0.23	+32
10/11	11 34.3	+82 46	0.86	1.32	18.4	49.1	90	110	+0.70	+34
10/16	11 55.2	+81 28	0.78	1.28	18.2	51.2	91	92	-1.00	+35
10/21	12 11.0	+80 08	0.71	1.24	18.0	53.5	92	71	-0.68	+37
10/26	12 23.5	+78 43	0.63	1.20	17.7	56.1	92	73	-0.18	+38
10/31	12 33.6	+77 10	0.55	1.16	17.4	59.1	93	91	+0.00	+40
11/05	12 41.7	+75 21	0.46	1.12	17.1	62.5	93	109	+0.25	+42
11/10	12 48.3	+73 01	0.38	1.08	16.7	66.6	93	111	+0.74	+44
11/15	12 53.9	+69 35	0.29	1.04	16.2	71.7	92	89	-0.99	+48

(462959) 2011 DU (Oct-Nov, *H* = 21.0)

The period for this NEA is unknown. The estimated size is about 190 meters, which makes it a candidate for being a super-fast rotator, i.e., with a period < 2 hours and possibly < 1 hour. Keep exposures as short as possible at the start, trailing considerations notwithstanding, and adjust exposures accordingly. According to Pravec *et al*. (2004), exposures should be no longer than 0.187x the period. Otherwise *rotational smearing* takes place and it becomes difficult if not impossible to determine the period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/05	08 29.0	-03 27	0.04	0.98	18.4	114.1	64	108	+0.15	+20
10/09	06 32.9	-04 05	0.04	1.00	16.9	81.6	96	156	+0.50	-6
10/13	05 01.6	-03 51	0.05	1.03	16.6	55.6	122	94	+0.88	-26
10/17	04 04.3	-03 20	0.06	1.05	16.7	38.4	139	27	-0.98	-38
10/21	03 28.5	-02 49	0.08	1.07	16.9	27.2	151	50	-0.68	-45
10/25	03 04.8	-02 21	0.10	1.09	17.2	19.9	158	106	-0.26	-50
10/29	02 48.2	-01 53	0.12	1.11	17.5	15.6	162	156	-0.02	-52
11/02	02 36.2	-01 24	0.14	1.13	17.9	14.2	164	148	+0.06	-54
11/06	02 27.4	-00 54	0.17	1.15	18.3	15.0	162	100	+0.34	-55
11/10	02 21.0	-00 22	0.19	1.17	18.7	17.0	160	47	+0.74	-56

2016 LX48 (Oct-Nov, *H* = 18.9)

This NEA has an estimated diameter of 0.5 km, so its rotation period is likely more than 2 hours. Remember, however, that rules (especially rule of thumb) are made to be broken.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	00 38.1	+43 48	0.12	1.10	16.0	36.4	139	138	+0.00	-19
10/05	00 55.7	+41 41	0.15	1.12	16.4	32.4	143	134	+0.15	-21
10/09	01 07.3	+39 48	0.17	1.15	16.7	28.7	146	102	+0.50	-23
10/13	01 15.4	+38 07	0.20	1.18	16.9	25.4	150	58	+0.88	-25
10/17	01 21.3	+36 35	0.23	1.20	17.2	22.3	153	31	-0.98	-26
10/21	01 25.8	+35 11	0.26	1.23	17.4	19.7	155	69	-0.68	-27
10/25	01 29.4	+33 53	0.29	1.27	17.6	17.7	157	115	-0.26	-28
10/29	01 32.4	+32 40	0.32	1.30	17.9	16.2	159	152	-0.02	-29
11/02	01 35.1	+31 32	0.36	1.33	18.1	15.4	159	139	+0.06	-30
11/06	01 37.8	+30 30	0.39	1.37	18.4	15.3	159	98	+0.34	-31

4179 Toutatis (Oct-Dec, NPAR (tumbler), *H* = 15.3)

This well-studied asteroid is in non-principal axis rotation (NPAR), commonly known as *tumbling*. The periods of rotation and precession are 176 and 130 h (Pravec *et al*., 2005). There are several radar generated "movies" showing the rotation of the asteroid, *e.g.*, *http://www.jpl.nasa.gov/video/details.php?id=1175*.

Period analysis of a tumbler requires specialized software such as that developed by Petr Pravec. Even so, because of the long periods involved, consideration should be given to a prolonged campaign involving several observers at widely-spaced locations and a standardized method so that all data can be put onto a common system (zero point), even if it's only internal and not one such as the Johnson-Cousins system.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	18 52.4	-23 21	0.63	1.22	16.9	55.0	94	92	+0.00	-11
10/11	19 05.4	-23 08	0.61	1.14	16.8	60.7	87	27	+0.70	-13
10/21	19 23.7	-22 42	0.58	1.07	16.7	66.4	81	167	-0.68	-17
10/31	19 47.1	-21 55	0.54	1.02	16.6	72.2	77	72	+0.00	-22
11/10	20 15.7	-20 40	0.49	0.97	16.5	77.8	74	46	+0.74	-27
11/20	20 49.9	-18 45	0.43	0.95	16.4	82.8	72	175	-0.62	-34
11/30	21 31.7	-15 49	0.37	0.94	16.1	86.2	72	65	+0.01	-42
12/10	22 24.6	-11 16	0.31	0.96	15.8	86.2	75	51	+0.80	-52
12/20	23 32.9	-04 20	0.27	0.99	15.4	80.9	84	176	-0.59	-60
12/30	00 57.0	+04 49	0.25	1.04	15.0	69.8	96	86	+0.01	-58

(164121) 2003 YT1 (Oct-Dec, PHA, Binary, *H* = 16.2)

Using radar, Nolan et al. (2004) found a satellite orbiting around this NEA. Their announcement did not include an estimated size ratio or orbital period. Pravec et al. (2006) found a primary period of 2.343 h and orbital period of about 30 hours. There are no subsequent photometry observations in the LCDB since 2006. It's time to get another good data set and see if the orbital period of the satellite can be confirmed and refined. Here again, an organized campaign is in order.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	05 28.7	-29 17	0.41	1.16	16.7	57.8	102	105	+0.00	-30
10/11	05 34.9	-27 22	0.28	1.11	15.8	59.3	107	116	+0.70	-28
10/21	05 39.0	-21 00	0.15	1.06	14.3	58.7	114	42	-0.68	-25
10/31	05 38.2	+50 01	0.03	1.01	10.9	51.8	127	128	+0.00	+10
11/10	17 43.0	+49 10	0.14	0.96	15.3	96.6	75	90	+0.74	+31
11/20	17 40.7	+41 28	0.27	0.92	16.7	97.2	67	107	-0.62	+30
11/30	17 37.6	+37 52	0.40	0.87	17.3	94.3	62	56	+0.01	+30
12/10	17 34.1	+34 44	0.52	0.83	17.6	90.5	58	111	+0.80	+30
12/20	17 31.2	+31 11	0.62	0.81	17.7	86.3	55	90	-0.59	+30
12/30	17 30.2	+26 57	0.70	0.79	17.8	82.2	53	53	+0.01	+29

(452389) 2002 NW16 (Oct-Dec, *H* = 18.0)

The estimated size of 2002 NW16 is 750 meters. The period is unknown. Unfortunately, the asteroid spends most of the quarter near the galactic plane. Combined with its relatively faint magnitude, it will be a difficult target.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
10/01	21 42.6	+68 34	0.27	1.12	17.5	57.7	109	107	+0.00	+12
10/11	21 21.8	+66 55	0.28	1.12	17.6	56.9	109	82	+0.70	+12
10/21	21 18.6	+64 31	0.29	1.13	17.6	56.1	110	91	-0.68	+11
10/31	21 29.6	+61 42	0.30	1.13	17.7	55.2	110	105	+0.00	+8
11/10	21 51.6	+58 36	0.30	1.14	17.7	54.5	111	66	+0.74	+4
11/20	22 21.6	+55 14	0.31	1.14	17.7	53.8	112	108	-0.62	-2
11/30	22 57.3	+51 31	0.31	1.14	17.7	53.5	112	103	+0.01	-7
12/10	23 36.7	+47 28	0.32	1.14	17.8	53.5	111	49	+0.80	-14
12/20	00 17.7	+43 09	0.33	1.14	17.9	54.0	110	129	-0.59	-19
12/30	00 58.7	+38 41	0.35	1.14	18.0	54.9	108	97	+0.01	-24

(96590) 1998 XB (Nov-Jan, *H* = 16.2)

Here's another photometry version of "War and Peace", i.e., an asteroid with a very long period that will take some time to resolve. Pravec *et al*. (2005) reported a period between 500-520 hours. Many things will conspire against the observer, large changes in declination and phase angle being the most significant. The lightcurve will likely change in shape and amplitude, making it very difficult to merge data taken over the several weeks needed to determine the period. A campaign of determined and well-coordinated observers is in order.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/01	08 01.7	-40 55	0.15	0.99	15.1	86.3	85	97	+0.02	-6
11/11	06 11.9	-33 01	0.12	1.04	13.9	60.9	113	90	+0.84	-22
11/21	04 24.2	-15 45	0.13	1.09	13.3	32.9	143	86	-0.52	-40
12/01	03 14.5	+00 56	0.16	1.13	13.6	24.0	152	138	+0.03	-46
12/11	02 39.2	+11 20	0.22	1.16	14.6	31.8	141	2	+0.88	-43
12/21	02 24.4	+17 36	0.29	1.19	15.4	39.3	130	141	-0.49	-40
12/31	02 21.6	+21 45	0.36	1.21	16.1	44.6	120	98	+0.04	-36
01/10	02 26.4	+24 52	0.44	1.22	16.7	48.3	112	39	+0.93	-33
01/20	02 36.4	+27 24	0.52	1.23	17.1	50.8	105	160	-0.48	-30
01/30	02 50.1	+29 34	0.60	1.22	17.5	52.7	99	73	+0.05	-27

(357024) 1999 YR14 (Nov-Jan, *H* = 19.1)

The period is unknown for the 450-meter 1999 YR14. Sky motion is no more than 2 arcsec/min at the start of the ephemeris and quickly drops to <1 arcsec/min. That and the good chances the period is > 2 hours will alllow longer exposures to increase the SNR.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/20	08 18.6	+34 52	0.26	1.14	18.4	50.0	118	23	-0.62	+32
11/27	08 11.3	+35 37	0.28	1.17	18.3	42.7	126	101	-0.05	+31
12/04	07 59.9	+36 17	0.29	1.21	18.3	34.9	135	160	+0.19	+29
12/11	07 45.0	+36 42	0.31	1.25	18.2	27.1	145	74	+0.88	+26
12/18	07 28.0	+36 48	0.33	1.29	18.2	19.5	154	37	-0.78	+23
12/25	07 10.9	+36 30	0.36	1.33	18.2	13.0	162	121	-0.15	+19
01/01	06 55.2	+35 51	0.39	1.37	18.4	9.3	167	145	+0.08	+16
01/08	06 42.5	+34 57	0.44	1.41	18.7	10.3	165	52	+0.76	+13
01/15	06 33.3	+33 56	0.49	1.45	19.2	13.9	159	54	-0.91	+11
01/22	06 27.7	+32 53	0.55	1.49	19.6	17.9	152	138	-0.29	+10

(433953) 1997 XR2 (Nov-Jan, *H* = 20.8)

There is no period in the LCDB for this 200 meter NEA. Here again, keep exposures as short as possible at the first, just in case the period is significantly less than 2 hours.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
11/20	08 03.5	+51 09	0.05	1.01	16.3	56.9	121	38	-0.62	+32
11/25	06 34.4	+38 06	0.05	1.03	15.9	34.9	143	98	-0.16	+13
11/30	05 46.8	+26 21	0.06	1.05	15.9	18.0	161	166	+0.01	-1
12/05	05 19.3	+18 00	0.08	1.06	16.0	8.1	171	124	+0.28	-11
12/10	05 02.3	+12 27	0.10	1.08	16.6	9.6	169	51	+0.80	-17
12/15	04 51.4	+08 50	0.12	1.10	17.2	15.5	163	28	-0.98	-22
12/20	04 44.5	+06 31	0.14	1.11	17.8	20.8	156	98	-0.59	-24
12/25	04 40.4	+05 05	0.16	1.13	18.3	25.3	151	156	-0.15	-26
12/30	04 38.5	+04 17	0.19	1.14	18.7	29.0	146	138	+0.01	-27
01/04	04 38.5	+03 55	0.22	1.16	19.2	32.3	141	76	+0.32	-27

2006 XD2 (Dec, *H* = 21.0)

Miles (2008) reported a period of 3.7 h based on observations in 2006. That is the only recorded lightcurve in the LCDB for the 190 meter NEA. With the period reasonably secured, you can adjust exposures based on magnitude and sky motion without worrying about the possibility of a super-fast rotator.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/01	06 55.7	+26 15	0.17	1.13	18.7	28.7	147	163	+0.03	+13
12/03	07 03.6	+27 06	0.15	1.12	18.4	28.9	147	169	+0.12	+14
12/05	07 13.1	+28 07	0.14	1.10	18.2	29.4	147	149	+0.28	+17
12/07	07 24.8	+29 19	0.12	1.09	17.9	30.4	146	126	+0.48	+20
12/09	07 39.8	+30 45	0.11	1.07	17.7	32.0	145	102	+0.70	+23
12/11	07 59.6	+32 28	0.09	1.06	17.4	34.6	142	77	+0.88	+28
12/13	08 26.8	+34 27	0.08	1.05	17.2	38.7	138	54	+0.99	+34
12/15	09 05.5	+36 32	0.07	1.03	17.0	44.9	132	36	-0.98	+42
12/17	10 00.9	+38 03	0.06	1.02	16.8	54.1	123	28	-0.86	+53
12/19	11 15.9	+37 31	0.05	1.00	16.9	67.0	110	30	-0.69	+67

2008 UL90 (Dec-Jan, *H* = 18.6)

The estimated diameter for this NEA is 570 meters. Unfortunately, the asteroid is within range of backyard telescopes only when the phase angles are very large. This is the common lament when working NEAs. However, it is better to try rather than not try at all. More times than not, useful data can be obtained despite difficult circumstances.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/01	12 29.8	-65 26	0.10	0.94	18.0	117.1	58	69	+0.03	-3
12/05	14 03.0	-71 13	0.07	0.95	17.7	122.4	54	82	+0.28	-9
12/09	18 14.1	-67 30	0.05	0.95	17.8	132.0	46	94	+0.70	-21
12/13	20 40.8	-33 40	0.04	0.96	17.6	133.9	44	123	+0.99	-36
12/17	21 26.9	-00 10	0.05	0.96	16.8	117.6	60	161	-0.86	-34
12/21	21 46.7	+16 24	0.08	0.96	16.9	107.1	69	141	-0.49	-28
12/25	21 57.0	+24 37	0.10	0.96	17.3	102.1	72	106	-0.15	-23
12/29	22 03.1	+29 16	0.13	0.95	17.7	99.7	73	71	+0.00	-21
œ										
01/06	22 08.8	+34 06	0.18	0.94	18.3	98.3	71	53	+0.54	-18

2102 Tantalus (Dec-Jan, Binary?, *H* = 16.5)

Pravec *et al.* (1997) reported a period of 2.391 h. Warner (2015) reported a possible satellite based on a second period of about 16 hours in addition to a "primary" period of 2.384 h. High-quality data (< 0.03 mag precision) will be needed to help confirm the satellite.

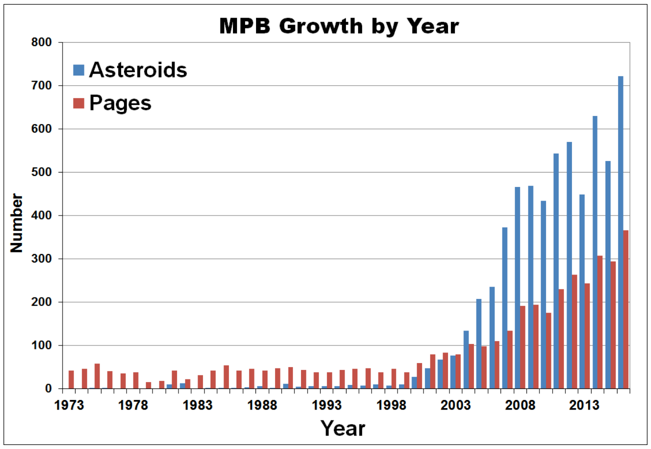
On the other hand, the lack of evidence (negative observations) will not automatically mean that the earlier analysis observations and analysis were incorrect. Favoring confirmation is that the phase angle bisector longitude will be about 180° from the time Warner observed the NEA. This means that the viewing geometry of the purported satellite orbit will be about the same, the difference being a view favoring the south pole of primary instead of its north pole.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/01	07 56.8	-49 12	0.56	1.18	17.1	56.4	95	106	+0.03	-10
12/06	07 42.1	-49 41	0.47	1.16	16.8	57.5	99	112	+0.38	-13
12/11	07 19.0	-49 49	0.39	1.13	16.3	58.3	102	86	+0.88	-16
12/16	06 42.0	-49 01	0.30	1.11	15.7	58.5	106	68	-0.93	-22
12/21	05 41.9	-45 26	0.22	1.08	15.0	57.8	111	95	-0.49	-31
12/26	04 11.3	-33 35	0.16	1.06	14.2	56.8	115	131	-0.09	-47
12/31	02 27.4	-06 59	0.14	1.04	14.0	62.0	111	92	+0.04	-60
01/05	01 04.5	+18 58	0.17	1.02	14.8	73.1	97	21	+0.43	-44
01/10	00 10.3	+32 24	0.24	1.00	15.7	79.2	87	68	+0.93	-30
01/15	23 35.1	+38 54	0.32	0.98	16.3	81.1	80	126	-0.91	-22

3103 Eger (Jul-Sep, *H* = 14.3)

The period is 5.710156 ± 0.000007 h, as of JD 24446617.0. Durech *et al.* (2012, *A&A* **547**:A10) reported a YORP-induced change of +4.2 ms/year, *i.e.*, the asteroid is slowing down. Additional observations can help confirm and/or improve this result.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
12/01	10 31.6	-10 27	0.64	1.13	16.8	60.2	86	105	+0.03	+39
12/11	10 46.7	-08 02	0.62	1.19	16.7	55.9	93	124	+0.88	+44
12/21	10 58.3	-04 53	0.59	1.24	16.6	50.8	102	18	-0.49	+48
12/31	11 05.3	-00 43	0.56	1.30	16.4	44.7	112	134	+0.04	+52
01/10	11 06.9	+04 39	0.53	1.35	16.2	37.2	124	88	+0.93	+56
01/20	11 02.2	+11 12	0.51	1.40	15.9	28.3	137	50	-0.48	+60
01/30	10 50.9	+18 25	0.51	1.45	15.7	18.9	151	170	+0.05	+61
02/09	10 34.5	+25 20	0.53	1.50	15.6	11.9	162	38	+0.96	+59
02/19	10 15.9	+30 55	0.58	1.55	15.9	12.4	160	98	-0.47	+56
03/01	09 58.9	+34 41	0.65	1.59	16.4	17.8	151	125	+0.08	+53



Editor's Note: Congratulations to all contributors to the *Minor Planet Bulletin* for making 2016 another record year for asteroid results reported and pages published!

INDEX TO VOLUME 43

Sada, P.V., Navarro-Meza, S., Reyes-Ruiz, M., Olguin, L.L., Saucedo, J.C., Loera-González, P. “Results of the 2015 Mexican Asteroid Photometry Campaign” 154–156.

Salvaggio, F., Franco, L., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for 2616 Lesya and (28910) 2000 NH11” 172–173.

Salvaggio, F., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for (12207) 1981 EU28” 9.

Salvaggio, F., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for 5318 Dientzenhofer and 9083 Ramboehm” 348–349.

Salvaggio, F., Marchini, A., Papini, R. “Lightcurve and Rotation Period Determination for (31450) 1999 CU9 and (91252) 1999 CS49” 24–25.

Santana-Ros, T., Marciniak, A., Bartczak, P. “Gaia-GOSA: A Collaborative Service for Asteroid Observers” 205–207.

Scardella, M., Tomassini, A., Franceschini, F. “Rotational Period Determination of 2717 Tellervo and (9773) 1993 MG1” 186.

Schmidt, R.E. “NIR Minor Planet Photometry from Burleith Observatory, 2015” 129–131.

Şonka, A.B., Popescu, M., Nedelcu, D.A. “Photometric Observations of Main-belt Asteroids 656 Beagle and 2649 Oongaq” 1–2.

Stephens, R.D. “Asteroids Observed from CS3”
  2015 July–September 52–56.
  2015 October–December 158–159.
  2016 January-March 252–255.
  2016 April–June 336–338.

Stephens, R.D., Coley, D.R., French, L.M. “Large L5 Jovian Trojan Asteroid Lightcurves from The Center for Solar System Studies” 15–22.

Stephens, R.D., Coley, D.R., French, L.M. “A Report from the L5 Trojan Camp – Lightcurves of Jovian Trojan Asteroids from The Center for Solar System Studies” 265–270.

Stephens, R.D., Coley, D.R., Warner, B.D., French, L.M. “Lightcurves of Jovian Trojan Asteroids from the Center for Solar System Studies: L4 Greek Camp and Spies” 323–331.

Stephens, R.D., French, L.M., James, D., Connour, K., Warner, B.D. “Main-belt Asteroid Lightcurves from Cerro Tololo Inter-American Observatory” 10–15.

Stephens, R.D., Warner, B.D. “5425 Vojtech: A New Binary Vestoid” 165–166.

Stephens, R.D., Warner, B.D. “19204 Joshuatree – Not So Fast” 220–222.

Stephens, R.D., Warner, B.D. “Lightcurve Observations of (348400) 2005 JF21: An NEA Binary” 22–24.
  Corrigendum 190.

Stephens, R.D., Warner, B.D., Marchini, A., Salvaggio, F., Papini, R. “Lightcurve Analysis of the Hungaria Binary 7958 Leakey” 166–169.

Stoelting, M., DeGraff, D.R. “Lightcurve Results for Asteroids 900 Rosalinde, 4666 Dietz, and 6302 Tengukogen” 44–45.

Tomov, D., Kurtenkov, A., Enimanev, M., Teneva, D. “Asteroid 4962 Vecherka: A High-amplitude Slow Rotator” 321–322.

Warner, B.D. “(53110) 1999 AR7: A New NEA Binary Discovery” 163–164.

Warner, B.D. “Asteroid-Deepsky Appulses in 2016” 32.

Warner, B.D. “Asteroid Lightcurve Analysis at CS3-Palmer Divide Station”
  2015 June–September 57–65.
  2015 October–December 137–140.
  2015 December – 2016 April 227–233.
  2016 April–July 300–304.

Warner, B.D. “Near-Earth Asteroid Lightcurve Analysis at CS3-Palmer Divide Station”
  2015 June–September 66–79.
  2015 October–December 143–154.
  2016 January-April 240–250.
  2016 April-July 311–319.

Warner, B.D. “Save the Lightcurves! An Update on the ALCDEF Project” 26–30.

Warner, B.D. “Three Additional Candidates for the Group of Very Wide Binary Asteroids” 306–309.

Warner, B.D., Benishek, V. “Lightcurve Analysis of NEA (331471) 1984 QY1: A Tumbling Asteroid” 285–286.

Warner, B.D., Benishek, V., Ferrero, A., Skiff, B.A. “Lightcurve Analysis of NEA (154244) 2002 KL6: A Potential New Binary Asteroid” 343–344.

Warner, B.D., Carbognani, A., Franco, L., Oey, J. “Lightcurve Analysis of the Near-Earth Asteroid 2015 TB145” 141–142.

Warner, B.D, Harris, A.W., Ďurech, J., Benner, L.A.M. “Lightcurve Photometry Opportunities”
  2016 January–March 103–108.
  2016 April–June 193–197.
  2016 July-September 277–281.
  2016 October–December 356–361.

Warner, B.D., Macías, A.A. “6384 Kervin: A Possible Hungaria Binary Asteroid” 184–185.

Warner, B.D., Ryan, W.H. “Lightcurve Analysis of NEA 2015 HM10” 30–31.

Zeigler, K., Hanshaw, B. “Photometric Observations of Asteroids 3829 Gunma, 6173 Jimwestphal, and (41588) 2000 SC46” 199–200.

IN THIS ISSUE

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

Number	Name	EP	Page
50	Virginia	22	304
58	Concordia	22	304
124	Alkeste	14	296
238	Hypatia	68	350
307	Nike	22	304
339	Dorothea	22	304
381	Myrrha	50	332
465	Alekto	14	296
481	Emita	50	332
503	Evelyn	50	332
507	Laodica	5	287
507	Laodica	50	332
512	Taurinensis	57	339
537	Pauly	50	332
569	Misa	14	296
569	Misa	50	332
585	Bilkis	54	336
857	Glasenappia	50	332
884	Priamus	41	323
895	Helio	28	310
1005	Arago	50	332
1085	Amaryllis	50	332
1108	Demeter	28	310
1145	Robelmonte	50	332
1259	Ogyalla	50	332
1263	Varsavia	50	332
1271	Isergina	57	339
1305	Pongola	50	332
1311	Knopfia	5	287
1320	Impala	57	339
1363	Herberta	5	287
1454	Kalevala	5	287
1480	Aunus	5	287
1583	Antilochus	41	323
1597	Laugier	5	287
1603	Neva	68	350
1647	Menelaus	41	323
1714	Sy	5	287
1715	Salli	50	332
1727	Mette	18	300
1791	Patsayev	5	287
1859	Kovalevskaya	68	350
1866	Sisyphus	29	311
1868	Thersites	41	323
1911	Schubart	5	287
1911	Schubart	54	336
2047	Smetana	18	300
2049	Grietje	18	300
2087	Kochera	5	287
2146	Stentor	41	323
2179	Platzeck	5	287
2241	Alcathous	41	323
2242	Balaton	64	346
2260	Neoptolemus	41	323
2312	Duboshin	54	336
2346	Lilio	54	336
2408	Astapovich	39	321
2408	Astapovich	57	339
2491	Tvashtri	54	336
2656	Evenkia	62	344
2660	Wasserman	5	287
2828	Iku-Turso	5	287
2854	Rawson	5	287
2904	Millman	57	339
3002	Delasalle	50	332
3002	Delasalle	68	350
3063	Makhaon	41	323
3103	Eger	29	311
3177	Chillicothe	50	332
3223	Forsius	17	299
3228	Pire	5	287
3606	Pohjola	5	287
3669	Vertinskij	5	287
3709	Polypoites	41	323
3754	Kathleen	50	332
3793	Leonteus	41	323
3812	Lidaksum	5	287
3829	Gunma	5	287
3840	Mimistrobell	5	287
3861	Lorenz	38	320
4060	Deipylos	41	323
4063	Euforbo	41	323
4068	Menestheus	41	323
4145	Maximova	57	339
4170	Semmelweis	68	350
4489	1988 AK	41	323
4542	Mossotti	50	332
4587	Rees	54	336
4640	Hara	5	287
4708	Polydoros	41	323
4764	Joneberhart	54	336
4833	Meges	41	323
4834	Thoas	41	323
4919	Vishnevskaya	57	339
4931	Tomsk	2	284
4962	Vecherka	39	321
5012	Eurymedon	41	323
5027	Androgeos	41	323
5232	Jordaens	2	284
5264	Telephus	41	323
5284	Orsilocus	41	323
5318	Dientzenhoffer	66	348
5836	1993 MF	29	311
5863	Tara	29	311
5899	Jedicke	18	300
6173	Jimwestphal	38	320
6310	Jankonke	18	300
6556	Arcimboldo	57	339
7016	Conandoyle	5	287
7543	Prylis	41	323
7660	1993 VM1	18	300
8013	Gordonmoore	29	311
8045	Kamiyama	5	287
9083	Ramboehm	66	348
9400	1994 TW1	29	311
9414	Masamimurakami	57	339
10150	1994 PN	29	311
10259	Osipovyurij	38	320
10259	Osipovyurij	71	353
11395	1998 XN77	41	323
11395	1998 XN77	41	323
12551	1998 QQ39	5	287
13388	1999 AE6	5	287
15436	1998 VU30	41	323
15440	1998 WX4	41	323
15502	1999 NV27	41	323
15535	2000 AT177	41	323
16233	2000 FA12	57	339
18060	1999 XJ156	41	323
18890	2000 EV26	18	300
24403	2000 AX193	41	323
29470	Higgs	38	320
31013	1996 DR	68	350
35396	1997 XF11	1	283
35396	1997 XF11	29	311
39810	1997 WQ35	57	339
54697	2001 FA70	18	300
68346	2001 KZ66	29	311
78857	2003 QO70	18	300
85628	1998 KV2	29	311
93768	2000 WN22	57	339
137170	1999 HF1	29	311
138325	2000 GO82	29	311
141354	2002 AJ29	29	311
153652	2001 TC103	57	339
154244	2002 KL6	61	343
154555	2003 HA	1	283
154555	2003 HA	29	311
162463	2000 JH5	29	311
214088	2004 JN13	8	290
215442	2002 MQ3	24	306
331471	1984 QY1	3	285
388945	2008 TZ3	29	311
436775	2012 LC1	57	339
441987	2010 NY65	29	311
464798	2004 JX20	29	311
	2002 CX58	29	311
	2002 LY1	29	311
	2003 KO2	29	311
	2009 DL46	29	311
	2009 EC	24	306
	2016 BU13	24	306
	2016 BU13	29	311
	2016 BX14	29	311
	2016 FE1	29	311
	2016 FY3	29	311
	2016 GS2	29	311
	2016 HO	29	311
	2016 JC6	29	311
	2016 JP17	29	311
	2016 LG	29	311

THE MINOR PLANET BULLETIN (ISSN 1052-8091) is the quarterly journal of the Minor Planets Section of the Association of Lunar and Planetary Observers (ALPO). Current and most recent issues of the *MPB* are available on line, free of charge from:

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Effective with Volume 38, the *Minor Planet Bulletin* is a limited print journal, where print subscriptions are available only to libraries and major institutions for long-term archival purposes. In addition to the free electronic download of the *MPB* noted above, electronic retrieval of all *Minor Planet Bulletin* articles (back to Volume 1, Issue Number 1) is available through the Astrophysical Data System

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The deadline for the next issue (44-1) is October 15, 2016. The deadline for issue 44-2 is January 15, 2017.