

THE MINOR PLANET BULLETIN

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

VOLUME 47, NUMBER 1, A.D. 2020 JANUARY-MARCH

1.

SECTION NEWS: STAFFING CHANGES FOR THE MINOR PLANET BULLETIN

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One staffing change and one staffing addition for *The Minor Planet Bulletin* are announced effective with this issue.

MPB Distributor Derald Nye is now retired from his 37 years of service to the *Minor Planets Bulletin*. Derald stepped in to service at the time the *MPB* made its transition from the original Editor and Section founder, Richard G. Hodgson. As Derald reflected in a short essay written in *MPB* 40, page 53 (2013), the Distributor position was the longest job he ever held, having retired from being a programmer for 30 years with IBM. (Work for IBM included programming for the space program.) At its peak, Derald was managing nearly 200 subscriptions. That number dropped to the dozen or so libraries maintaining a permanent collection following the *MPB* transitioning to becoming an on-line electronic journal with limited printing. However, each and every issue continues to be printed and mailed to the permanent libraries, and in 37 years, Derald accomplished this task without ever missing a beat. Subscription funds are no longer collected, so the printing and mailing costs are supported by private contributions to the *MPB*. Derald himself has been a major contributor for many years, choosing to cover all of these costs himself. The Minor Planets Section is pleased to announce that Derald has received a Special Service Award in recognition and with gratitude for bringing forward the *Minor Planet Bulletin* to where it is today.

New! MPB Distributor: Melissa Hayes-Gehrke of the University of Maryland succeeds Derald Nye with this issue. As an Instructor in the Astronomy Department, Dr. Hayes-Gehrke encourages class projects on asteroid lightcurve photometry, projects whose results are regularly reported on these pages. Contact information for the new Distributor appears in the Masthead on the last page of this issue.

New! MPB Associate Producer: Pedro A. Valdés Sada of the Universidad de Monterrey (México) takes on the role of Associate Producer. Dr. Valdés Sada is a Professor at the Physics and Mathematics Department and his role is to assist *MPB* Producer Dr. Robert Werner (retired from NASA JPL) who has seen the *MPB* published page count increase exponentially over the course of his 35 years of service.

Please join me in thanking Derald Nye and in welcoming Melissa and Pedro to the *Minor Planet Bulletin* team.

COLLABORATIVE ASTEROID PHOTOMETRY FOR ASTEROID 2051 CHANG

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(Received: 2019 October 15)

Photometric observations of this main-belt asteroid were conducted in order to determine its rotation period. The authors found a synodic rotation period of 12.013 ± 0.001 h and a light curve amplitude of 0.64 ± 0.01 mag.

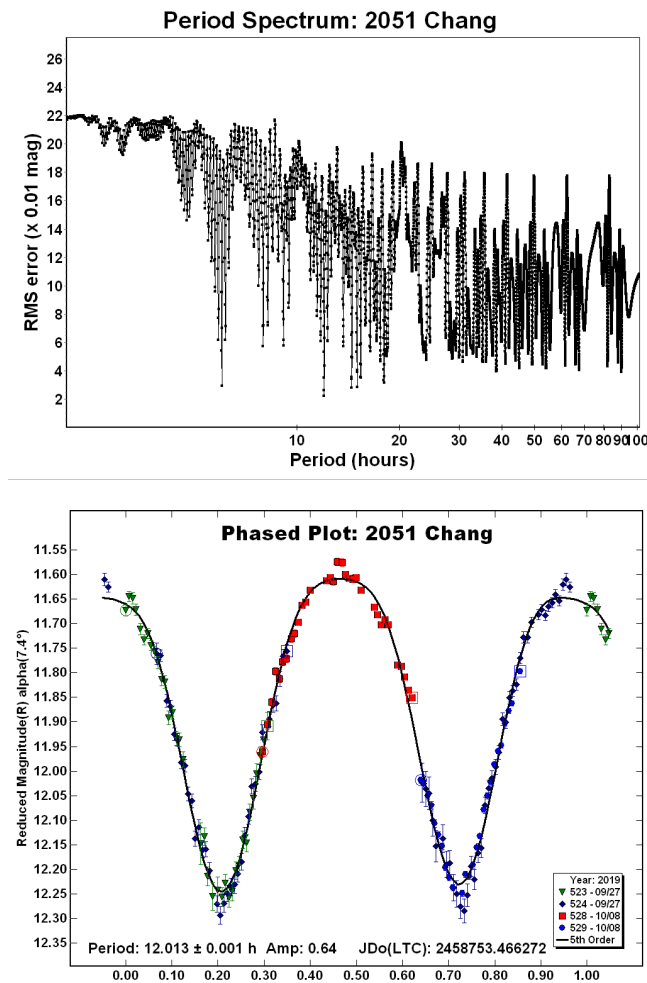
After two initial sessions in late September 2019 from the Astronomical Observatory of the University of Siena (DSFTA, 2019), the Italian authors realized that a possible rotation period for this target was very close to 12 hours. Therefore, they asked for an international collaboration to obtain data at a substantial different longitude. Melissa Hayes-Gehrke and Eric Yates answered this request and obtained a third session on October 8 using a remotely operated telescope in New Mexico that completed the lightcurve for this asteroid.

Data at University of Siena were collected on Sept. 26 and 27 using 0.30-m f/5.6 Maksutov-Cassegrain telescope, a SBIG STL-6303E CCD camera, and clear filter. The pixel scale was 2.30 arcsec/pixel when binned at 2x2 pixels. At New Mexico Skies Observatory (MPC H06) in Mayhill, New Mexico (iTelescope-T21, 2019) data were collected on Oct. 8 using a 0.43-m f/6.8 reflector telescope, a FLI-PL6303E CCD camera, and clear filter. The pixel scale was 0.96 arcsec/pixel when binned 1x1 pixels.

Lightcurve analysis was performed with MPO Canopus (BDW Publishing, 2018). All the images were calibrated with dark and flat frames and converted to R magnitudes using solar colored field stars from CMC15 catalogue, distributed with MPO Canopus. Table I shows the observing circumstances and results.

2051 Chang (1976 UC) was discovered on 1976 October 23 at Agassiz Station by Harvard College and named after Yu-Che Chang, one of the leading astronomers in the Peoples Republic of China and director of the Purple Mountain Observatory (Nanjing) since 1950. Long an active observer of minor planets and comets, he also determined rotation periods of many asteroids [Ref: Minor Planet Circ. 4420]. 2051 Chang is a main-belt asteroid with a semi-major axis of 2.841 AU, eccentricity 0.756, inclination 1.356 deg, and an orbital period of 4.79 years. Its absolute magnitude is $H = 11.5$ (JPL, 2019). The WISE/NEOWISE satellite infrared radiometry survey (Masiero *et al.*, 2012) found a diameter $D = 14.361 \pm 2.977$ km. using an absolute magnitude $H = 11.35$.

Collaborative observations over three nights collected 171 data points. The period analysis shows a bimodal solution for the rotational period of $P = 12.013 \pm 0.001$ h with an amplitude $A = 0.64 \pm 0.01$ mag.



Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2051	Chang	09/26-10/08	7.5, 2.4	20	1	12.013	0.001	0.64	0.01	MB

Table I. Observing circumstances and results. The first line gives the results for the primary of a binary system. The second line gives the orbital period of the satellite and the maximum attenuation. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

Acknowledgements

The authors Melissa Hayes-Gehrke and Eric Yates thank the Astronomy Department of the University of Maryland for their support and *iTelescope.net* for the use of their facilities.

Minor Planet Circulars (MPCs) are published by the International Astronomical Union's Minor Planet Center.

https://www.minorplanetcenter.net/iau/ECS/MPCArchive/MPCArchive_TBL.html

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

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<http://ssd.jpl.nasa.gov/sbdb.cgi#top>

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

Warner, B.D. (2018). MPO Software, MPO Canopus v10.7.7.0. Bdw Publishing. <http://minorplanetobserver.com>

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2019 Aug. <http://www.minorplanet.info/lightcurvedatabase.html>

MEASURED LIGHTCURVES AND ROTATIONAL PERIODS OF 3122 FLORENCE, 3830 TRELLEBORG, AND (131077) 2000 YH105

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(Received: 2019 June 16 Revised: 2019 November 12)

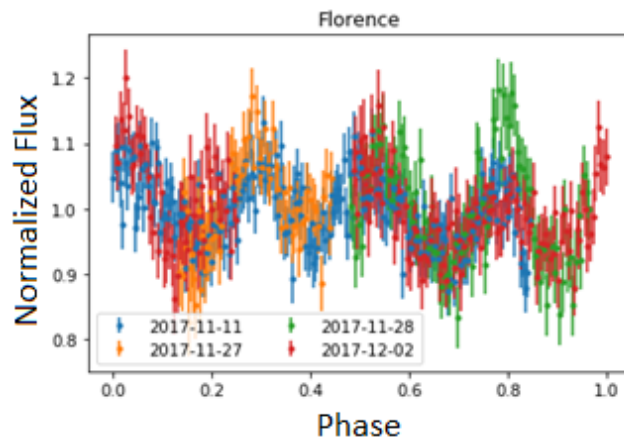
We determined the rotational periods of 3122 Florence, 3830 Trelleborg, and (131077) 2000 YH105 with the Harvard Clay Telescope and KeplerCam at the Fred L. Whipple Observatory. We found the rotational periods to be 2.3580 ± 0.0015 h, 17.059 ± 0.017 h, and 1.813 ± 0.00003 h, respectively. Our measurement of 3122 Florence's period agrees with Warner (2016), who reported 2.3580 ± 0.0002 h.

Photometric observations of 3122 Florence, 3830 Trelleborg, and (131077) 2000 YH105 were collected using a combination of data from the Clay Telescope at Harvard University in Cambridge, MA, and KeplerCam at the Fred L. Whipple Observatory in Arizona. The Clay Telescope is a 0.4-m telescope with 13x13 arcmin FOV and an Apogee Alta U47 imaging CCD. The data collected with the Clay Telescope were in R-band Bessel-system filter. KeplerCam is a 1.2-m telescope with a 23x23 arcmin FOV; the data were taken in the Sloan i-band.

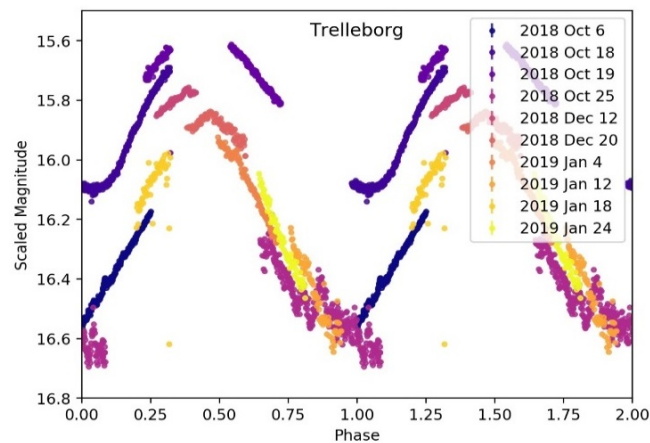
3122 Florence was chosen since it has a known rotational period of 2.3580 ± 0.0002 h (Warner, 2016). We chose to begin with an asteroid with a known rotational period in order to validate our methodology. Using *Minorplanet.info* to look up the brightest targets without known rotational periods, we selected 3830 Trelleborg and 2000 YH105 because they were observable by the Clay telescope for at least several months.

In our analysis, we reduced the images from the Clay Telescope using *MaximDL* (Diffraction Limited, 1997) and from KeplerCam using standard *IDL* procedures. We determined an astrometric solution using *astrometry.net* and produced a lightcurve using the *AstroImageJ* multi-aperture photometry function (Collins et al., 2017). We used the Python package *gatspy* to calculate the Lomb-Scargle periodogram and determine the rotational period (VanderPlas and Ivezić, 2015). Uncertainties in the rotational periods were determined by establishing a maximum and minimum rotational period at which the phased lightcurve no longer had recognizable rotational modulation. Amplitudes were determined by subtracting the maximum from the minimum normalized magnitude, and errors were found by measuring the scatter of one of the peaks. For normalized flux, the amplitude was found by $|-2.5\log(\max \text{ flux}/\min \text{ flux})|$.

3122 Florence was discovered 1981 March 2 at Siding Spring Observatory in Australia. It is one of the bigger and brighter near-Earth asteroids that have been discovered and it has recently been found to have two moons (Benner et al., 2017). It was observed with the Harvard Clay Telescope in the R-band over the course of seven nights, though three were unusable due to poor weather and high scatter. We found the rotational period to be 2.3580 ± 0.0015 h, which agrees well with the previously determined rotational period of 2.3580 ± 0.0002 h (Warner, 2016).



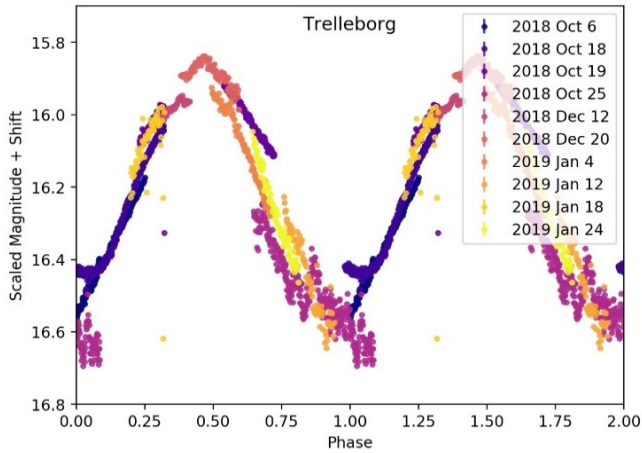
3830 Trelleborg was discovered 1986 September 11 at the Brofelde Observatory in Denmark. It was observed with KeplerCam in the i-band over the course of nine nights. Since we observed it over a long period of time, the visual magnitude of the asteroid changed over the course of the observations, so we did absolute photometry using *AstroImageJ* and normalized the lightcurve by subtracting the magnitudes corresponding to a linear brightness decline. We then determined the rotational period as described above and found the following phase diagram with a period of 17.059 ± 0.017 h.



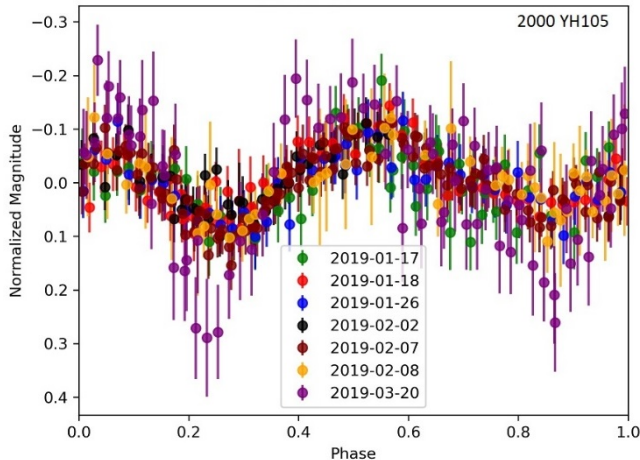
Number	Name	20yy/mm/dd	Phase	L _{PAB}	B _{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
3122	Florence	17/10/02-12/01	77.9, 20.7	55	51	2.3580	0.0015	0.17	0.04	Amor
3830	Trelleborg	*18/10/06-01/24	6.7, 18.9	356	9	17.059	0.017	0.76	0.01	Eos
131077	2000 YH105	19/01/17-02/08	8.9, 13.7	121	12	1.8130	0.0003	0.19	0.02	MB-O

Table I. Observing circumstances and results. *Observations extended into 2019. The phase angle is given for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). MB-O: outer main-belt.

Due to intrinsic variability of the asteroid, there were variations in the peak heights, so we manually shifted the magnitude. This had no effect on the measured rotational period.



(131077) 2000 YH105 was discovered 2000 December 28 in Socorro, New Mexico. We observed it over the course of seven nights with KeplerCam in the i-band. We were the first to measure its rotational period and found that it is 1.813 ± 0.00003 h. We realize this period is short and would be rare for an asteroid this diameter, so we performed a second analysis on the data. Using the Phase Dispersion Minimization (PDM) technique (Plavchan et al. 2008), we found the same period again. We cannot completely rule out a multiple of our best period being the true period given our current data. Ultimately more data is required for confirmation of the suggested period.



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ROTATIONAL PERIOD DETERMINATION FOR ASTEROIDS 2460 MITLINCOLN, 3070 AITKEN AND (11116) 1996 EK

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(Received: 2019 July 8 Revised: 2019 August 26)

CCD photometric observations of three main-belt asteroids were obtained in order to measure their rotation period. These measures were performed during several nights from 21/3/2019 to 6/5/2019, using the instrumentation available at the Osservatorio Astronomico Margherita Hack located on the hills near Florence (Italy).

CCD photometric observations of three main-belt asteroids were carried out in 2019 from March to May at the Osservatorio Astronomico Margherita Hack (A57). We used a 0.35-m f/8,25 Smith-Cassegrain telescope, a SBIG ST10 XME CCD camera, and clear filter. The pixel scale was 1 arcsec when binned at 2x2 pixels. Exposures were 240 sec. for all three asteroids and data processing and analysis were done with MPO Canopus (Warner, 2017). All the images were calibrated with dark and flat field frames using Astroart 6.0. Table I shows the observing circumstances and results.

2460 Mitlincoln was discovered on 1980 Oct 01 at Socorro by Taff, L. G. and Beatty, D and dedicated to the MIT Lincoln Laboratory. It was chosen from the list of lightcurve photometry opportunities on the Minor Planet Bulletin (Warner et al., 2019 Apr-Jun). It is a main-belt asteroid with a semi-major axis of 2.2567 AU, eccentricity 0.1106, inclination 3.739 deg, and an orbital period of 3.39 years. Its absolute magnitude is $H = 12.6$ mag (JPL, 2019; MPC, 2019). Our observations were conducted in the period from 21/3/2019 to 06/04/2019 and provided 229 data points. The period analysis shows a bimodal solution of $P = 3.0052 \pm 0.0002$ h and an amplitude $A = 0.10 \pm 0.01$ mag (Figure 1).

Moreover, we consulted the asteroid lightcurve database (LCDB; Warner et al., 2009) and we found four previous calculated periods: $P = 2.77 \pm 0.005$ h (Warner, 2002), $P = 3.009 \pm 0.002$ h (Behrend, 2004), $P = 2.6677 \pm 0.002$ h (Warner, 2011) and $P = 2.8277 \pm 0.0005$ h (Kryszczyńska, 2012). Only one of them is in good accordance with our data (Behrend, 2004). Further investigation about this asteroid period seems to be necessary.

(3070) Aitken was discovered 1949-Apr-04 by Goethe Link Observatory at Brooklyn. It was chosen from the list of lightcurve photometry opportunities on the Minor Planet Bulletin (Warner et al., 2019 Apr-Jun). It is a main-belt asteroid with a semi-major

axis of 2.3054 AU, eccentricity 0.1977, inclination 2.3456 deg, and an orbital period of 3.50 years. Its absolute magnitude is $H = 13.8$ mag (JPL, 2019; MPC, 2019).

Our observations were conducted in the period from 30/3/2019 to 31/03/2019 and provided 194 data points. The period analysis shows a bimodal solution for the rotational period with $P = 6.394 \pm 0.002$ h and an amplitude $A = 0.47 \pm 0.01$ mag (Figure 2).

Consulting the asteroid lightcurve database (LCDB; Warner et al., 2009) we found one previous calculated period: $P = 6.396 \pm 0.0026$ h (Waszczak, 2015). This value is in tight accordance with our data.

(11116) 1996EK was discovered by Ueda, S., Kaneda, H. at Kushiho on 1996 March 10. It is a main-belt asteroid with the semi-major axis of 2.196 AU, eccentricity 0.227, inclination 7.74 deg, and an orbital period of 4.58 years. Its absolute magnitude is $H = 14.2$ mag (JPL, 2019; MPC, 2019).

Observations of this asteroid were conducted in the night across 2/5/2019 and 6/5/2019, and provided 128 data points. The period analysis shows a bimodal solution for the rotational period $P = 4.4010 \pm 0.0007$ h with an amplitude $A = 0.11 \pm 0.02$ mag (Figure 3).

We have checked the asteroid lightcurve database (LCDB; Warner et al., 2009) and we found three previous calculated periods: $P = 4.4017 \pm 0.0002$ h (Pravec 2006web), $P = 4.4018 \pm 0.0001$ h (Pravec 2009web) and $P = 4.401 \pm 0.002$ h (Oey, 2010b). In this case our calculated period is in strong agreement with the existing calculated period.

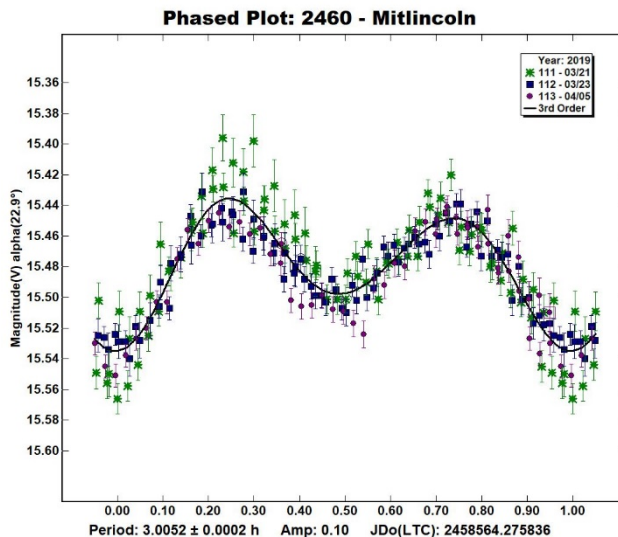


Figure 1. Phased lightcurve of 2460 Mitlincoln.

Number	Name	2019 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2460	Mitlincoln	21/03-06/04	229	22.8-26.4	141.2	-1.8	3.0052	0.0002	0.10	0.01	MB
3070	Aitken	03/30-03/31	194	1.2-0.97	191	1.2	6.3939	0.0020	0.47	0.01	MB
11116	1996EK	05/02-05/06	128	18.5-16.3	241	12.7	4.4010	0.0007	0.11	0.02	MB

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009).

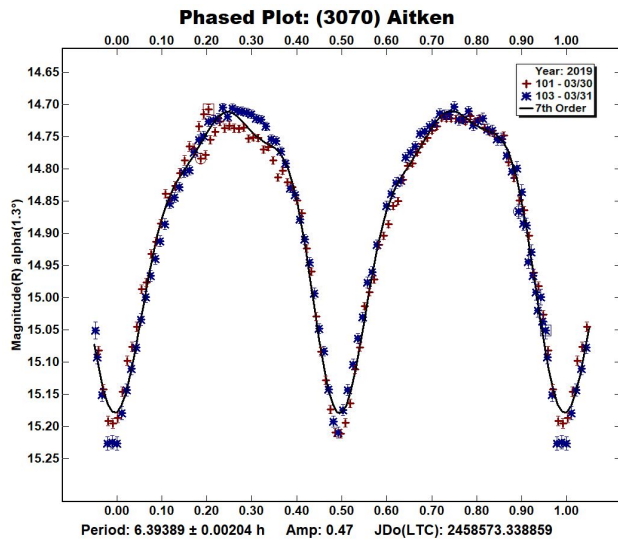


Figure 2. Phased lightcurve of 3070 Aitken.

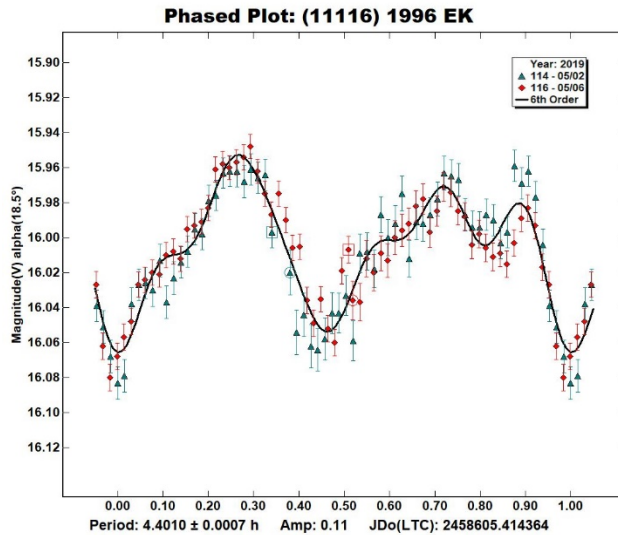


Figure 3. Phased lightcurve of (11116) – 1996 EK.

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**TWELVE MAIN BELT ASTEROIDS, ONE NEAR EARTH
AND ONE POTENTIALLY HAZARDOUS ASTEROID
LIGHTCURVES AT ASTEROIDS OBSERVERS
(OBAS) – MPPD: 2017 MAY- 2019 JAN**

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(Received: 2019 July 15; Revised: 2019 November 11)

We report on the photometric analysis result of twelve main-belt asteroids (MBA), one near-Earth asteroid (NEA) and one potentially hazardous asteroid (PHA) by Asteroides Observers (OBAS). This work is part of the Minor Planet Photometric Database effort that was 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 for twelve asteroids analyzed 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>). This database shows graphic results of the data, mainly lightcurves, with the plot phased to a given period.

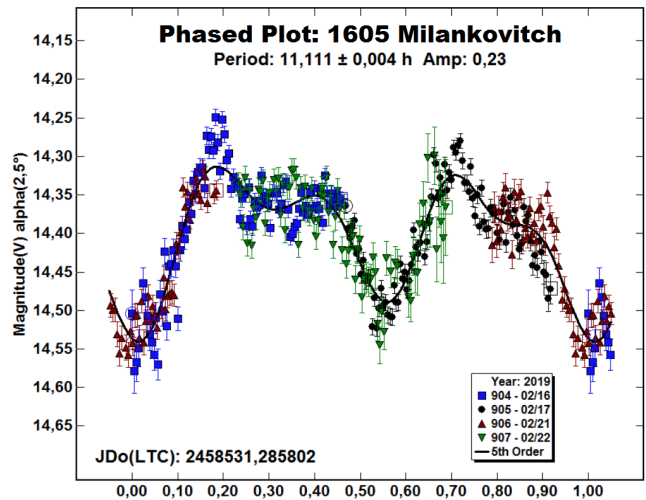
Observatory	Telescope (meters)	CCD
C.A.A.T.	0.45 DK	SBIG STL-11002
Zonalunar	0.20 NW	ATIK 314L
Vallbona	0.20 NW	ATIK414EX

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

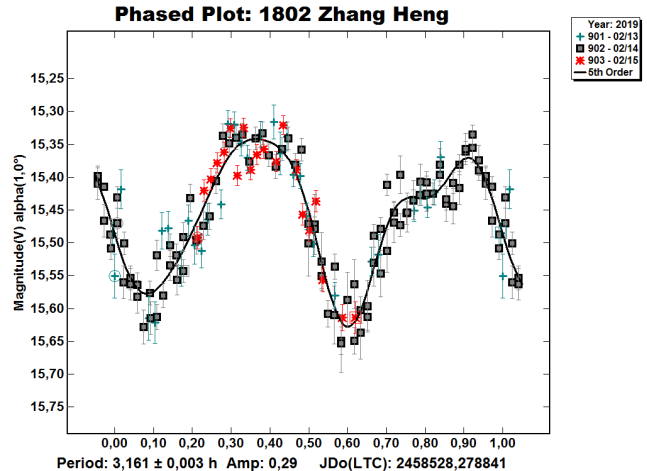
Table I shows the equipment at observatories that participated in this work. We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. All the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website 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. The comparison stars were restricted to near solar-color to avoid introducing color dependences, especially at larger air masses. The lightcurves give the synodic rotation period. The amplitude (peak-to-peak) that is shown is that for the Fourier model curve and not necessarily the true amplitude.

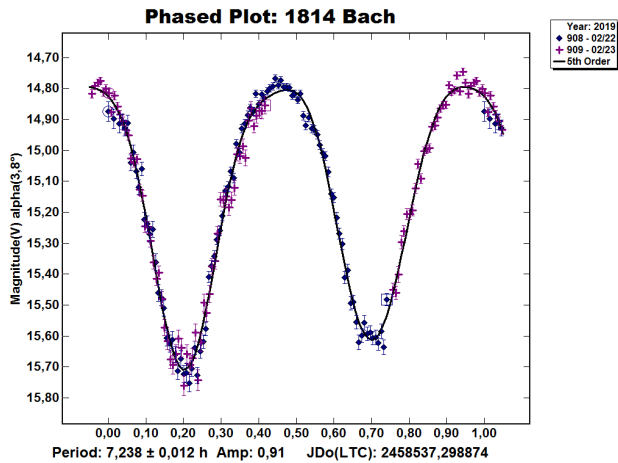
1605 Milankocith. This outer main-belt asteroid was discovered on 1936 April 13 by Petar Đurković from the Royal Observatory of Belgium, Uccle. The OBAS group made observations on 2019 Feb 16-22. From our data we derive a rotation period of 11.111 ± 0.004 h and amplitude of 0.23 mag. Cooney 2005 found a period of 11.6 h and Behrend 2006 web found 11.63 h.



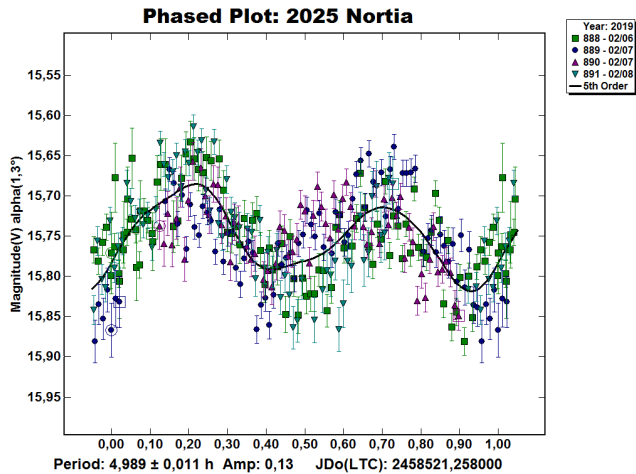
1802 Zhang Heng. This main-belt asteroid (outer) was discovered on 1964 Oct 14 by the Purple Mountain Obs., Nanking, China. The OBAS group made observations on 2019 Feb 13-15. From our data we derive a rotation period of 3.161 ± 0.003 h and amplitude of 0.29 mag. Simpson 2013 found a period of 3.162 h and Waszczak et al. (2015) found 3.160 h.



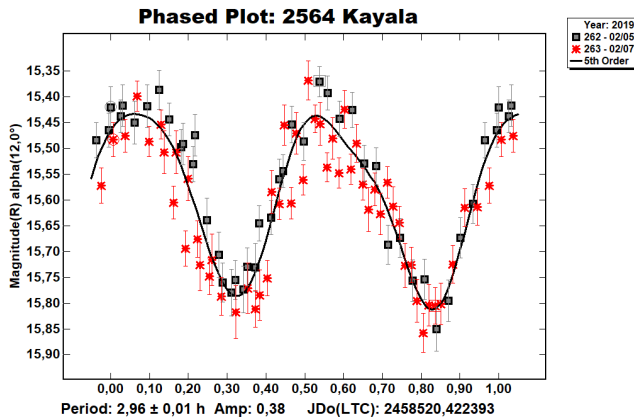
1814 Bach. This inner main-belt asteroid was discovered on 1931 Oct 9 by Karl Wilhelm Reinmuth at Heidelberg-Königstuhl Observatory, Deutschland. The OBAS group made observations on 2019 Feb 22-23. From our data we derive a rotation period of 7.238 ± 0.012 h and amplitude of 0.91 mag. Durech et al. (2016) found a period of 7.24 h and Pravec et al. (2019, website) found 7.24 h.



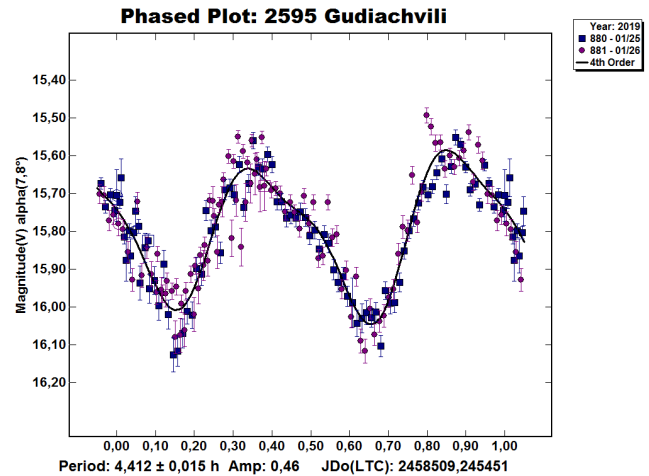
2025 Nortia. This outer main-belt asteroid was discovered on 1953 Jun 06 by Joseph Churms at Union Observatory, Johannesburg, Southafrica. The OBAS group made observations on 2019 Feb 06-08. From our data we derived a rotation period of 4.989 ± 0.011 h and amplitude of 0.13 mag. The LCDB (Warner et al., 2009) did not list any previous period results.



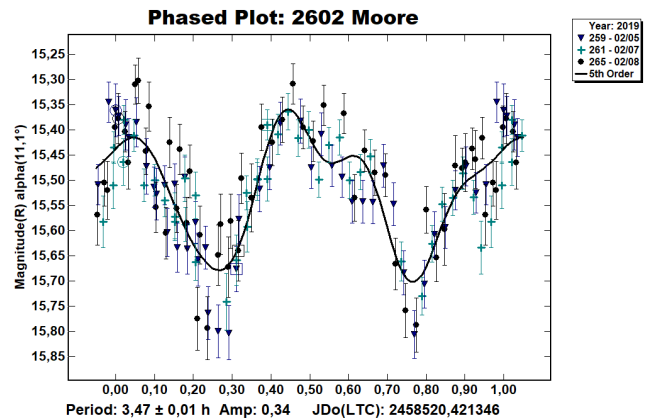
2564 Kayala. This inner main-belt asteroid was discovered on 1977 Aug 19 by Nikolái Stepánovich Chernyj at Crimea astrophysical observatory. The OBAS group made observations in 2019 Feb 05 and 07. From our data we derived a rotation period of 2.96 ± 0.01 h and amplitude of 0.38 mag. Chang et al. (2016) found a period of 2.95 h.



2595 Gudiachvili. This Main Belt asteroid (middle) was discovered on 1979 May 19 by R. M. West at La Silla observatory, Chile The OBAS group made observations from 2019 Jan 25-26. From our data we derived a rotation period of 4.412 ± 0.015 h and amplitude of 0.46 mag. DeGraff (1998-2003) found 4.72 h.



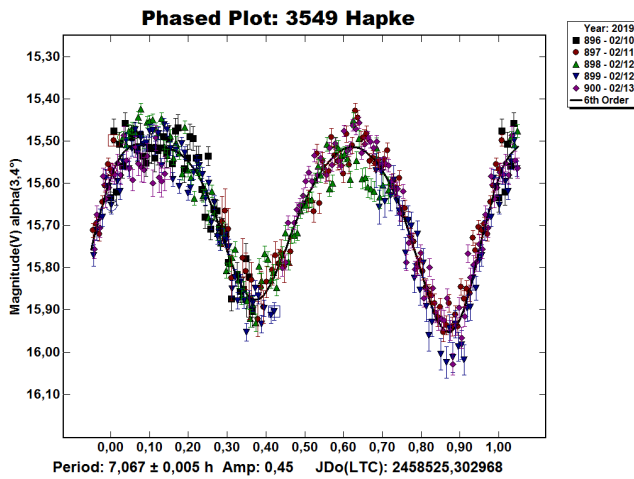
2602 Moore. This inner main-belt asteroid was discovered on 1982 Jan 24 by Edward. Bowell at Anderson Mesa, Arizona. The OBAS group made observations in 2019 Feb 5-8. From our data we derived a rotation period of 3.47 ± 0.01 h and amplitude of 0.34 mag. We have not found previous data about this asteroid.



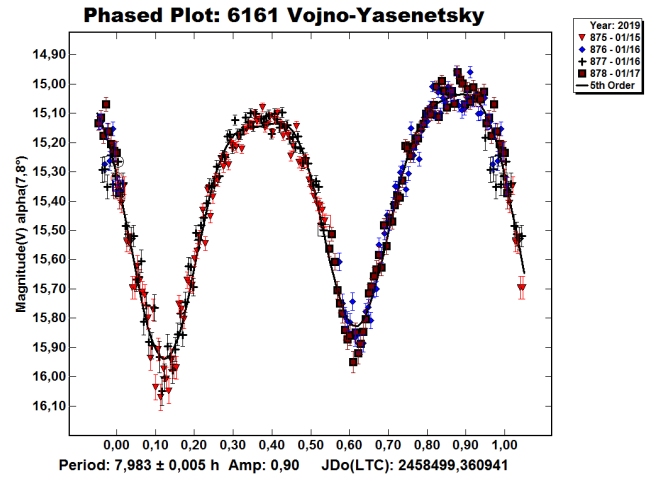
3549 Hapke. This inner main-belt asteroid was discovered on 1981 Dec 30 by Edward. Bowell at Anderson Mesa, Arizona. We observed it from 2019 Feb 10 to 13. Data analysis found a rotation period of 7.07 ± 0.005 h and amplitude of 0.45 mag. Waszczak et al. (2015) found a period of 7.071 h too.

Number	Name	20xx mm/dd	Phase	LPAB	BPAB	Period(h)	P.E.	Amp	A.E.	Grp
1605	Milankovitch	16/02/16-02/22	2.4, 2.9	149	-6	11.111	0.004	0.23	0.05	MB-O
1802	Zhang Heng	19/02/13-02/15	1.3, 1.9	141	0	3.161	0.003	0.29	0.02	MB-O
1814	Bach	19/02/23-02/23	3.4, 3.3	157	4	7.238	0.012	0.91	0.05	MB-I
2025	Nortia	19/02/06-02/08	1.5, 1.9	133	2	4.989	0.011	0.13	0.05	MB-O
2564	Kayala	19/02/05-02/07	11.9, 10.9	157	0	2.96	0.01	0.38	0.02	MB-I
2595	Gudiachvili	19/01/25-01/26	8.2	110	-7	4.412	0.015	0.46	0.02	MB-M
2602	Moore	19/02/05-02/08	11.1, 10.1	157	-1	3.47	0.01	0.34	0.03	MB-I
3549	Hapke	19/02/10-02/13	3.6, 4.3	139	-6	7.070	0.005	0.45	0.02	MB-I
4148	McCartney	19/02/03-02/06	2.8, 1.5	139	1	10.438	0.014	0.14	0.03	MB-I
6161	Vojno-Yasenetsky	19/01/15-01/17	7.4, 6.8	127	-5	7.983	0.005	0.9	0.02	MB-O
7081	Ludibunda	18/09/29-10/01	4.1, 4.3	9	7	2.885	0.006	0.08	0.02	MB-M
18348	1990 BM1	19/01/13-01/15	3.4, 2.8	116	-4	7.520	0.009	0.29	0.03	MB-I
162082	1998 HL1	19/10/01-01/09	81.0, 77.8	11	49	3.024	0.003	0.28	0.05	NEA

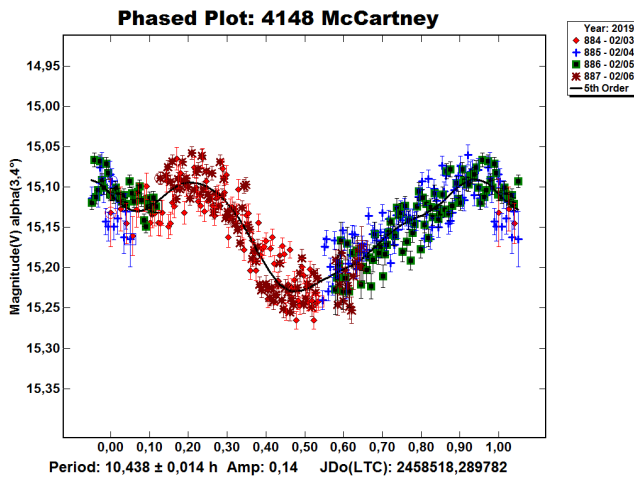
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). ERI: Erigone; EUN: Eunomia; MB-I/O: Main-belt inner/outer; MC: Mars-crosser; NEA: near-Earth; THM: Themis; TRJ: Jupiter Trojan.



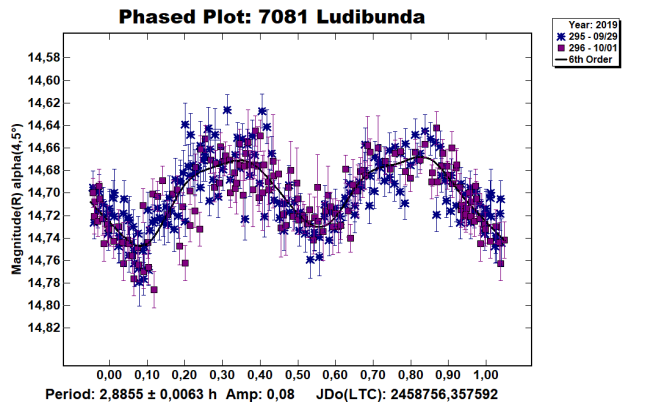
6161 Vojno-Yasenetsky. This Main Belt (outer) asteroid was discovered on 1971 Oct 14 by Liudmila Chernyj from Crimea observatory at Crimea. Our observations were made from 2019 Jan 15-17. Data analysis found a rotation period of 7.983 ± 0.005 h and amplitude of 0.9 mag. Durech et al. (2016) found a period of 7.98 h.



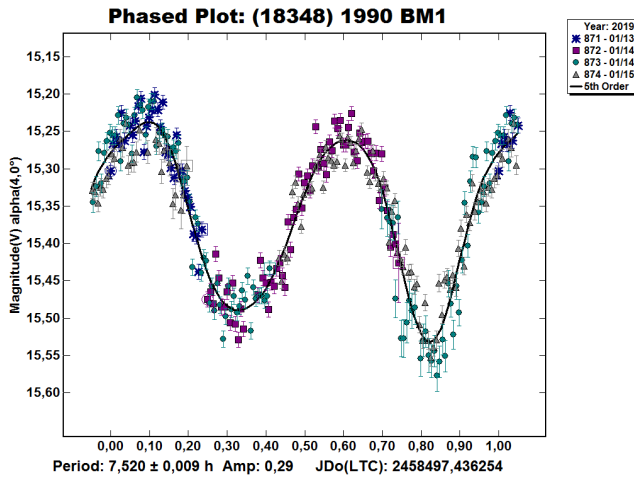
4148 McCartney. This inner main-belt asteroid was discovered on 1983 Jul 11 by Edward Bowell at Anderson Mesa, Arizona. The OBAS group observed it from 2019 Feb 3-6. From our data we derived a rotation period of 10.438 ± 0.014 h and amplitude of 0.14 mag. We have not found previous data about this asteroid.



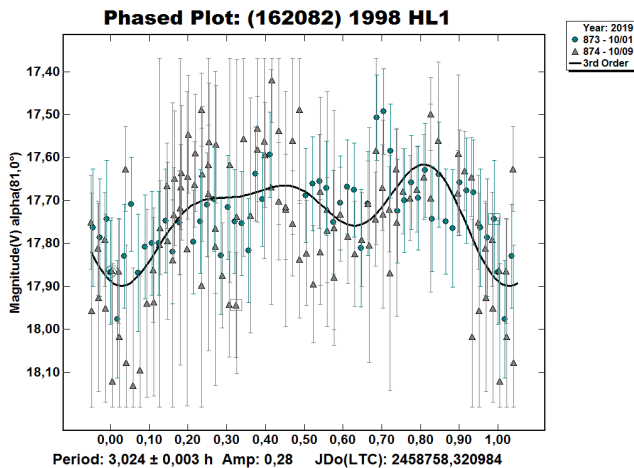
7081 Ludibunda. This middle main-belt asteroid was discovered on 1987 Aug 30, by Paul Wild at Berna - Zimmerwald Observatory. We observed it from 2019 Sep 9 to Nov 1. From our data we derived a rotation period of 2.885 ± 0.0063 h and amplitude of 0.08 mag. We have not found previous data about this asteroid.



(18348) 1990 BM1. This inner main-belt asteroid was discovered on 1990 Jan 22, by Eleanor Francis Helin at Palomar Observatory. We observed it from 2019 Jan 13-15. We derived a rotation period of 7.52 ± 0.009 h and amplitude of 0.29 mag. Pravec et al. (2019 website) found a period of 7.54 h and Klinglesmith (2019) found 7.53 h.



(162082) 1998 HL1. This Apollo - PHA asteroid was discovered on 1998 Apr 18, by LINEAR at Socorro Observatory. We observed it from 2019 Oct 01-09. We derived a rotation period of 3.024 ± 0.003 h and amplitude of 0.28 mag. We have not found previous data about this asteroid.



Acknowledgements

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

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**ROTATION PERIOD DETERMINATION FOR
ASTEROID 2602 MOORE**

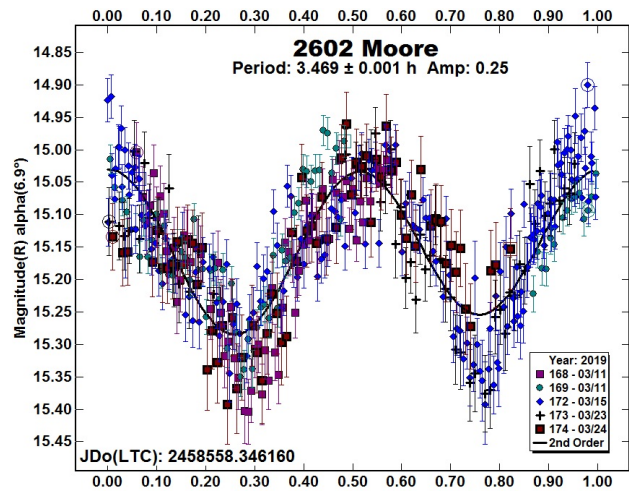
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Photometric observations of main-belt asteroid, 2602 Moore, were made at the Filzi School Observatory (School in country Laives - Italy). Results of lightcurve analysis are presented.

CCD photometric observations of 2602 Moore asteroid were made at the Filzi School Observatory (MPC code required in March 2019), the observations were made in four nights in March 2019 (440 points), all are with filter R. All images were obtained with a 0.35-m reflector telescope reduced to *f*/8.0, a QHY9 CCD camera, and then calibrated with dark and flat-field frames. The pixel scale was 1.56 arcsec when binned at 4x4 pixels. All exposures were 120 seconds. The computer clock was synchronized with an Internet time server before each session. Differential photometry and period analysis were done using *MPO Canopus* version 10.7.12.9 (Warner, 2018). Solar type stars from CMC15 catalog in R band were used as comparison stars.

2602 Moore This main-belt asteroid was reported as a lightcurve photometry opportunity for 2019 March on the MinorPlanet.info web site (<http://www.MinorPlanet.info>; hereafter referenced as MPI). 2602 Moore, was discovered on 1982 Jan 24, by Bowell at the Anderson Mesa station, Flagstaff, which is operated by the Lowell Observatory. It is a main belt asteroid with a semi-major axis of 2.38 AU, eccentricity 0.107, inclination 5.54 deg, and orbital period of 3.68 yr. Its absolute magnitude is *H* = 12.70. The derived synodic period was *P* = 3.469 ± 0.001 h with an amplitude of *A* = 0.25 ± 0.08 mag. Warner (in Minorplanet.Info 2019-04-30) <http://www.minorplanet.info/PHP/generateOneAsteroidInfo.php> reported a period of 3.46723 h with *A* = 0.15 mag. Which is in very close agreement with the result given here. A color index of *V*-*R* = 0.48 ± 0.03 mag was found from the mean of 20 values. This is typical for an S type asteroid (Shevchenko and Lupishko, 1998). Assuming S-type, the geometric albedo is *p_v* = 0.20 ± 0.07. From this and the assumed albedo, we can estimate a diameter of *D* = 8.6S ± 1 km using the expression (Pravec and Harris, 2007): $D_{(km)} = (1329/\sqrt{P_V})10^{-0.2H_V}$



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Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2602	Moore	2019 03/11-03/24	6.9,13.4	158.6	0.6	3.469	0.001	0.25	0.08	MB

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

PHOTOMETRIC OBSERVATIONS OF MAIN-BELT ASTEROID (10422) 1999 AN22

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Photometric observations of main-belt asteroid (10422) 1999 AN22 were obtained from May 20 to July 09, 2019, in order to determine its synodic rotation period. Observations were acquired from two observatories in Malta and one from Spain. Through our observational campaign, we present our results obtained for this asteroid that were based on 30 sessions.

Photometric observations of main-belt asteroid (10422) 1999 AN22 were carried out from three observatories shown in the Table 1.

Observatory (Location)	Telescope	CCD Sensor	Pixel Scale/ Binning
Flarestar Obs. (San Gwann, Malta)	0.25-m SCT	Moravian G2 1600/KAF 1603ME	0.99" / 1x1
Tacande Obs. (La Palma, Spain)	0.5-m Optimized Dall Kirkham	FLI ML3200/ KAF3200M E	0.98" / 2x2
Znith Obs. (Naxxar, Malta)	0.20-m SCT	Moravian G2- 1600/KAF 1603ME	1.17" / 1x1

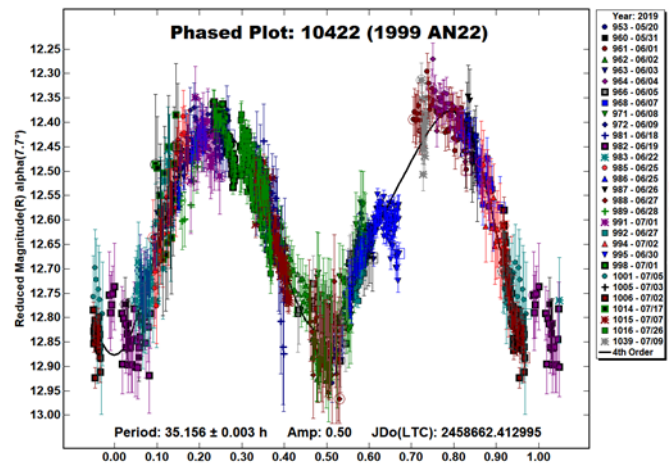
Table 1. Observatories and Equipment

All telescopes and cameras were controlled remotely. The observatories in Malta were operated from a nearby location via *Sequence Generator Pro* (Main Sequence Software, 2019), while the Tacande Observatory was controlled over the internet through *ACP Expert* Software (DC-3 Dreams, 2019). Photometric reduction, lightcurve construction and analyses were derived through *MPO Canopus* software (Warner, 2017). Differential aperture photometry was utilized and photometric measurements were derived through the use of *MPO Canopus*. Near-solar color comparisons stars were selected through the Comparison Star Selector (CSS) as used by the same software. All measurements

were based on the CMC-15 catalogue with magnitudes converted from J-K to BVRI. All images utilized in this research were dark subtracted and flat-fielded.

(10422) 1999 AN22, a large main-belt asteroid, was discovered on 1999 January 14 by the Beijing Schmidt CCD Asteroid Program from the XINGLONG station situated in the Yanshan mountains, China. The asteroid orbits the sun with a semi-major axis of 2.854 AU, eccentricity 0.2087, and orbital period of 4.82 years (JPL, 2019). The JPL Small-Bodies Database Browser lists the diameter of asteroid 10422 as 20.87 ± 0.09 km based on an absolute magnitude H of 12.2 (JPL, 2019).

The asteroid was observed from May 20 to July 09, 2019. Observations were acquired over 30 sessions generating 1350 data points. We determined the synodic period of (10422) 1999 AN22 as 35.156 ± 0.003 h with an amplitude of 0.50 ± 0.05 mag. Our results are consistent with the 2019 results obtained by Pravec and Benishek as shown on the Minorplanet.info website (Warner, 2011).



Acknowledgements

We would like to thank Brian Warner his work in the development of *MPO Canopus* and for his efforts in maintaining the CALL website. This research has made use of the JPL's Small-Body Database and the CALL website. This research was made possible in part based on data from CMC-15 Data Access Service at CAB (INTA-CSIC) (<http://svo2.cab.inta-csic.es/vocats/cmc15/>).

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
(10422)	1999 AN22	201905/20-07/09	7.6, 23.8	230	4.4	35.156	0.003	0.50	0.05	MB-O

Table 2. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

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PHOTOMETRIC OBSERVATIONS OF TEN MINOR PLANETS

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Phased lightcurves and synodic rotation periods are presented for eight main-belt asteroids. Results are: 243 Ida, 4.634 ± 0.002 h; 874 Rotraut, 14.311 ± 0.010 h; 1686 De Sitter, 11.292 ± 0.012 h; 2285 Ron Helin, 52.77 ± 0.07 h; 2302 Florya, 16.557 ± 0.024 h; 3306 Byron, 6.999 ± 0.005 h; 5391 Emmons, 3.029 ± 0.001 h; and 7365 Sejong, 2.579 ± 0.001 h. No period solutions were found for 1466 Mundleria or 5199 Dortmund. All the data have been submitted to the ALCDEF database.

CCD photometric observations of ten main-belt asteroids were performed at Command Module Observatory (MPC V02) in Tempe, AZ. Images were taken using a 0.32-m *f*/6.7 modified Dall-Kirkham telescope, SBIG STXL-6303 CCD camera, and a ‘clear’ glass filter. Exposure time for all the images was 2 minutes. The image scale after 2x2 binning was 1.76 arcsec/pixel. Table I shows the observing circumstances and results. All of the images for these ten asteroids were obtained between 2019 August and September.

Images were calibrated using a dozen bias, dark, and flat frames. Flat-field images were made using an electroluminescent panel. Image calibration and alignment was performed using *MaxIm DL* software.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2019). The 45’x30’ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B-V < 0.95$ to correspond with color ranges of asteroids. In order to reduce the internal scatter in the data, the brightest stars of appropriate color that had peak ADU counts below the range where chip response becomes nonlinear were selected. The *MPO Canopus* internal star catalogue was useful in selecting comp stars of suitable color and brightness.

Since the sensitivity of the KAF-6303 chip peaks in the red, the clear-filtered images were reduced to Sloan *r’* to minimize error

Number	Name	2019/mm/dd	Phase	L _{PAB}	B _{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
243	Ida	09/04-09/07	1.5,2.5	338	0	4.634	0.002	0.63	0.03	KOR
874	Rotraut	08/23-08/28	*3.2,3.4	330	9	14.311	0.010	0.26	0.03	MB-O
1466	Mundleria	08/19-08/22	2.0,1.1	328	4	–	–	–	–	MB-I
1686	De Sitter	08/19-08/23	4.4,2.7	335	0	11.292	0.012	0.18	0.02	MB-O
2285	Ron Helin	08/23-09/07	*1.2,9.4	331	1	52.77	0.07	0.33	0.05	FLOR
2302	Florya	08/30-09/06	*5.4,5.9	339	9	16.557	0.024	0.08	0.03	EUN
3306	Byron	08/23-08/28	11.0,13.4	314	6	6.999	0.005	0.18	0.05	FLOR
5199	Dortmund	08/19-08/22	5.8,5.5	330	9	–	–	–	–	EUN
5391	Emmons	09/01-09/07	7.6,3.6	348	1	3.029	0.001	0.14	0.03	MB-I
7365	Sejong	08/30-09/06	*1.6,3.4	338	0	2.579	0.001	0.07	0.03	FLOR

Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, and marked with an asterisk if it reached a minimum between the two values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

with respect to a color term. In a departure from the method used for the past several years, comp star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *MPO Canopus*. The ATLAS catalog derives Sloan *griz* magnitudes using a number of available catalogs.

Comp star magnitudes had been previously derived from a combination of CMC15 (Muñoz et al., 2014), APASS DR9 (Munari et al., 2015), and GAIA2 G catalogues to set the zero-points each night. Magnitudes of the comps using the ATLAS catalog were spot checked against this previous method and typically showed an agreement within 0.010 mag.

This careful adjustment of the comp star magnitudes and color-indices allowed the separate nightly runs to be linked often with no zero-point offset required, or shifts of only a few hundredths of a magnitude in a series.

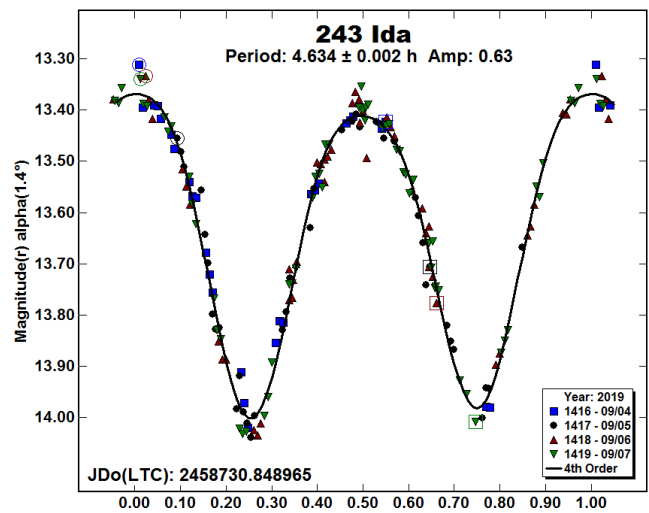
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comp stars, the asteroid itself, and the period-fit. Period determination was done using the *MPO Canopus* Fourier-type FALC fitting method (cf. Harris et al., 1989). Phased lightcurves show the maximum at phase zero. Magnitudes in these plots are apparent, and scaled by *MPO Canopus* to the first night.

Most asteroids were selected from the CALL website (Warner, 2011) using the criteria of magnitude $V < 15.0$ and quality of results, U , less than 2+. In this set of observations, three of the ten asteroids had no previous period analysis and two had $U = 1$.

The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. All the new data for these asteroids can be found in the ALCDEF database.

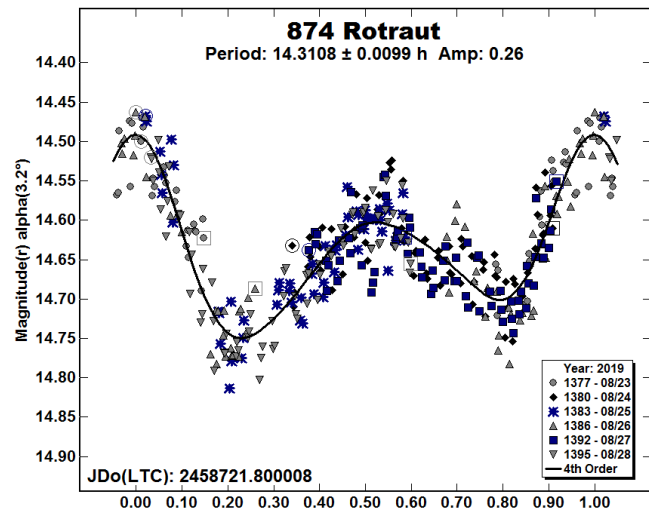
243 Ida is a Koronis-family asteroid in the outer regions of the main-belt. It was discovered by Johann Palisa at Vienna in 1884. Being low-numbered and bright, its rotation period is already well characterized. It was included in this batch only because of its serendipitous presence in the same field as 7365 Sejong for three observing nights. Various sources put the synodic period near 4.634 h, most recently Hanus (2013a), who show a sidereal period of 4.633632 ± 0.000005 h.

Over the course of four observing nights, 177 images were sufficient to obtain a synodic period of 4.634 ± 0.002 h. The amplitude is 0.63 mag and the RMS scatter on the fit shown in the phased plot is 0.027 mag.



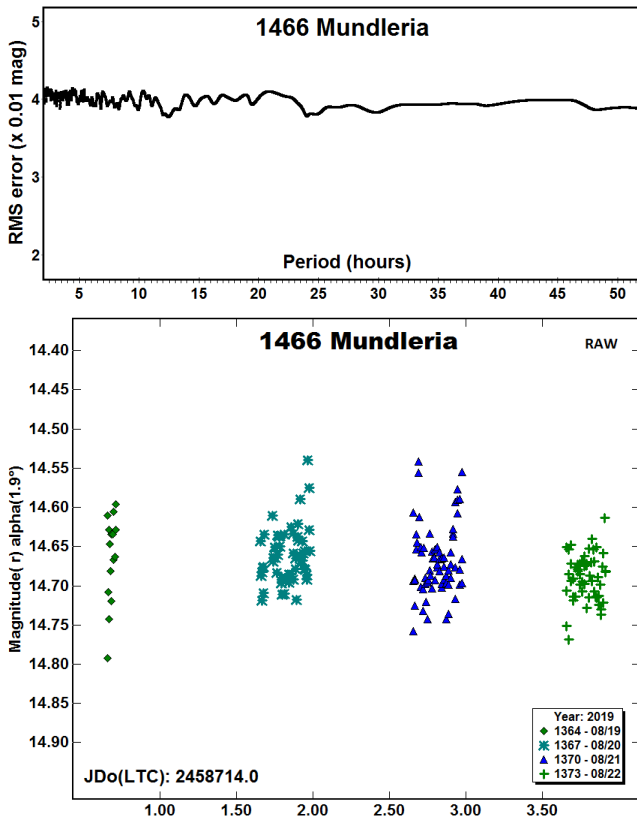
874 Rotraut. This asteroid was discovered at Heidelberg by Max Wolf in 1917. Several similar periods appear in the LCDB. Hanus (2013b) found a period of 14.3007 ± 0.002 h, Ditteon (2018) obtained 14.297 ± 0.006 h, and Polakis (2018) found 14.297 ± 0.009 h.

A total of 379 images were taken during six nights, producing a period of 14.311 ± 0.010 h, in agreement with previous determinations. The lightcurve amplitude is 0.26 mag with an RMS scatter of 0.034 mag.



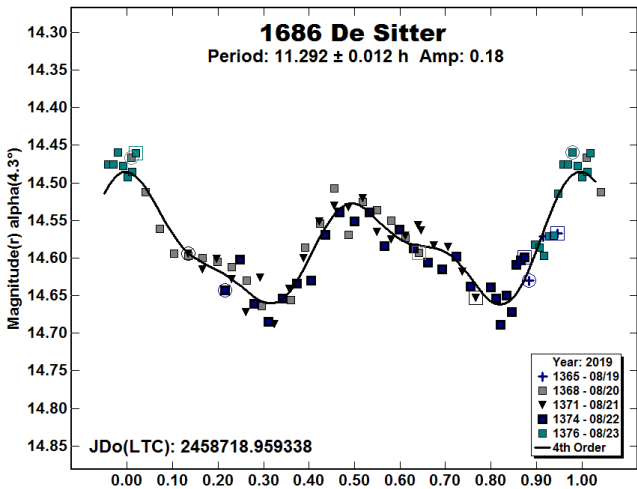
1466 Mundleria. Karl Reinmuth discovered this minor planet from Heidelberg in 1938. No period solutions appear in the LCDB.

During four nights, 193 images were taken, which was sufficient to conclude that a period solution would not become available. The period spectrum showed no significant minima. Raw data from the four nights are presented.



1686 De Sitter was discovered in 1935 by Hendrik Van Gent in Johannesburg. No period solutions appear in the LCDB.

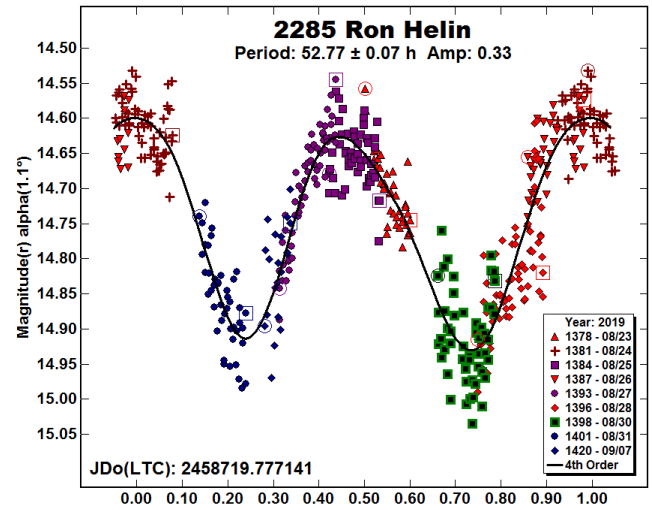
A total of 241 images were taken during five nights. The fit was improved by binning sets of three points, which produced a period solution of 11.292 ± 0.012 h. The amplitude of the phased lightcurve is 0.18 mag, with an RMS error on the fit of 0.021 mag.



2285 Ron Helin was discovered by Schelte Bus at Palomar in 1976; it is named after the husband of prolific asteroid discoverer Elanor Helin. *The only period published in the LCDB is that of Behrend (2009), who gives >12 h.*

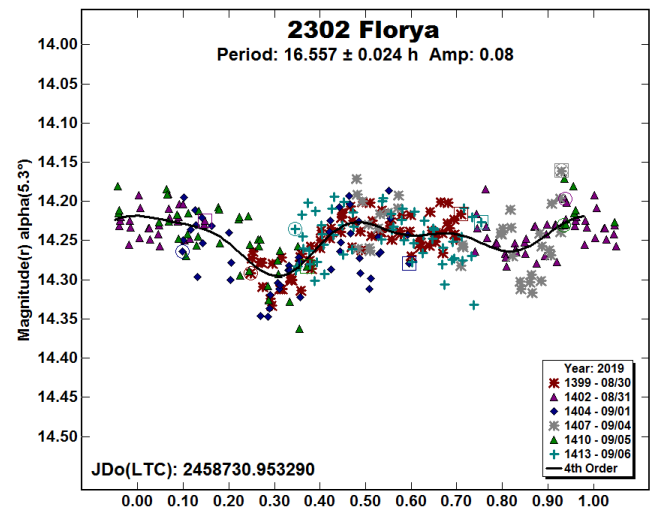
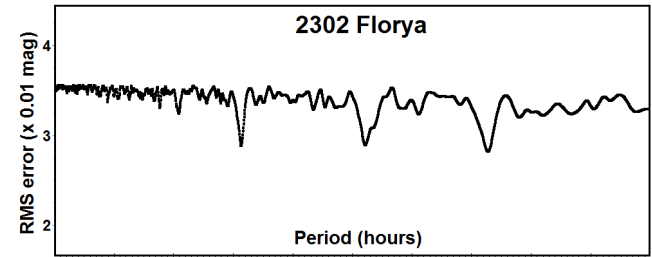
During nine nights around its perihelic opposition, 446 data points were acquired, producing a period solution of 52.77 ± 0.07 h. The RMS scatter on the fit is 0.046 mag. The amplitude is 0.33 mag.

The asteroid will be 2.6 magnitudes fainter during its next opposition in 2021.



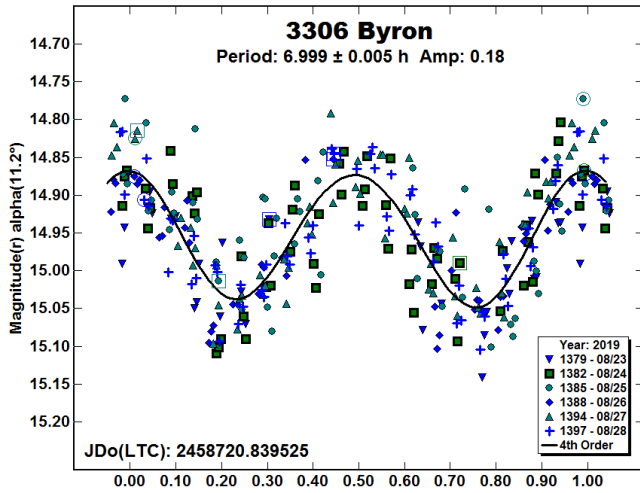
2302 Florya. This Eunomia-family minor planet was discovered at Nauchnyj by N.E. Kurochkin in 1972. Behrend (2006) computed a period >12 h.

A total of 306 images were taken during six nights. The period spectrum has a minimum coinciding with a bimodal solution of 16.557 ± 0.024 h. Due to its small amplitude of 0.08 mag., the RMS error of the Fourier fit is significant (0.028 mag).



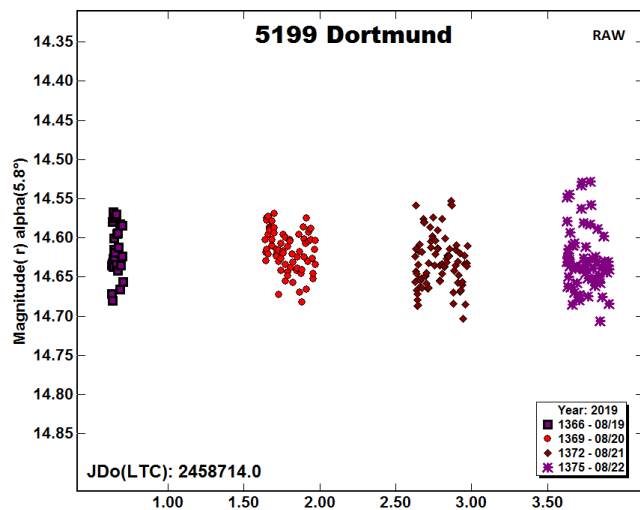
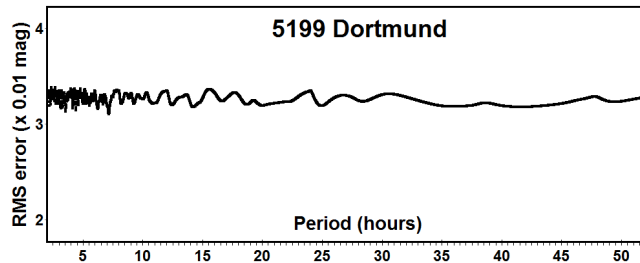
3306 Byron was discovered at Nauchnyj by Nikolai Chernykh in 1979. Two rotation periods appear in the LCDB. Moravec (2013) computed 7.321 ± 0.005 h and Behrend (2019) found 7.013 ± 0.004 h.

During six nights in 2019 August, 294 data points were collected. The rotation period is 6.999 ± 0.005 h, agreeing closely with Behrend's determination. The lightcurve shows an amplitude of 0.18 mag with an RMS error on the fit of 0.049 mag.

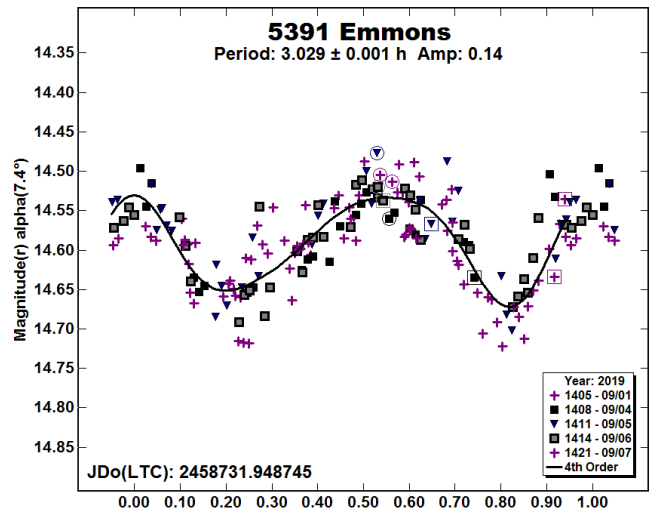


5199 Dortmund was discovered in 1972, also by N.E. Kurochkin at Nauchnyj. No rotation periods appear in the LCDB.

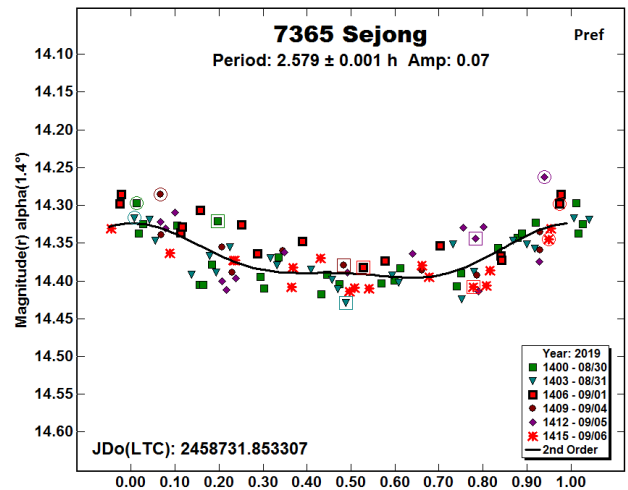
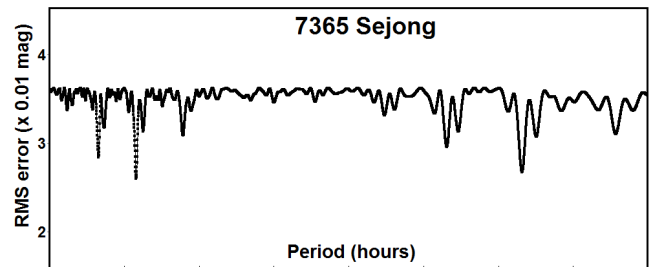
During four nights in 2019 August, 242 images were taken. The period spectrum showed no significant troughs, and the raw lightcurve exhibits no long-term trend. Therefore, a period could not be determined. The next opposition in 2020 will be aphelic, at which time the minor planet will be 1.6 magnitudes fainter.



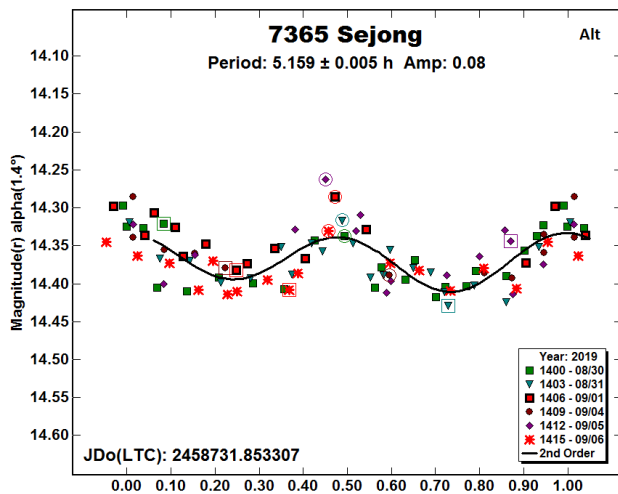
During five nights near the perihelic opposition of 2019 September, 189 images were sufficient to obtain a good period solution of 3.029 ± 0.001 h, agreeing with Clark. The lightcurve amplitude is 0.14 mag, and the RMS error of the curve fit is 0.033 mag.



7365 Sejong. Kazuro Watanabe discovered this Flora-family asteroid in 1996 at Sapporo. Pravec (2019) shows a period of 2.5802 ± 0.0002 h.



5391 Emmons. Elanor Helin discovered this inner main-belt asteroid at Palomar in 1985. The only period in the LCDB is that of Clark (2003), who published 3.028 ± 0.004 h.



During six nights, 269 data points were acquired. The amplitude of the phased lightcurve is small, so binning sets of three points improved the RMS error of the fit. Whereas 4th-order fits are appropriate elsewhere, 2nd-order fits were more appropriate due to the high scatter associated with these points. The derived monomodal period is 2.579 ± 0.001 h, agreeing with Pravec's assessment. However, the bimodal period of 5.159 ± 0.005 h cannot be ruled out. The RMS error for the monomodal fit is 0.026 mag, which is significant relative to the amplitude of 0.07 mag. Due to its highly eccentric orbit, 7365 Sejong will be 2.7 magnitudes fainter during its 2021 opposition.

Acknowledgments

The author would like to express his gratitude to Brian Skiff for his indispensable mentoring in data acquisition and reduction. Thanks also go out to Brian Warner for support of his *MPO Canopus* software package.

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PHOTOMETRIC OBSERVATIONS OF 2096 VAINO AND 5104 SKRIPNICHENKO

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(Received: 2019 September 19)

Photometric observations of 2096 Vaino and 5104 Skripnichenko were obtained on two nights, 2019 July 3 and 29. The following rotational periods were determined: 2096 Vaino, 5.55 ± 0.01 h, amplitude 0.10 ± 0.02 ; 5104 Skripnichenko, 2.84 ± 0.01 h, amplitude 0.22 ± 0.02 .

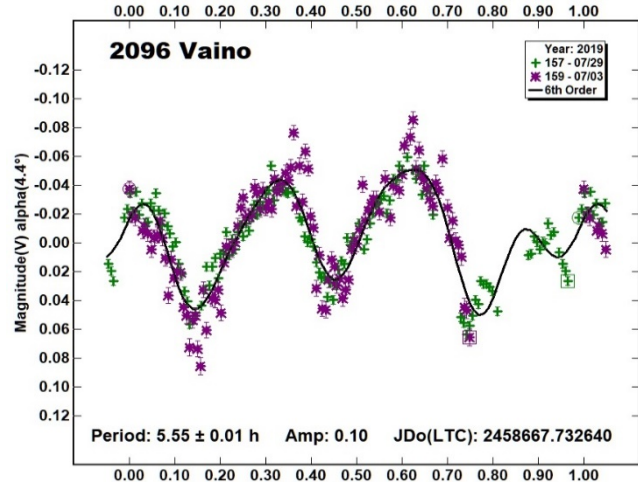
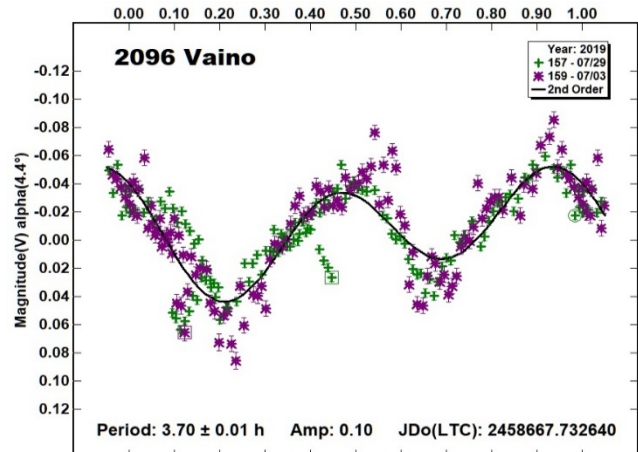
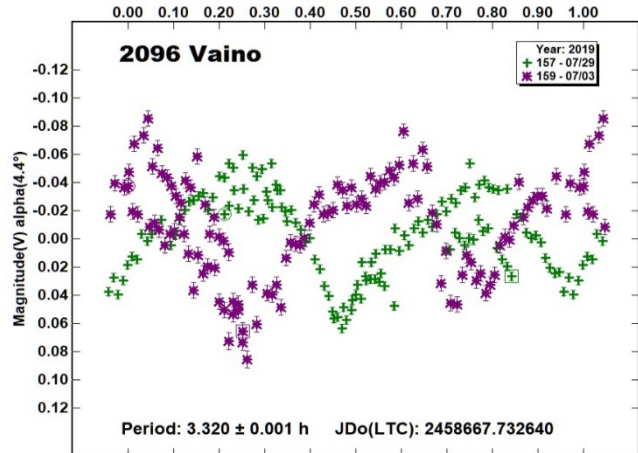
Photometric observations obtained with the 0.6-m telescope of the Southeastern Association for Research in Astronomy (SARA) consortium at Cerro Tololo Inter-American Observatory are reported. The telescope is coupled with an Andor iKon-L series CCD. A detailed description of the instrumentation and setup can be found in the paper by Keel et al. (2017). The data were calibrated using *MaximDL* and photometric analysis was performed using *MPO Canopus* (Warner, 2017). Four additional nights in July and September fell victim to poor weather conditions and technical issues.

2096 Vaino was previously observed in 2010 by Polishook et al. (2012) and Waszczak et al. (2015). These observations were made on consecutive days and there is partial overlap in the list of co-authors on the two papers. Unfortunately, we were unable to retrieve a copy of the paper by Polishook et al. (2012), but since the results by Waszczak et al. (2015) are based on sparse data, we assume the same for this paper.

Polishook et al. derived a period of 3.32 ± 0.07 h with an amplitude of 0.06 ± 0.01 mag. Waszczak et al. derived a period of 3.324 ± 0.0012 h with an amplitude of 0.1 mag. Whereas the periods are in good agreement, there appears to be a bigger disagreement in the amplitude; again, both sets of data are from consecutive days. As can be seen in the plot below, our data are not able to reproduce a period of 3.32 h. Instead, the best fit for a bimodal distribution appears to be 3.70 ± 0.01 h with an amplitude of 0.10 ± 0.02 mag.

We observed the asteroid for approximately 4 and 5.5 hours on the two nights, thereby covering more than one complete rotation on each night. A look at the individual nights seems to indicate a less than perfect overlap of the data. Therefore, we decided to look for possible solutions that are more complex. Indeed, a solution with

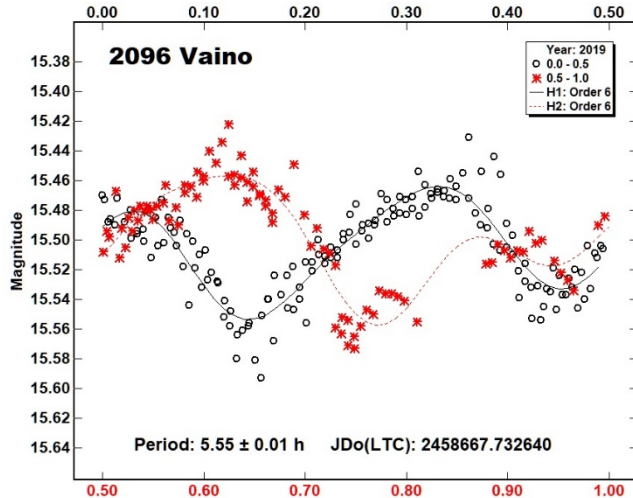
four maxima and a period of 5.55 ± 0.01 h appears to be a much better fit to the data. However, since this value is close to the time we observed each night, extra care needs to be taken to ensure that this is not simply an artifact.



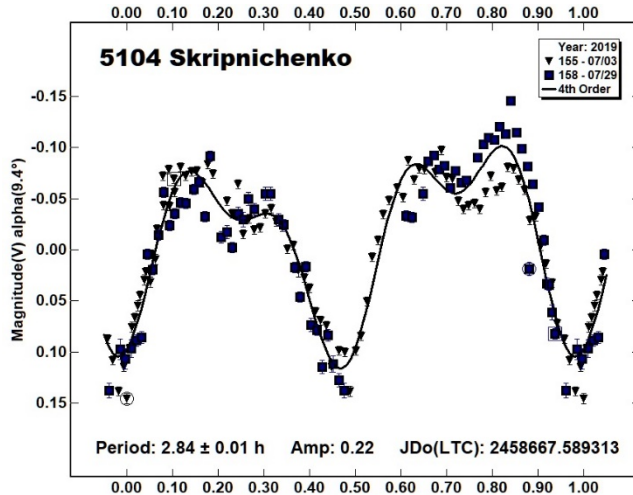
Number	Name	2019 mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2096	Vaino	07/03-07/29	17.8, 4.5	310	0	5.55	0.01	0.10	0.02	MB-I
5104	Skripnichenko	07/03-07/29	9.3, 13.8	281	19	2.84	0.01	0.22	0.02	EUN

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

Looking at the split-halves plot, it appears obvious that the two halves of the plot are not identical and that indeed a solution with four maxima appears to be preferred. Therefore, we suggest a new period of 5.55 ± 0.01 h for 2096 Vaino. Additional nights in July and early September, when the asteroid was still well placed for observations, unfortunately fell victim to either bad weather or equipment failure.



5104 Skripnichenko is a member of the Eunomia family of asteroids. It was selected from the Shape Modelling Target list published in the *Minor Planet Bulletin* (Warner et al., 2019). The asteroid was observed over two nights for a approximately 3 h and 4 h, respectively. The derived period of 2.84 ± 0.01 h with an amplitude of 0.22 mag in excellent agreement with prior measurements (Behrend, 2006, 2011, 2014). We will submit our data to the Database of Asteroid Models from Inversion Techniques (DAMIT) (Durech et al., 2010) web site and hopefully contribute to a viable shape model of 5104 Skripnichenko.



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ROTATIONAL PERIOD DETERMINATION OF TWO MAIN BELT ASTEROID: 4807 NOBORU AND 1435 GARLENA

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(Received: 2019 September 19)

The main-belt asteroids 4807 Noboru and 1435 Garlena have been observed over several nights throughout December 2018 to February 2019 in order to determine their synodic rotational periods.

The observations of the analyzed asteroids were carried out from F. Fuligni Observatory using a 0.35-m f/10 ACF telescope and SBIG ST8-XE CCD camera with Clear filter and from Franceschini's equipment using a 9.25" f/6.3 reflector telescope equipped with Atik 314L- CCD camera with Clear filter. All images were dark and flat-field calibrated with *Maxim DL*. Differential photometry and period analysis performed using *MPO Canopus* (Warner, 2012).

4807 Noboru. This inner main-belt asteroid (discovered on January 10, 1991 by T. Kobayashi) has taken the name of Noboru Yamada (1950-1989), one of the greatest Japanese climbers. Its orbit ranges between 1.83 to 2.82 AU from the Sun. Our measurements have been taken from 18 December since 11 of January (4 sessions in total). The observations carried out from "F. Fuligni" Observatory and from Franceschini personal equipment, allowed to derive the synodic period of $P = 4.00 \pm 0.01$ h with an amplitude of $A = 0.18$ mag (Figure 1).

1435 Garlena. This asteroid, observed during the period 06-22 of February in 4 sessions, is another main-belt asteroid discovered on November 23, 1936 by K. Reinmuth at Heidelberg Observatory and named in honor of an acquaintance of the German astronomer W. Schaub. Our observations show a synodic period of $P = 5.75 \pm 0.01$ h with an amplitude of $A = 0.62$ mag (Figure 2).

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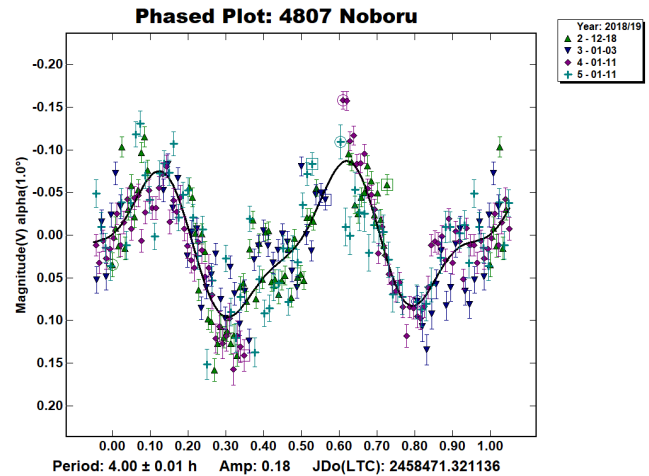


Figure 1. Lightcurve of 4807 Noboru. Period $P = 4.00 \pm 0.01$ h with an amplitude $A = 0.18$ mag.

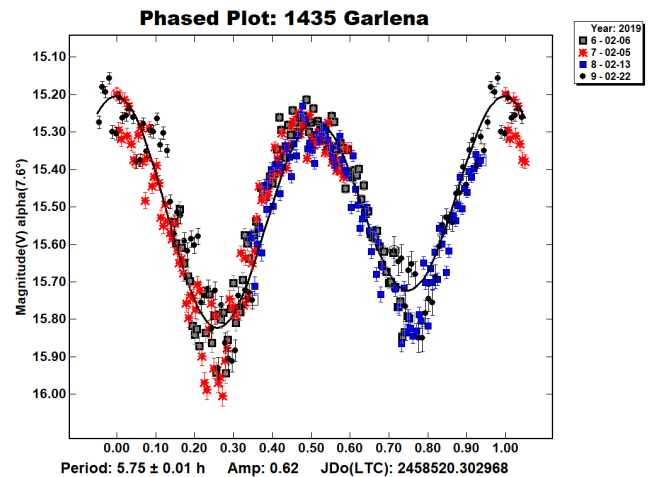


Figure 2. The lightcurve of 1435 Garlena. The period found is $P = 5.75 \pm 0.01$ h with an amplitude of $A = 0.62$ mag.

Number	Name	2018-19 mm/dd		Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4807	Noboru	2018	12/18-01/11	366	1.6,13.5	89	0.6	4.00	0.01	0.18	0.1	MB-I
1435	Garlena	2019	02/06-02/22	363	7.0,12.1	127	-4.83	5.75	0.01	0.62	0.1	MB_M

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). Grp is the asteroid family/group (Warner *et al.*, 2009). MB-M = Main Belt-Middle, MB-I = Inner Main Belt.

TRAPPIST-NORTH AND -SOUTH COMBINED LIGHTCURVES OF NEAR-EARTH ASTEROID 3122 FLORENCE

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(Received: 2019 September 28)

A long lightcurve of the near-Earth asteroid 3122 Florence was obtained by combining observations from the TRAPPIST-South (TS) and TRAPPIST-North (TN) telescopes during the night of 2017 September 3. We found its synodic rotation period and amplitude to be 2.352 ± 0.005 h and 0.19 mag. All the data have been submitted to the ALCDEF database.

Observations of the near-Earth asteroid (NEA) 3122 Florence (hereafter Florence) were obtained with the robotic telescopes TRAPPIST-North (TN, Z53) and TRAPPIST-South (TS, I40) of the Liège University (Jehin et al., 2011). They are located, respectively, at the Oukaïmeden Observatory in Morocco and the ESO La Silla Observatory in Chile. Both are 0.6-m Ritchey-Chrétien telescopes operating at f/8 on German Equatorial mounts. At TN the camera is an Andor IKONL BEX2 DD (0.60 arcsec/pixel) and at TS it is a FLI ProLine 3041-BB (0.64 arcsec/pixel).

The raw images were calibrated with *IRAF* scripts using corresponding flat fields, bias and dark frames. The photometry was derived using the *Photometry Pipeline* developed by Mommert (2017). This pipeline allows photometric zero point calibration by matching field stars with catalogs. The PanSTARRS DR1 catalog was used and about 100 stars with solar colors were matched for each image. The aperture was 14 pixels in diameter (8.6 arcsec at TN and 9.0 arcsec at TS). The rotation period was determined with the software *Peranso* (Vanmunster, 2018), which implements the FALC algorithm (Harris et al., 1989). The reported amplitude is from the Fourier model curve.

3122 Florence is the 5th largest known potentially hazardous asteroid with a diameter of 4.40 ± 0.03 km (Mainzer et al., 2011) and a trinary system. Its flyby of the Earth on 2017 September, with a closest approach at 0.047 au, was a good opportunity for an observational campaign. Here we report on the advantages of combining both the TRAPPIST-North and -South telescopes to obtain longer continuous observation of the same target during a given night with Florence as an example. Thanks to their location, in Morocco for TN (latitude = 31.2° N, longitude = -7.9° W) and

in Chile for TS (latitude = -29.3° S, longitude = -70.7° W), it is possible to observe first with TN and then with TS targets with a declination between about $+30^\circ$ and -30° . For targets near the equator, observations can span on up to ~ 13 h. It is especially useful for NEAs, for which it is important to gather as much data as possible in a short amount of time. It also helps for period determination as longer observations reduces the number of possible aliases.

We observed Florence during 6.6 h with TN from 21h20 UT to 3h UT and 2.8 h with TS from 1h to 4h UT through the V filter, resulting in a lightcurve spanning on 7.7 h with 1.7 h of overlap (Figure 1).

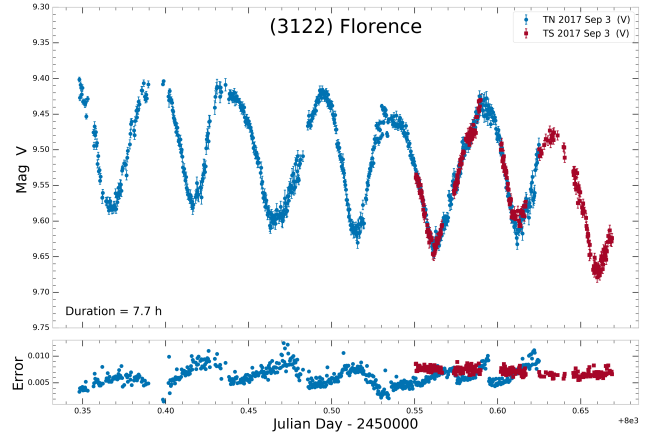


Figure 1. The non-phased lightcurve.

The period best fitting our data is 2.352 h, in agreement with values in the asteroid lightcurve database (LCDB; Warner et al., 2009). The second rotation period of ~ 10.3 h (Warner, 2016; Sonka et al., 2018) was not detected here as it requires multiple nights of observations. After correcting for the effects of changing geocentric distances and solar phase angle, the lightcurves were phased using our determined rotation period (Figure 2).

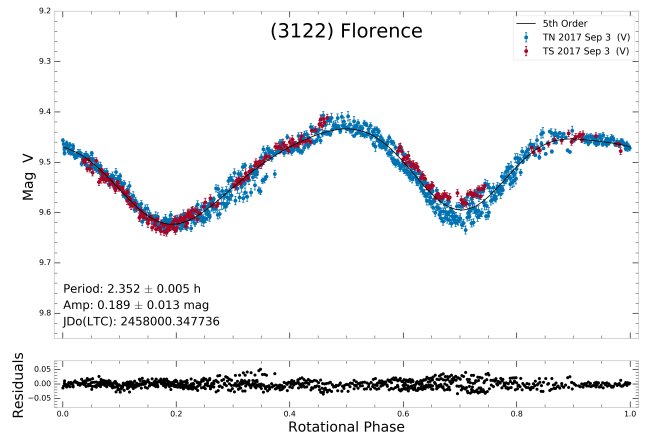


Figure 2. The phased lightcurve after de-trending.

Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.
3122	Florence	09/03	927	43.7	331	22	2.352	0.005	0.19	0.01

Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

It was also possible to illustrate the parallax effect by using images taken at the same time from the two observatories (Figure 3). From the angular separation, we could determine the distance of Florence to the Earth on 2017 Sep 4 at 1h20 UT. We obtained $d = 0.050 \pm 0.002$ au while the distance from the JPL Horizons ephemerids was 0.051 au.

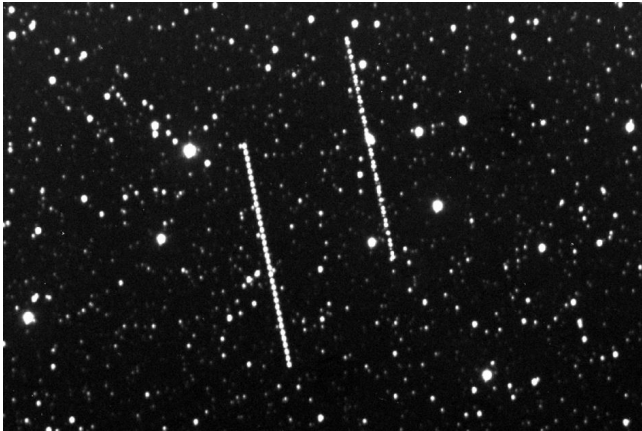


Figure 3. Images of Florence with TN and TS on 2017 Sep 3 taken at the same time (between 1h12 and 1h30 UT) and stacked together. Florence is seen as two separated trails of points for TN (left) and TS (right) because of the parallax effect.

Acknowledgements

TRAPPIST-South is a project funded by the Belgian Fonds (National) de la Recherche Scientifique (F.R.S.-FNRS) under grant FRFC 2.5.594.09.F. TRAPPIST-North is a project funded by the University of Liège, in collaboration with the Cadi Ayyad University of Marrakech (Morocco). Y. Moulane acknowledges the support of Erasmus+ International Credit Mobility. E. Jehin is FNRS Senior Research Associate. The website of the TRAPPIST project can be visited at <https://www.trappist.uliege.be>.

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**NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS
AT THE CENTER FOR SOLAR SYSTEM STUDIES:
2019 JULY-SEPTEMBER**

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(Received: 2019 October 13)

Lightcurves for 28 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2019 July to September were analyzed for rotation period, peak-to-peak amplitude, and signs of satellites or tumbling. 2059 Baboquivari, (90403) 2003 YE45, and 2016 AU130 are candidates for membership within the *very wide binary asteroids* class. The 2019 data led to a seemingly unambiguous period of 4.7906 h for (441987) 2010 NY65, which overturned previous results that have now been updated.

CCD photometric observations of 28 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2019 July to September. Table I lists the telescopes and CCD cameras that are combined to make observations.

Up to nine telescopes can be used for the campaign, although seven is more common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel.

Telescopes	Cameras
0.30-m f/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Proline 1001E
0.40-m f/10 Schmidt-Cass	SBIG STL-1001E
0.40-m f/10 Schmidt-Cass	
0.50-m f/8.1 Ritchey-Chrétien	

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

All lightcurve observations were unfiltered since a clear filter can cause a 0.1-0.3 mag 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*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Comp star magnitudes were taken from ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs, among others. The authors state that systematic errors are generally no larger than 0.005 mag, although they can reach 0.02 mag in small areas near the Galactic plane. BVRI magnitudes were derived by Warner using formulae from Kostov and Bonev (2017). The overall errors for the BVRI magnitudes, when combining those in the ATLAS catalog and the conversion formulae, are on the order of 0.04-0.05.

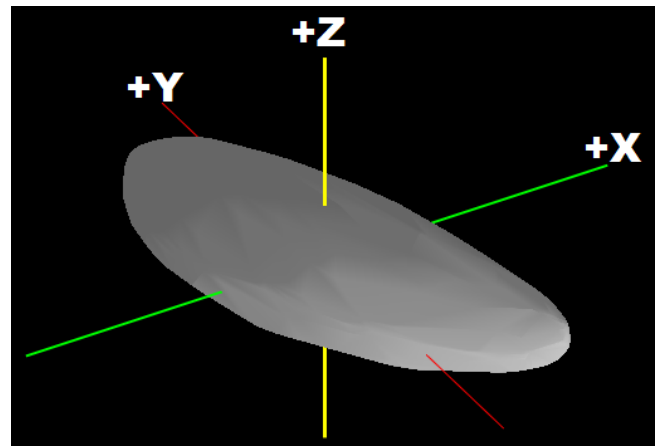
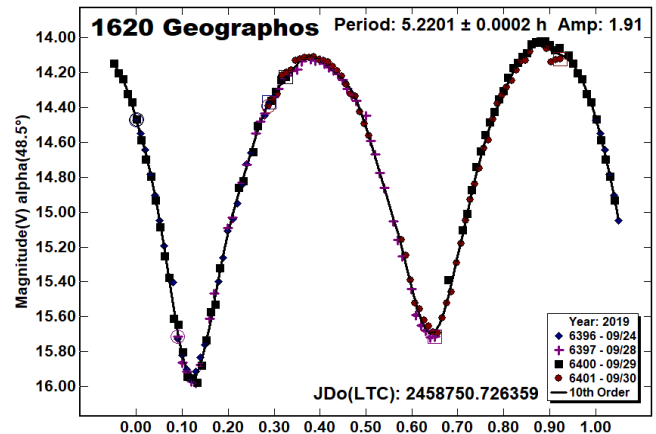
Even so, we found in most cases that nightly zero point adjustments of no more than 0.02-0.03 mag were required during period analysis. There were occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms. Regardless, the systematic errors seem to be considerably less than other catalogs, which reduces the uncertainty in the results when analysis involves data from extended periods or the asteroid is tumbling.

The Y-axis of lightcurves is labeled “Reduced Magnitude” or “Magnitude.” Unless otherwise indicated, the values are Johnson V. The latter are sky magnitudes while “Reduced Magnitude” are sky magnitudes corrected to unity distances by applying $-5 \cdot \log(r\Delta)$, 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 $G = 0.15$. The X-axis rotational phase ranges 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*.

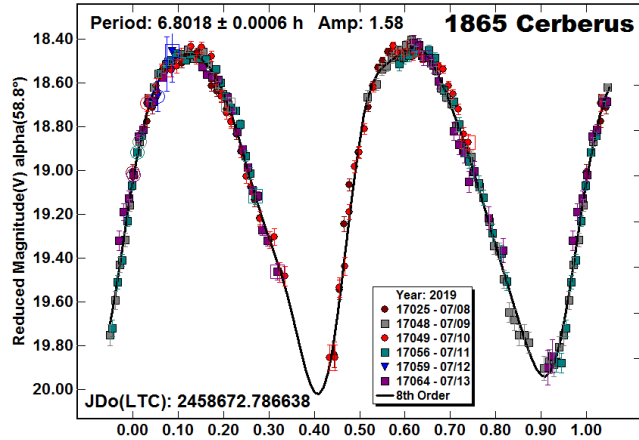
Our initial search for previous results started with the asteroid lightcurve database (LCDB; Warner *et al.*, 2009) found on-line at <http://www.minorplanet.info/lightcurvedatabase.html>. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB.

1620 Geographos. Numerous observations and subsequent data analysis have been carried out over the years for this 2-km NEA.



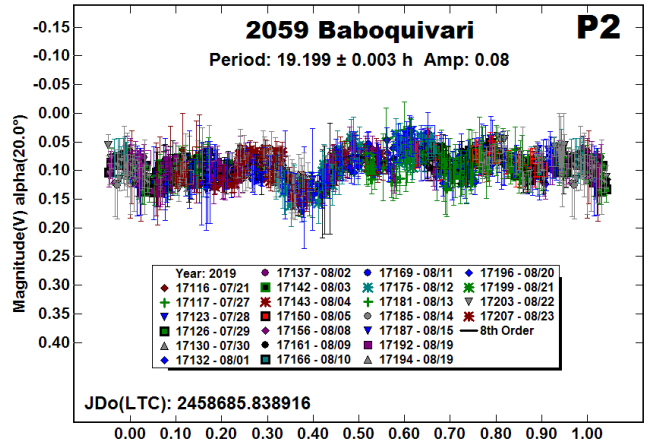
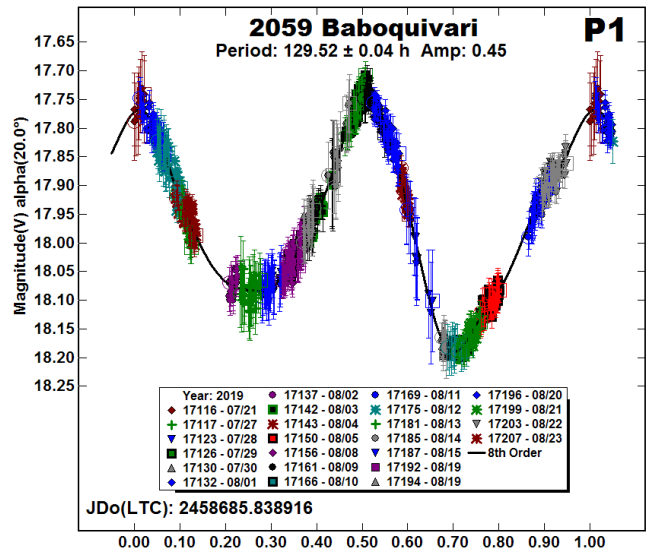
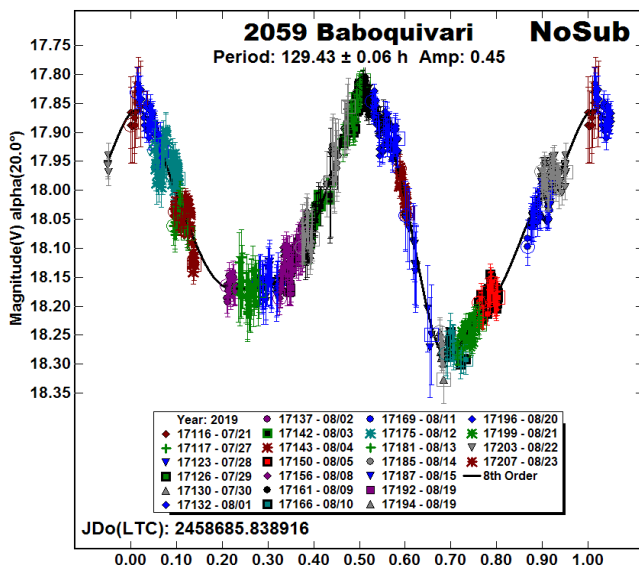
Durech et al. (2008) found that the YORP effect (Yarkovsky–O’Keefe–Radzievskii–Paddack; Rubincam, 2000) was causing the asteroid’s rotation period to increase. The model above used data from the DAMIT site Durech et al. (2010) imported into *MPO LCInvert*. From the model, it’s easy to see why the lightcurve amplitude is always large, 0.95-2.03 mag.

1865 Cerberus. Our result is in good agreement with numerous previous results, e.g., Skiff et al. (2012) and Warner and Stephens (2019a).



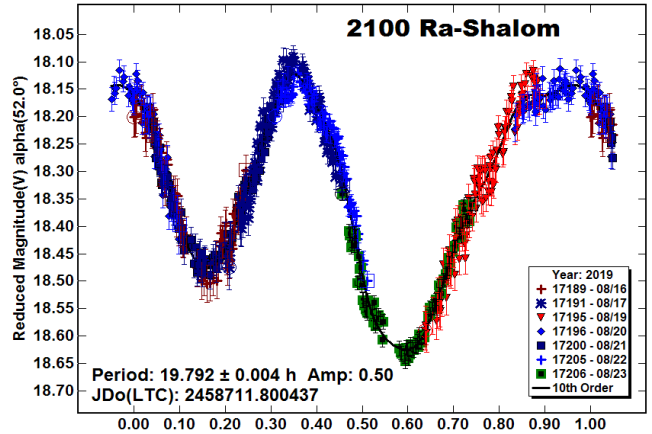
2059 Baboquivari. This 2-km NEA had no previous results listed in the LCDB. Our analysis found a basic period of 129.43 h. However, as seen in the “NoSub” plot, the fit to the Fourier curve showed some deviations. The long period and amplitude made this a possible member of the *very wide binary asteroids* class (see, e.g., Warner, 2016a) or a tumbler with a low amplitude component, and so we used *MPO Canopus* for a dual-period search.

This led to finding a second period (“P2”) of 19.199 h with a maximum amplitude of 0.08 mag. If the P2 lightcurve had a simple monomodal or bimodal shape, tumbling could not be formally excluded. However, there is an obvious deviation near 0.4 rotation phase and maybe one at 0.9. This is typical in a small binary asteroid as the satellite and primary undergo occultations/eclipses (*mutual events*).



If there was a third period that represented the independent rotation of a satellite, its lightcurve was buried in the noise after subtracting the two periods given here. We urge observers, especially in a coordinated campaign, to work this asteroid in the future.

2100 Ra-Shalom. This is another asteroid where the rotation rate was being affected by YORP (Durech et al., 2018). In this case, the effect is decreasing the period. Our result agrees with previous ones such as Harris et al. (1992; 19.79 h), Pravec et al. (1998; 19.797 h), and Shepard et al. (2008; 19.793 h).

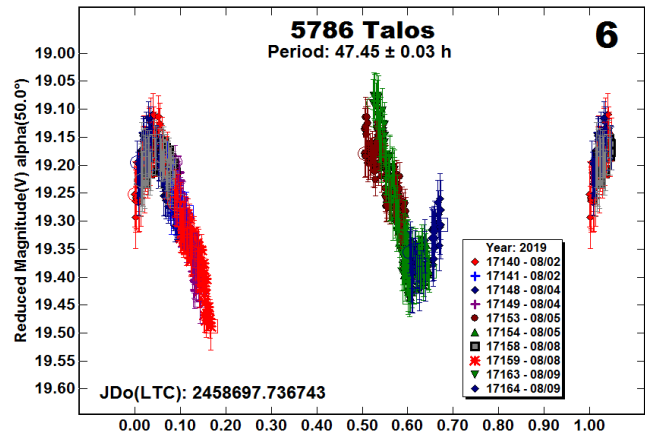
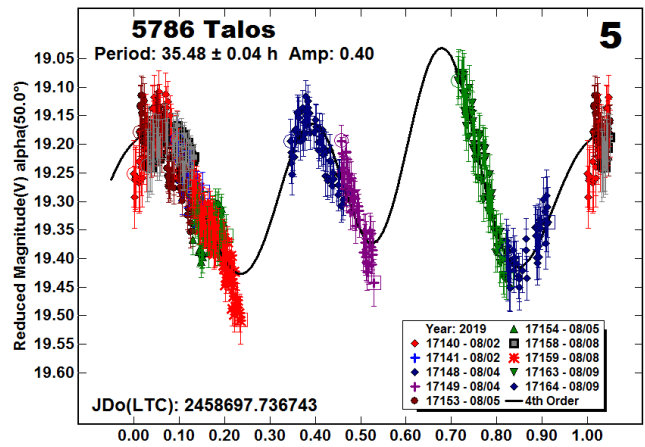
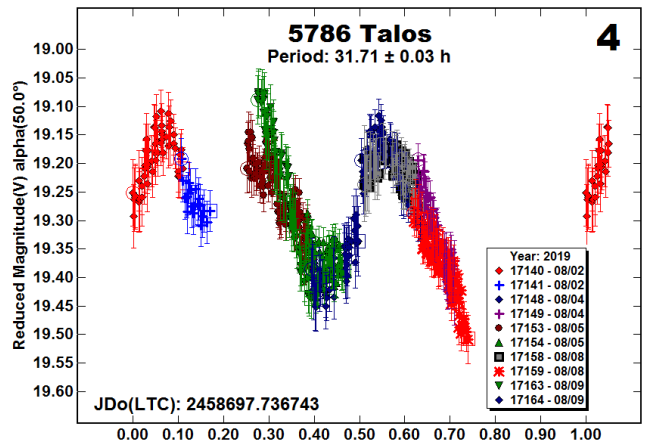
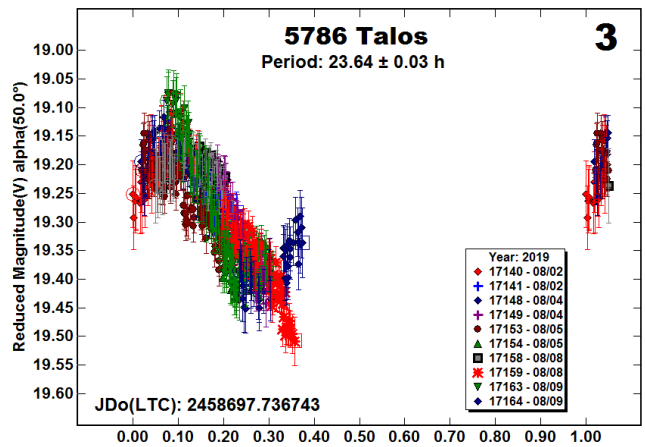
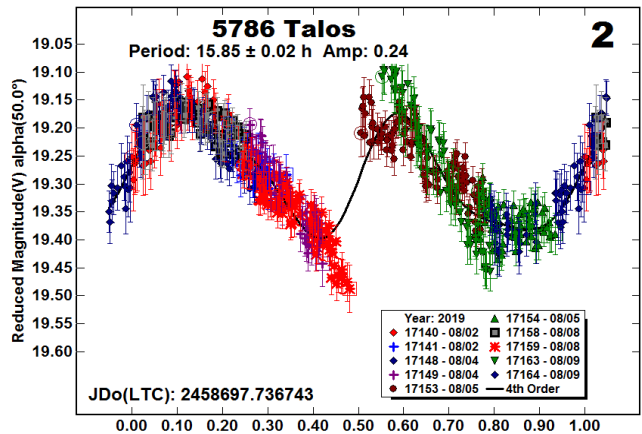
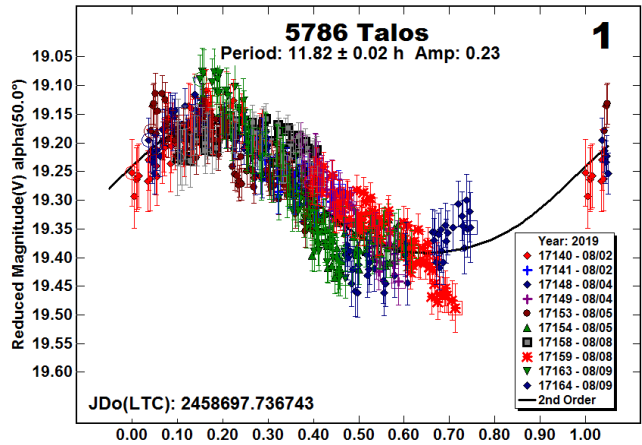
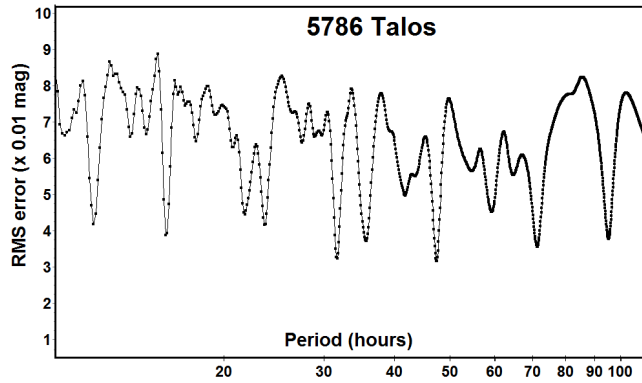


5786 Talos. Pravec et al. (2001) found a period of 38.52 h for the 900-m Talos. That was the only previous listing in the LCDB.

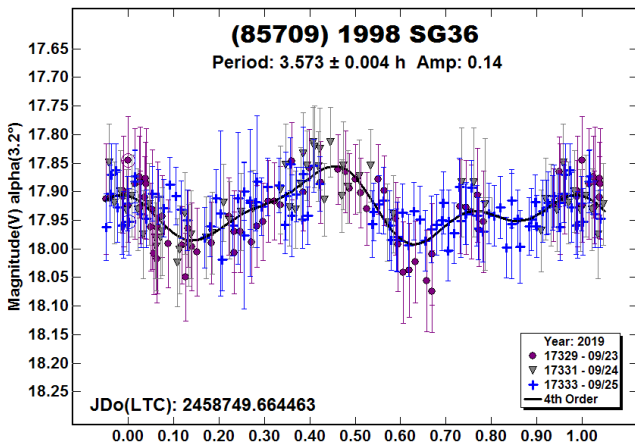
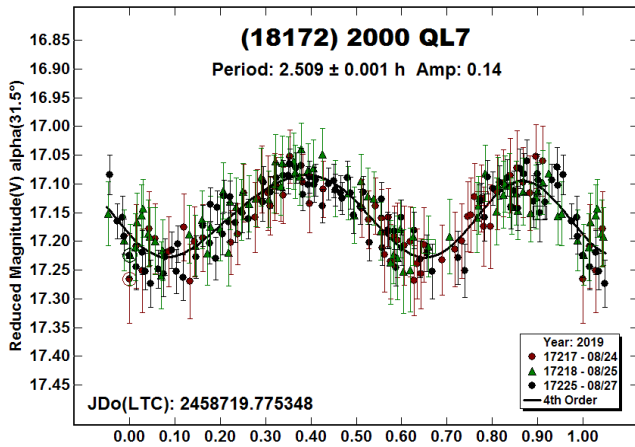
We observed it for a week in 2019 August and obtained 613 useable data points for analysis. The period spectrum showed several possibilities, the more prominent ones being close to commensurate with an Earth day. Lightcurves are shown for the several possible solutions. Each one has its own problems.

In the end, we adopted a period of 23.64 h based on a half-period of 11.8 h and double period of 47 h. However, we note that it's possible that the asteroid is tumbling (Pravec et al., 2014; 2005). This would explain why some sessions don't fit the Fourier model in each solution.

MPO Canopus does not handle tumbling asteroids very well and so our solutions may be the dominant periods of tumbling but they also be the sum or difference of the fundamental periods.

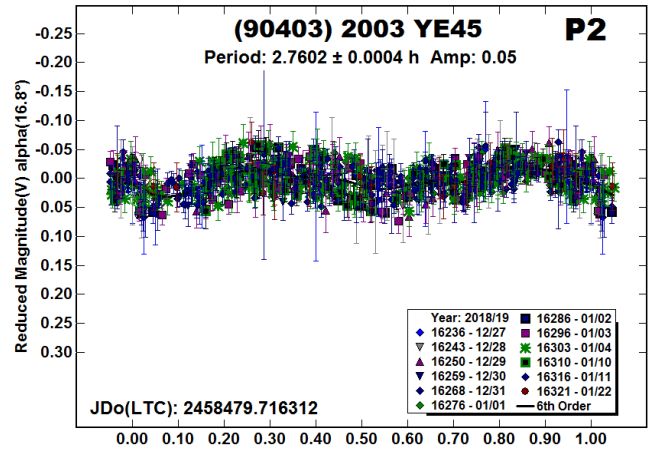
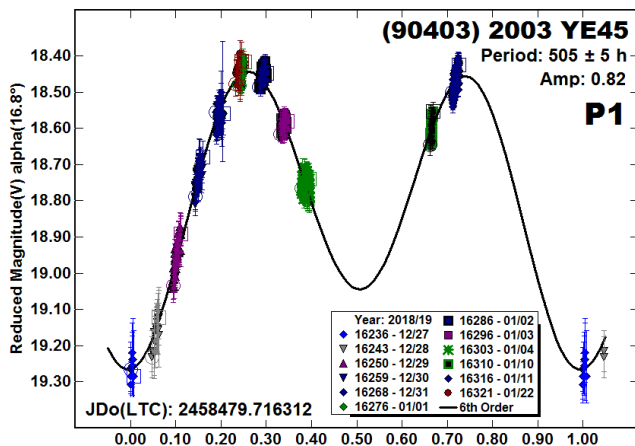


(18172) 2000 QL7, (85709) 1998 SG36. Ours appear to be the first reported lightcurve periods for these two asteroids. Both have a diameter of about 2 km.

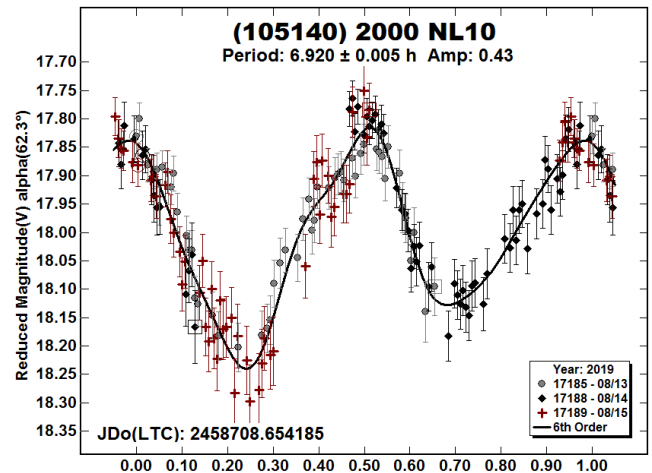


(90403) 2003 YE45. We first reported a solution of 500 h (Warner and Stephens, 2019b) and pointed out that it might be a tumbler because the slopes of some session didn't follow the Fourier model curve.

Even though *MPO Canopus* cannot handle tumbling asteroids, we took another look at the data with a dual-period search. This led to finding a weak asymmetric bimodal lightcurve with a period of 2.76 h. Whether or not this is tied to a fundamental period of tumbling or just "garbage collection" by the Fourier algorithm is not clear. Either way, the asteroid is still likely a tumbler.

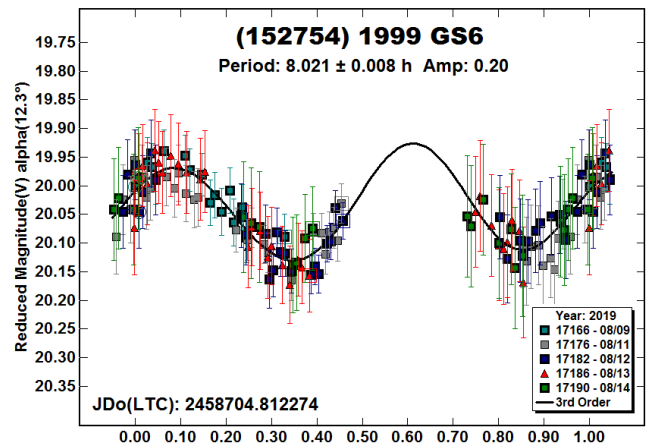


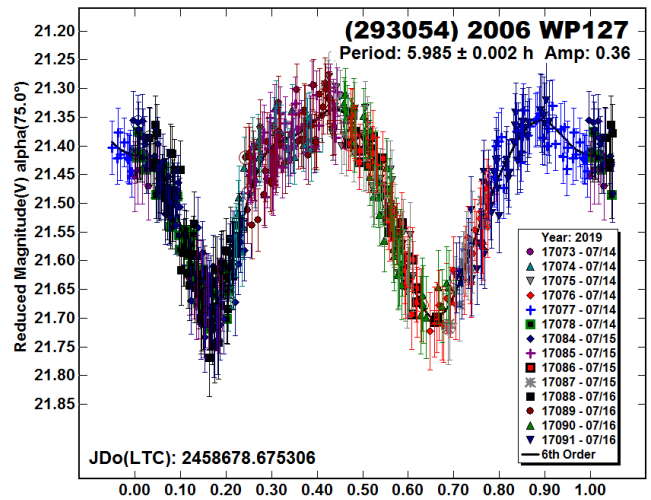
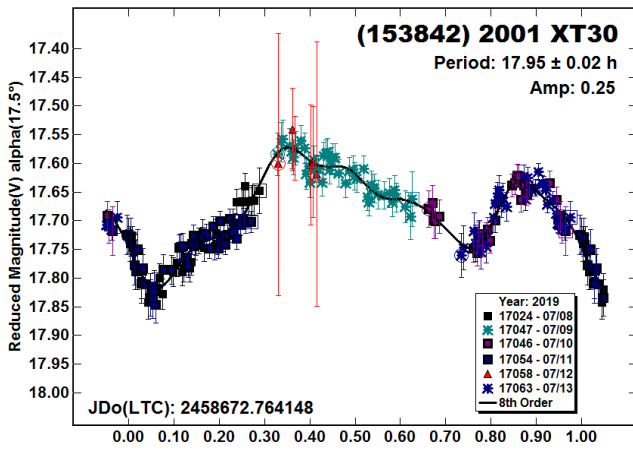
(105140) 2000 NL10. Pravec et al. (2002) first reported a period of 6.927 h. This was followed with 6.9269 h by Polishook (2012). Our result is in good keeping with theirs.



(152754) 1999 GS6, (153842) 2001 XT30. These are both new rotation period entries into the LCDB. Our solution of 8.021 h for 1999 GS6 is based on finding a good fit to its half-period. Even so, the large gap allows only U = 2 in the LCDB.

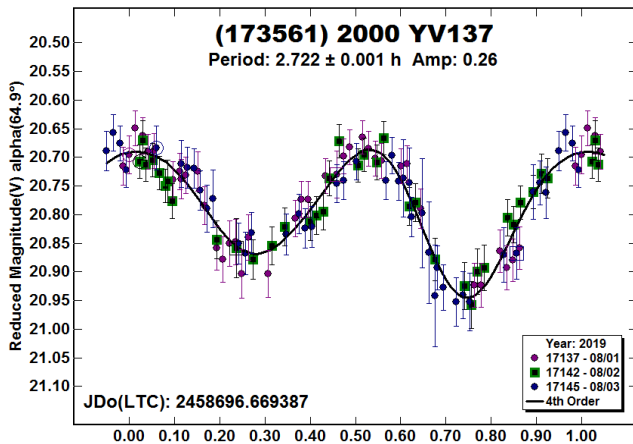
The unusual shape of the lightcurve and lack of double coverage of all segments for 2001 XT30 puts some doubt in our period of 17.95 h. No other solution provided a plausible fit to the data.



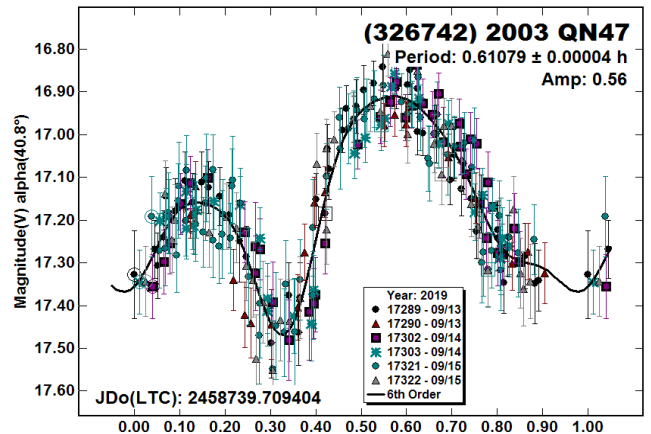
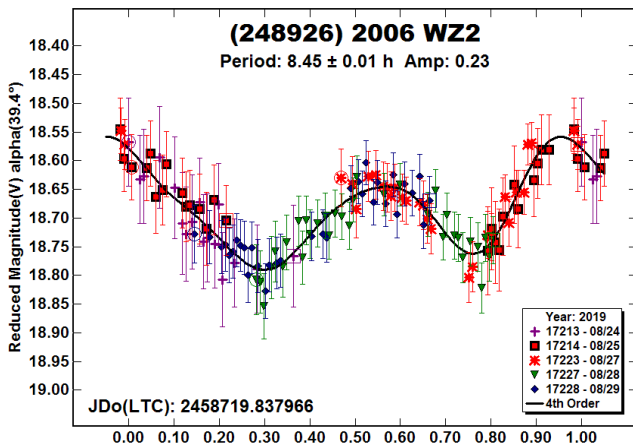


(173561) 2000 YV137, (248926) 2006 WZ2. There were no previous rotation period listings in the LCDB for either of these NEAs. The estimated diameter of 2000 YV137 is only 680 m but 2006 WZ2 is almost double that at 1300 m.

(326742) 2003 QN47, (354030) 2001 RB18, (405212) 2003 QC1, (429733) 2011 LX10. There were no rotation periods given in the LCDB for these four asteroids. The estimated diameters are, respectively, 750 m, 600 m, 750 m, and 1500 m.

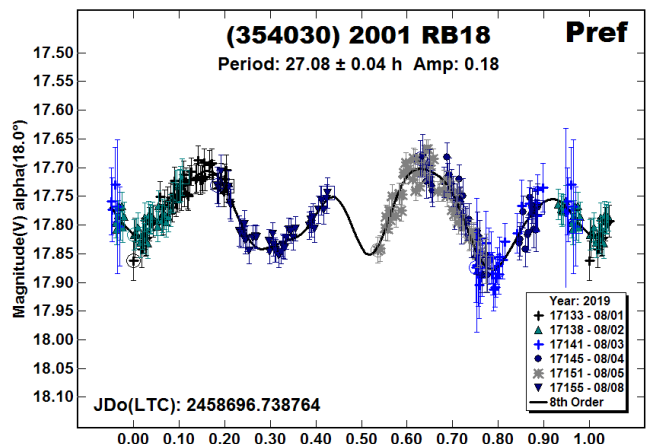


2003 QN47 is a super-fast rotator with a period of about 36.6 minutes. The unusual shape may be due in part to shadowing effects at the large phase angle. The period is a bit unexpected given the size. Of all entries rated $U \geq 2-$ in the LCDB, only 14 have $0.2 < D < 1.0$ km and $0 < P < 1.0$ h.



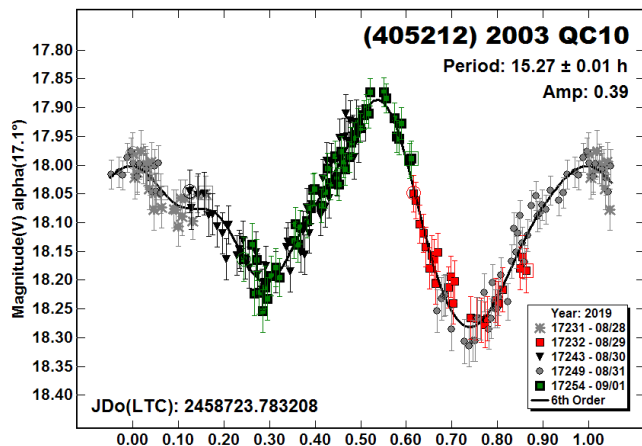
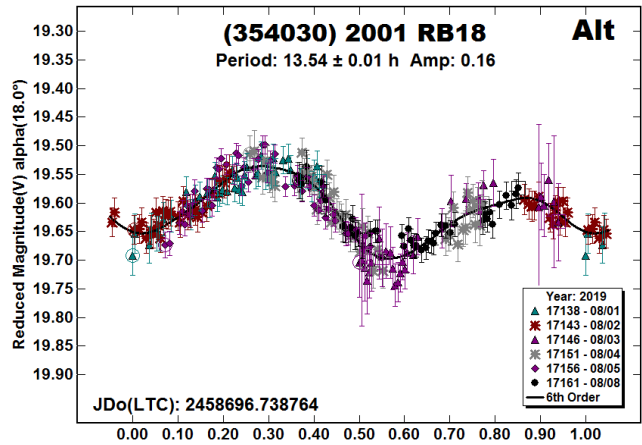
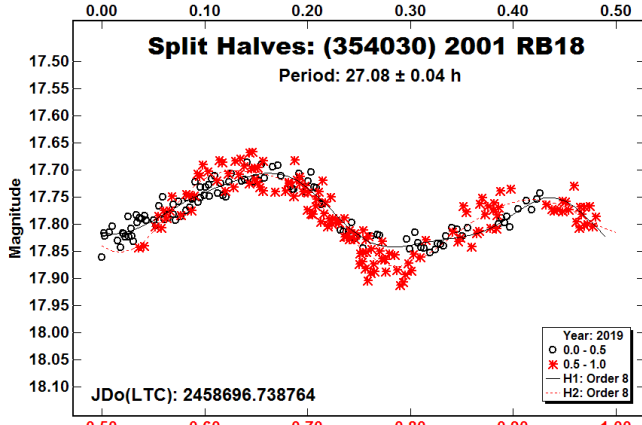
Initial analysis indicated a period of about 13.5 h for 2001 RB18, but the period spectrum showed a nearly as strong solution at 27 h.

(293054) 2006 WP127. Behrend (2015) reported a period of 12 h for this 650-m asteroid. However, it's rated only $U = 1$ (probably wrong) in the LCDB.

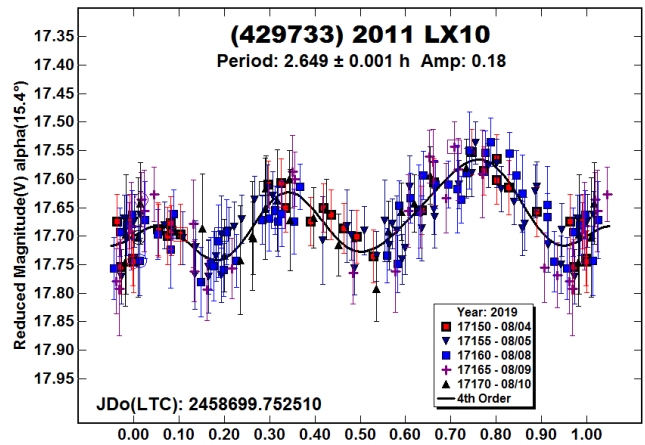


We observed it on three nights in 2019 July when the phase angle was $\sim 75^\circ$. This can be problematic because of deep shadowing effects on the lightcurve. More so, the period is very close to one-quarter of an Earth day. Even so, we believe our solution to be secure.

While writing this paper, Pravec et al. (2019) reported that observations by Don Pray indicated that the longer period was preferred. Pravec's period was 26.755 h. The difference is probably due to the longer date range for the Pravec data set. The CS3 data were reanalyzed and the split-halves plot seemed to indicate that the longer period should be preferred. However, our solution of 13.54 h cannot be formally excluded and so our result is considered ambiguous.



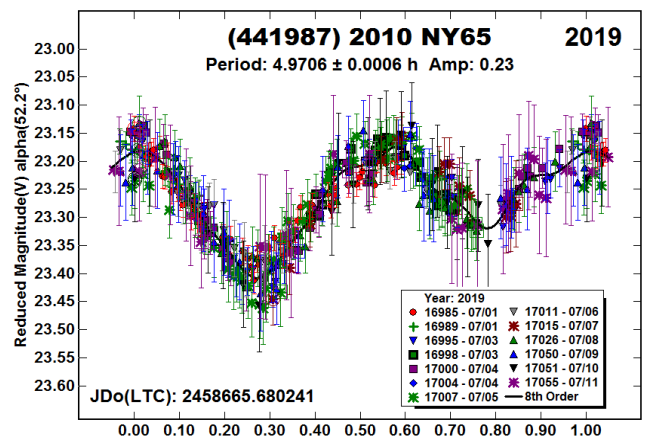
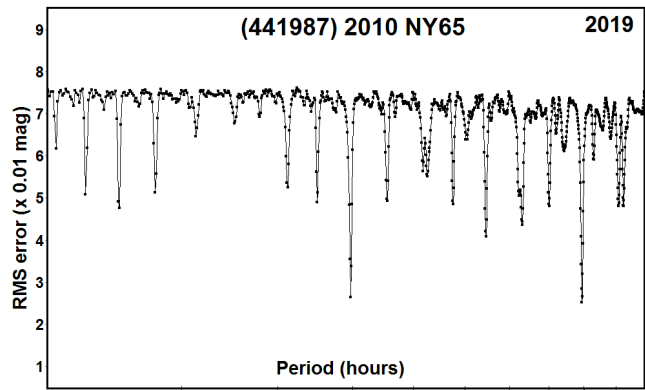
The trimodal shape of the lightcurve for 2011 LX10 is not uncommon at low amplitudes and phase angles (Harris et al., 2014).

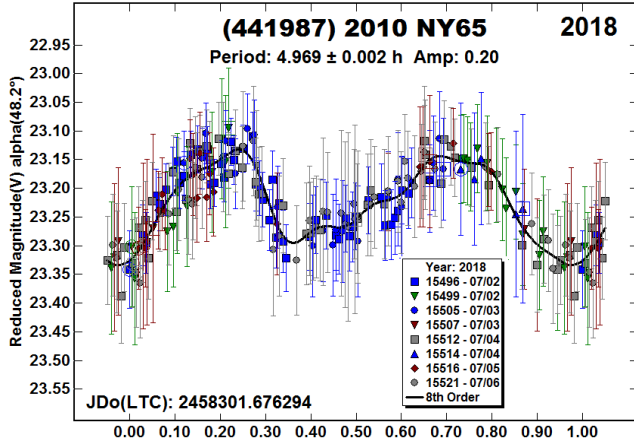
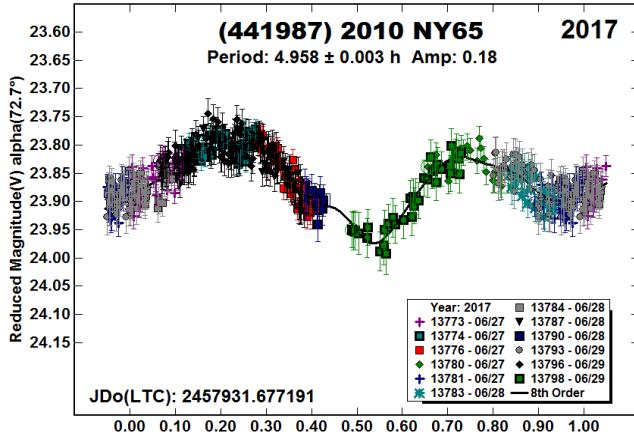
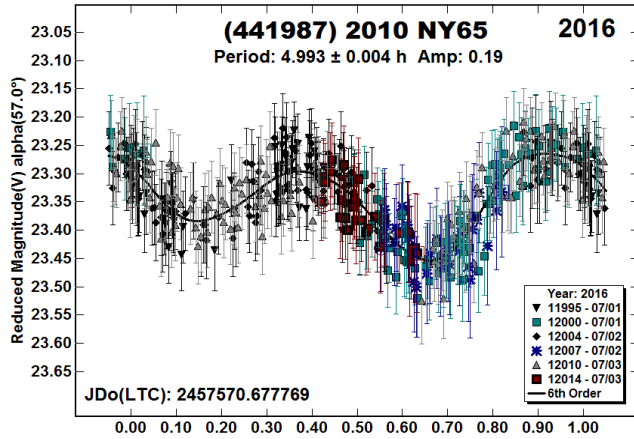
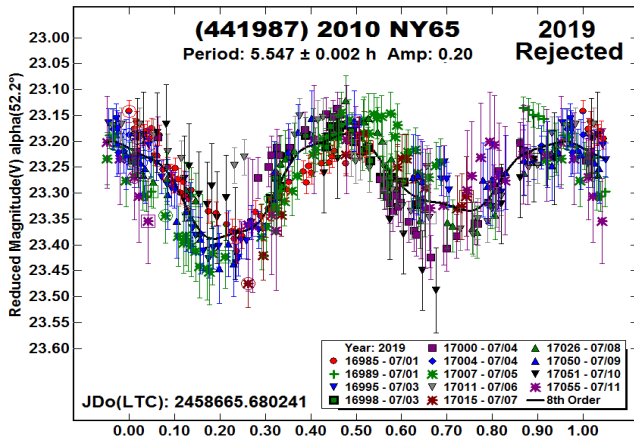


(441987) 2010 NY65. Among the data sets from 2016-2019, the one from 2019 had the most data points and covered a substantially larger range of dates. This was important because previous efforts to find a secure period were suspect.

Warner (2016b; 2017) reported a period of about 4.97 h. After we obtained data in 2018 (Warner and Stephens, 2019a), a solution near 5.5 h was found. This prompted another look at the data from 2016 and 2017 and solutions near 5.5 h could be found but they were not secure.

From the 2019 data, a secure solution of 4.9706 h was found. The period spectrum showed a significantly weaker solution near the previously adopted longer period of 5.5 h. The fit to that longer period ("Rejected") is clearly wrong and so we again reviewed the data from 2016-2018. The results were similar (4.958 h to 4.99 h).

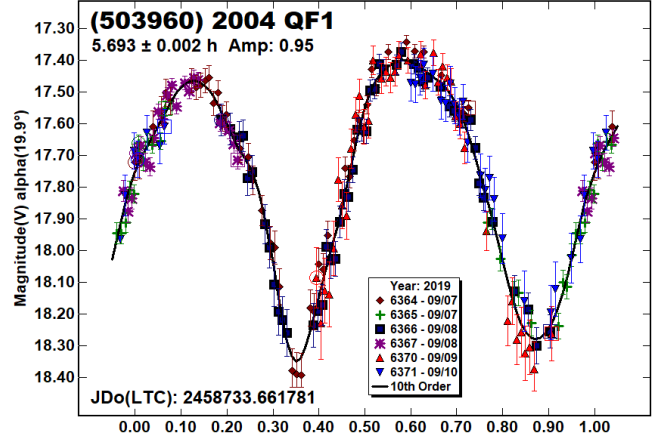
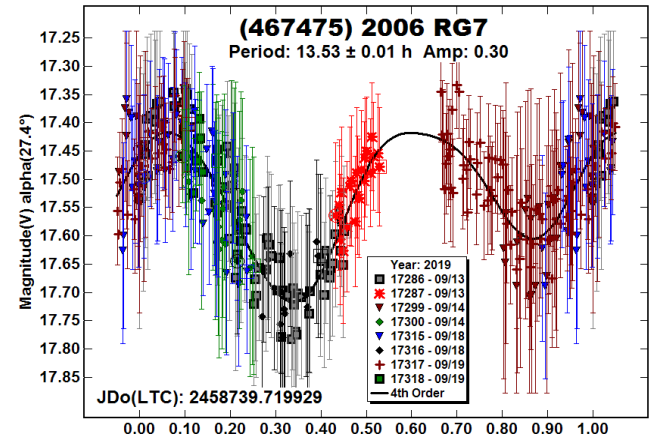
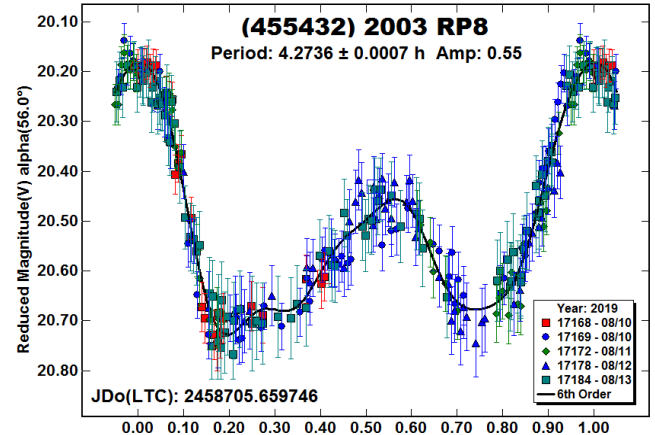




(455432) 2003 RP8, (467475) 2006 RG7, (503960) 2004 QF1. There were no previous rotation period listings in the LCDB for these three NEAs with diameters of 680 m, 520 m, and 650 m, respectively. For 2003 RP8, the solution is bimodal but highly asymmetrical. This may be due to shadowing effects at the large phase angle.

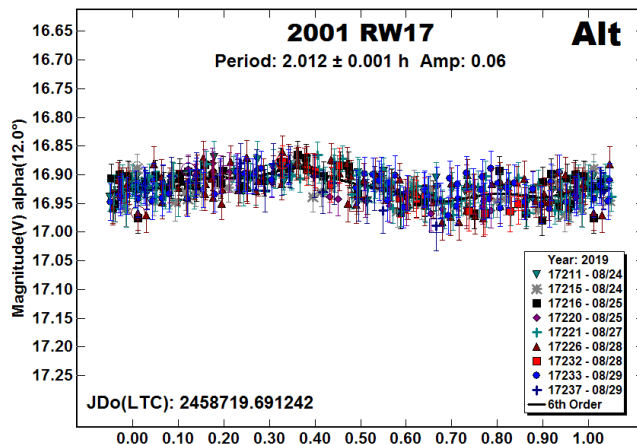
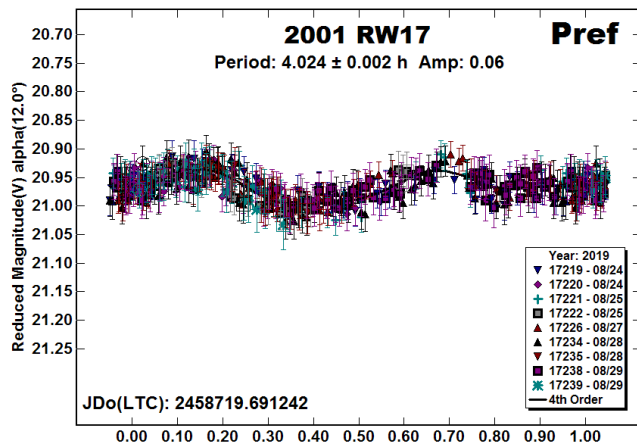
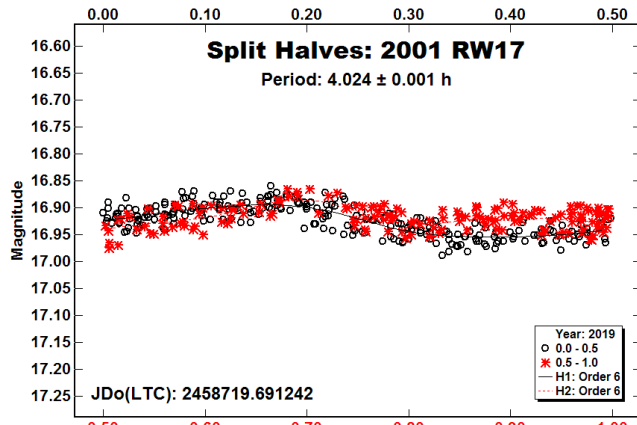
Despite the large error bars, we were able to find a mostly reliable solution for 2006 RG7. The SNR was lower than we'd expect for $V \sim 17.5$; it's possible that exposures of only 120 s and a full moon had something to do with the lower quality.

On the other hand, the data for 2004 QF1 are of much better quality even though a waxing gibbous moon (0.59 – 0.85 lit) was in the sky. Fortunately it was about 75° away.

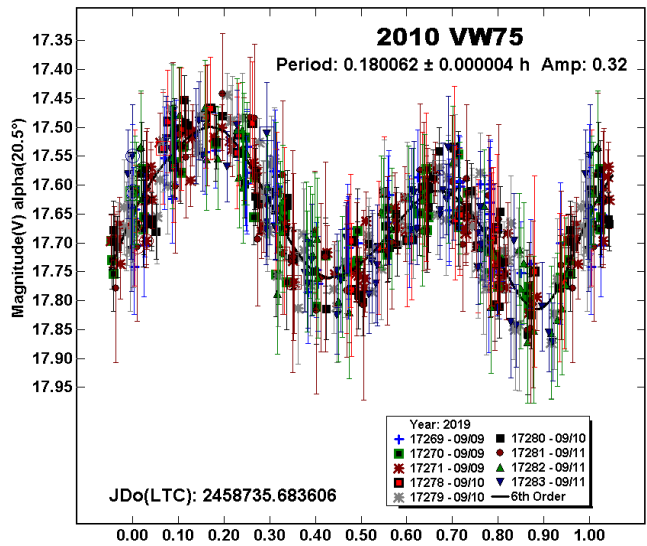


2001 RW17. There were no previous period listings in the LCDB for 2001 RW17, which has an estimated diameter of 260 m. The low amplitude and low phase angle made a monomodal and bimodal (or higher) lightcurve possible (Harris et al., 2014). We assumed that the lightcurve would not be more complex than bimodal.

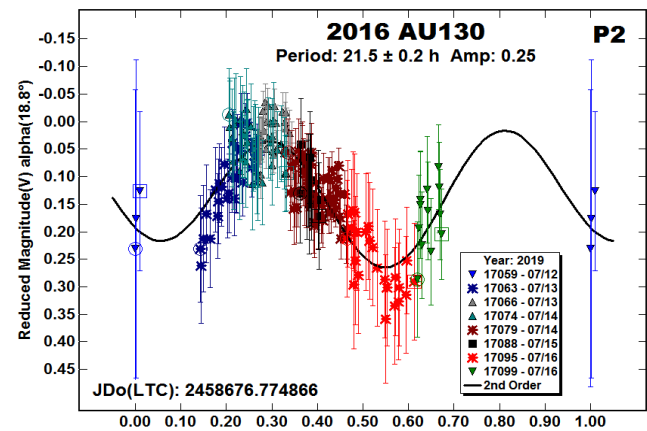
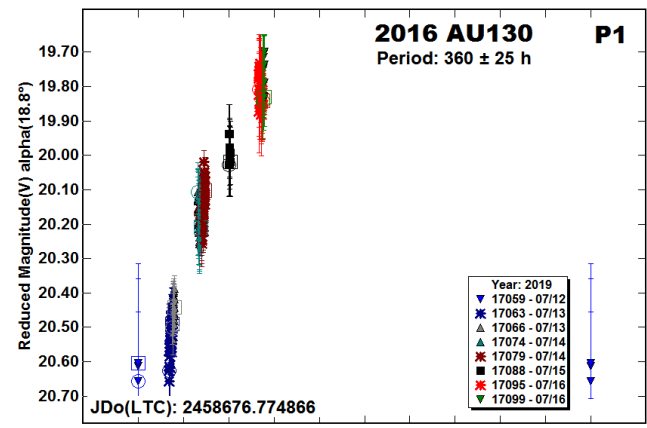
The bimodal solution of 4.024 h had nearly complete coverage, which removes some doubt about a *fit by exclusion*. This is where the Fourier analysis finds a local rather than global RMS minimum by reducing the number of overlapping data points. The split-halves plot for 4.024 h had just enough asymmetry for us to adopt the longer bimodal solution. However, neither can be formally excluded. Future observations when, hopefully, the lightcurve amplitude is larger, may resolve the ambiguity.



2010 VW75. Based on the LCDB as of 2019 October 8, this appears to be the first reported lightcurve analysis result for this 130-m asteroid that has a rotation period of only 10.8 min.

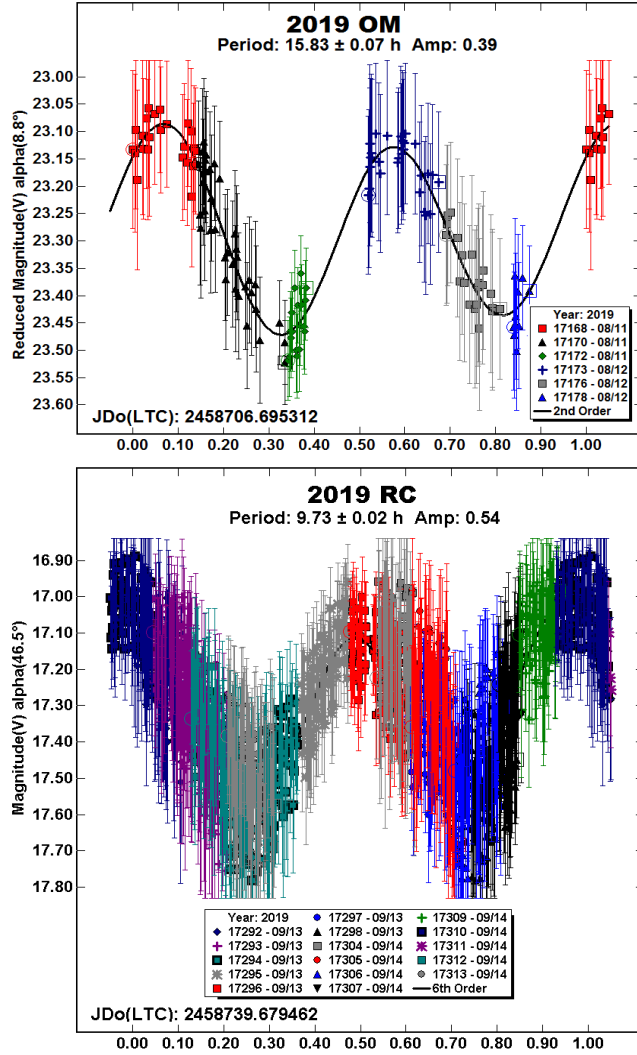


2016 AU130. This 540-m NEA could be observed for only a short period in 2019 July. Bad luck had that it appears to have a very long period. The adopted period of 360 h is based on the assumption that the data went from a minimum to a maximum of a bimodal lightcurve. Further assuming a symmetrical shape, the rise from minimum to maximum would be about 0.25 of the adopted period. A half-period solution supported our result.



The individual nights show trends that indicated a somewhat long second period. Our dual-period search with *MPO Canopus* found a solution of about 21 h where the amplitude was large enough to overcome the large error bars. Both periods are suspect but, if real, could be due to a satellite or be the dominant periods of tumbling.

2019 OM, 2019 RC. There were no previous LCDB listings for either asteroid. The diameters are 90 m and 130 m, respectively.



2019 MA2. The estimated diameter is only 490 m (some estimates are > 1.5 km). On first look at the raw data for each night, the plots looked like random, noisy data points. However, in some cases, there is something to be found by looking at very short periods with very high precision.

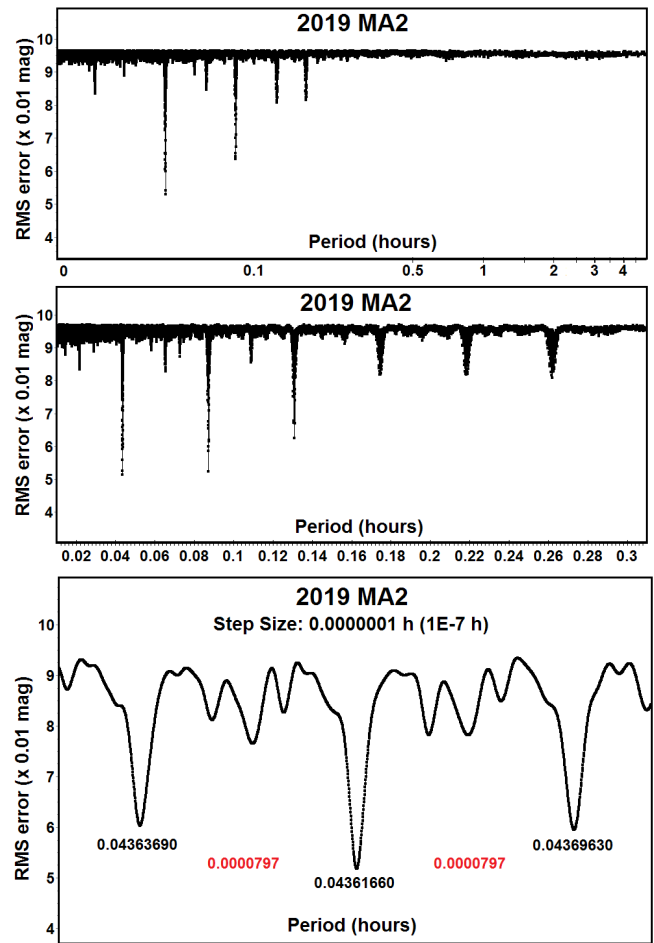
Using some noise filtering and binning data points led to a period of just over 2 minutes (0.0436166 h, 0.27 mag)! If this is true, it makes 2019 MA2 an extraordinary object, as seen by its location in the frequency-diameter plot from the LCDB. Such an object would have to be strength-bound or, if a rubble pile, have an extreme density. Given the extraordinary claim, we asked Alan Harris (formerly JPL, now MoreData!) to comment on the finding. We offer his response nearly in full.

Density can't be important; it would have to [be] several thousand gm/cc to be held together by gravity. But strength is no problem. As has been pointed out by Dan Scheeres and

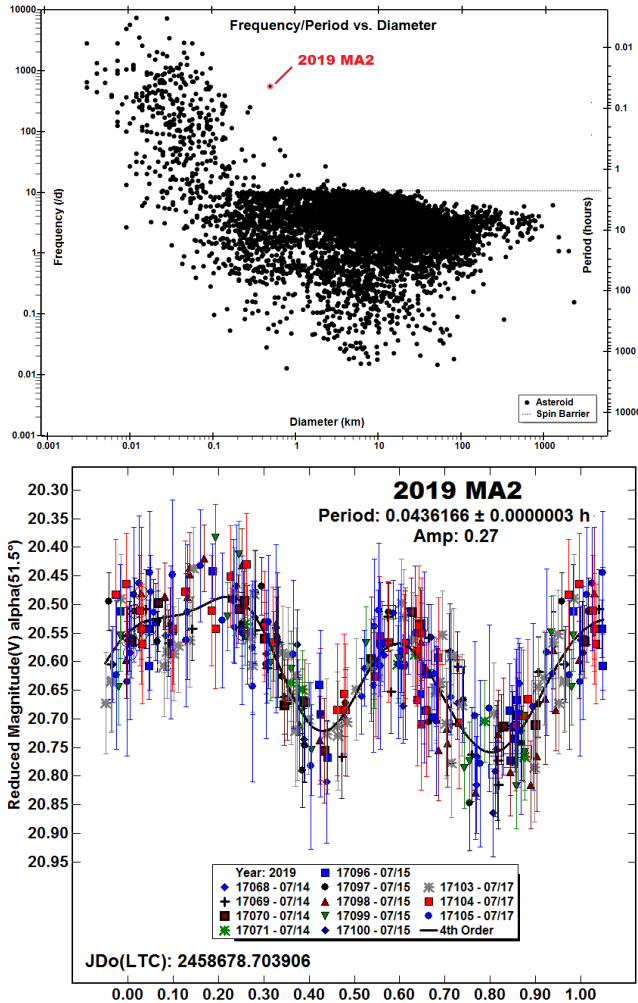
others, the strength needed to hold a rock together at such a spin rate is modest, so there is nothing un-physical about a rock that size spinning at that rate; it's just uncommon. I have said many times in meetings and such that the fact that that part of the spin-diameter plot [seen below] is mostly empty doesn't reflect [the] impossibility of ordinary rocks being there; it's just that nature doesn't work that way for the majority of bodies, i.e., they're mostly strengthless rubble piles. Exceptions are not prohibited, they're just rare.

All that being said, your [solution] is only marginal, for the reason (as I've also said frequently) that if you search the period spectrum down to such short periods, the number of possible independent solution frequencies becomes very large, and seeing 2 or 3 sigma apparent solutions is expected and may be just noise – or not. So I'd go with the solution you plot [...] but give it at most a U = 2 rating, maybe even 2–. Including a noise-frequency spectrum to show level of uniqueness would be good.

We searched several ranges that covered 0.01 h to 100 h. Based on our data set and analysis, it appears that there is very little or no chance for a solution of $P > 0.05$ h. The first period spectrum shown here covers a range of 0.001 h to 5 h. The second shows a range of 0.02 h to 0.3 h and concentrates on the extremely short period section. The third period spectrum shows a very narrow range centered on the adopted period of 0.04361660 h and the local minimums on either side that could not be seen in the first two spectra.



The third spectrum shows some of what Harris meant by the large number of independent solutions. The periods for the two most prominent “sidebands” differ from the adopted period by 0.0000797 h. Even if we tripled our period error to 1E-6 h, the sidebands are about 80-sigma removed from the best period. We used the high period precision (3E-7 h) because it wasn’t until the search step size reached 1E-7 h that the error was more than one unit in the last decimal place.



A search of the Internet and a full text search on the ADS found no reported rotation period. If there are sufficient data for period analysis available, we would be grateful to get those data and try to confirm our result with an independent data set. Otherwise, it will be a long wait for more data. The asteroid returns in 2023 but will be V~19.3. It’s not until 2046 July (V~15.9) that those with small ($D \leq 1.0$ m) telescopes have an opportunity.

Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database (Warner et al., 2009) and ALCDEF database (*alcddef.org*) are supported by NASA grant 80NSSC18K0851.

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research.

This work includes data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. ATLAS is primarily funded to

search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen’s University Belfast, the Space Telescope Science Institute, and the South African Astronomical Observatory.

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Number	Name	20xx mm/dd#	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
1620	Geographos	09/24-09/30	48.5, 46.3	331	11	5.2201	0.0002	1.91	0.01
1865	Cerberus	07/08-07/13	58.9, 55.4	334	32	6.8018	0.0006	1.58	0.03
2059	Baboquivari P2/NPAR	07/16-08/23	*21.2, 15.8	322	17	129.52 19.199	0.04 0.003	0.45 0.08	0.02 0.02
2100	Ra-Shalom	08/16-08/23	52.0, 45.9	3	9	19.792	0.004	0.50	0.03
5786	Talos	08/02-08/09	50.0, 33.3	339	21	23.60	0.05	0.30	0.05
18172	2000 QL7	08/24-08/27	31.5, 31.3	14	9	2.509	0.001	0.14	0.02
85709	1998 SG36	09/23-09/25	3.2, 2.0	4	3	3.573	0.004	0.14	0.03
90403	2003 YE45 P2	18/12/28-01/22	*15.8, 18.3	111	-1	500 2.7602	10 0.0004	0.81 0.05	0.05 0.01
105140	2000 NL10	08/13-08/15	62.2, 60.3	292	59	6.920	0.005	0.43	0.03
152754	1999 GS6	08/09-08/14	12.4, 6.6	326	1	8.021	0.008	0.20	0.03
153842	2001 XT30	07/08-07/13	17.5, 15.3	303	7	17.95	0.02	0.25	0.02
173561	2000 YV137	08/01-08/03	64.9, 66.0	276	30	2.722	0.001	0.26	0.02
248926	2006 WZ2	08/24-08/29	39.4, 38.8	11	-3	8.45	0.01	0.23	0.03
293054	2006 WF127	07/14-07/16	74.0, 61.0	291	39	5.985	0.002	0.36	0.03
326742	2003 QN47	09/13-09/15	40.8, 39.7	17	16	0.61079	0.00004	0.56	0.05
354030	2001 RB18 Alternate	08/01-08/08	18.0, 17.0	321	10	27.08 13.54	0.04 0.01	0.18 0.16	0.02 0.02
405212	2003 QC10	08/28-09/01	17.1, 13.6	350	-3	15.27	0.01	0.39	0.03
429733	2011 LX10	08/04-08/10	15.4, 13.9	323	17	2.649	0.001	0.18	0.02
441987	2010 NY65 Revised Revised Revised	16/07/01-07/03 17/06/27-06/29 18/07/02-07/06 19/07/01-07/11	56.6, 51.9 71.2, 58.3 48.2, 43.3 52.1, 41.5	259 257 268 268	21 29 22 21	4.993 4.958 4.969 4.9706	0.004 0.003 0.002 0.0006	0.19 0.18 0.20 0.23	0.03 0.02 0.03 0.02
455432	2003 RP8	08/10-08/13	56.1, 59.6	306	36	4.2736	0.0007	0.55	0.03
467475	2006 RG7	09/13-09/19	27.4, 23.2	12	2	13.53	0.01	0.30	0.05
503960	2004 QF1	09/07-09/10	19.9, 19.2	355	13	5.693	0.002	0.95	0.02
	2001 RW17 Alternate	08/24-08/29	11.9, 4.8	334	5	4.012 2.012	0.002 0.001	0.06 0.06	0.01 0.01
	2010 VW75	09/09-09/11	20.7, 23.1	358	7	0.180062	0.000004	0.32	0.04
	2016 AU130 P2/NPAR	07/12-07/16	18.7, 11.2	301	5	360 21.5	25 0.2	0.8 0.25	0.1 0.04
	2019 OM	08/11-08/11	8.7	318	5	15.83	0.07	0.39	0.05
	2019 RC	09/13-09/14	46.4, 46.2	12	14	9.73	0.02	0.54	0.05
	2019 MA2	07/14-07/17	52.6, 79.9	259	18	0.0436166	0.0000003	0.27	0.04

Table II. Observing circumstances. # The year is 2019 except when a two digit year is at the start. The year is for the first date and may be the following year for the last date. The phase angle (α) is given at the start and end of each date range. If there is an asterisk before the first phase value, the phase angle reached a maximum or minimum during the period. L_{PAB} and B_{PAB} are, respectively the average phase angle bisector longitude and latitude (see Harris et al., 1984). Some asteroids have more than one line. If the additional lines have "Alternate", the result is ambiguous. The first line is the period adopted for this work and the additional lines give alternate solutions. If "P2" is the second line, it is a secondary period that is due to a confirmed or suspected satellite. "NPAR" indicates that the line has the second period of a tumbling asteroid. If P2 and NPAR both appear, it's not possible to confirm which is correct. "Revised" indicates a new period using a previous data set that is based on the period adopted in this work.

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LIGHTCURVES AND ROTATION PERIODS OF 33 POLYHYMNIA, 206 HERSILIA, 395 DELIA, 400 DUCROSA, 900 ROSALINDE, AND 1066 LOBELIA

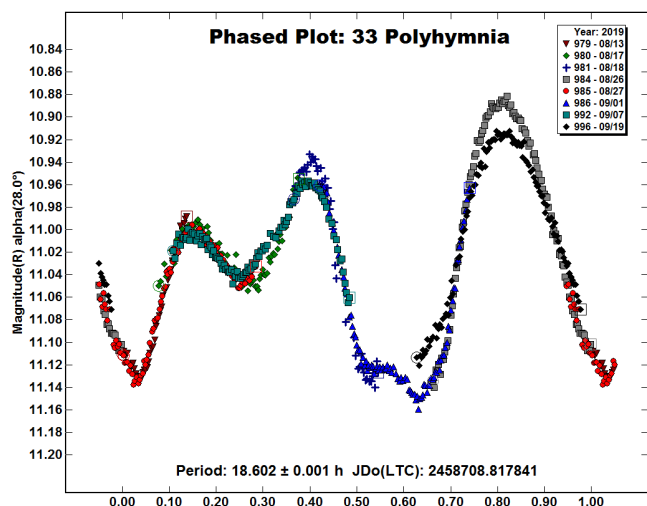
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(Received: 2019 October 6)

Synodic rotation periods and amplitudes are found for
33 Polyhymnia: 18.602 ± 0.001 h, 0.25 ± 0.02 mag;
206 Hersilia: 11.113 ± 0.002 h, 0.17 ± 0.01 mag;
395 Delia: 19.681 ± 0.001 h, 0.16 ± 0.02 mag;
400 Ducrosa: 6.8678 ± 0.0001 h, 0.57 ± 0.03 mag;
900 Rosalinde: 16.689 ± 0.001 h, 0.29 ± 0.02 mag; and
1066 Lobelia: 5.0176 ± 0.0001 h, 0.42 ± 0.02 mag.

Observations to obtain the data used in this paper were made 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 an R filter for the very bright 33 Polyhymnia and clear filter for all other targets. Photometric measurement and lightcurve construction were with *MPO Canopus* software. To reduce the number of points on the lightcurve and make them easier to read, data points have been binned in sets of 3 with a maximum time difference of 5 minutes.

33 Polyhymnia. Six previously published periods in the Asteroid Lightcurve Data Base (LCDB; Warner et al., 2009) all lie in the range from 18.601 to 18.610 hours. New observations on eight nights 2019 Aug 13 to Sep 19 provide a good fit to a lightcurve with three unequal maxima and minima per cycle phased to 18.602 hours. This is within the range of previous determinations. The lightcurve shows that the amplitude of 0.25 mag from Aug 13 to Sept 1 at phase angles 28 to 22 deg had decreased to 0.20 mag from Sept 7-19 at phase angles 20 to 15 deg. In this interval, the phases at which the maxima and minima occurred did not change perceptibly. This decrease of amplitude with phase angle is commonly found for many asteroids.

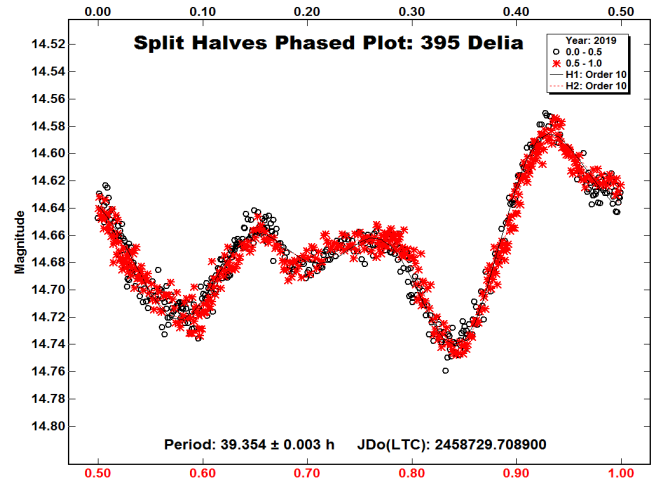
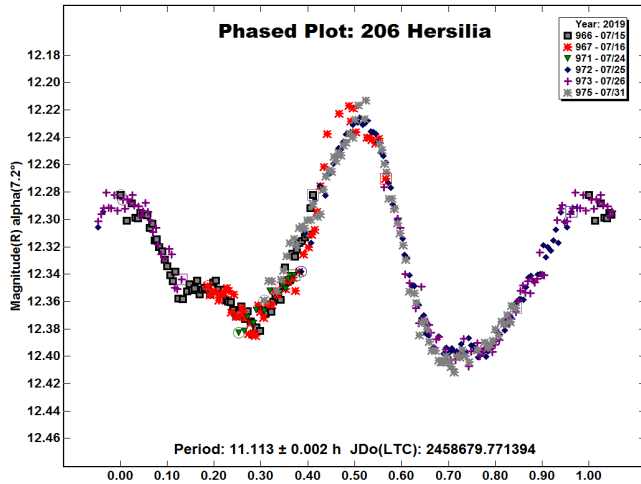


206 Hersilia. Previously published periods are by Shevchenko et al. (1992, 7.33 h), Willis (2004, 11.11 h), Behrend (2008, 11.135 h), and Behrend (2013, 11.122 h). New observations on six

Number	Name	2019/mm/dd	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
33	Polyhymnia	08/13-09/19	28.0, 14.5	14	0	18.602	0.001	0.25	0.02
206	Hersilia	07/15-07/31	7.2, 0.8	309	1	11.113	0.002	0.17	0.01
395	Delia	09/03-10/06	15.5, 4.2	21	4	19.681	0.001	0.16	0.02
400	Ducrosa	09/02-09/23	*4.3, 3.7	350	5	6.8678	0.0001	0.57	0.03
900	Rosalinde	07/05-07/30	*12.0, 11.8	294	16	16.689	0.001	0.29	0.02
1066	Lobelia	08/11-09/04	*4.2, 10.7	323	-2	5.0176	0.0001	0.42	0.02

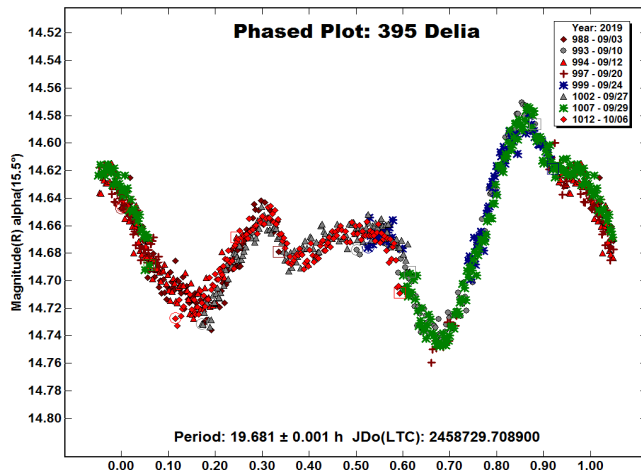
Table I. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. The * symbol indicates that a minimum or maximum value occurred between these dates. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

nights 2019 July 15-31 provide a good fit to a lightcurve phased to 11.113 ± 0.002 h, amplitude 0.17 ± 0.01 mag. This is consistent with all previous results, except Shevchenko *et al.* (1992).

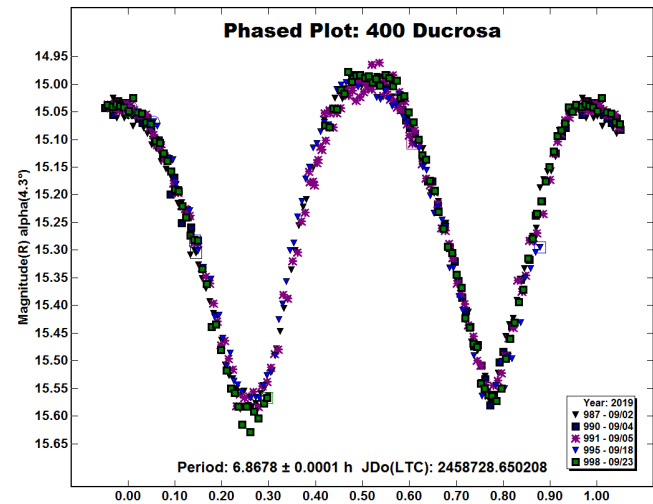


A split-halves plot to this double period shows agreement of the two halves within reasonable errors of observation. The double period is rejected and the 19.681 hour period may be considered secure. This period is consistent with all previously published periods except Ditteon *et al.* (2018).

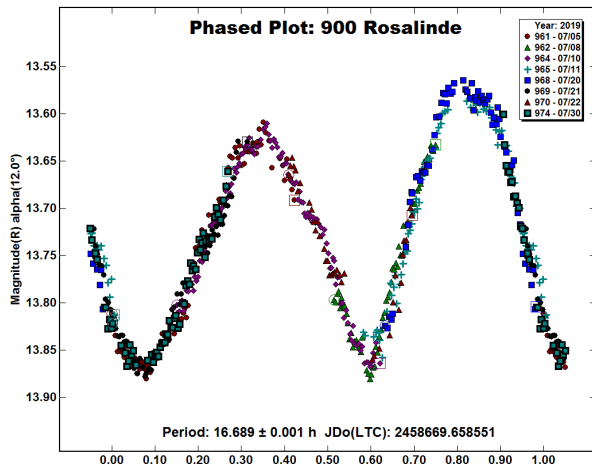
395 Delia. Previously published periods are by Behrend (2001, 19.71 h), Behrend (2006, 19.69 h), Ditteon *et al.* (2018, 18.98 h), and Marciniak *et al.* (2015, 19.680 h). New observations on eight nights 2019 Sep 3 to Oct 6 provide a good fit to an irregular lightcurve phased to 19.681 ± 0.001 h, amplitude 0.16 ± 0.02 mag. Dates for the eight sessions were carefully chosen for full phase coverage of the entire double period of 39.354 h.



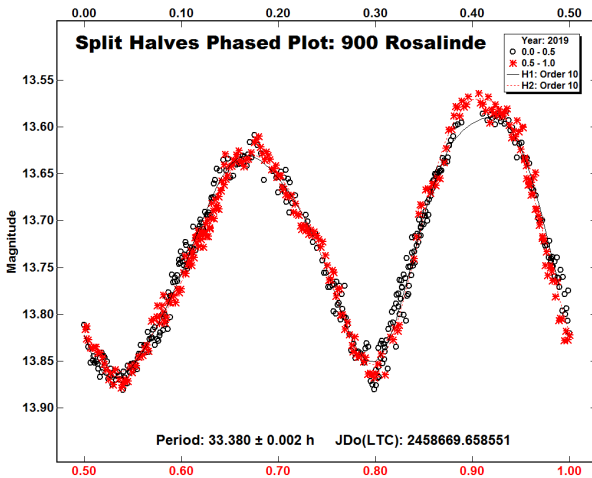
400 Ducrosa. The only previously published period for 400 Ducrosa is by Warner (2005), who found 6.87 hours. New observations on five nights from 2019 Sept. 2-23 provide a good fit to a lightcurve phased to 6.8678 ± 0.0001 h, amplitude 0.57 ± 0.03 mag. This period is consistent with the period by Warner.



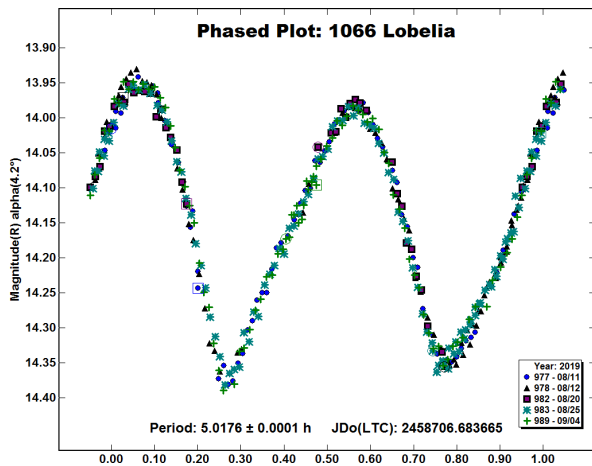
900 Rosalinde. Previously published periods are by Binzel (1987, 16.5 h), Behrend (2007, 23.5 h), Garceran *et al.* (2016, 16.70 h), and Stoelting and De Graff (2016, 16.648 h).



New observations on eight nights 2019 July 5-30 provide a good fit to a lightcurve phased to 16.689 ± 0.001 h, amplitude 0.29 ± 0.02 mag. A split-halves plot to the double period of 33.380 hours shows excellent agreement between the two halves and rules out the double period. The 16.689-hour period found in this study is consistent with all previously reported periods, except Behrend (2007).



1066 Lobelia. The Asteroid Lightcurve Data Base (Warner et al., 2009) shows no previous photometric observations. New observations on five nights, 2019 Aug 11 to Sep 4, provide a good fit to a lightcurve phased to 5.0176 ± 0.0001 h, amplitude 0.42 ± 0.02 mag.



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**LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS
AT THE CENTER FOR SOLAR SYSTEM STUDIES:
2018 SEPTEBER – 2019 SEPTEMBER**

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(Received:2019 October 4)

CCD photometric observations of three Hilda asteroids were made at the Center for Solar System Studies (CS3) in 2019 September. Analysis of the 2019 data for 4495 Dassanowsky, a reported binary (Warner and Stephens, 2019), found three periods, one being very long (431 h). The long period and a secondary one made it a potential member of the *very wide binary asteroids* but, for the first time for a member of this class, a third period seems to be present. A review of the 2018 data set using comparison star magnitudes from the ATLAS catalog (Tonry et al., 2018) found the previously unnoticed very long period. The secondary and tertiary periods were still in good agreement with the original two-period solution found in 2018. Though the odds are remote and considerable more data are required, the new results from the 2018 data are encouraging in the on-going effort to find evidence that validates claims of the existence of the *very wide binary asteroid* class.

CCD photometric observations of three Hilda asteroids were made at the Center for Solar System Studies (CS3) in 2019 September. This is another installment of an on-going series of papers on this group of asteroids, which is located between the outer main-belt and Jupiter Trojans in a 3:2 orbital resonance with Jupiter. The goal is to determine the spin rate statistics of the group and find pole and shape models when possible. We also look to examine the degree of influence that the YORP (Yarkovsky–O’Keefe–Radzievskii–Paddack) effect (Rubincam, 2000) has on distant objects and to compare the spin rate distribution against the Jupiter Trojans, which can provide evidence that the Hildas are more “comet-like” than main-belt asteroids.

Telescopes	Cameras
0.30-m f/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Proline 1001E
0.35-m f/11 Schmidt-Cass	SBIG STL-1001E
0.40-m f/10 Schmidt-Cass	
0.50-m f/8.1 Ritchey-Chrétien	

Table I. List of available telescopes and CCD cameras at CS3. The exact combination for each telescope/camera pair can vary due to maintenance or specific needs.

Table I lists the telescopes and CCD cameras that are combined to make observations. Up to nine telescopes can be used for the campaign, although seven is more common. All the cameras use CCD chips from the KAF blue-enhanced family and so have essentially the same response. The pixel scales ranged from 1.24-1.60 arcsec/pixel. All lightcurve observations were unfiltered since a clear filter can result in a 0.1-0.3 magnitude loss. The exposures varied depending on the asteroid’s brightness and sky motion.

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. Comp star magnitudes were taken from ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs, among others. The authors state that systematic errors are generally no larger than 0.005 mag, although they can reach 0.02 mag in small areas near the Galactic plane. BVRI magnitudes were derived by Warner using formulae from Kostov and Bonev (2017). The overall errors for the BVRI magnitudes, when combining those in the ATLAS catalog and the conversion formulae, are on the order of 0.04-0.05.

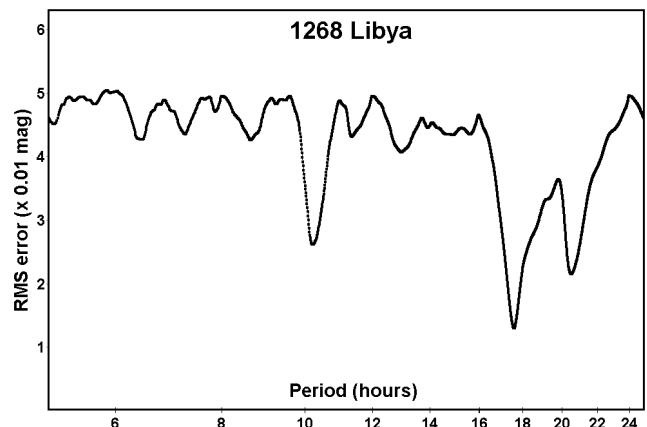
Even so, we found in most cases that nightly zero point adjustments on the order of only 0.02-0.03 mag were required during period analysis. There were occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms. Regardless, the systematic errors seem to be considerably less than other catalogs, which reduces the uncertainty in the results when analysis involves data from extended periods or the asteroid is tumbling.

Period analysis was done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris et al., 1989). The same algorithm is used in an iterative fashion when it appears there is more than one period. This works well for binary but not for tumbling asteroids.

In the plots below, the Y-axis gives the Johnson V sky (catalog) magnitude of the asteroid. For plots of additional periods, the zero point is the average magnitude of the primary lightcurve. The magnitudes were normalized to the phase angle in parentheses using $G = 0.15$. The X-axis is the rotational phase ranging from -0.05 to 1.05 . If the plot includes an amplitude, it is for the peak-to-peak Fourier model curve and *not necessarily the adopted amplitude for the lightcurve*.

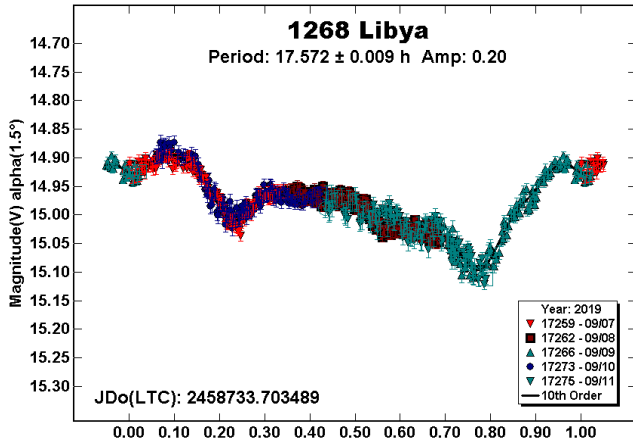
Our initial search for previous results started with the asteroid lightcurve database (LCDB; Warner et al., 2009), which is on-line at <http://www.minorplanet.info/lightcurvedatabase.html>. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB.

1268 Libya. The only previously reported period for this 94 km Hilda was from Dahlgren et al. (1998), who found a period of 14.05 h.



The period spectrum based on our data from 2019 shows a very shallow local minimum at about 14.5 h. Considerably stronger solutions are near 10 h, 17.5 h, and 20.2 h with the one near 17.5 h being the most favored.

The lightcurve has an unusual shape. However with the amplitude about 0.20 mag and the very low phase angle, it's not unreasonable (Harris et al., 2014). Not even significant nightly zero point shifts allowed finding a plausible alternate solution.

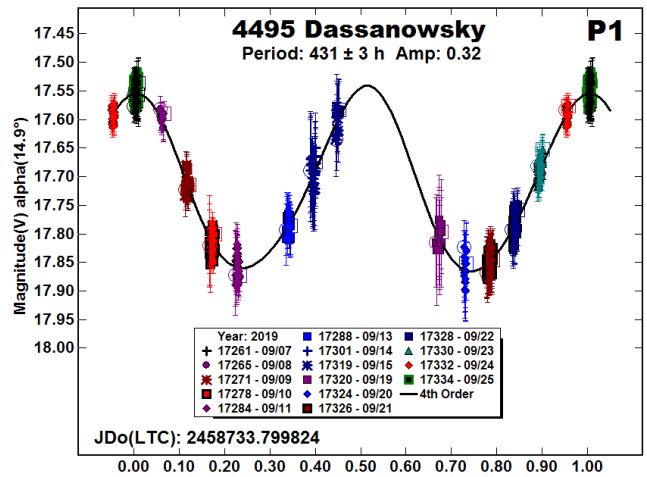
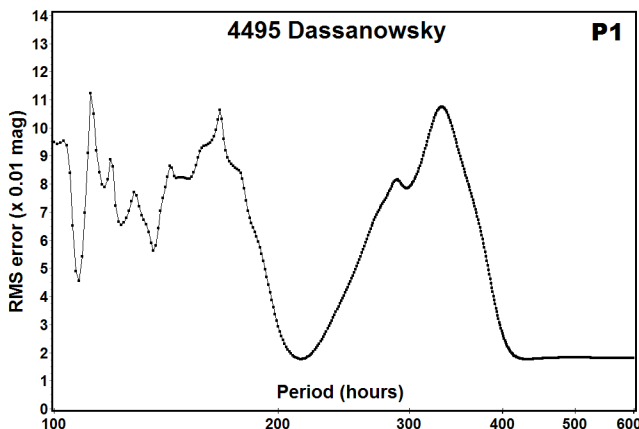


4495 Dassinowsky. The estimated diameter of this Hilda is 24 km (Mainzer et al., 2016). We first observed it in 2018 Sept-Oct and found it to be a binary candidate (Warner and Stephens, 2019) with a primary period of $P_1 = 2.6314$ h and $P_{ORB} = 18.516$ h. The primary period solution was not unique. The double period at 5.263 h was also possible. Revised lightcurves of these solutions are given below.

Analysis of the 2019 Data

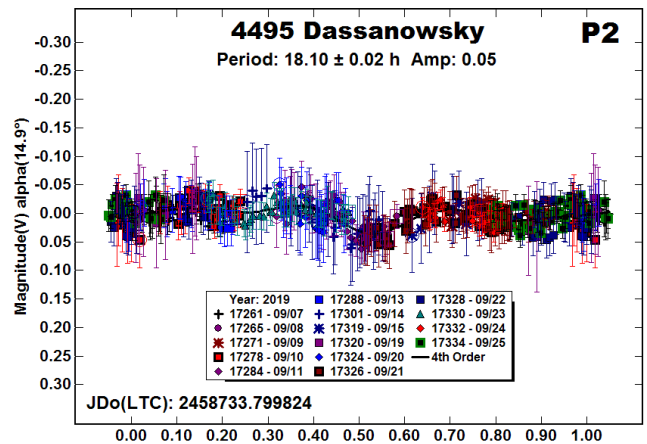
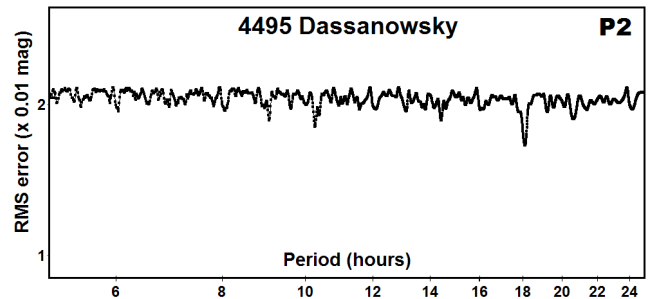
Not long after our observations in 2018, the ATLAS catalog (Tonry et al., 2018) became available. As noted previously, this reduced nightly zero shift points considerably; this raised confidence significantly in solutions where a very long period was involved.

A raw plot of the 2019 data clearly showed a long period component with a period on the order of 400 h. The lower RMS solution in the period spectrum near 200 h is for a monomodal lightcurve. Given the amplitude and phase angle, this was unlikely (Harris et al., 2014).

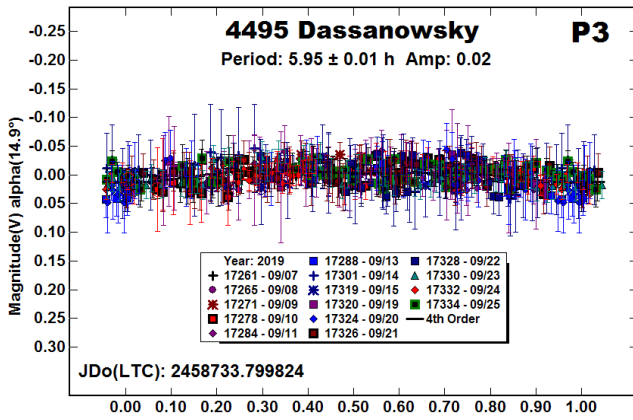


After almost three weeks of observations, the data set was sufficient to find a 4th order Fourier fit for the long period; earlier attempts were limited to a 2nd order fit to the half-period.

Once the long period was subtracted, a weak secondary period of 18.1 h was found. This was close to the previous solution at 18.5 h. Although less prominent than in 2018, the P_2 lightcurve had a similar shape to the one in 2018 that appeared to show distinct mutual events (occultations/eclipses) that would be due to a satellite of the “primary” body (secondary body in the newly proposed model).



The back-and-forth iterative process of subtracting the two periods from the data found a third, also weak tertiary period of $P_3 = 5.95$ h. Here again, it was somewhat similar to the short, bimodal solution found in 2018. A possible reason for the discrepancies is discussed below.

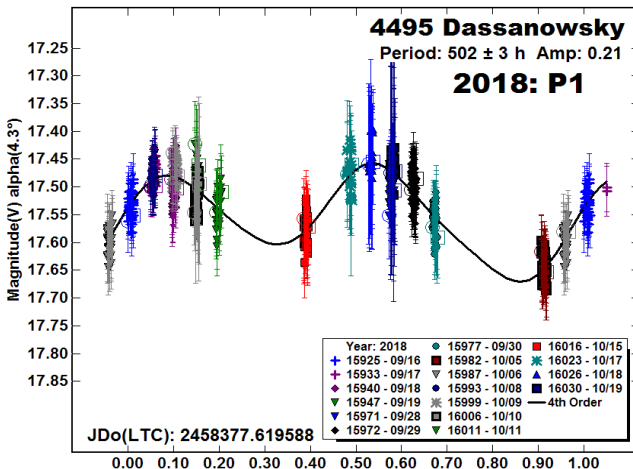
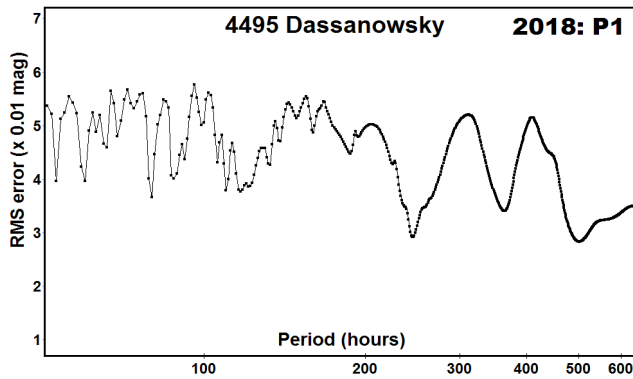


Another Look at the 2018 Data

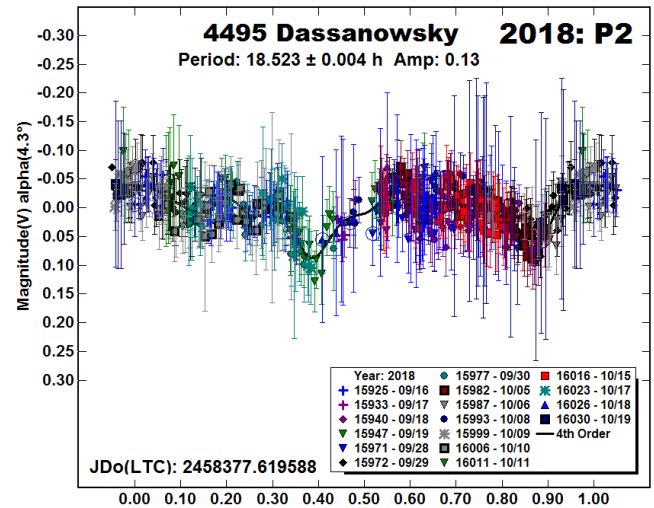
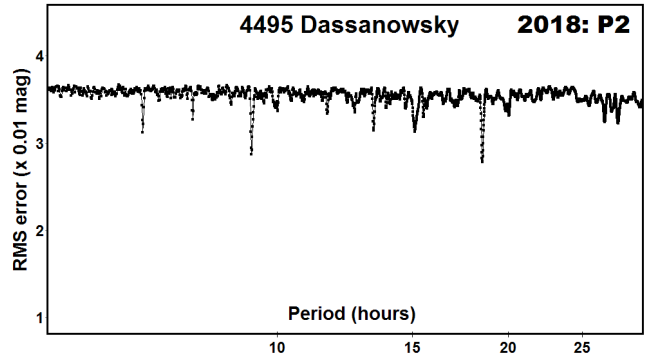
With a long period clearly seen in the 2019 data, we went back to the 2018 data set, removed all zero-point adjustments, and used values from the ATLAS catalog for the comparison stars instead of the APASS catalog values (Henden et al., 2009).

The initial raw plot of the data using the new comp star magnitudes immediately showed a long-period component. Apparently, the nightly zero point adjustments used in 2018 slowly but surely removed the long-period component, which is a cautionary tale of “trusting the data” until there’s a reason not to.

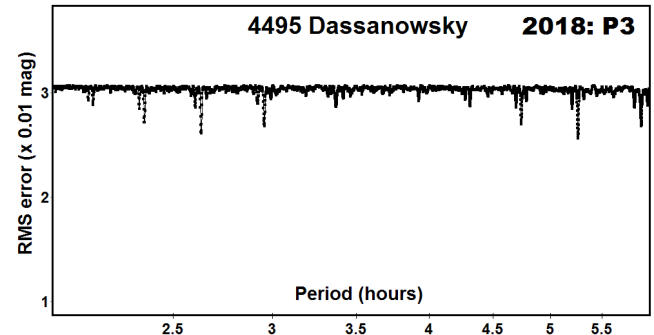
The 2018 data set was nearly double the density of that in 2019 but the overall quality was less in terms of SNR. This was a case where “overwhelming the noise with data” worked. Sometimes, however, adding more noisy data just makes matters worse.

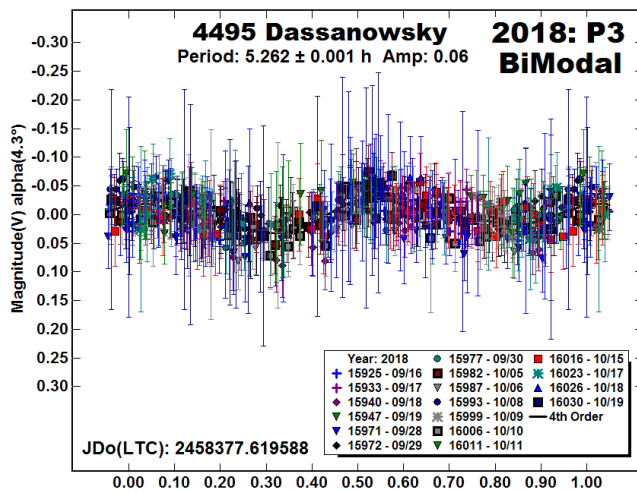
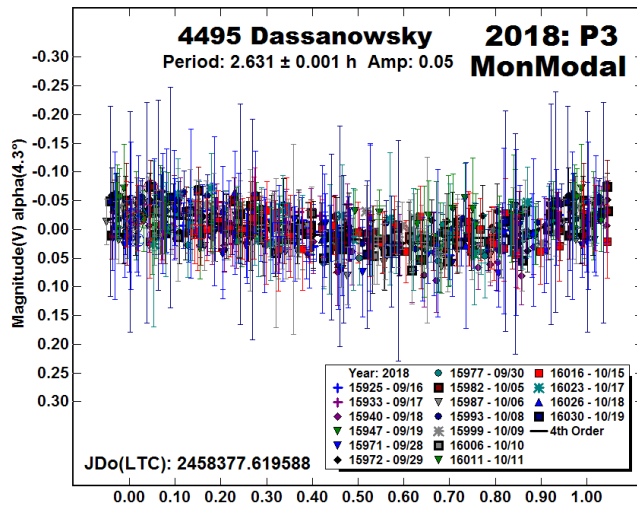


The coverage of P_1 in 2018 was not as good as in 2019, but it was still sufficient to use a 4th order Fourier fit to find a solution. Subtracting the long period eventually lead to a purported P_{ORB} (P_2 lightcurve) of 18.523 h, or about 0.007 h longer than we initially reported. Once again, there appear to be mutual events in the lightcurve with depths 0.06-0.08 mag. Assuming the validity of a trinary system, this leads to an estimated effective diameter ratio $D_s/D_p \geq 0.24 \pm 0.03$ between the primary satellite and a third body orbiting around the primary satellite, not the main body producing the long period lightcurve. Such evidence has not been seen before among candidates of the very wide binary asteroids class.



We then moved to subtracting P_1 and P_2 to see if the short period originally reported in Warner and Stephens (2019) could be found. The period spectrum for P_3 shows several good candidates, some being integral multiples of shorter periods. For our analysis, we assumed that the tertiary lightcurve would be monomodal or bimodal. The results are shown in the two P_3 lightcurves.





The two P_3 periods are essentially identical to those we reported in our initial analysis of the 2018 data (Warner and Stephens, 2019). We note that either one fits well within previous two-period solutions for the secondary body in the *very wide binary asteroids* class. For this paper, we are adopting the shorter $P_3 = 2.631$ h but, as before, cannot formally exclude the double period.

More Data!

As noted above, the discrepancies in the periods using the 2018 and 2019 data sets are significant but the results are still “similar.” Two contributing factors come to mind: 1) the much higher density of the 2018 data set and, 2) a difference in the viewing aspect between the two apparitions. In 2018 L_{PAB} was $\sim 340^\circ$ while in 2019 L_{PAB} was $\sim 40^\circ$, or about 60° separation. It’s plausible that this is a sufficient difference to account for the differences amplitudes.

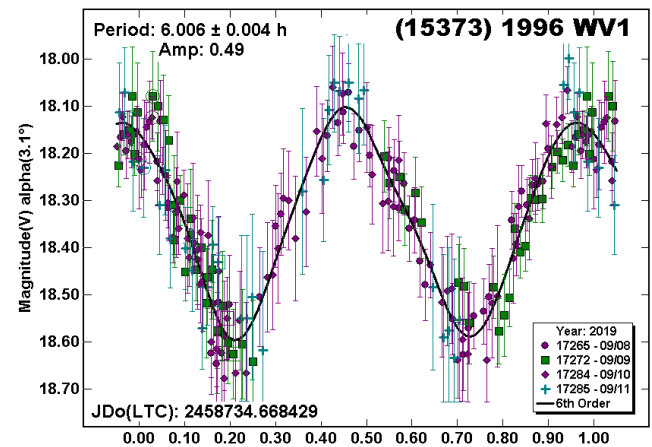
The larger amplitude in 2019 might imply a more equatorial view for the primary body. On the other hand, the amplitudes for the secondary and tertiary periods were considerably smaller.

We have not worked out the required densities and other values to say if a trinary system with the reported periods is even physically probable. Assuming so, the new results from the 2018 data set are encouraging in the attempt to establish the existence of members of the *very wide binary asteroid* class.

There are favorable apparitions ($V < 17.5$) in almost every year from 2020 to 2050. We encourage observing campaigns involving observers at well-spread longitudes and being able to calibrate all data to a common system (even an internal one) to 0.02 mag or better.

The ultimate victory would be to observe mutual events between the long-period primary and the suggested binary satellite. Unfortunately, the general model for the *very wide binary asteroids* has a very long orbital period for the (main) satellite and so the chances of seeing those events are extremely remote. This puts further emphasis on having a campaign of several observers each of who produces a dense data set each night. Short, sporadic runs will not find the shorter periods in this system.

(15373) 1996 WV1. This appears to be the first reported rotation period for 1996 WV1, which has an approximate diameter of 13 km (Mainzer et al., 2016). The almost exactly Earth-day commensurate period was overcome by being able to observe the asteroid just a little more or less than the adopted period and doing so on four consecutive nights.



Acknowledgements

Funding for observations at CS3 and work on the asteroid lightcurve database (Warner et al., 2009) and ALCDEF database (alcdef.org) are supported by NASA grant 80NSSC18K0851.

This work includes data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. ATLAS is primarily funded to search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen’s University Belfast, the Space Telescope Science Institute, and the South African Astronomical Observatory.

The authors gratefully acknowledge Shoemaker NEO Grants from the Planetary Society (2007, 2013). These were used to purchase some of the telescopes and CCD cameras used in this research.

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Number	Name	20xx/mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.
1268	Libya	19/09/07-09/11	1.5,0.4	350	0	17.572	0.009	0.20	0.01
2018 September-October									
4495	Dassanowsky	18/09/16-10/19	4.3,5.9	327	3	502	3	0.21	0.02
	P2					18.523	0.004	0.13	0.02
	P3 (Monomodal)					2.631	0.001	0.05	0.01
	P3 (Bimodal)					5.262	0.001	0.06	0.01
2019 September									
4495	Dassanowsky	19/09/07-09/25	14.9,11.9	41	1	431	3	0.32	0.02
	P2					18.10	0.02	0.05	0.01
	P3					5.95	0.01	0.02	0.01
15373	1996 WV1	19/09/08-09/11	3.1,2.5	352	7	6.006	0.004	0.49	0.05

Table II. Observing circumstances. The phase angle (α) is given at the start and end of each date range. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude (see Harris *et al.*, 1984). The P2/P3 lines for 4495 Dassanowsky are for a secondary and tertiary period.

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

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Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2019 July. <http://www.minorplanet.info/lightcurvedatabase.html>

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ASTEROID-DEEPSKY APPULSES IN 2020

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(Received: 2019 October 4)

The following list is a *very small* subset of the results of a search for asteroid-deepsky appulses for 2020, presenting only the highlights for the year based on close approaches of brighter asteroids to brighter DSOs. For the complete set visit

<http://www.minorplanet.info/ObsGuides/Appulses/DSOAppulses.htm>

For any event not covered, the Minor Planet Center's web site at <https://www.minorplanetcenter.net/cgi-bin/checkmp.cgi> allows you to enter the location of a suspected asteroid or supernova and check if there are any known targets in the area.

The table gives the following data:

Date/Time	Universal Date (MM DD) and Time of closest approach
#/Name	The number and name of the asteroid
RA/Dec	The J2000 position of the asteroid
AM	The approximate visual magnitude of the asteroid
Sep/PA	The separation in arcseconds and the position angle from the DSO to the asteroid
DSO	The DSO name or catalog designation
DM	The approximate total magnitude of the DSO
DT	DSO Type: OC = Open Cluster; GC = Globular Cluster; G = Galaxy
SE/ME	The elongation in degrees from the sun and moon, respectively
MP	The phase of the moon: 0 = New, 1.0 = Full. Positive = waxing; Negative = waning

Date	UT	#	Name	RA	Dec	AM	Sep	PA	DSO	DM	DT	SE	ME	MP
01 24 06:59		238	Hypatia	06:34.80	+05 17.1	12.5	398	207	NGC 2252	7.7	OC	150	154	0.00
01 25 21:41		83	Beatrix	09:05.63	+25 23.0	11.6	190	198	NGC 2750	11.9	G	170	173	0.01
02 18 11:32		124	Alkeste	11:32.69	+00 56.2	11.9	560	28	NGC 3720	12.9	G	156	97	-0.24
02 18 19:16		124	Alkeste	11:32.50	+00 57.8	11.9	591	27	NGC 3719	13.0	G	156	101	-0.21
02 19 17:45		241	Germania	10:14.24	+03 30.1	12.3	130	18	NGC 3169	10.2	G	172	132	-0.14
02 20 03:38		241	Germania	10:13.91	+03 31.6	12.3	351	17	NGC 3166	10.4	G	172	137	-0.11
02 25 07:45		71	Niobe	12:05.66	-27 54.2	10.8	154	315	IC 2995	12.2	G	136	145	0.03
03 16 16:37		511	Davida	07:25.65	+29 26.2	11.0	173	167	NGC 2371	13.0	PN	112	160	-0.47
03 16 16:37		511	Davida	07:25.65	+29 26.2	11.0	173	167	NGC 2372	13.0	PN	112	160	-0.47
03 18 13:52		99	Dike	12:22.61	+15 34.2	12.5	73	8	NGC 4312	11.7	G	164	115	-0.28
03 21 17:04		674	Rachele	11:33.18	+24 19.3	11.3	460	182	NGC 3728	13.0	G	154	161	-0.06
03 23 13:34		89	Julia	13:28.97	-33 00.6	11.3	573	350	NGC 5161	11.2	G	143	133	-0.01
03 29 13:02		485	Genua	10:42.10	+00 24.5	11.9	205	243	NGC 3340	13.0	G	152	96	0.23
04 15 03:53		38	Leda	13:13.17	-19 35.4	12.1	287	204	NGC 5022	12.9	G	169	93	-0.48
04 15 13:18		38	Leda	13:12.83	-19 33.2	12.1	148	204	NGC 5018	10.8	G	169	98	-0.44
04 16 02:08		704	Interamnia	11:07.42	-19 26.4	11.6	139	46	NGC 3528	13.0	G	143	128	-0.39
04 16 06:08		5	Astraea	08:19.48	+20 39.7	10.9	584	7	NGC 2558	12.9	G	96	170	-0.37
04 16 06:26		6	Hebe	13:12.80	+12 42.6	10.0	436	24	NGC 5020	11.7	G	156	120	-0.37
04 20 13:01		5	Astraea	08:25.38	+20 28.5	11.0	512	8	NGC 2582	13.0	G	93	121	-0.06
04 24 05:28		92	Undina	14:22.50	+00 18.8	11.5	325	16	NGC 5584	11.4	G	167	164	0.01
04 25 01:23		52768	1998 OR2	09:42.43	+00 23.1	11.5	349	57	NGC 2967	11.6	G	112	90	0.04
04 25 07:27		674	Rachele	11:14.06	+22 08.4	12.0	476	102	UGC 6253	12.0	G	124	101	0.05
04 27 16:42		129	Antigone	19:42.69	-10 16.6	11.2	25	348	NGC 6814	11.2	G	102	152	0.19
04 29 17:06		261	Prymno	15:21.49	-13 13.0	12.1	487	191	NGC 5915	12.3	G	167	116	0.38
04 30 01:20		52768	1998 OR2	10:55.40	-26 04.0	10.8	300	53	NGC 3463	12.9	G	129	63	0.42
05 22 12:55		404	Arsinoe	14:40.91	+03 25.7	11.7	167	144	NGC 5718	12.9	G	150	153	0.00
06 13 16:32		6	Hebe	12:51.43	+12 00.4	10.9	574	241	NGC 4746	12.6	G	104	166	-0.46
06 17 11:25		349	Dembowska	14:45.00	-21 02.0	10.7	486	190	NGC 5743	13.0	G	139	171	-0.14
06 20 08:29		6	Hebe	12:53.41	+11 19.3	11.0	485	49	NGC 4762	10.3	G	98	109	-0.01
07 18 16:04		126	Velleda	20:24.95	-24 40.9	11.9	445	344	NGC 6907	11.2	G	172	148	-0.05
07 20 13:15		753	Tiflis	22:02.75	-32 05.8	12.4	413	123	NGC 7173	12.0	G	150	150	0.00
07 22 09:59		751	Faina	21:55.90	-34 52.7	12.1	433	121	NGC 7154	12.4	G	152	163	0.04
08 18 17:49		737	Arequipa	23:53.50	+07 59.5	11.4	368	285	NGC 7782	12.2	G	144	138	0.00
08 19 15:41		737	Arequipa	23:53.33	+07 52.3	11.4	62	284	NGC 7779	12.7	G	144	150	0.01
08 19 16:45		737	Arequipa	23:53.33	+07 51.9	11.4	24	105	NGC 7778	12.7	G	145	151	0.01
09 11 07:02		102	Miriam	01:24.05	+12 55.4	11.9	56	128	NGC 514	11.6	G	144	65	-0.41
09 18 09:53		7	Iris	18:05.20	-19 43.4	10.2	456	0	NGC 6537	12.0	PN	96	82	0.02
09 21 18:53		185	Eunike	18:39.85	-08 28.3	12.5	56	46	Tr 34	8.6	OC	101	42	0.26
09 23 18:41		1	Ceres	22:32.16	-25 18.1	8.0	293	354	NGC 7294	12.5	G	146	64	0.47
10 15 05:54		471	Papagena	02:40.96	-07 06.3	9.5	498	174	NGC 1051	13.0	G	155	142	-0.04
10 21 14:48		471	Papagena	02:35.60	-07 11.0	9.5	183	180	NGC 991	11.7	G	158	117	0.30
11 08 18:44		471	Papagena	02:18.72	-06 29.7	9.5	335	19	NGC 881	12.4	G	155	110	-0.48
11 10 16:35		194	Prokne	01:49.06	-15 03.0	11.1	245	168	NGC 682	13.0	G	143	142	-0.27
11 15 23:10		196	Philomela	08:22.90	+24 14.3	12.1	181	152	NGC 2575	12.7	G	111	122	0.01
12 09 14:31		163	Erigone	06:08.39	+14 03.1	11.5	367	359	NGC 2169	5.9	OC	163	97	-0.32
12 12 10:14		29	Amphitrite	10:48.02	+12 43.0	10.5	517	22	M105	9.3	G	102	71	-0.07
12 12 23:44		29	Amphitrite	10:48.38	+12 41.1	10.5	196	20	NGC 3384	9.9	G	102	79	-0.04
12 13 12:22		29	Amphitrite	10:48.69	+12 39.3	10.4	467	21	NGC 3389	11.9	G	103	87	-0.02

**LIGHTCURVE ANALYSIS OF L4 TROJAN ASTEROIDS
AT THE CENTER FOR SOLAR SYSTEM STUDIES:
2019 JULY TO SEPTEMBER**

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(Received: 2019 October 7)

Lightcurves for 11 L₄ Jovian Trojan asteroids were obtained at the Center for Solar System Studies (CS3) from 2019 July to September.

CCD Photometric observations of 11 Trojan asteroids from the L₄ (Trojan) Lagrange point were obtained at the Center for Solar System Studies (CS3, MPC U81). For several years, CS3 has been conducting a study of Jovian Trojan asteroids. This is another in a series of papers reporting data analysis being accumulated for family pole and shape model studies. It is anticipated that for most Jovian Trojans, two to five dense lightcurves per target at oppositions well distributed in ecliptic longitudes will be needed and can be supplemented with reliable sparse data for the brighter Trojan asteroids. For all of these targets we were able to get preliminary pole positions and create shape models from sparse data and the dense lightcurves obtained to date. These preliminary models will be improved as more data are acquired at future oppositions and will be published at a later date.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

Telescope	Camera
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.40-m f/10 Schmidt-Cass	Fli Microline 1001E
0.35-m f/10 Schmidt-Cass	Fli Microline 1001E

Table I. List of telescopes and CCD cameras used at CS3.

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). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the CMC-15 or the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs, among others. The authors state that systematic errors are generally no larger than 0.005 mag, although they can reach 0.02 mag in small areas near the Galactic plane. BVRI magnitudes were derived by Warner using formulae from Kostov and Boney (2017). The overall errors for the BVRI magnitudes, when combining those in the ATLAS catalog and the conversion formulae, are on the order of 0.04-0.05 mag.

Even so, we found in most cases that nightly zero point adjustments for the ATLAS catalog to be on the order of only 0.02-0.03 mag were required during period analysis. There were

occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centroiding of the reference stars, and not correcting for second-order extinction terms. Regardless, the systematic errors seem to be considerably less than other catalogs, which reduces the uncertainty in the results when analysis involves data from extended periods or the asteroid is tumbling.

In the lightcurve plots, the Y-axis may be labeled “Reduced Magnitude” or “Magnitude.” Unless otherwise indicated, the values are Johnson V. The latter are sky (catalog-derived) magnitudes while “Reduced Magnitude” indicates that sky magnitudes were corrected to unity distances by applying $-5 \cdot \log(r\Delta)$ 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 $G = 0.15$. The X-axis rotational phase ranges from -0.05 to 1.05 .

The amplitude indicated in the plots (e.g. Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

Targets were selected for this L₄ observing campaign based upon the availability of dense lightcurves acquired in previous years. We obtained two to four lightcurves for most of these Trojans at previous oppositions.

For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

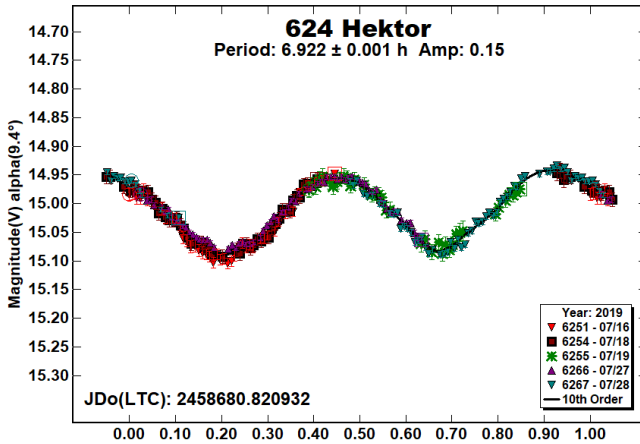
To evaluate the quality of the data obtained and to determine how much more data might be needed, preliminary pole and shape models were created for all of these targets. Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (<http://hamilton.dm.unipi.it/asdys2/>). These sparse data were combined with our dense data as well as any other dense data found in the ALCDEF asteroid photometry database (<http://www.alcdef.org/>) using *MPO LCInvert*, (Bdw Publishing). This Windows-based program incorporates the algorithms developed by Kassalain et al (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values.

624 Hektor. Hektor has been previously found to be a binary asteroid (Marchis et al., 2006) with a primary that might have a bilobated shape approximately 350x210 km and a secondary estimated to be 15 km in size. They found a pole position with ecliptic coordinates of $\lambda_1 = 332^\circ$ and $\beta_1 = -32^\circ$. Pole positions have been independently found a number of times over the years, the latest by Hanus et al. (2015), which is similar to the Marchis et al solution. Both solutions reported a sidereal period of 6.920509 ± 0.000005 h.

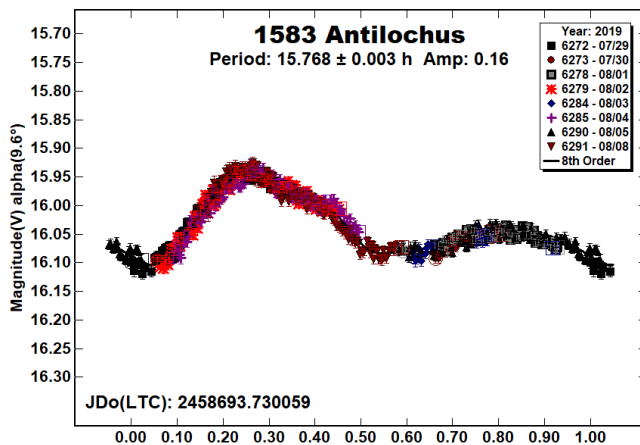
The synodic period found this year produced a classic bimodal lightcurve consistent with rotational periods found in previous years. We combined these data with our data from 2014 (Stephens et al., 2014) and available sparse data to create a preliminary shape model with a pole position of $\lambda_1 = 336^\circ$ and $\beta_1 = -22^\circ$ and a sidereal period of 6.92051 ± 0.00001 h, consistent with the prior findings.

Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
624	Hektor	07/16-07/28	9.4, 8.0	348	0	6.922	0.001	0.15	0.01
1583	Antilochus	07/29-08/08	9.6, 8.5	350	26	15.768	0.003	0.16	0.02
1868	Thersites	08/09-08/12	3.8, 3.7	317	16	10.492	0.004	0.27	0.02
2920	Automedon	08/17-08/21	5.2, 5.0	332	23	10.192	0.003	0.31	0.02
3709	Polypoites	08/10-08/13	3.7, 3.8	313	18	10.02	0.12	0.12	0.02
3793	Leonteus	08/28-08/30	3.4, 3.3	335	17	5.621	0.001	0.24	0.02
4060	Deipylos	08/17-08/22	2.0, 2.6	318	9	9.29	0.01	0.18	0.02
4501	Eurypylos	08/31-09/07	2.5, 2.0	344	9	6.941	0.002	0.23	0.02
5244	Amphilochos	08/23-08/27	3.0, 2.3	342	5	9.793	0.002	0.57	0.02
15436	1998 VU30	08/22-08/25	3.7, 3.8	325	17	8.970	0.002	0.33	0.02
15527	1999 YY2	08/27-08/29	3.4, 3.6	326	11	6.968	0.003	0.5	0.02

Table II. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).

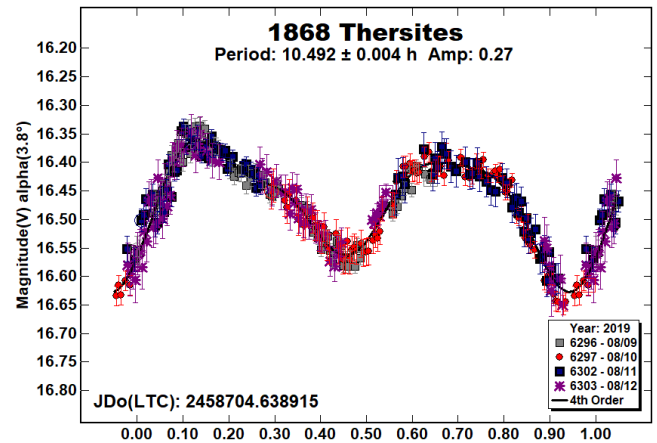


1583 Antilochus. We observed Antilochus four times in the past. Lightcurves obtained in 2009, 2016, 2017 and 2018 (Stephens 2010), Stephens et al. (2016b), Stephens and Warner (2018 and 2019). Over this timespan the amplitude increased from 0.05 to 0.31 mag. The 2009 and 2016 data produced a single modal lightcurve while the 2017 to 2019 observations resulted in bimodal lightcurves. The data collected this year, when combined with our previous data and available sparse data, were used to create a preliminary shape model with a sidereal rotational period of 15.77132 ± 0.00001 h was created.

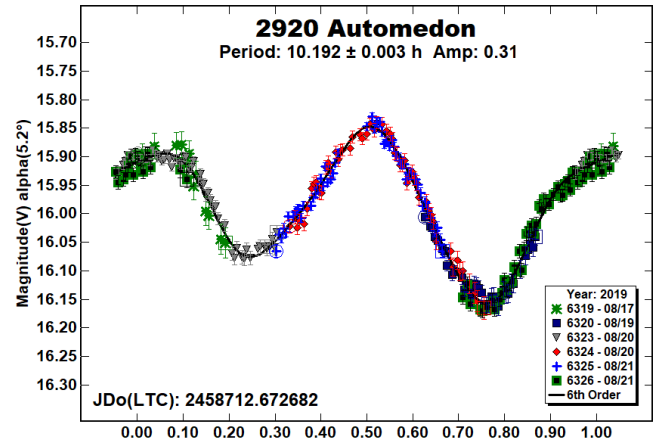


1868 Thersites. We have observed this L_4 Jovian Trojan twice in the past (Stephens et al. 2016b; Stephens and Warner 2018) reporting rotational periods near 10.4 h. Mottola et al. (2011) found a rotational period of 10.416 h. Using sparse data from the Asteroids – Dynamic Site, combined with our data, a preliminary

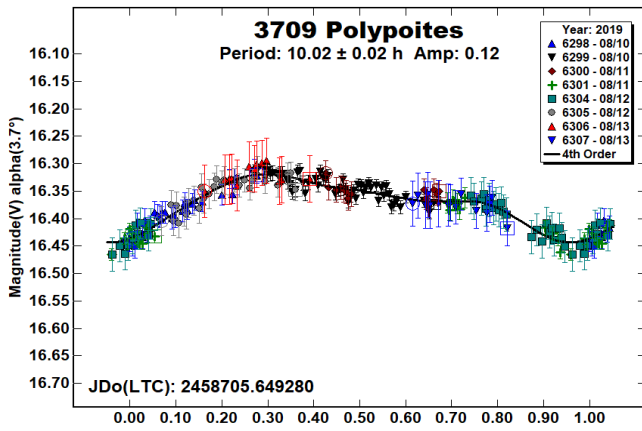
shape model with a sidereal rotational period of 10.47520 ± 0.00001 h was found.



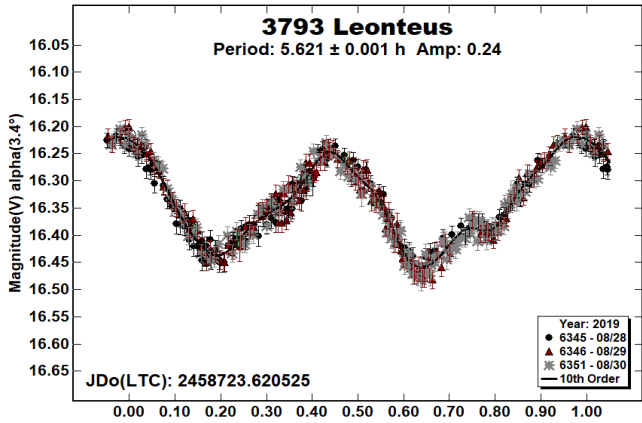
2920 Automedon. The synodic period found in 2019 using CS3 data agrees with previous synodic results (Molnar et al., 2008; Mottola et al., 2011; Stephens and Warner 2017 and 2019) near 10.2 h. The data analysis in 2019 is in good agreement and when combined with our previous data and available sparse data, were used to create a preliminary shape model with a sidereal rotational period of 10.20598 ± 0.00001 h.



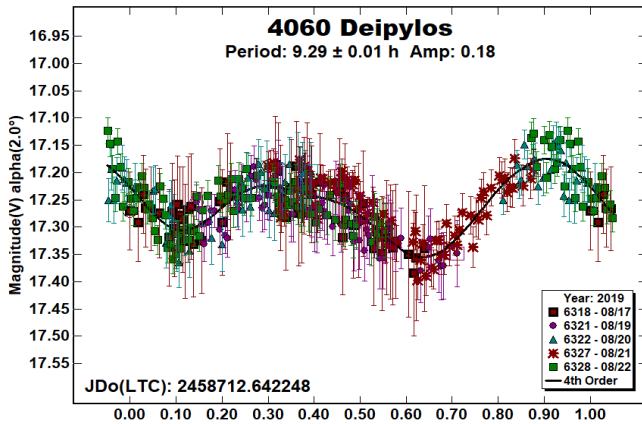
3709 Polypoites. We observed this Trojan five times in the past (French et al., 2011; Stephens et al., 2016a; 2016b; 2017; and 2019), each time finding a period near 10.04 h. The 2019 data resulted in a monomodal lightcurve that in good agreement with those prior results. We were able to create a preliminary shape model with a sidereal rotational period of 10.03705 ± 0.00001 h.



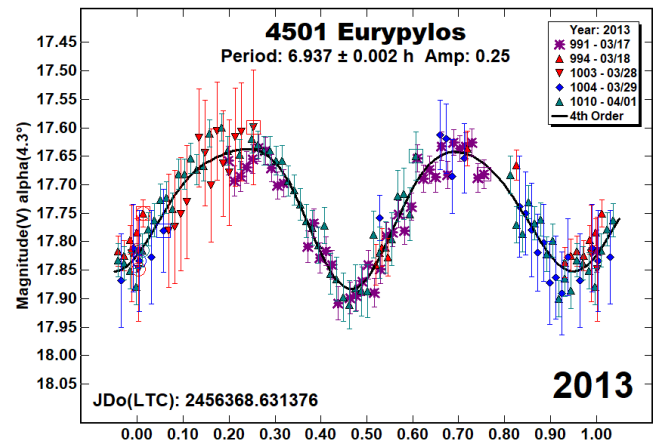
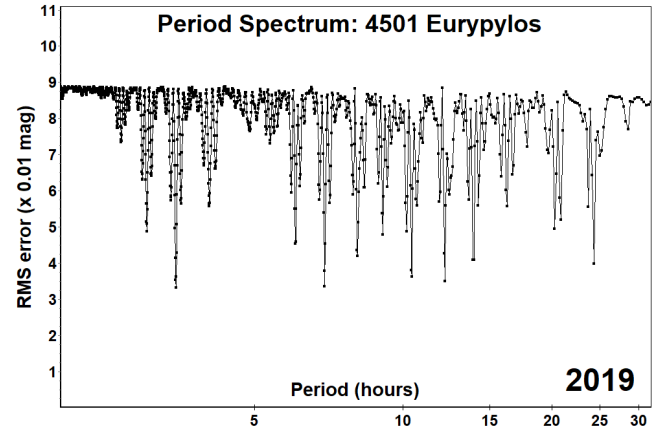
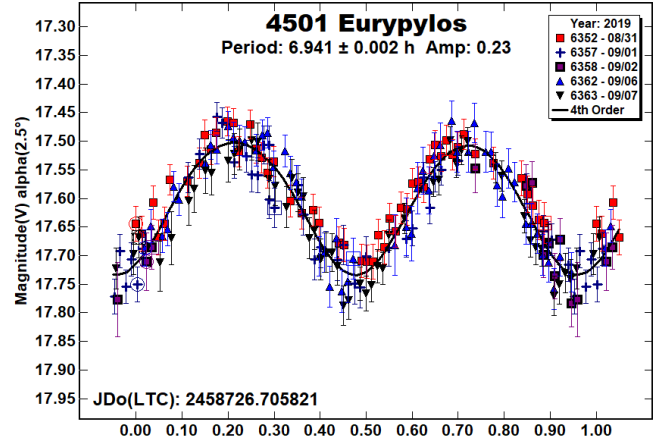
3793 Leonteus. This large Trojan has been well studied in the past. Mottola et al., (2011) observed it in 1994 and 1997. We found periods in 2009, 2015, 2016 and 2018 (Stephens et al., 2016a; 2016b; and 2019). Each of these periods was found to be close to 5.62 h. This year’s data analysis result is in good agreement. We were able to create a preliminary shape model with a sidereal rotational period of 5.62192 ± 0.00001 h.

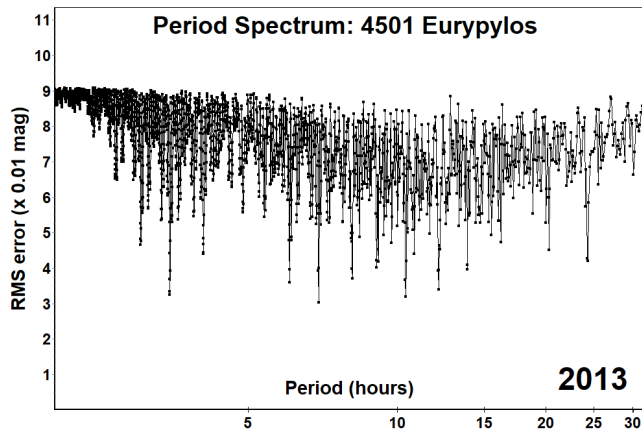


4060 Deipylos. Using sparse photometry from the Palomar Transient Factory, Waszczak et al. (2015) reported a period of 11.4905 h for Deipylos. We observed it four times (Stephens et al 2016a; 2016b; 2017; and 2019) finding periods near 9.3 h. That period appears to be a 5:4 alias of the Waszczak et al. period. The data from 2019 are noisy but the result of 9.29 h, but in good agreement with our prior results. We were able to create a preliminary shape model with a sidereal rotational period of 9.30836 ± 0.00001 h.

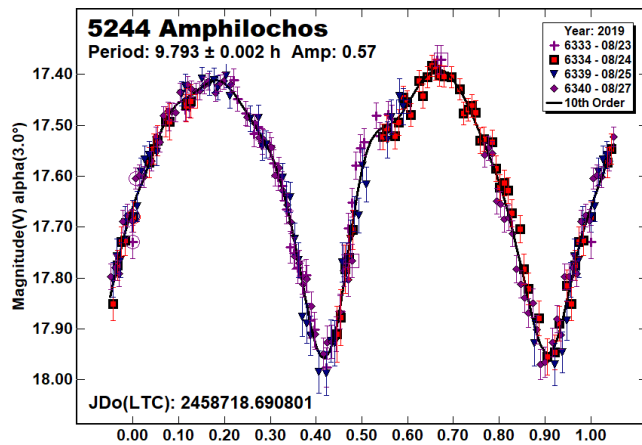


4501 Eurypylos. Only one prior rotational period is reported in the lightcurve database (LCDB; Warner et al., 2009), which is from our data in 2013 (French et al. 2013) when we reported a rotational period of 6.054 h. The data we collected in 2019 were not a good fit to that rotational period. The period spectrum for the 2019 data shows the half period near 3.5 h, the preferred period of 6.9 h, and an 8:7 alias near 6 h. Rephasing the 2013 data to the 6.9 h period shows a good fit after eliminating a couple of outlier data points. The new period spectrum for the 2013 data now shows the preferred period to be 6.937 h. Using sparse data from the Asteroids – Dynamic Site, we were able to create a preliminary shape model with a sidereal rotational period of 6.93545 ± 0.00001 h.

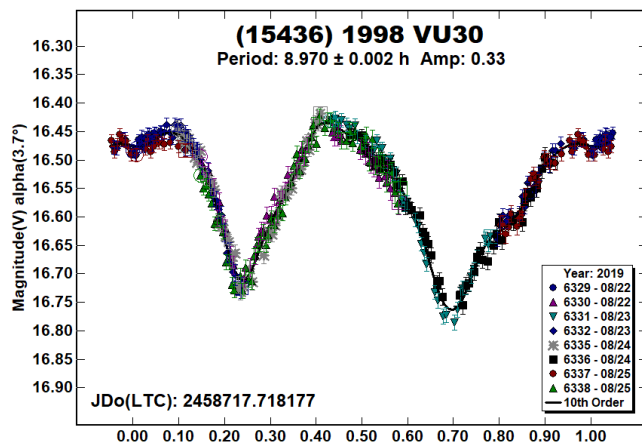




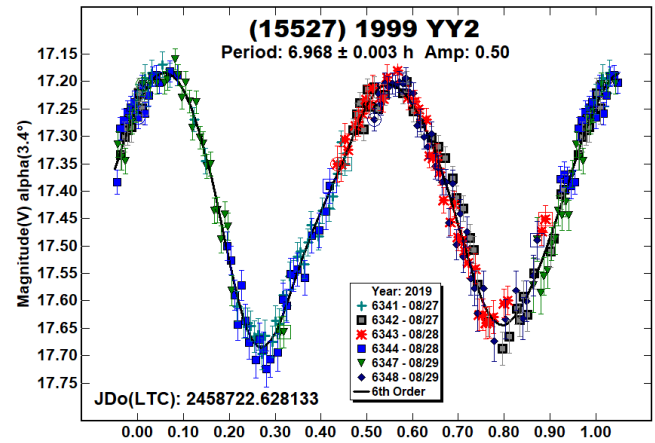
5244 Amphilochos. We observed this L₄ Trojan once before (Stephens et al., 2016b) and found a rotational period of 9.768 h. This year's result is in good agreement. The lightcurves from both oppositions had relatively large amplitudes. The shoulders present in the 2019 data are suggestive of being a bilobed object. Using sparse data from the Asteroids – Dynamic Site, we were able to create a preliminary shape model with a sidereal rotational period of 9.78572 ± 0.00001 h.



(15436) 1998 VU30. We observed this Trojan twice in the past (French et al. 2013 and Stephens et al. 2016b) and both times found a rotational period of 8.97 h. This year's result agrees with those periods. Using sparse data from the Asteroids – Dynamic Site, we were able to create a preliminary shape model with a sidereal rotational period of 8.96657 ± 0.00001 h.



(15527) 1999 YY2. We observed this Trojan once before (Stephens and Warner, 2017) and found a rotational period of 6.9903 h. This year's result is in good agreement. Using sparse data from the Asteroids – Dynamic Site, we were able to create a preliminary shape model with a sidereal rotational period of 6.99181 ± 0.00001 h.



Acknowledgements

Observations at CS3 and continued support of the asteroid lightcurve database (LCDB; Warner et al., 2009) are supported by NASA grant 80NSSC18K0851. Work on the asteroid lightcurve database (LCDB) was also partially funded 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) (<http://svo2.cab.inta-csic.es/vocats/cmc15/>). This work includes data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. ATLAS is primarily funded to search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen's University Belfast, the Space Telescope Science Institute, and the South African Astronomical Observatory. The purchase of a FLI-1001E CCD camera was made possible by a 2013 Gene Shoemaker NEO Grants from the Planetary Society.

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MINOR PLANETS AT UNUSUALLY FAVORABLE ELONGATIONS IN 2020

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A list is presented of minor planets which are much brighter than usual at their 2020 apparitions.

The minor planets in the lists which follow will be much brighter at their 2020 apparitions than at their average distances at maximum elongation. Many years may pass before these planets will be again as bright as in 2020. Observers are encouraged to give special attention to those which lie near the limit of their equipment.

These lists have been prepared by an examination of the maximum elongation circumstances of minor planets computed by the author for all years through 2060 with a full perturbation program written by Dr. John Reed, and to whom he expresses his thanks. Elements are from EMP 1992, except that for all planets for which new or improved elements have been published subsequently in the Minor Planet Circulars or in electronic form, the newer elements have been used. Planetary positions are from the JPL DE-200 ephemeris, courtesy of Dr. E. Myles Standish.

Any planets whose brightest magnitudes near the time of maximum elongation vary by at least 2.0 in this interval and in 2020 will be within 0.3 of the brightest occurring, or vary by at least 3.0 and in 2020 will be within 0.5 of the brightest occurring; and which are visual magnitude 14.5 or brighter, are included. For planets brighter than visual magnitude 13.5, which are within the range of a large number of observers, these standards have been relaxed somewhat to include a larger number of planets. Magnitudes have been computed from the updated magnitude parameters published in MPC28104-28116, on 1996 Nov. 25, or more recently in the Minor Planet Circulars.

Oppositions may be in right ascension or in celestial longitude. Here we use still a third representation, maximum elongation from the Sun, instead of opposition. Though unconventional, it has the advantage that many close approaches do not involve actual opposition to the Sun near the time of minimum distance and greatest brightness and are missed by an opposition-based program. Other data are also provided according to the following tabular listings: Minor planet number, date of maximum elongation from the Sun in format yyyy/mm/dd, maximum elongation in degrees, right ascension on date of maximum elongation, declination on date of maximum elongation, both in J2000 coordinates, date of brightest magnitude in format yyyy/mm/dd, brightest magnitude, date of minimum distance in format yyyy/mm/dd, and minimum distance in AU.

Users should note that when the maximum elongation is about 177° or greater, the brightest magnitude is sharply peaked due to enhanced brightening near zero phase angle. Even as near as 10 days before or after minimum magnitude the magnitude is generally about 0.4 greater. This effect takes place in greater time interval for smaller maximum elongations. There is some interest in very small minimum phase angles. For maximum elongations E near 180° at Earth distance Δ, an approximate formula for the minimum phase angle φ is $\phi = (180^\circ - E) / (\Delta + 1)$.

Planet	Max Elon D	Max E	RA	Dec	Br Mag D	Br Mag	Min Dist D	Min Dist	Planet	Max Elon D	Max E	RA	Dec	Br Mag D	Br Mag	Min Dist D	Min Dist
582	2020/02/25	179.7°	10h30m	+ 9°	2020/02/25	11.2	2020/02/20	1.176	6792	2020/09/23	171.7°	0h17m	- 7°	2020/09/23	14.2	2020/09/23	0.798
516	2020/02/29	175.2°	10h41m	+ 3°	2020/03/01	10.7	2020/03/11	1.233	62	2020/09/24	177.0°	0h12m	- 1°	2020/09/24	12.2	2020/09/27	1.693
2134	2020/02/29	140.5°	11h13m	+46°	2020/02/26	14.2	2020/02/26	1.113	4945	2020/09/24	177.7°	0h 2m	+ 2°	2020/09/24	14.0	2020/09/14	0.803
1263	2020/03/06	172.5°	11h23m	+12°	2020/03/05	13.7	2020/02/29	1.511	225	2020/09/29	173.7°	0h12m	+ 8°	2020/09/28	12.6	2020/09/20	1.828
485	2020/03/08	169.4°	10h54m	- 4°	2020/03/06	11.4	2020/03/02	1.432	2299	2020/09/29	177.6°	0h27m	+ 0°	2020/09/29	14.5	2020/09/21	0.858
949	2020/03/30	166.4°	12h15m	-16°	2020/03/30	12.9	2020/04/02	1.466	68	2020/09/30	171.5°	0h39m	- 5°	2020/09/30	9.5	2020/09/26	1.289
663	2020/04/30	173.6°	14h22m	-20°	2020/04/30	12.7	2020/04/28	1.681	2534	2020/10/02	179.3°	0h37m	+ 3°	2020/10/02	14.1	2020/10/01	1.622
404	2020/05/02	158.8°	14h58m	+ 5°	2020/05/02	11.5	2020/05/02	1.110	1024	2020/10/04	158.3°	1h 9m	-16°	2020/10/04	13.5	2020/10/03	1.273
638	2020/05/03	168.2°	14h56m	- 4°	2020/05/04	12.6	2020/05/05	1.307	574	2020/10/05	172.5°	0h35m	+12°	2020/10/06	13.5	2020/10/12	0.799
910	2020/05/06	178.9°	14h55m	-15°	2020/05/06	13.3	2020/05/10	1.517	2819	2020/10/05	179.3°	0h44m	+ 4°	2020/10/05	14.4	2020/10/02	1.207
632	2020/05/09	176.7°	15h 1m	-20°	2020/05/09	13.8	2020/05/13	1.169	4132	2020/10/05	159.8°	1h36m	-10°	2020/10/09	13.5	2020/10/15	0.892
849	2020/05/14	176.9°	15h28m	-15°	2020/05/14	11.6	2020/05/20	1.709	1564	2020/10/06	174.9°	0h58m	+ 0°	2020/10/06	14.3	2020/10/09	1.625
312	2020/05/16	167.9°	15h40m	-31°	2020/05/17	11.9	2020/05/21	1.387	1928	2020/10/06	177.9°	0h53m	+ 3°	2020/10/06	14.5	2020/09/29	1.035
1594	2020/05/21	177.0°	15h53m	-17°	2020/05/21	13.7	2020/05/29	0.926	6265	2020/10/06	175.3°	0h56m	+ 0°	2020/10/06	14.7	2020/09/27	0.836
4844	2020/05/21	178.4°	15h51m	-21°	2020/05/21	14.0	2020/05/22	0.986	21652	2020/10/06	156.4°	0h 9m	+26°	2020/10/04	14.5	2020/09/30	1.019
1396	2020/05/24	171.3°	16h 1m	-29°	2020/05/25	13.5	2020/05/28	0.887	713	2020/10/07	173.7°	0h42m	+11°	2020/10/07	12.9	2020/10/05	1.893
544	2020/05/31	168.5°	16h22m	-33°	2020/05/31	12.5	2020/06/04	1.236	21182	2020/10/08	177.1°	0h57m	+ 8°	2020/10/08	14.5	2020/10/14	0.777
1715	2020/06/07	163.6°	17h 7m	-30°	2020/06/07	13.6	2020/06/05	0.829	193	2020/10/10	168.5°	0h50m	+17°	2020/10/12	11.7	2020/10/20	1.014
769	2020/06/09	172.2°	17h 9m	-30°	2020/06/09	12.4	2020/06/13	1.632	518	2020/10/10	178.5°	1h 1m	+ 8°	2020/10/10	13.0	2020/09/30	1.119
1304	2020/06/13	178.0°	17h29m	-21°	2020/06/13	12.3	2020/06/12	1.838	747	2020/10/11	147.3°	2h10m	-21°	2020/10/16	10.3	2020/10/18	1.116
163348	2020/06/13	173.8°	17h39m	-17°	2020/06/10	14.3	2020/06/06	0.034	102	2020/10/12	177.9°	1h 7m	+ 9°	2020/10/12	11.0	2020/10/07	1.021
1712	2020/06/15	165.0°	17h44m	- 8°	2020/06/15	13.5	2020/06/14	1.693	1171	2020/10/12	175.1°	1h17m	+ 2°	2020/10/12	13.3	2020/10/15	1.637
5971	2020/06/17	170.5°	17h40m	-32°	2020/06/18	14.5	2020/06/21	1.193	296	2020/10/20	176.3°	1h47m	+ 3°	2020/10/20	14.0	2020/10/17	0.884
52768	2020/06/21	156.6°	17h20m	-45°	2020/05/01	11.2	2020/04/29	0.042	512	2020/10/23	159.6°	2h15m	- 8°	2020/10/19	11.8	2020/10/12	0.710
7750	2020/06/24	164.4°	18h26m	- 8°	2020/06/28	14.2	2020/07/08	0.841	200	2020/10/24	169.1°	1h43m	+22°	2020/10/25	11.3	2020/10/25	1.407
2308	2020/06/27	156.2°	18h38m	-47°	2020/06/26	14.4	2020/06/25	1.143	735	2020/10/24	172.2°	2h 1m	+ 4°	2020/10/23	11.3	2020/10/14	0.948
56	2020/06/28	163.8°	18h29m	- 7°	2020/06/30	10.4	2020/07/03	1.004	1700	2020/10/25	174.4°	1h50m	+17°	2020/10/24	13.8	2020/10/19	0.855
699	2020/06/28	157.6°	18h47m	- 1°	2020/07/08	13.0	2020/07/20	0.722	471	2020/10/27	159.2°	2h30m	- 7°	2020/10/27	9.5	2020/10/27	1.275
6634	2020/06/29	165.6°	18h38m	- 8°	2020/07/01	14.2	2020/07/07	0.787	4103	2020/10/30	164.6°	2h 9m	+29°	2020/10/28	13.4	2020/10/23	1.053
2604	2020/07/04	167.8°	18h41m	-11°	2020/07/03	14.4	2020/06/29	0.850	23997	2020/10/30	171.3°	2h14m	+22°	2020/10/31	14.4	2020/11/04	0.907
2896	2020/07/05	167.4°	18h53m	-10°	2020/07/06	14.0	2020/07/07	0.802	8	2020/11/01	168.1°	2h41m	+ 3°	2020/11/01	8.0	2020/10/31	0.876
335	2020/07/11	173.5°	19h16m	-15°	2020/07/11	10.9	2020/07/10	1.034	499	2020/11/03	178.2°	2h31m	+16°	2020/11/03	13.8	2020/11/05	2.226
3266	2020/07/13	179.3°	19h31m	-22°	2020/07/13	14.5	2020/07/18	0.814	41223	2020/11/03	174.5°	2h33m	+20°	2020/11/02	14.3	2020/10/20	0.778
197	2020/07/14	172.0°	19h44m	-29°	2020/07/15	12.0	2020/07/18	1.336	383	2020/11/05	176.7°	2h48m	+12°	2020/11/05	13.2	2020/11/06	1.633
1608	2020/07/15	172.2°	19h44m	-29°	2020/07/15	14.3	2020/07/18	0.842	2525	2020/11/07	177.1°	2h54m	+13°	2020/11/07	13.9	2020/11/03	1.658
6569	2020/07/15	169.6°	20h20m	-26°	2020/07/15	14.7	2020/07/12	0.262	1578	2020/11/09	179.5°	3h 0m	+16°	2020/11/09	14.3	2020/11/12	2.061
129	2020/07/16	171.9°	19h34m	-13°	2020/07/15	9.9	2020/07/09	1.373	523	2020/11/14	176.6°	3h17m	+21°	2020/11/15	12.7	2020/11/18	1.527
1650	2020/07/20	174.8°	19h55m	-15°	2020/07/20	13.7	2020/07/15	1.094	177	2020/11/15	177.6°	3h19m	+20°	2020/11/14	11.7	2020/11/09	1.175
967	2020/07/22	172.7°	20h16m	-7°	2020/07/22	13.4	2020/07/24	0.846	21242	2020/11/18	179.5°	3h36m	+19°	2020/11/18	14.3	2020/11/11	0.741
3519	2020/07/24	178.7°	20h18m	-20°	2020/07/24	13.9	2020/07/23	0.772	266	2020/11/19	179.3°	3h38m	+18°	2020/11/19	11.6	2020/11/15	1.425
1180	2020/07/26	174.0°	20h31m	-25°	2020/07/26	13.9	2020/07/25	2.364	457	2020/11/19	175.5°	3h35m	+23°	2020/11/19	14.1	2020/11/15	1.654
530	2020/07/28	179.1°	20h32m	-17°	2020/07/28	12.3	2020/07/31	1.510	1313	2020/11/19	159.6°	3h10m	+38°	2020/11/18	14.4	2020/11/15	1.171
885	2020/08/01	178.1°	20h43m	-16°	2020/08/01	14.0	2020/08/05	1.622	157	2020/11/21	178.7°	3h47m	+18°	2020/11/21	12.8	2020/11/26	1.207
577	2020/08/03	177.4°	20h56m	-19°	2020/08/03	12.8	2020/08/01	1.622	748	2020/11/25	178.8°	4h 4m	+22°	2020/11/25	13.4	2020/11/26	2.248
221	2020/08/08	178.1°	21h 9m	-14°	2020/08/08	11.1	2020/08/08	1.701	305	2020/11/26	175.7°	4h12m	+16°	2020/11/26	12.1	2020/11/30	1.616
1978	2020/08/09	169.6°	21h33m	-25°	2020/08/09	13.9	2020/08/10	0.719	2215	2020/11/30	178.8°	4h25m	+20°	2020/11/30	13.9	2020/11/25	1.111
1093	2020/08/10	137.6°	21h47m	-54°	2020/08/07	12.3	2020/08/05	1.437	153201	2020/12/02	176.8°	4h28m	+24°	2020/11/30	13.2	2020/11/29	0.029
1514	2020/08/15	179.4°	21h39m	-13°	2020/08/15	13.4	2020/08/14	0.781	1934	2020/12/03	163.0°	4h26m	+ 5°	2020/11/29	14.3	2020/11/22	0.823
4369	2020/08/18	169.3°	21h44m	- 2°	2020/08/20	14.1	2020/08/26	1.087	2617	2020/12/05	179.3°	4h51m	+22°	2020/12/05	13.2	2020/12/03	1.427
2532	2020/08/20	177.3°	22h 2m	-14°	2020/08/20	14.3	2020/08/23	0.983	1463	2020/12/09	168.9°	4h58m	+33°	2020/12/08	14.1	2020/12/05	1.615
550	2020/08/21	162.8°	21h44m	+ 4°	2020/08/20	11.6	2020/08/18	1.031	4729	2020/12/09	179.5°	5h 5m	+22°	2020/12/09	14.5	2020/12/02	0.978
138	2020/08/22	173.7°	22h15m	-17°	2020/08/22	10.7	2020/08/19	1.050	2950	2020/12/14	171.2°	5h29m	+14°	2020/12/14	14.2	2020/12/08	1.136
870	2020/08/23	172.5°	22h23m	-18°	2020/08/22	13.9	2020/08/18	0.706	3935	2020/12/14	169.5°	5h22m	+33°	2020/12/13	14.2	2020/12/08	1.048
5026																	

MAIN-BELT ASTEROIDS OBSERVED FROM CS3: 2019 JULY TO SEPTEMBER

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CCD photometric observations of 25 main-belt asteroids were obtained at the Center for Solar System Studies (CS3) from 2019 July to September.

The Center for Solar System Studies (CS3) has seven telescopes which are normally used in program asteroid family studies. The focus is on near-Earth asteroids, but when suitable targets are not available, Jovian Trojans and Hildas are observed. When a nearly full moon is too close to the family targets being studied, targets of opportunity amongst the main-belt families were selected.

Table I lists the telescopes and CCD cameras that were used to make the observations. Images were unbinned with no filter and had master flats and darks applied. The exposures depended upon various factors including magnitude of the target, sky motion, and Moon illumination.

Telescope	Camera
0.30-m f/6.3 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/9.1 Schmidt-Cass	FLI Microline 1001E
0.35-m f/11 Schmidt-Cass	FLI Microline 1001E
0.40-m f/10 Schmidt-Cass	FLI Proline 1001E
0.50-m F8.1 R-C	FLI Proline 1001E

Table I: List of CS3 telescope/CCD camera combinations.

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). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the CMC-15 or the ATLAS catalog (Tonry et al., 2018), which has Sloan *griz* magnitudes that were derived from the GAIA and Pan-STARR catalogs, among others. The authors state that systematic errors are generally no larger than 0.005 mag, although they can reach 0.02 mag in small areas near the Galactic plane. BVRI magnitudes were derived by Warner using formulae from Kostov and Bonev (2017). The overall errors for the BVRI magnitudes, when combining those in the ATLAS catalog and the conversion formulae, are on the order of 0.04-0.05 mag.

Even so, we found in most cases that nightly zero point adjustments for the ATLAS catalog to be on the order of only 0.02-0.03 mag were required during period analysis. There were occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centering of the reference stars, and not correcting for second-order extinction terms. Regardless, the systematic errors seem to be considerably less than other catalogs, which reduces the

uncertainty in the results when analysis involves data from extended periods or the asteroid is tumbling.

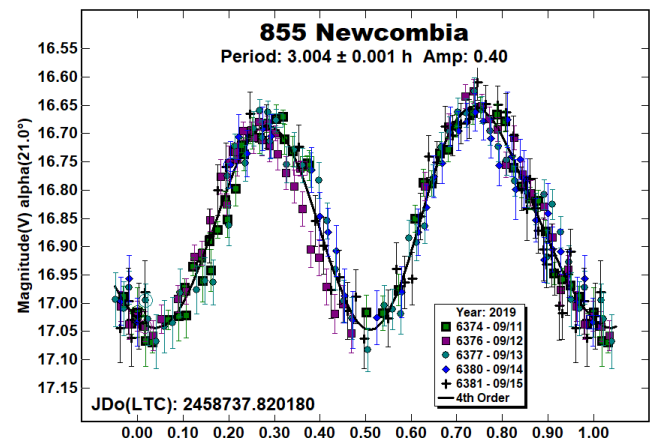
The Y-axis for some lightcurves may be given as “Reduced Magnitude” instead of “Magnitude.” Both are Johnson V with the former corrected to a unity distance by applying $-5 \cdot \log(r\Delta)$ to the measured sky magnitudes with r and Δ being, respectively, the Sun-asteroid and the Earth-asteroid distances in AU. Otherwise, the values are the sky magnitudes. The magnitudes were normalized to the phase angle given in parentheses using $G = 0.15$. The X-axis rotational phase ranges from -0.05 to 1.05 .

In the lightcurve plots, the Y-axis may be labeled “Reduced Magnitude” or “Magnitude.” Unless otherwise indicated, the values are Johnson V. The latter are sky (catalog-derived) magnitudes while “Reduced Magnitude” indicates that sky magnitudes were corrected to unity distances by applying $-5 \cdot \log(r\Delta)$ 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 $G = 0.15$. The X-axis rotational phase ranges from -0.05 to 1.05 .

The amplitude indicated in the plots (e.g. Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

For brevity, only some of the previously reported rotational periods may be referenced. A complete list is available at the lightcurve database (LCDB; Warner et al., 2009).

855 Newcombia. Per the LCDB, this inner main-belt asteroid has been observed several times in the past. Cooney et al. (2007); Klinglesmith et al. (2014, 2016, 2017); and Stephens (2014) all found periods near 3.004 h, in agreement with this year’s result.

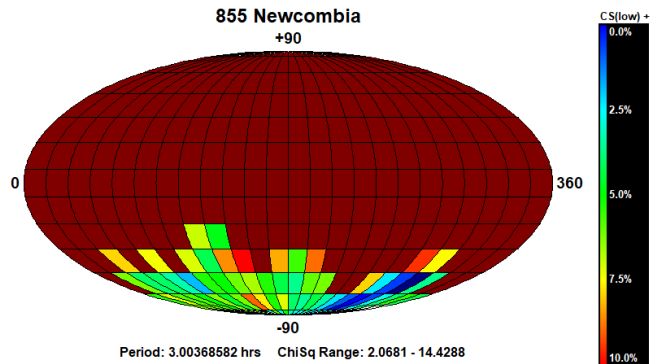
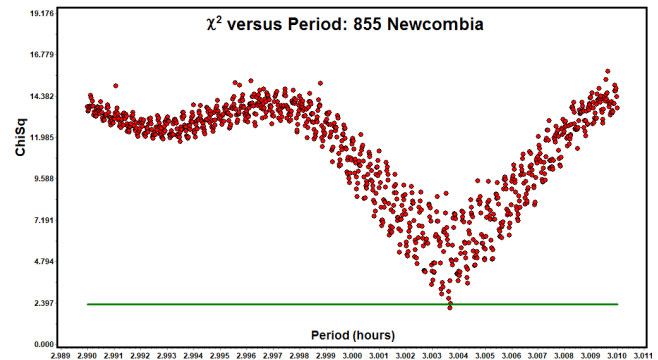
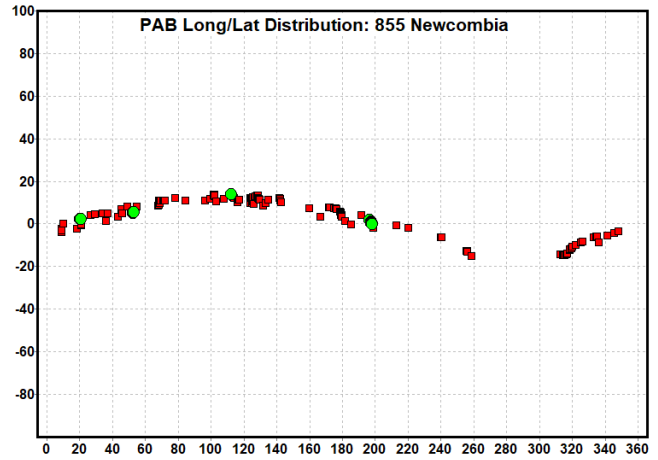
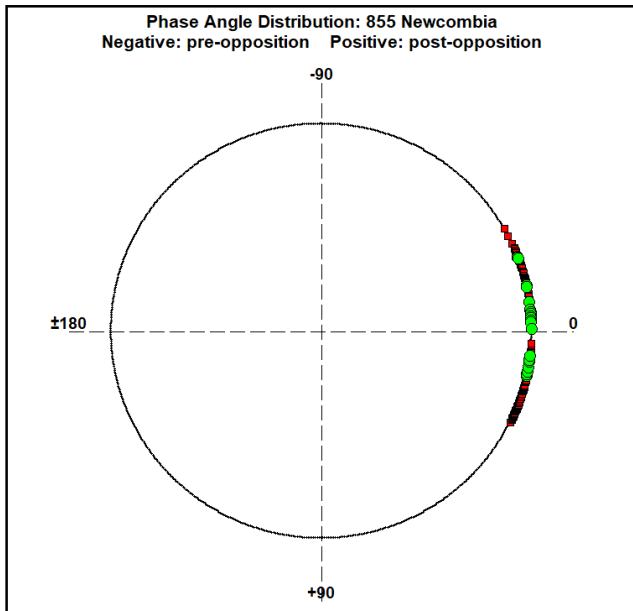
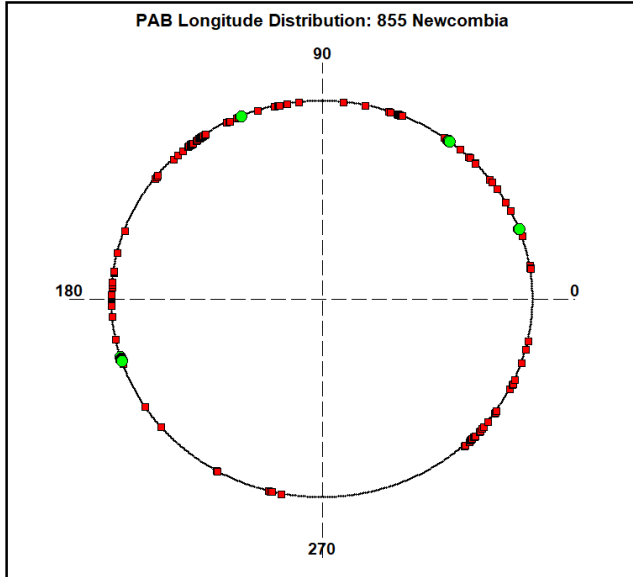


The Klinglesmith data were available in the ALCDEF asteroid photometry database (<http://www.alcdef.org/>) (Warner et al. 2011), so we attempted a pole and shape model.

Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (<http://hamilton.dm.unipi.it/asdys2/>). These sparse data were combined with our dense data using *MPO LCInvert*, (Bdw Publishing). This Windows-based program incorporates the algorithms developed by Kassalain et al (2001a, 2001b) and converted by Josef Durech from the original FORTRAN to C. A period search was made over a sufficiently wide range to assure finding a global minimum in χ^2 values.

The modeling processing using lightcurve inversion has been detailed previously (e.g., Warner et al., 2017, and references therein). The idea is to find a shape and its orientation such that its modeled lightcurves closely match the original data. Main-belt asteroids usually require data from at least three oppositions at different phase angle bisector longitudes before a reliable model can be developed.

In the PAB longitude plot, green circles represent dense lightcurves while red squares represent sparse data from one or more of the surveys. The green line in the period plot lies 10% above the lowest χ^2 value. This was an ideal solution as it has a well-defined shape with only one data point below the line.



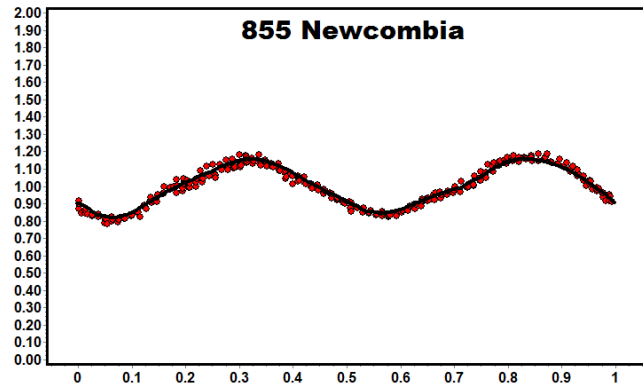
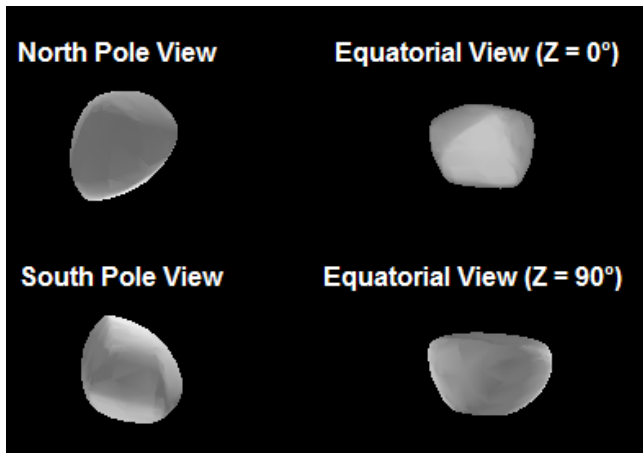
In the pole plot, dark red represents a solution that is more than 10% above the lowest χ^2 value. A “perfect” solution is when there is only one dark blue region and all the others are dark red. This result shows a strong solution of ecliptic coordinates $(287^\circ, -72^\circ, 3.003687 \text{ h})$ and a weak, competing solution of $(61^\circ, -73^\circ, 3.003687 \text{ h})$, which is about 180° apart. The longitude mirroring is a common trait of the inversion process.

We chose $(287^\circ, -72^\circ, 3.003687 \text{ h})$ because it had the lowest χ^2 value. In both cases, the estimated error for the pole is a circle of about 10° radius and 0.000001 h for the period.

The solid black line in the lightcurve plots is the model lightcurve and the red dots are the original data. The model curves in are from the solution for ecliptic coordinates $(287^\circ, -72^\circ)$ although the fits to the model based on $(61^\circ, -73^\circ)$ are essentially identical.

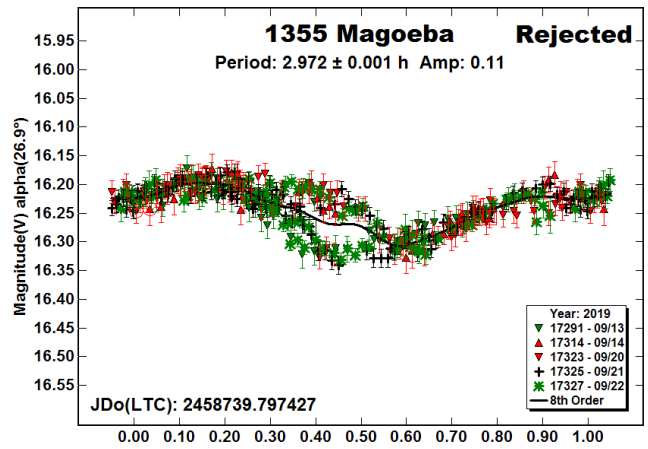
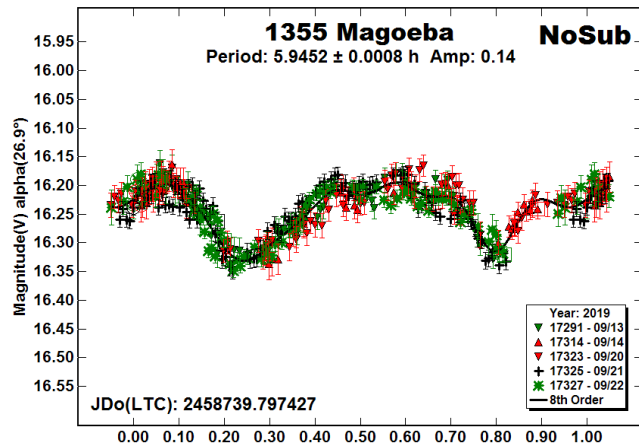
855 Newcombia	Ecliptic Long/Lat	Sidereal Period (hours)
Preferred	$(287^\circ, -72^\circ)$	3.003687 ± 0.000001
Alternate	$(61^\circ, -73^\circ)$	

Table II. The two pole solutions for 855 Newcombia. It is common in lightcurve inversion to get two solutions that differ by about 180° in longitude.

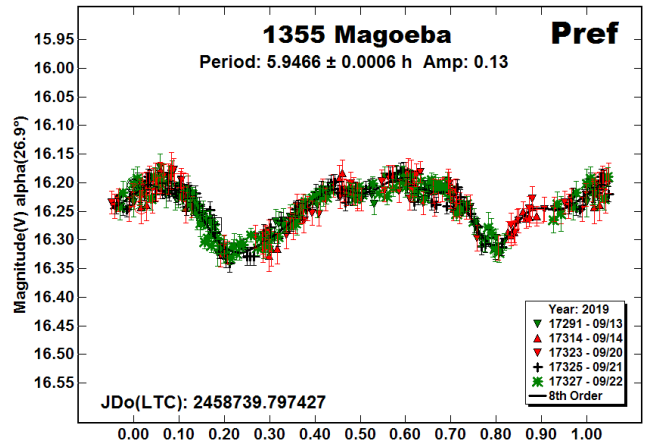
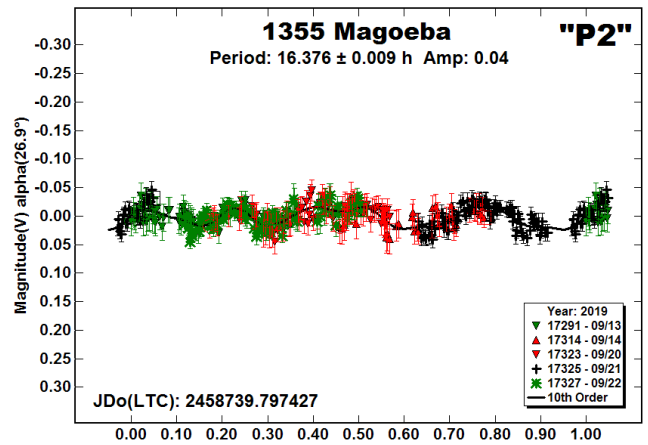


1355 Magoeba. This Hungaria has been observed numerous times by Warner (2007; 2010a; 2011a; 2013a; and 2015a). With each new set of observations, the solution seemed to favor a new period. Eventually, they settled to an ambiguous solution of about 2.9 h or 5.9 h. The observations in 2014 (Warner, 2015a), indicated the possibility of a satellite with an orbital period of about 15 h.

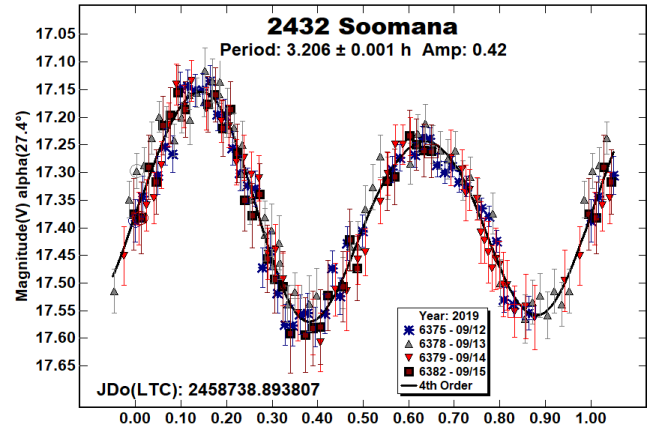
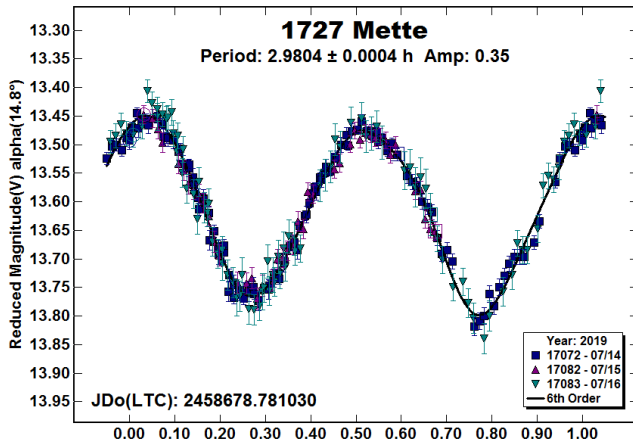
The raw data from the 2019 campaign, with observing runs of 6 hours or more, virtually assure that a rotation period of 5.9452 h is correct because of the asymmetry of the lightcurve.



Since a satellite was suspected from the 2014 data (Warner, 2015e), a dual-period search was done using the 2019 data. The result was an unconvincing lightcurve with $P = 16.376$ h and $A = 0.04$ mag. This period and the adopted one of 5.9466 h have an almost exact 11:4 ratio. This would often indicate that the second period is the result of harmonics in the Fourier search. A cleaner result for the preferred solution was produced by using the “P2” solution as a “noise reduction filter.”

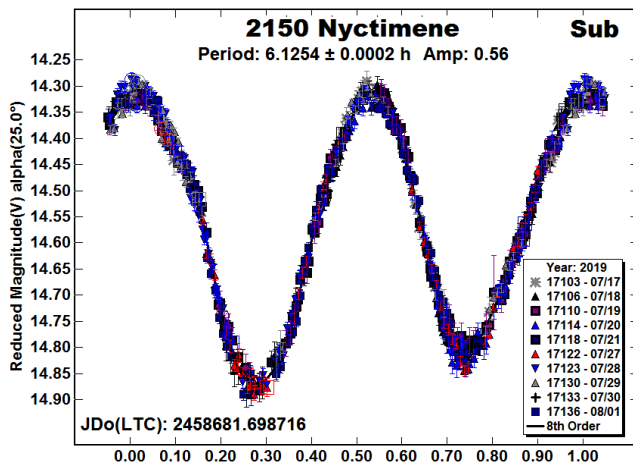
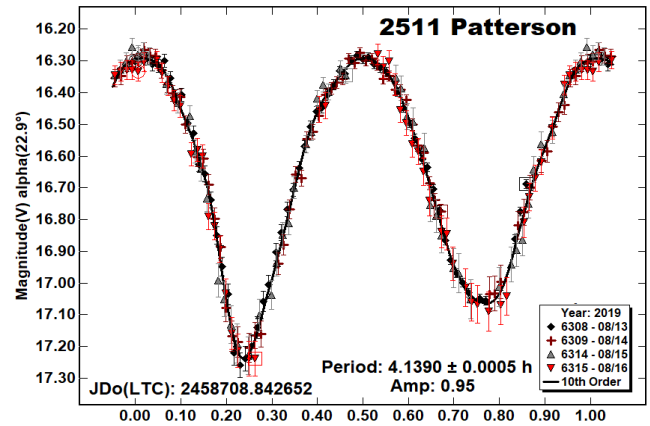
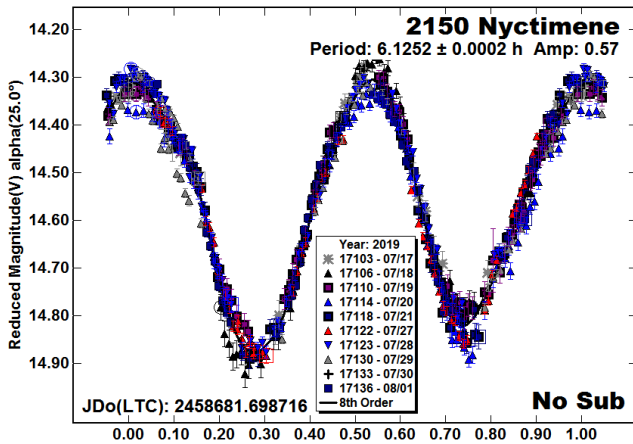


1727 Mette. This Hungaria was observed in 2019 to extend the time range of the available data, which serves to refine the sidereal period in spin axis modeling. The latest result of $P = 2.9804$ h agrees with previous ones found by Warner (2011a; 2015b) for the primary of this known binary (Warner et al., 2013b; 2013c). There were no indications of the satellite in the 2019 data set.



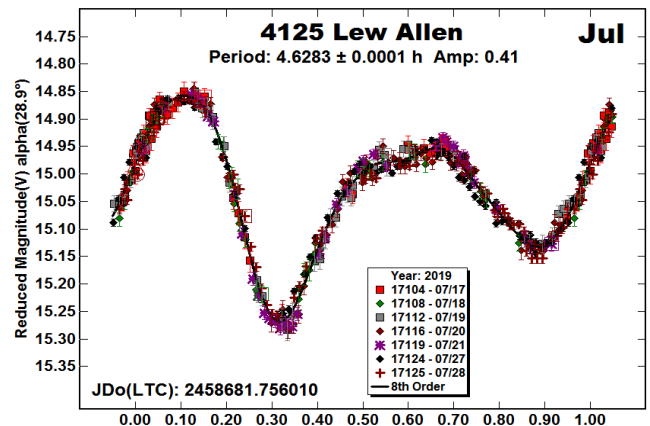
2150 Nyctimene. This is another Hungaria member that has been studied numerous times by the authors (e.g., Warner, 2007; 2013a; 2017; Stephens, 2016). As with 1355 Magoeba, a dual-period search found a result that, while improbable but not impossible, served to improve the fit of the data to the Fourier model curve.

2511 Patterson. This member of the Vesta family has been observed several times in the past. Juarez et al. (2005); Hasegawa et al. (2012); Waszczak et al. (2015) all found rotational periods near 4.14 h. Durech et al. (2018) found a pole solution with ecliptic coordinates of (194°, 50°) and a sidereal period of 4.14065 h. They found an alternate pole solution of (10°, 31°). This year's period is in good agreement with those results.



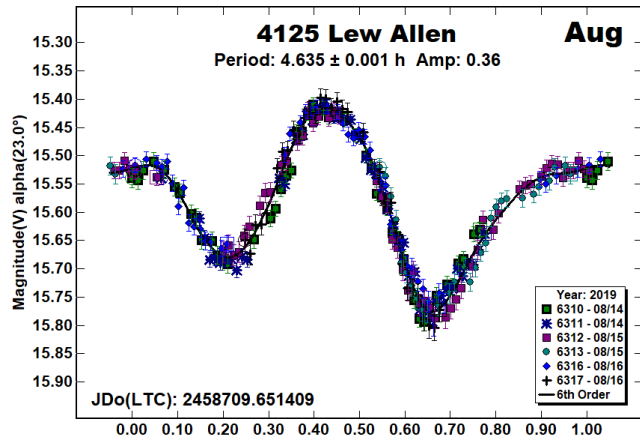
4125 Lew Allen. The apparition in 2019 was the fifth one that Warner observed this Hungaria (Warner 2015c and references therein) each time finding a period neat 4.62 h. Both authors observed it in 2019, Warner in July and then Stephens in August.

2432 Soomana. Waszczak et al. (2015) using sparse data found a period of 3.207 h, rated U = 2. Our period agrees with that result.

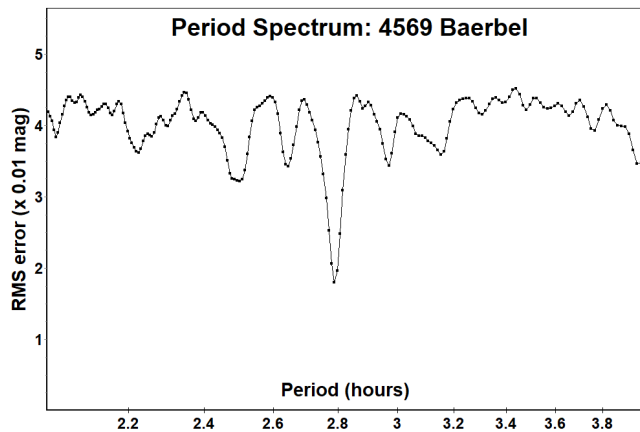
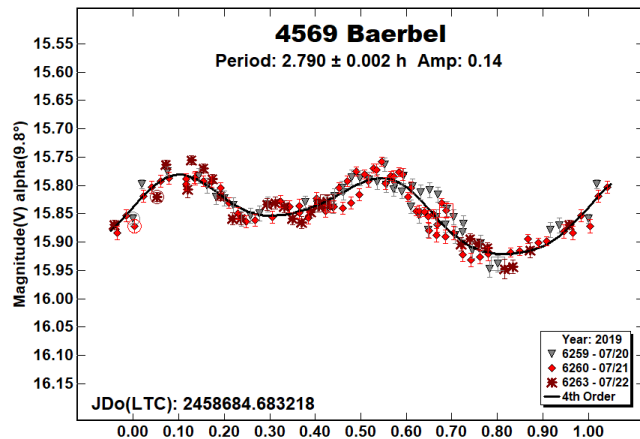


Both periods are in good agreement with prior results. While the overall shape of the lightcurve did not change significant, its amplitude decreased from 0.41 to 0.36 mag as the phase angle

decreased from about 29° to 23°. This is a common phenomenon (Zappala et al., 1990).



4569 Baerbel. Brinsfield (2010) observed this inner main-belt asteroid in 2010, finding a rotational period of 2.737 h. The Brinsfield observations were on two nights spaced seven days apart and the resulting lightcurve, although having an amplitude of 0.24 mag, was somewhat noisy. This year's result differs from Brinsfield by 0.05 h. The period spectrum does not show a possibility of a shorter period, which was probably caused by an alias resulting from the seven day gap between sessions.

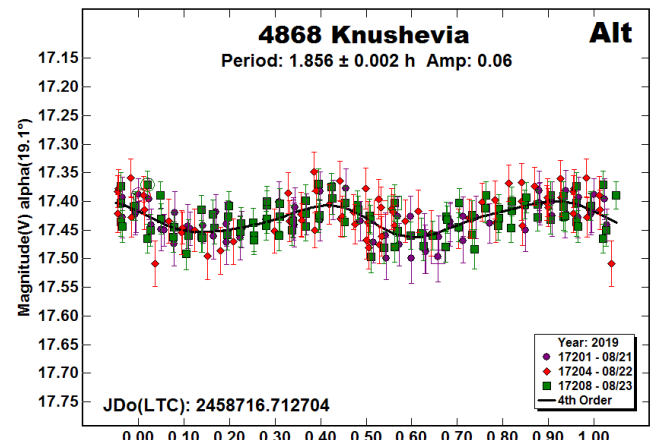
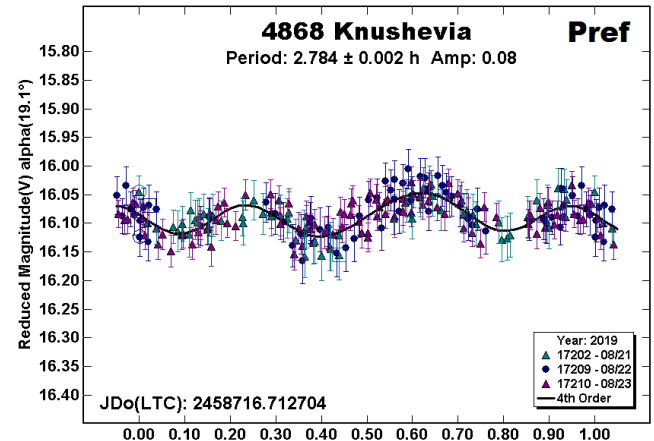
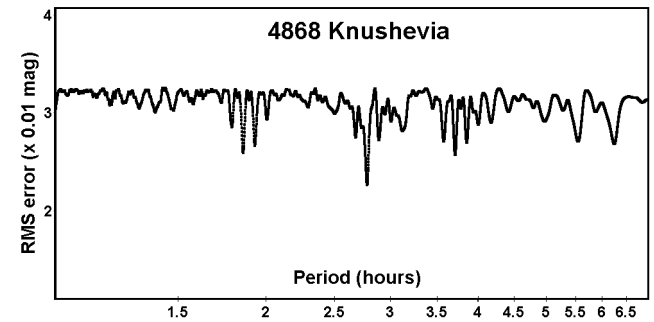


4868 Knushevia. Adding data from the 2019 apparition did more to confuse than refine the solution for this Hungaria. At three previous apparitions (Warner, 2009; 2010b; Warner et al., 2012a), the period ranged from 4.45 and 4.72 h. Observations in 2013

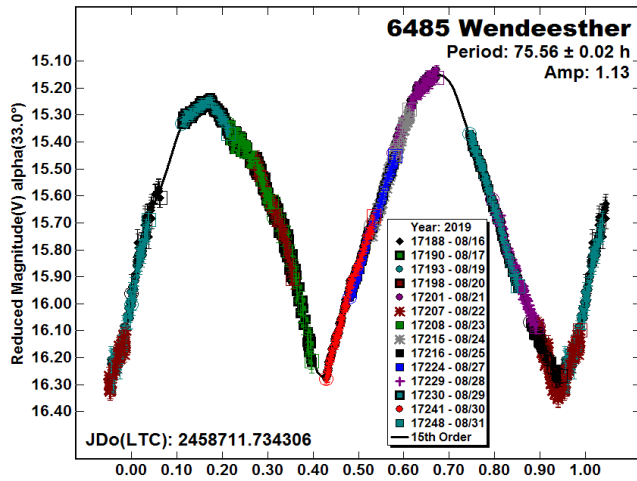
(Warner and Stephens, 2015) found a period of 3.1422 h and the possibility of a satellite with an orbital period of 11.9 or 23.8 h. The data from 2019 supported none of these results.

The best fit was found at $P = 2.784$ h, but there was a small gap in the coverage, which indicated the possibility of a “fit by exclusion,” which is where a local minimum is found by the Fourier analysis by minimizing the number of overlapping data points. A search between 3-4 hours found a very symmetric quadramodal solution at about 3.7 h. This is entirely possible (Harris et al., 2014). So is the half-period, bimodal solution at 1.856 h (Alt).

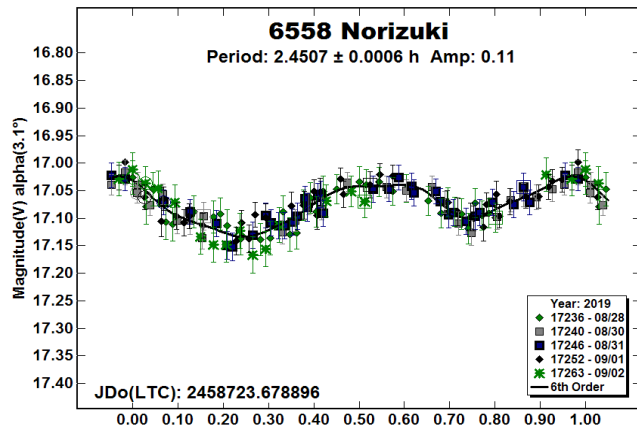
While the shorter period puts the asteroid ($D \sim 2.3$ km) above the so-called “spin barrier” at about 2.2 h, it would be in good company in that region of the frequency-diameter plot from the LCDB (Warner et al., 2009). For example, (60716) 2000 GD65, rated $U = 3$, has a period of 1.953 h and diameter of 2.25 km (Warner et al., 2009). High-quality observations at future apparitions are encouraged.



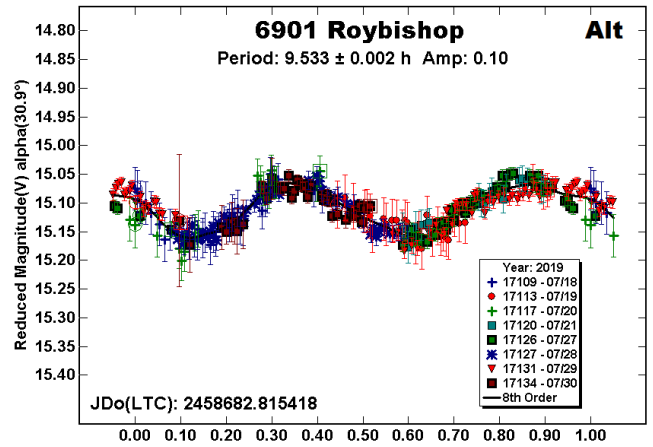
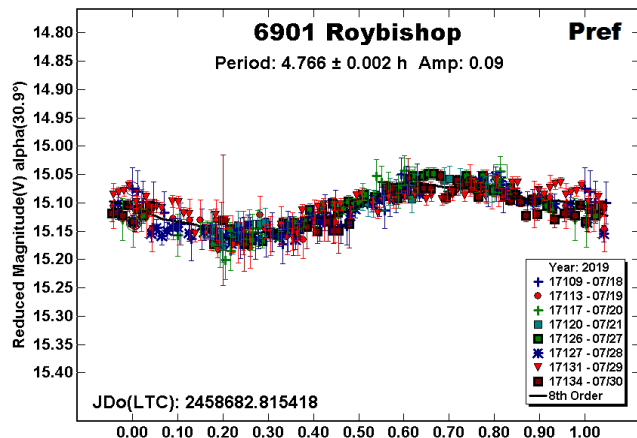
6485 Wendeesther. Warner (2012) found a period of 74.82 h. The 2019 data set was more extensive and allowed finding a refined period of 75.56 h.



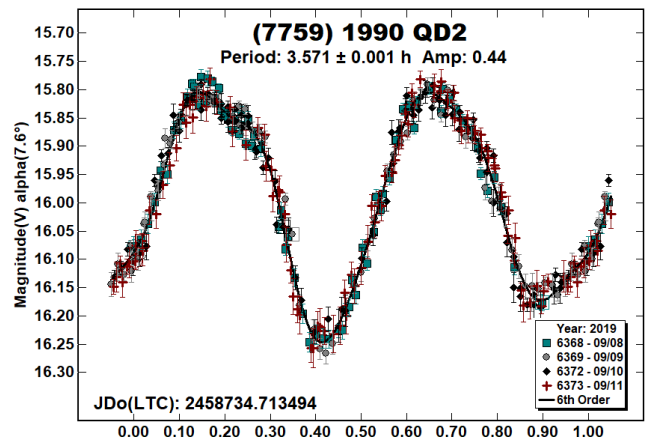
6558 Norizuki. This appears to be the first reported lightcurve period for Norizuki, which is a member of the Flora group/family with an estimated diameter of 3.9 km.



6901 Roybishop. This 5.8 km Hungaria is another example of ambiguous solutions as a result of low amplitude (0.04-0.09 mag) lightcurves. Previous results (Warner 2009; 2015d; Warner et al. 2012b) were close to 4.7 h, the same result found from the 2019 data. However, the bimodal solution with a period of 9.533 h cannot be formally excluded.

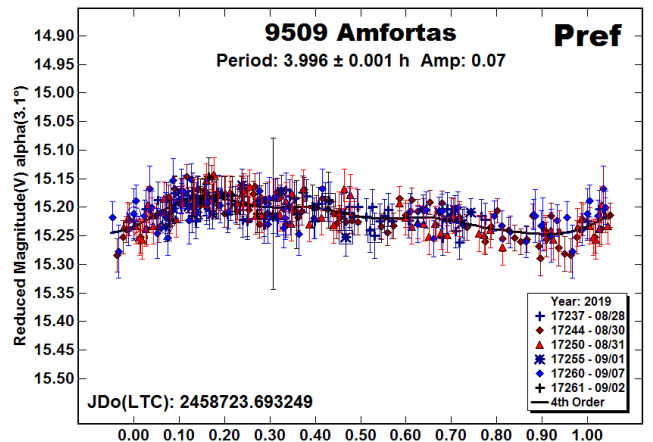


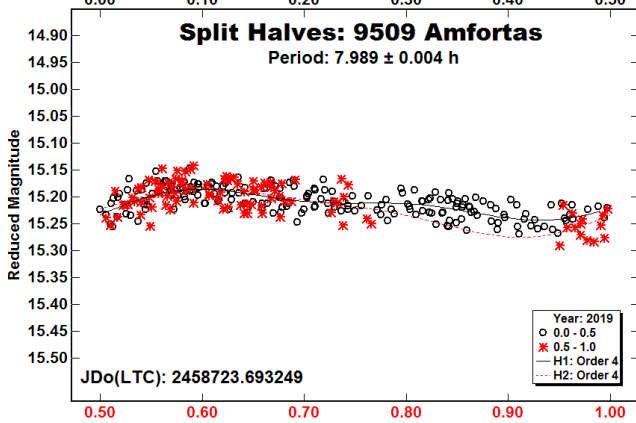
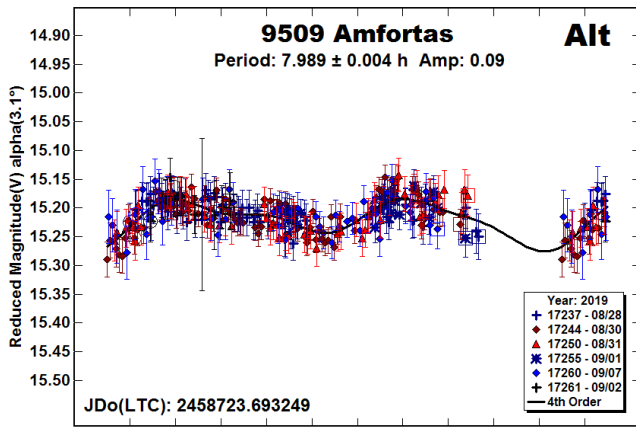
(7759) 1990 QD₂. This appears to be the first reported lightcurve period in the LCDB for this inner main-belt asteroid.



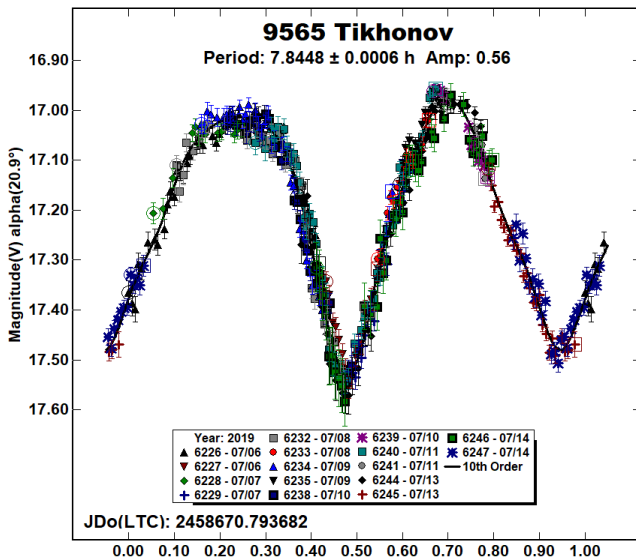
9509 Amfortas. There were no previously reported periods in the LCDB for this Flora member to guide the analysis of the 2019 data. The period spectrum shows several likely candidates.

We have adopted the monomodal solution of 3.996 h over the bimodal, double-period solution of 7.989 h based mostly on the possible *fit by exclusion* (large gap in lightcurve) and the nearly symmetrical split-halves lightcurve. Both solutions are possible (Harris et al., 2014) and so neither can be formally excluded.



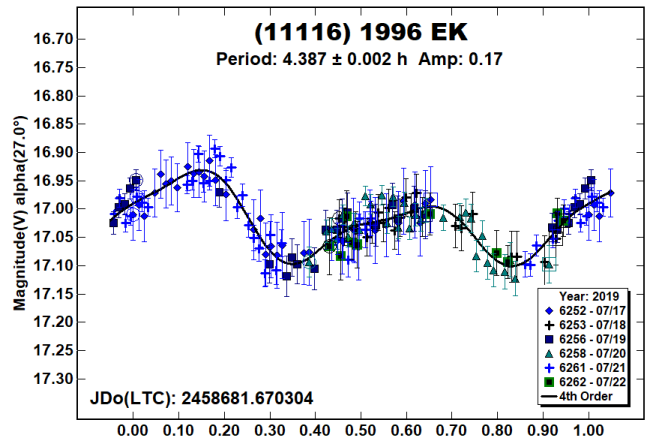


9565 Tikhonov. There are no previously reported lightcurves in the LCDB for this member of the Flora family, which is estimated to have an effective diameter of 4.5 km.

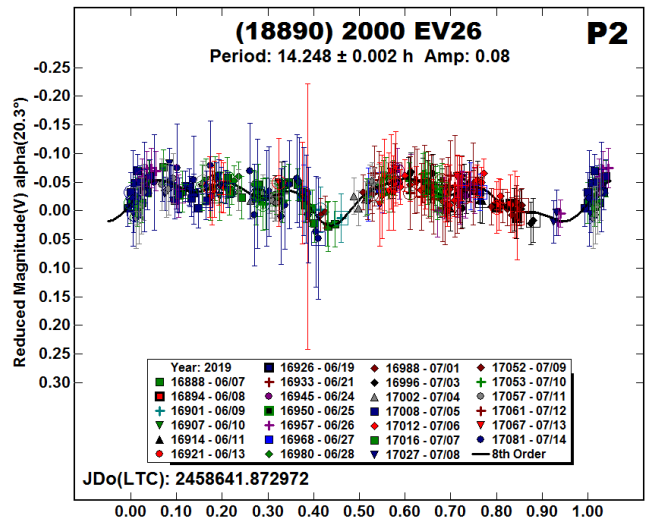
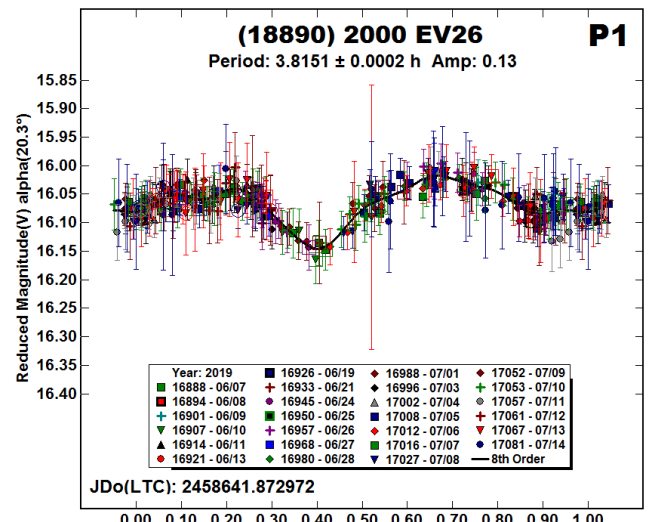


(11116) 1996 EK. Pravec et al. (2019) reported this member of the Flora family as a likely binary asteroid candidate from the Photometric Survey for Asynchronous Binary Asteroids. Marginal attenuation detections were found in 2006; inconclusive attenuations were seen in 2009 with a primary rational period reported of 4.4018 h. The survey did not see any attenuations in

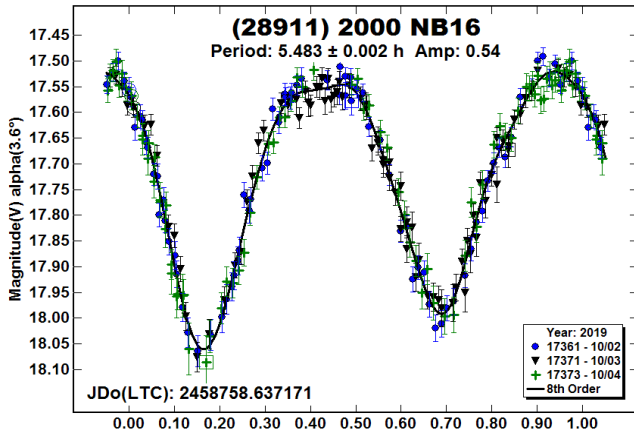
May 2019, and none are seen in our data. Our period is consistent with their reported results.



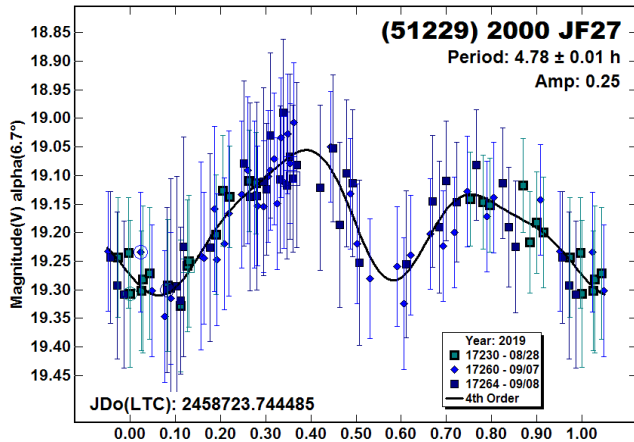
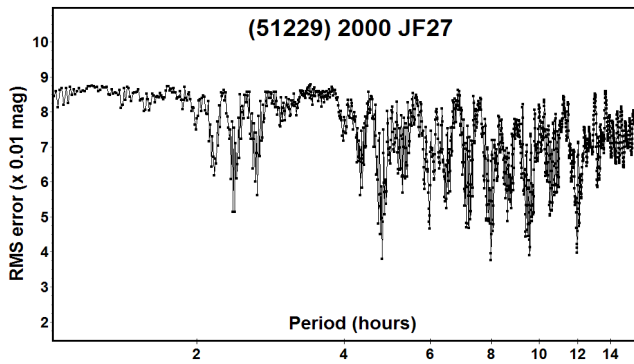
(18890) 2000 EV26. This Hungaria is a known binary (Warner, 2015a). The asteroid was moving through rich star fields, forcing rejecting of nearly half the data points. The primary (“P1”) period is in good agreement with previous results. The orbital (“P2”) period is similar to those found on two previous occasions.



(28911) 2000 NB16. Waszczak et al. (2015) reported a period of 5.486 h for this outer main-belt object.

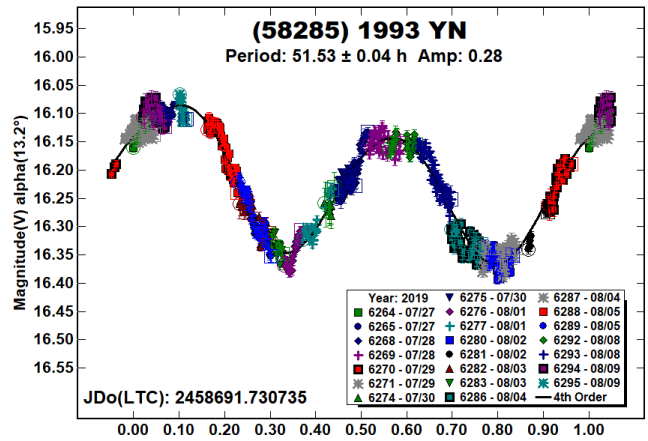


(51229) 2000 JF27. This looks to be the first rotation period found for this 4.8 km outer main-belt object. The period spectrum shows several likely candidates. The limited data set and low SNR did not allow doing better. We adopted the solution closest to a bimodal lightcurve. Given the 0.25 mag amplitude, this seems a safe assumption (Harris et al., 2014).

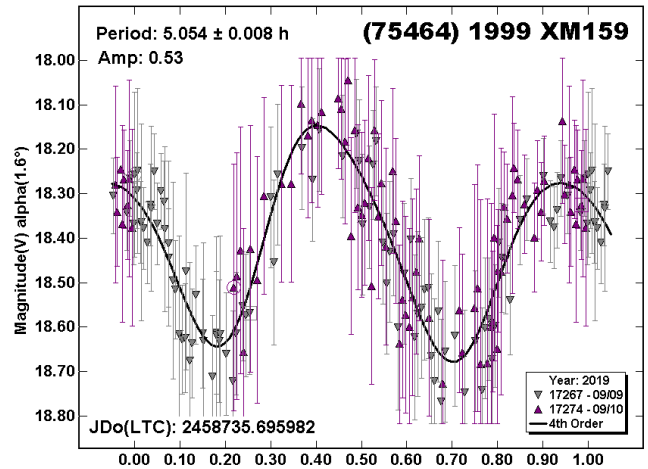


(58285) 1993 YN. There are no rotation periods posted for this Mars-crosser in the LCDB. The period we were able to find is close to an integral multiple of Earth days, requiring almost two weeks of observing time to complete the lightcurve.

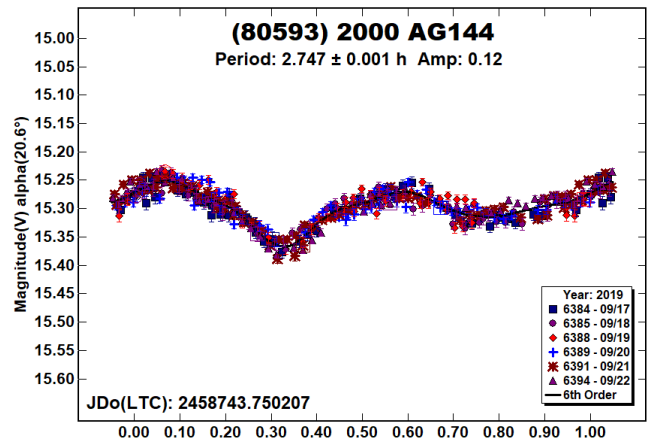
The period is close to where tumbling would be more likely than not (Pravec et al., 2005). However, we saw no obvious signs such as data from a given night not matching the slope of the Fourier curve.



(75464) 1999 XM159. Despite a noisy data set but because of the large amplitude, we were able to find a reasonably secure solution for this Flora member. There were no previously reported periods listed in the LCDB.

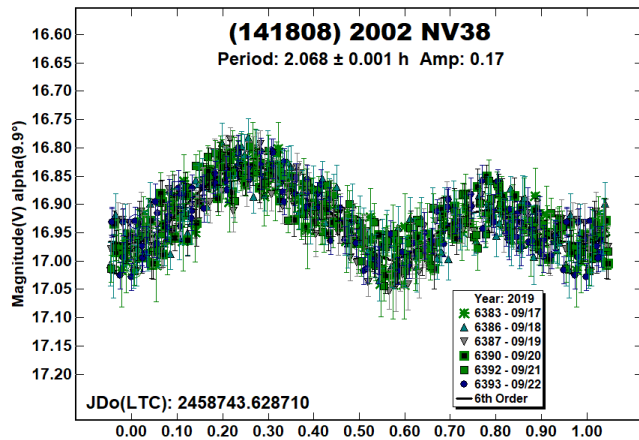


(80593) 2000 AG144. No records were found in the LCDB for this Mars-crosser, so this is another new discovery of an asteroid rotational period. With a period close to the spin barrier of about 2.2 h, it's prudent to be on the lookout for a possible secondary period due to a satellite. We found no evidence of such.

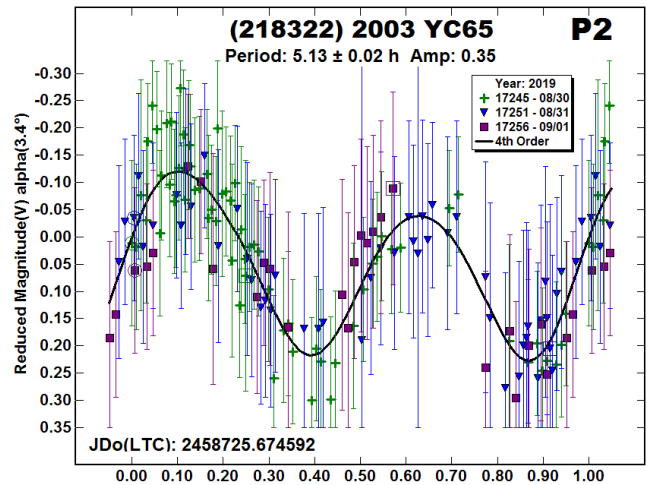
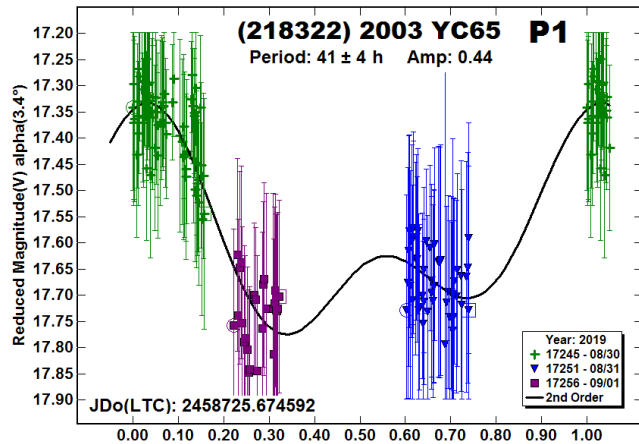
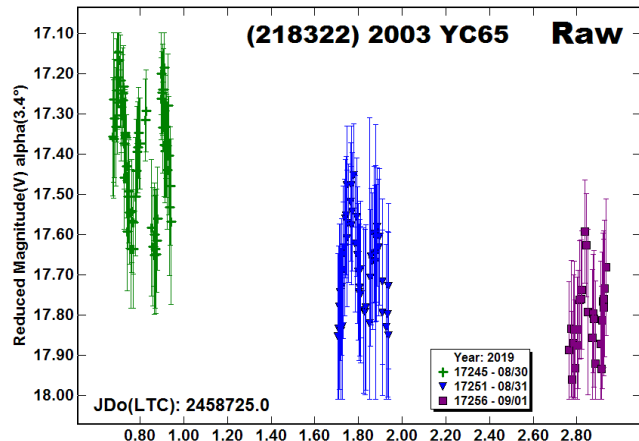


(141808) 2002 NV38. This Mars-crosser also did not have any previous rotation periods posted in the LCDB. It is rotating a little faster than the accepted 2.2 h spin barrier, although that is more of

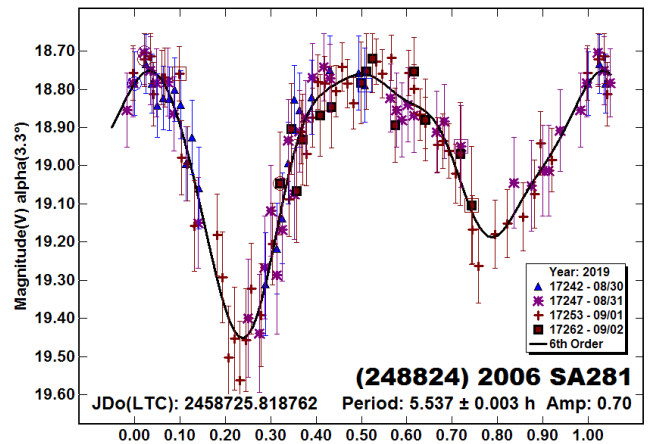
a guideline than a hard and fast rule. Again, no secondary periods were noted over six nights of observations.



(218322) 2003 YC65. For various reasons, it was not possible to follow this Flora member longer than the three nights in late August. Each night's data clearly showed a short period of $P < 6$ h. The raw plot of all three nights shows what appears to be a long period lightcurve near a minimum. On this assumption, a low-order dual-period search was done. This found a possible long period of 41 h. Once this was subtracted, a noisy but clear solution of 5.13 h was found. We believe this may be a candidate for member in the rare class of very wide binary asteroids (see, e.g., Warner, 2016).



(248824) 2006 SA281. This 1.8 km Eunomia member had no previously reported period in the LCDB.



Acknowledgements

Observations at CS3 and continued support of the asteroid lightcurve database (LCDB; Warner et al., 2009) are supported by NASA grant 80NSSC18K0851. Work on the asteroid lightcurve database (LCDB) was also partially funded 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) (<http://svo2.cab.inta-csic.es/vocats/cm15/>).

This work includes data from the Asteroid Terrestrial-impact Last Alert System (ATLAS) project. ATLAS is primarily funded to search for near earth asteroids through NASA grants NN12AR55G, 80NSSC18K0284, and 80NSSC18K1575; byproducts of the NEO search include images and catalogs from the survey area. The ATLAS science products have been made possible through the contributions of the University of Hawaii Institute for Astronomy, the Queen's University Belfast, the Space Telescope Science Institute, and the South African Astronomical Observatory.

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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Number	Name	2019 mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
855	Newcambia	09/12-09/15	20.9,20.6	53	5	3.004	0/001	0.4	0.02	MB-I
1355	Magoeba	09/13-09/22	26.9,24.1	37	12	5.9466	0.0006	0.13	0.01	H
1727	Mette	07/14-07/16	14.8,13.7	314	4	2.9804	0.0004	0.35	0.02	H
2150	Nyctimene	07/17-08/01	25.0,22.3	324	33	6.1254	0.0002	0.56	0.02	H
2432	Soomana	09/12-09/15	27.4,27.2	56	4	3.206	0.001	0.42	0.02	V
2511	Patterson	08/13-08/16	23.0,22.2	7	-10	4.139	0.0005	0.95	0.02	V
4125	Lew Allen	07/17-07/28	28.9,26.2	330	21	4.6283	0.0001	0.41	0.02	H
4125	Lew Allen	08/14-08/16	23.0,22.7	334	27	4.635	0.001	0.36	0.02	H
4569	Baerbel	07/20-07/22	9.8,10.0	293	19	2.79	0.002	0.14	0.02	MB-I
4868	Knushevia	08/21-08/23	19.1,18.1	353	14	2.784	0.002	0.08	0.02	H
	Alternate					1.856	0.002	0.06	0.02	
6485	Wendeesther	08/16-08/31	33.0,30.1	6	27	75.56	0.02	1.13	0.03	H
6558	Norizuki	08/28-09/02	3.1,4.0	335	5	2.4507	0.0006	0.11	0.01	FLOR
6901	Roybishop	07/18-07/30	30.9,29.6	349	24	4.766	0.002	0.09	0.01	H
7759	1990 QD2	09/08-09/11	7.6,5.8	356	-2	3.571	0.001	0.44	0.02	MB-I
9509	Amfortas	08/28-09/07	3.1,6.1	335	5	0.001	0.07	0.07	0.01	FLOR
9565	Tikhonov	07/06-07/14	20.9,18.1	319	9	7.8448	0.0006	0.56	0.02	FLOR
11116	1996 EK	07/17-07/22	27.1,28.2	257	10	4.387	0.002	0.17	0.02	FLOR
18890	2000 EV26	06/26-07/14	19.5,21.4	271	32	3.8151	0.0002	0.13	0.02	H
	Satellite orbit					14.248	0.002	0.08	0.02	
28911	2000 NB16	10/02-10/04	3.6,3.4	12	8	5.483	0.02	0.54	0.03	MB-O
51229	2000 JF27	08/28-09/08	6.7,3.5	355	-4	4.78	0.01	0.25	0.03	MB-O
58285	1993 YN	07/27-08/09	13.2,11.0	314	13	51.53	0.04	0.28	0.03	MC
75464	1999 XM159	09/09-09/10	1.6,1.1	349	0	5.054	0.008	0.53	0.07	FLOR
80593	2000 AG144	09/17-09/22	20.7,23.3	343	22	2.747	0.001	0.12	0.02	MC
141808	2002 NV38	09/17-09/22	10.0,12.6	347	7	2.068	0.001	0.17	0.02	MC
218322	2003 YC65	08/30-09/01	3.4,4.0	335	5	41	4	0.44	0.05	FLOR
248824	2006 SA281	08/30-09/02	3.3,3.9	335	5	5.537	0.003	0.7	0.05	MB-O

Table III. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009). For a binary, the first line gives the rotation period of the primary and the second line gives the orbital period of the satellite.

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COLLABORATIVE ASTEROID PHOTOMETRY FROM UAI: 2019 JULY-SEPTEMBER

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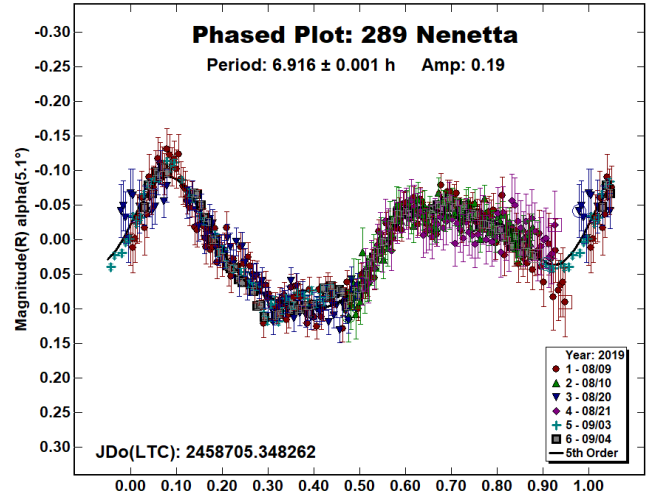
(Received: 2019 October 14)

Photometric observations of five main-belt and one near-Earth asteroid were made in order to acquire lightcurves for shape/spin axis models. The synodic period and lightcurve amplitude were found for: 289 Nenetta, 6.916 ± 0.001 h, 0.19 mag; 472 Roma, 9.792 ± 0.002 h, 0.29 mag.; 635 Vundtia, 11.794 ± 0.002 h, 0.21 mag; 869 Mellena, 6.528 ± 0.008 h, 0.30 mag; 2131 Mayall, 2.5677 ± 0.0001 h, 0.08 mag; 2019 NN3, 0.03750 ± 0.00003 h, 0.98 mag. We also confirmed the binary nature of the asteroid 2131 Mayall.

Collaborative asteroid photometry was made inside the UAI (Italian Amateur Astronomers Union) group. The targets were selected mainly in order to acquire lightcurves for shape/spin axis models. The CCD observations were made in 2019 July-September using the instrumentation described in Table I. Lightcurve analysis was performed at the Balzaretto Observatory with *MPO Canopus* (Warner, 2016). All the images were

calibrated with dark and flat frames and converted to R magnitudes using solar colored field stars from CMC15 catalogue, as distributed with *MPO Canopus*. Table II shows the observing circumstances and results.

289 Nenetta is an A-type (Bus & Binzel, 2002) outer main-belt asteroid discovered on 1890 March 10 by A. Charlois at Nice. Collaborative observations were made over six nights. We found a synodic period of $P = 6.916 \pm 0.001$ h with an amplitude $A = 0.19 \pm 0.03$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009b).



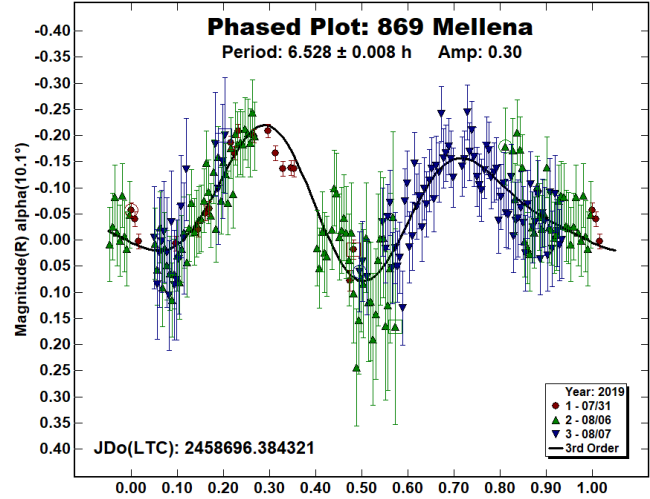
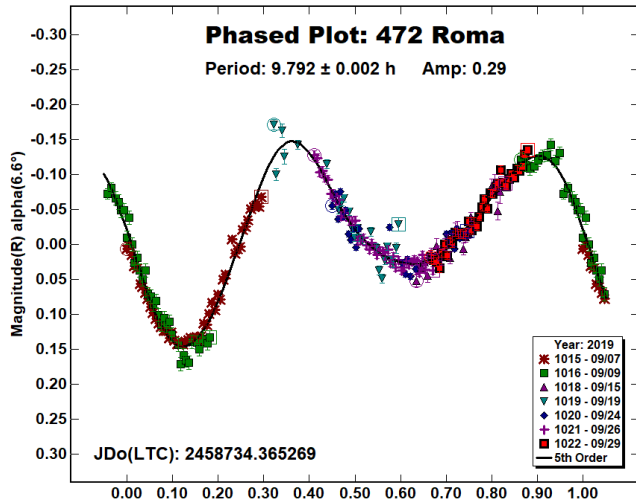
472 Roma is an S-type member of the Eunomia group; it was discovered on 1901 July 11 by L. Carnera at Heidelberg. Observations were made over seven nights at DSFTA Observatory. We found a synodic period of $P = 9.792 \pm 0.002$ h with an amplitude $A = 0.29 \pm 0.02$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009b).

Observatory (MPC code)	Telescope	CCD	Filter	Observed Asteroids
DSFTA Observatory (K54)	0.30-m MCT $f/5.6$	SBIG STL-6303e (bin 2x2)	Rc	289, 472, 635, 2131
ObsCT (L45)	0.20-m NRT $f/5.0$	Atik 314L	Rc	289, 869
Filzi School Observatory	0.35-m RCT $f/8.0$	QHY9 (KAF8300)	Rc	635, 2131
AAB (L19)	0.30-m SCT $f/5.6$	Moravian KAF-1603ME	Rc	635, 869, 2131
GAMP(104)	0.60-m NRT $f/4.0$	Apogee Alta	C	2131, 2019 NN3
M57 (K38)	0.30-m RCT $f/5.5$	SBIG STT-1603	C	2131
GiaGa Observatory (203)	0.36-m SCT $f/5.8$	Moravian G2-3200	C	2131
Margherita Hack (A57)	0.35-m SCT $f/8.3$	SBIG ST10XME (bin 2x2)	C	2131

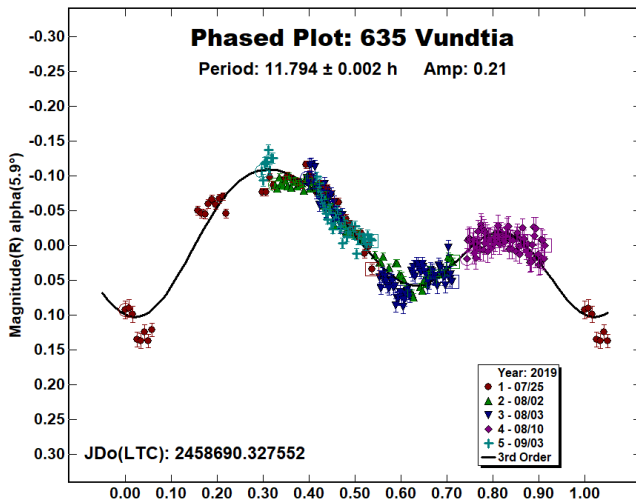
Table I. Observing Instrumentations. MCT: Maksutov-Cassegrain, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain, NRT: Newtonian Reflector.

Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
289	Nenetta	08/09-09/04	5.1, 8.6	325	5	6.916	0.001	0.19	0.03	MB-O
472	Roma	09/07-09/29	6.5, 13.9	339	-13	9.792	0.002	0.29	0.02	EUN
635	Vundtia	07/25-09/03	5.9, 10.2	314	10	11.794	0.002	0.21	0.04	MB-O
869	Mellena	07/31-08/07	9.9, 12.9	293	7	6.528	0.008	0.30	0.10	MB-M
2131	Mayall	07/23-09/16	23.2, 28.6	329	24	2.5677	0.0001	0.08	0.04	H
		P_{ORB}					23.47	0.01	0.09	0.03
2019 NN3		07/09-07/09	59.6, 59.1	264	19	0.03750	0.00003	0.98	0.10	NEA

Table II. Observing circumstances and results. For 2131, the first line gives the results for the primary of a binary system. The second line gives the orbital period of the satellite and the maximum attenuation. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009b).



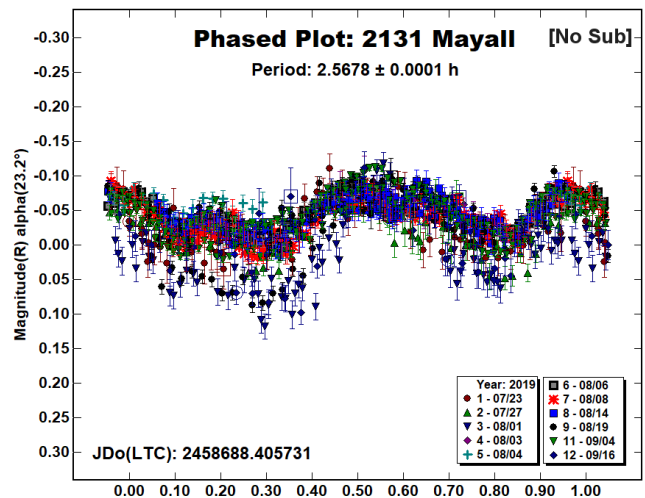
635 Vundtia is a C-type outer main-belt asteroid discovered on 1907 June 9 by K. Lohnert at Heidelberg. Collaborative observations were made over five nights. We found a synodic period of $P = 11.794 \pm 0.002$ h with an amplitude $A = 0.21 \pm 0.04$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009b).

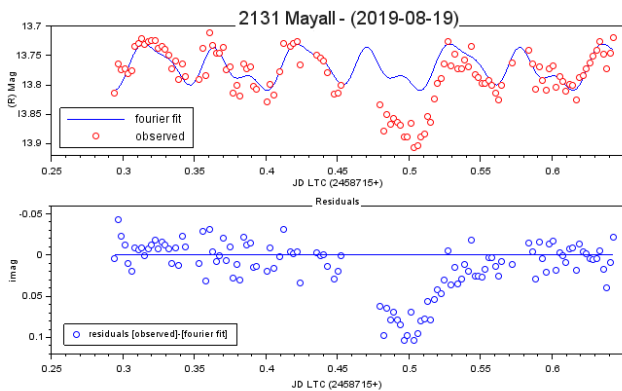
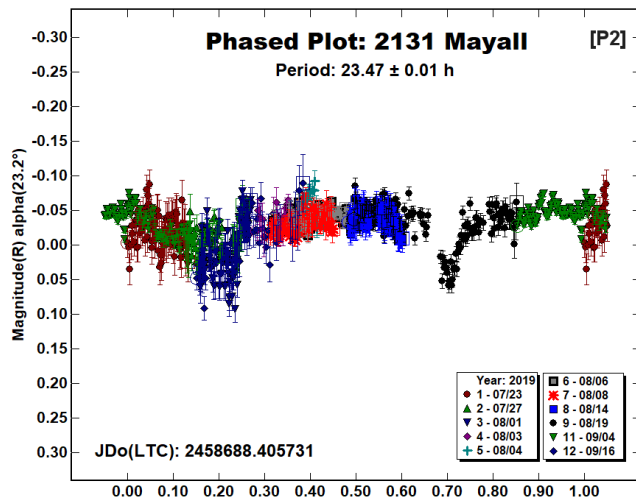
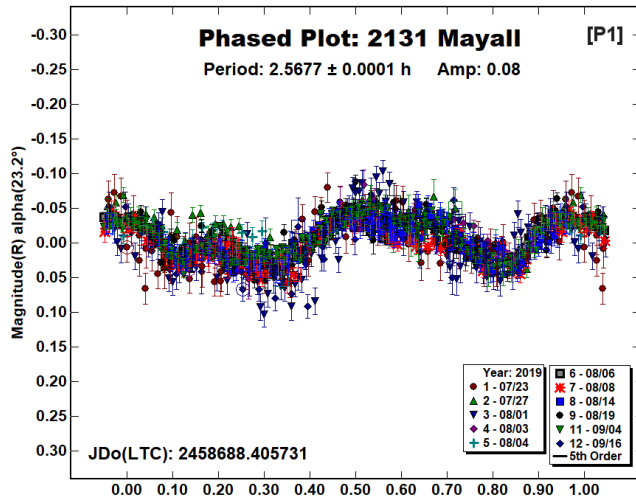


869 Mellena is a low albedo middle main-belt asteroid discovered on 1917 May 9 by R. Schorr at Bergedorf. Collaborative observations were made over three nights. We found a synodic period of $P = 6.528 \pm 0.008$ h with an amplitude $A = 0.30 \pm 0.10$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009b).

2131 Mayall is an S-type (Bus & Binzel, 2002) member of the Hungaria group; it was discovered on 1975 September 3 by A. Klemola at the Lick Observatory. This asteroid is a binary system as reported by Warner et al. (2009a).

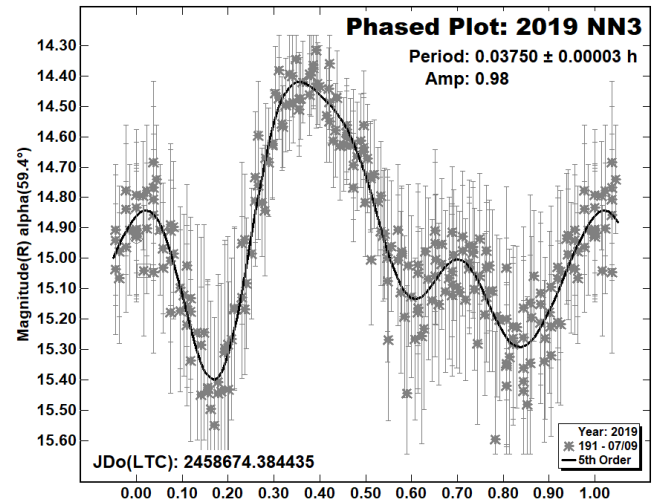
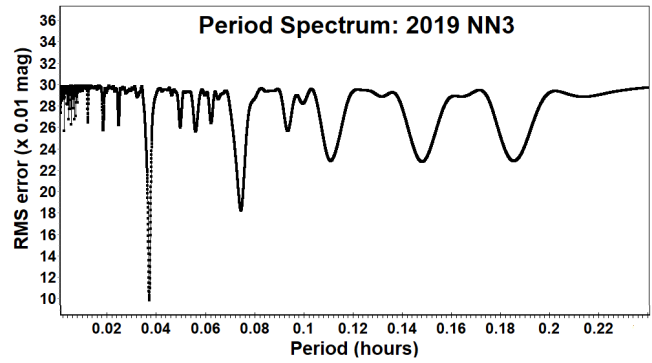
Collaborative observations were made over eleven nights. The analysis was done using the dual-period search function implemented in *MPO Canopus*. We found a primary synodic rotational period of $P_1 = 2.5677 \pm 0.0001$ h with an amplitude $A_1 = 0.08 \pm 0.04$ mag and orbital period $P_{ORB} = 23.47 \pm 0.01$ h with a maximum attenuation for the deeper event of 0.09 ± 0.03 mag observed on 2019 August 19. Those periods are consistent with the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009b).





Top: data points observed for deeper event on August 19, 2019 superimposed to the 5th order Fourier model curve. Bottom: residuals after the Fourier model curve has been subtracted from the observed data.

2019 NN3 is an Amor near-Earth asteroid; it was first observed on 2019 July 7 by ATLAS Mauna Loa. Observations were made at GAMP during the fly-by of Earth on 2019 July 9 from 21:13 to 21:38 UT. We found a synodic period of $P = 0.03750 \pm 0.00003$ h, or about 2.25 minutes, with an amplitude $A = 0.98 \pm 0.10$ mag. It is, therefore, an elongated fast rotator asteroid.



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ROTATIONAL PERIOD OF FIVE ASTEROIDS

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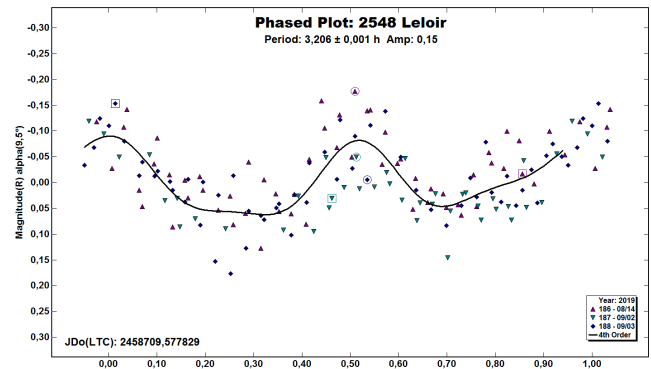
Here we present the result of a photometric work on five asteroids: 2548 Leloir, $P = 3.206 \pm 0.001$ h, $A = 0.15$ mag; 6527, $P = 3.016 \pm 0.002$ h, $A = 0.22$ mag; 7527 Marples, $P = 9.091 \pm 0.002$ h, $A = 0.46$ mag; (58285) 1993 YN, $P = 51.81 \pm 0.02$ h, $A = 0.43$ mag; (354030) 2001 RB18, $P = 13.27 \pm 0.02$ h, $A = 0.11$ mag.

Starting from 2019 July, Bigmuskie Observatory and Osservatorio Astronomico BSA joined forces to perform photometric studies on asteroids. Both observatories are in northwestern Italy (Piedmont) in rural places where light pollution, even if present, still permits obtaining acceptable results. This collaboration led to the determination of the rotational periods of five asteroids that were chosen on the CALL website (Warner, 2019) because no previous observations were reported: 2548 Leloir, 6527 Takashiito, 7527 Marples, (58285) 1993 YN, and (354030) 2001 RB18.

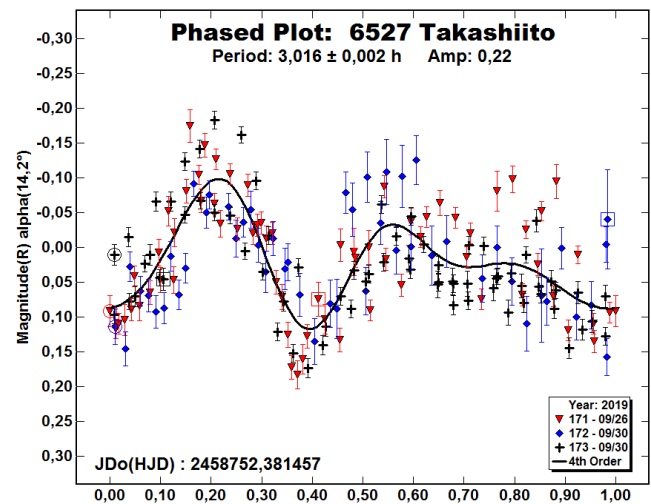
Bigmuskie Observatory is run by Andrea Ferrero; its standard setup is a Marcon 0.30-m $f/8$ Ritchey-Chretien telescope coupled with a Moravian G3 01000 that uses a KAF-1001E CCD with a pixel array of 1024x1024x24 microns. This gives a pixel scale of exactly 2 arcsec/pixel and a field of view of 36x36 arcmin. Exposures were all unguided and taken through a Toptec R filter.

Osservatorio Astronomico BSA is run by Roberto Bonamico and its standard setup is a Marcon 0.30-m $f/5$ Newtonian telescope with Atik 314L+ CCD camera using a Sony ICX285AL sensor with a pixel array 1360x1024x6.45 microns. A Chroma R filter was used. Software setup for both observatories is *Maxim DL* for camera control, Software Bisque *The Sky6 Pro* (Software Bisque, 2019) for telescope control, and *Voyager* (Voyagerastro, 2019) for observatory control. Photometric reductions were done with *MPO Canopus* v10.7.12.9 (Warner, 2019). In particular, precise night-to-night zero point calibration was obtained using the Comparison Star Selector utility in *MPO Canopus*, which helped choose five solar-colored comparison stars from the MPOSC3 catalog supplied with *MPO Canopus*.

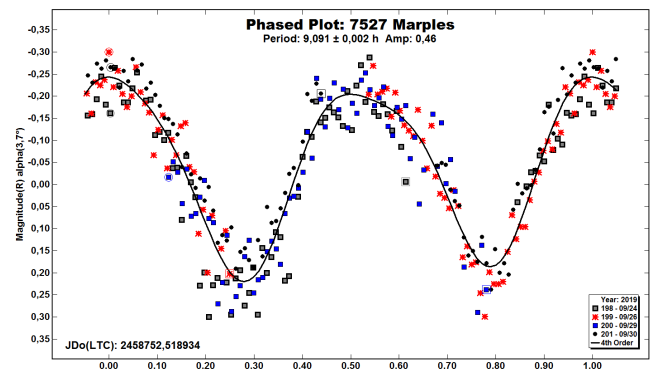
2548 Leloir was worked with the 0.30-m RC telescope. Despite the short rotational period we found, it took three nights to reach a satisfactory fitting among the sessions. This was because of the relative faintness of the target and, most of all, the low amplitude of the lightcurve. The final result is $P = 3.206 \pm 0.001$ h with an amplitude of $A = 0.15$ mag. This appears to be a reliable period with no other alias found.



6527 Takashiito. Photometric observations were performed with the 0.30-m Newtonian telescope on three nights for a total of more than 23 hours. Thanks to the good amplitude of the curve, this target showed a reliable period of $P = 3.016 \pm 0.002$ h, $A = 0.22$ mag.



7527 Marples was worked with the 0.30-m RC telescope. This target was previously observed by Behrend (2018), who reported a period 7.85 ± 0.05 h. This new set of observation showed a more reliable period of $P = 9.091 \pm 0.002$ h and $A = 0.46$ mag. An attempt to link all the sessions to the 7.85-hour period was made but the result was not satisfactory and so led to favoring the longer period.

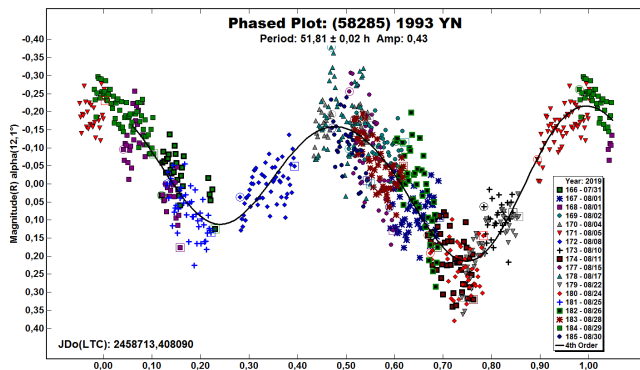


Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2548	Leloir	08/14-09/03	9.5, 6.8	337	14	3.206	0.001	0.15	0.05	MB
6527	Takashiito	09/26-09/30	14.2, 12.1	23	7	3.016	0.002	0.22	0.10	MB
7527	Marples	09/24-09/30	*3.6, 5.5	1	5	9.091	0.002	0.46	0.10	MB
58285	1993 YN	07/31-08/30	12.1, 16.9	37	13	51.81	0.02	0.43	0.10	MC
354030	2001 RB18	09/11-09/18	18.6, 19.2	355	10	13.27	0.02	0.11	0.10	AMO

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

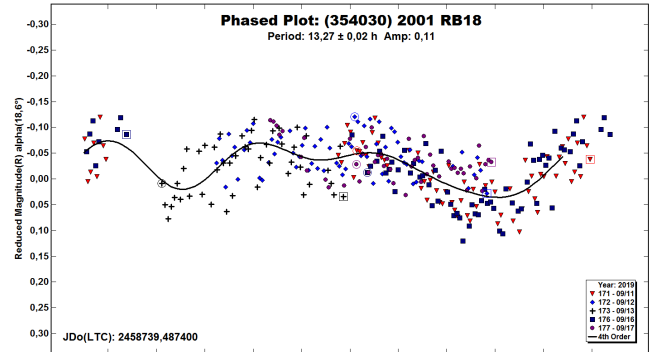
(58285) 1993 YN was worked with the 0.30-m RC telescope. This target, in contrast with 7527 Marples, proved to be the most difficult of the list and the final period appeared only in the end. In the early stages of work, a reliable period seemed to be in the range of 70-80 h but, after adding more sessions, *MPO Canopus* started to eliminate this period, which produced a strange lightcurve with a main maximum followed by an unusual continuum with low amplitude maxima and minima, and favored a shorter period of about 30 h. However, this result proved to be wrong after adding even more data.

During the last sessions, the final lightcurve, as we show it, emerged with a period of $P = 51.81 \pm 0.02$ h, $A = 0.43$ mag. To reach a satisfactory linkage between sessions in this lightcurve, it was necessary to change the zero-point offset of many sessions; in particular, it was necessary to lower session number 177 by 0.3 mag while others were in a more acceptable range of 0.05-0.06 mag. The reason of these large correction is probably due to the fact that many sessions were when a full Moon was not far from the asteroid. Because of these large corrections, most of all because session number 182 could not be to fit with the other sessions, we do not believe this is a secure solution.



(354030) 2001 RB18 was worked with the 0.30-meter RC telescope. When the work on this target was finished, we realized that it was already been observed by Brian Warner (private communications), who posted a period of 13.54 ± 0.01 h. We found a slightly different period of $P = 13.27 \pm 0.02$ h, $A = 0.11$ mag. After email communications between Warner, Petr Pravec, and Ferrero, we were informed that a third period of 26.755 ± 0.004 h was found by Don Pray during the BinAstPhotSurvey together with Petr Pravec.

Even if the differences between Warner and Ferrero's data are not "dramatic", the presence of the longer period by Don Pray prompted Petr Pravec to suppose that this target could be either a tumbler with a more complex lightcurve or that the lightcurve was rapidly evolving over only a few days. More observations of good quality and in good sky conditions are needed on this target.



Acknowledgements

Thanks to Brian Warner, Petr Pravec, and Don Pray for their support with the work on (354030) 2001 RB18.

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ROTATIONAL PROPERTIES OF THREE HILDA ASTEROIDS

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(Received: 2019 October 14)

We determine the rotation periods, lightcurve amplitudes, and H-G parameters for three Hilda asteroids with previously measured large brightness variations. We measured a rotation period of 8.4070 ± 0.0009 h and amplitude of 0.64 ± 0.04 R-mag, $H_R = 14.56 \pm 0.03$ mag, and $G_R = 0.44 \pm 0.08$ for (64390) 2001 UY149. For (16927) 1998 FX68, we measure a rotation period of 33.85 ± 0.07 h, an amplitude of 0.68 ± 0.04 R-mag, $H_R = 12.02 \pm 0.06$ mag, and $G_R = 0.7 \pm 0.2$. For (209512) 2004 RO2, we determine a rotation period of 15.78 ± 0.02 h, an amplitude of 0.30 ± 0.04 r' mag, $H_r = 15.40 \pm 0.06$ magnitudes, and $G_r = 0.4 \pm 0.1$.

This study is a continuation of an ongoing project (e.g., Williamson *et al.* 2019; Witry *et al.* 2019) to characterize physical properties of Hilda asteroids that were flagged as binary system candidates via their comparably large brightness variation from sparse lightcurve sampling (Sonnett *et al.* 2015). Determining these properties will enable further understanding and characterization of the material strength and potentially binary nature of these asteroids.

For the objects in this study, CCD data were acquired at the Las Cumbres Observatory (LCO), using 0.4-, 1-, and 2-meter telescopes. These telescopes employed CCD camera properties described in Williamson *et al.* (2019). These images were taken with exposure times designed to reach a signal to noise ratio of $S/N \sim 30$ to facilitate adequate light curve resolution. CCD images for objects (64390) 2001 UY149 and (16927) 1998 FX68 were taken in the Bessel-R filter, while object (09512) 2004 RO2 was taken in the Sloan-r filter. Within the dates observed, object (64390) 2001 UY149 had an airmass range of 1.011 to 2.375 and a visual magnitude range between 19.73 and 19.50. Object (16927) 1998 FX68 exhibited an airmass range of 1.019 to 1.979 and a visual magnitude range between 19.20 and 19.01. Object (209512) 2004 RO2 exhibited an airmass range of 1.064 to 1.887 and a visual magnitude range between 20.99 and 20.94.

Astrometry and image reduction were automatically performed through the LCO processing pipeline. All images were visually inspected to remove any images with blending of background sources and poor focus. All photometry, systematic uncertainties, magnitude calibration, and photometric transformations of field stars and the targets within these images were performed as described in Williamson *et al.* (2019).

Solutions for period, H-, and G-parameters were determined by iteratively fitting an optimized n th-order Fourier series to our data. The solutions presented are those with the minimum reduced χ^2 statistic that rendered a double-peaked lightcurve shape. This iterative fitting process was repeated for a range of Fourier n -orders. Each parameter reported in this study was produced by the lowest-order Fourier series that best reproduced the data (minimized the reduced χ^2 value). To determine uncertainties for period and amplitude, a Gaussian bootstrapping method was employed. Functional fits and their uncertainties for the H-G magnitudes were determined by the SciPy “curve fit” routine. In the periodograms for each object, the orange arrow indicates the minimum which corresponds to the best fit period solution, with all other minima corresponding to trivial harmonics.

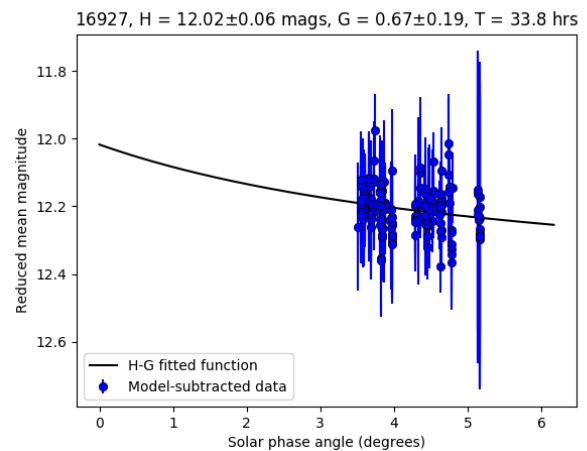
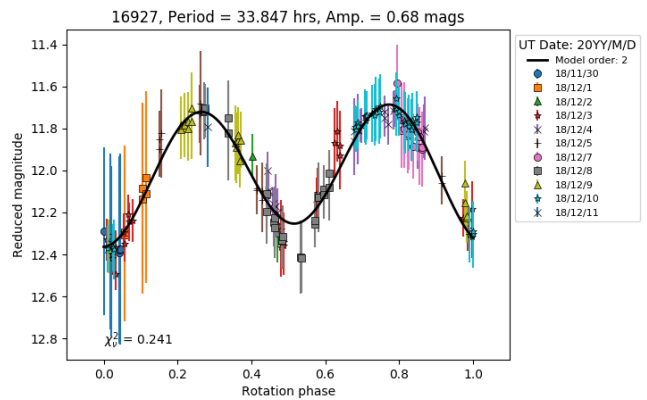
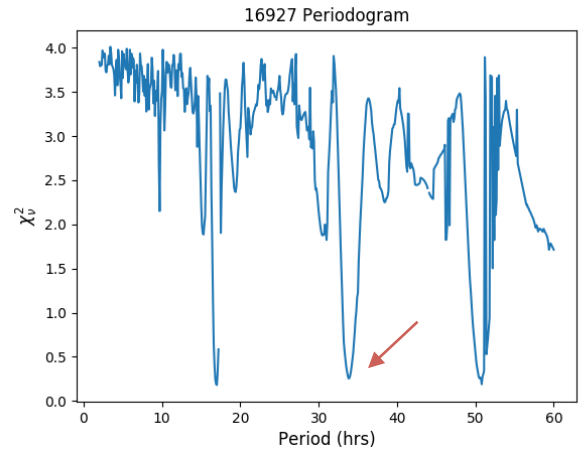
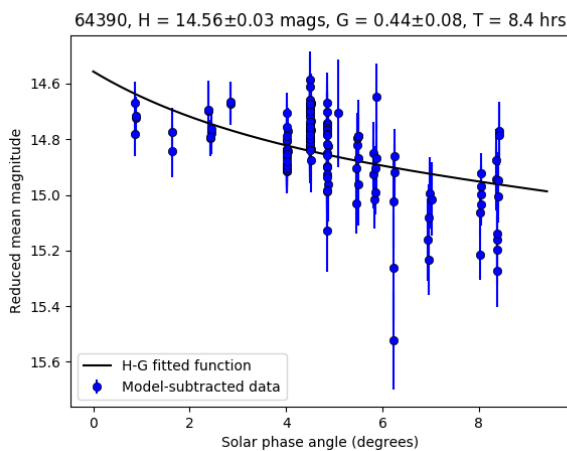
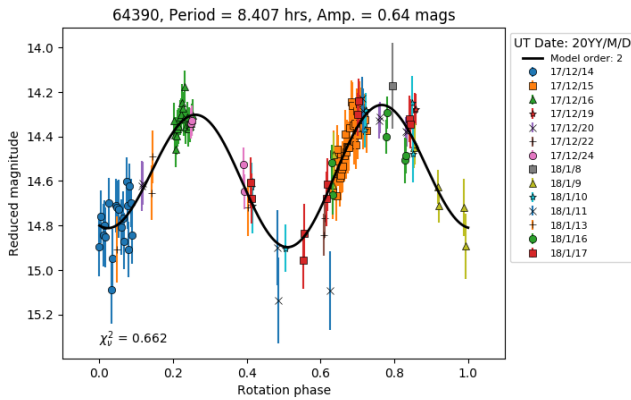
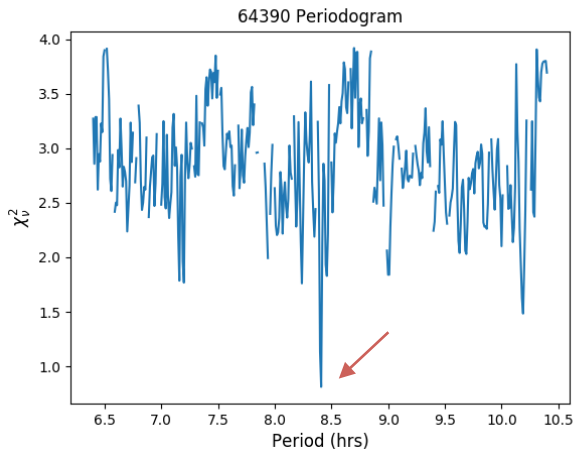
(64390) 2001 UY149. Vereš *et al.* (2015) reported H and G magnitudes of $H_V = 15.03 \pm 0.04$ mag and $G = 0.42 \pm 0.11$. Sonnett *et al.* (2015) reported a maximum amplitude of 1.5 ± 0.2 mag from 12-micron photometry developed from NEOWISE. A 2nd order Fourier fit of 64390’s lightcurve to our Bessel-R data produced a period solution of 8.4070 ± 0.0009 h and a maximum amplitude of 0.64 ± 0.04 mag. We determined $H_R = 14.56 \pm 0.03$ mag and $G_R = 0.44 \pm 0.08$. We suspect that rotational modulation and/or differences in the bandpass in which the H-magnitude is

Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PA}	Period.	P.E.	Amp.	A.E.	H	H.E.	G.	G.E.
64390	2001 UY149	17/12/14–18/01/17	0.9, 8.4	94.5	-0.8	8.4070	0.0009	0.64	0.04	14.56	0.03	0.44	0.08
16927	1998 FX68	18/09/07–18/10/06	3.6, 5.4	86.1	-12.4	33.85	0.07	0.68	0.04	15.40	0.06	0.7	0.2
209512	2004 RO2	19/06/26–19/08/05	3.5, 6.9	295.6	9.1	15.775	0.008	0.30	0.04	14.38	0.06	0.5	0.1

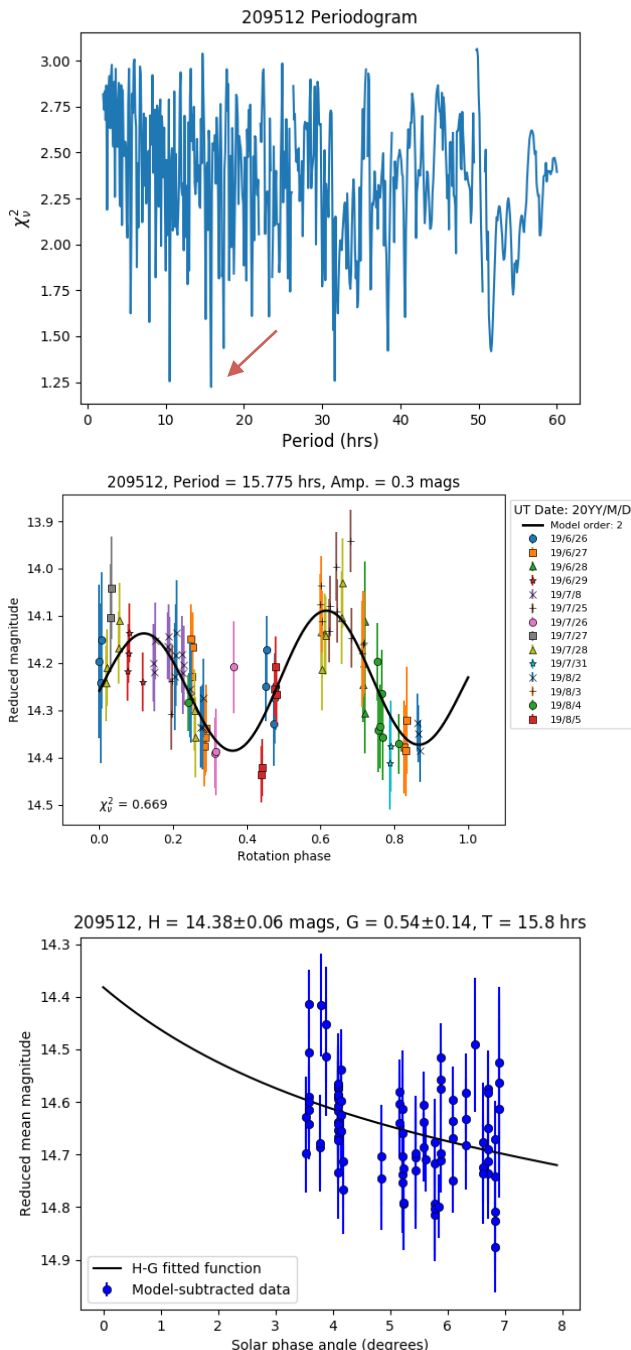
Table I. Observing circumstances and results. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range. H is the absolute magnitude and G the slope parameter of the solar phase function in r' for 209512 (2004 RO2) and in Bessel-R for 64390 (2001 UY149) and 16927 (1998 FX68).

reported may be responsible for discrepancies between the Vereš et al. (2015) results and our own H and G solution.

(16927) 1998 FX68. Sonnett *et al.* (2015) reported a maximum amplitude of 0.92 ± 0.04 mag from infrared bandpasses (12 microns). Vereš *et al.* (2015) reported $H_V = 12.3 \pm 0.4$ mag and $G = 0.6 \pm 0.3$. Warner *et al.* (2017) published a period of 33.856 ± 0.003 h and an amplitude of 0.73 ± 0.04 V-mag. Āurech *et al.* (2018) found a period of 33.8781 ± 0.0002 h. Fumihiko *et al.* (2011) reported $H = 12.40$ mag, and Mainzer *et al.* (2016) reported $H = 11.80$ mag from infrared data. Under our iterative Fourier fitting technique, a 2nd order model fit to our Bessel-R lightcurve for this object yielded a period of 33.85 ± 0.07 h and an amplitude of 0.68 ± 0.04 R-mag. We determined $H_R = 12.02 \pm 0.06$ mag and $G_R = 0.7 \pm 0.2$. Our period, amplitude, H, and G solutions were thus consistent with previous publications.



(209512) 2004 RO₂. A search of the Light Curve Database for this object yielded no previously determined period solutions. Sonnett *et al.* (2015) reported a minimum amplitude of 1.1 ± 0.3 mag from infrared 12-micron observations. Vereš *et al.* (2015) found $H_V = 14.3 \pm 0.2$ mag and $G = -0.2 \pm 0.4$. Fourier curve fitting to our Sloan r' data for this object produced a 2nd order period solution of 15.78 ± 0.02 h and an amplitude of 0.30 ± 0.04 r' -mag. Additionally, we determined H-G magnitudes of $H_r = 14.38 \pm 0.06$ mag and $G_r = 0.5 \pm 0.1$. We note that our solution is poorly constrained since the large photometric uncertainties allowed many period possibilities to yield a reduced χ^2 value. We also suggest rotational modulation as a possible source of the unexpected similarity between our H_r fit and the published H_V values.



Acknowledgements

This paper makes use of data from the AAVSO Photometric All Sky Survey, whose funding has been provided by the Robert Martin Ayers Sciences Fund and from the NSF (AST-1412587). This material is based upon work supported by the National Aeronautics and Space Administration under Grant / Contract / Agreement No. NNX17AF20G issued through the SSO Planetary Astronomy Program. This publication makes use of data products from NEOWISE, which is a project of the Jet Propulsion Laboratory/California Institute of Technology, funded by the Planetary Science Division of the National Aeronautics and Space Administration.

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ROTATION PERIOD DETERMINATION FOR ASTEROIDS 3295 MURAKAMI AND 4961 TIMHERDER

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Photometric observations of two main-belt asteroids were conducted from the Astronomical Observatory of the University of Siena and the Wild Boar Remote Observatory, both located in Italy, in order to determine the synodic rotation periods for the asteroids. For 3295 Murakami we found $P = 3.534 \pm 0.002$ h, $A = 0.14 \pm 0.02$ mag; for 4961 Timherder we found $P = 4.121 \pm 0.001$ h, $A = 0.45 \pm 0.02$ mag.

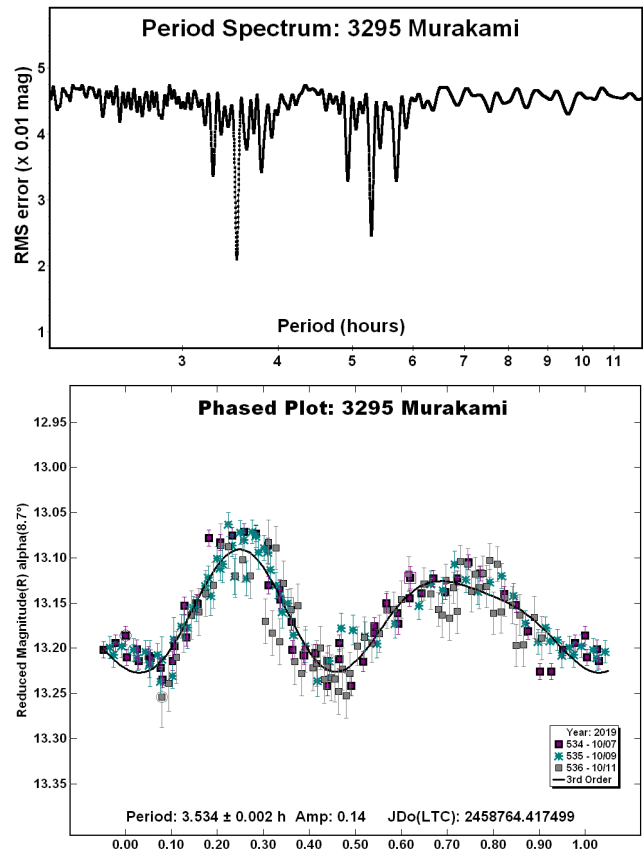
CCD photometric observations of two main-belt asteroids were carried out in 2019 August-October at the Astronomical Observatory of the University of Siena (K54), a facility inside the Department of Physical Sciences, Earth and Environment (DSFTA, 2019), and at the Wild Boar Remote Observatory (K49) in San Casciano in Val di Pesa (Florence). At the Astronomical Observatory, data were obtained with a 0.30-m $f/5.6$ Maksutov-Cassegrain telescope, SBIG STL-6303E NABG CCD camera, and clear filter; the pixel scale was 2.30 arcsec when binned at 2×2 pixels. At the Wild Boar Remote Observatory, data were obtained with a 0.235-m $f/10$ (SCT) telescope, SBIG ST8-XME NABG CCD camera, and no filter; the pixel scale was 1.6 arcsec when binning 2×2 . All exposures were 300 seconds.

Data processing and analysis were done with *MPO Canopus* (Warner, 2018). All images were calibrated with dark and flat-field frames and converted to R magnitudes using solar-colored field stars from a version of the CMC-15 catalogue distributed with *MPO Canopus*. Table I shows the observing circumstances and results.

A search through the asteroid lightcurve database (LCDB; Warner et al., 2009) indicates that our results may be the first reported lightcurve observations and results for 3295 Murakami, while for 4961 Timherder, we found a synodic rotation period that confirms the sidereal one found by Durech et al. (2018).

3295 Murakami (1950 DH) was discovered at Heidelberg on 1950 Feb. 17 by K. Reinmuth and is named in memory of Tadayoshi Murakami (1907-1985), professor of astronomy at the Hiroshima University. [Ref: Minor Planet Circ. 11442] It is a main-belt asteroid with a semi-major axis of 2.696 AU, eccentricity 0.254, inclination 8.801 degrees, and an orbital period of 4.43 years. Its absolute magnitude is $H = 12.8$ (JPL, 2019; MPC, 2019) while its

diameter is $D = 13.415 \pm 0.031$ km (Masiero et al., 2014). Observations of this asteroid were conducted on three nights, collecting 188 data points. The period analysis shows a bimodal solution for the rotational period $P = 3.534 \pm 0.002$ hours with an amplitude $A = 0.14 \pm 0.02$ magnitudes.

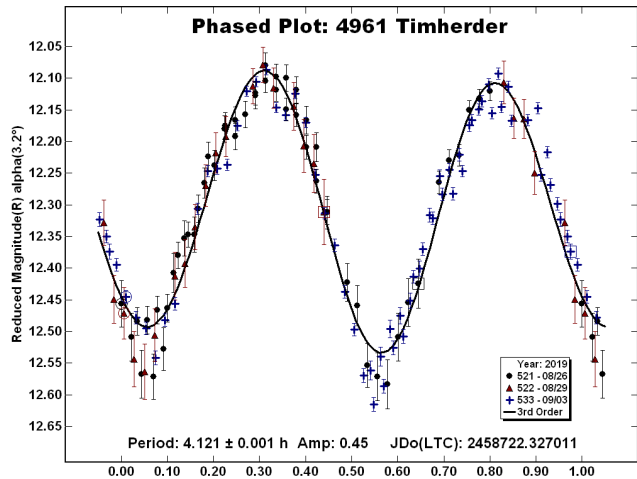
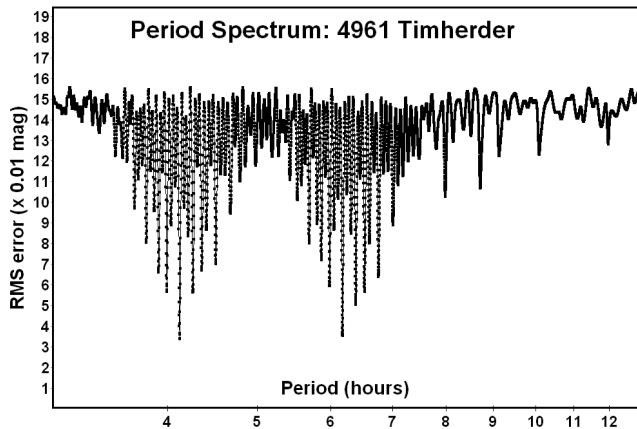


A sudden fall of light is clearly visible in the light curve between phases 0.20 and 0.40. Nevertheless, the error bars are too large to say more about the cause of the attenuation. Additional observations of this asteroid would be welcome in order to verify its actual nature.

4961 Timherder (1958 TH1) was discovered on 1958 Oct 8 at the Lowell Observatory; it is named after Timothy Scott Herder (b. 1955), deputy project manager of NASA's New Horizons-Pluto Kuiper Belt mission. [Ref: Minor Planet Circ. 55719]. It is an outer main-belt asteroid with a semi-major axis of 3.157 AU, eccentricity 0.219, inclination 7.799 degrees, and orbital period of 5.61 years. Its absolute magnitude is $H = 12.1$ (JPL, 2019; MPC, 2019) while its diameter is $D = 11.484 \pm 0.258$ km (Masiero et al., 2011). Observations of this asteroid were conducted on three nights, collecting 140 data points. The period analysis shows a period $P = 4.121 \pm 0.001$ hours with an amplitude $A = 0.45 \pm 0.02$ magnitudes as the most likely bimodal solution for the rotational period of this asteroid.

Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3295	Murakami	10/07-10/11	8.7, 7.3	25	-7	3.534	0.002	0.14	0.02	MB
4961	Timherder	08/26-09/04	*3.3, 2.8	338	4	4.121	0.001	0.45	0.02	MB-O

Table I. Observing circumstances and results. The first line gives the results for the primary of a binary system. The second line gives the orbital period of the satellite and the maximum attenuation. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



Acknowledgements

Minor Planet Circulars (MPCs) are published by the International Astronomical Union's Minor Planet Center.

https://www.minorplanetcenter.net/iau/ECS/MPCArchive/MPCArchive_TBL.html

The authors want to thank a group of high school students involved in an interesting vocational guidance project about astronomy during a summer school in physics. They attended some observing sessions of the asteroid 4961 Timherder and participated in data analysis: T.G. Bors, G. Cannari (Liceo "Galileo Galilei", Siena); R. Pela, D. Risorti (Liceo "Francesco Redi", Arezzo); M. Olivetta (Liceo "Pietro Aldi", Grosseto); A. Bors, A. Checcacci (Liceo "Poliziano", Montepulciano); E. Falini (Liceo "Giovanni da Castiglione", Castiglione Fiorentino).

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LIGHTCURVES OF SIX ASTEROIDS FROM 2018 DECEMBER THROUGH 2019 APRIL

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Lightcurves of six asteroids were obtained from 2018 December through 2019 April. Synodic periods and amplitudes were found for: 4148 McCartney, $P = 20.799 \pm 0.002$ h, $A = 0.27$ mag; 4807 Noboru, $P = 4.0415 \pm 0.0005$ h, $A = 0.19$ mag; 6843 Heremon, $P = 8.2875 \pm 0.002$ h, $A = 0.16$ mag; and (7520) 1990 BV, $P = 3.826 \pm 0.002$ h, $A = 0.32$ mag. For asteroids 5522 De Rop and (12416) 1995 TS, no definitive periods could be determined.

All observations reported here were made without filters and unbinned. Exposure times were between 60 and 150 s depending on the brightness of the target asteroids. A 0.35-m $f/4.5$ Newtonian telescope was used with a Moravian G2-3200 camera and Wynne-Riccardi coma corrector. The mount was a German equatorial friction drive model Mesu-200. The camera was thermoelectrical cooled to -30 °C and all images were calibrated with a master flat and master darks of same exposure length as the science frames, using *Astro Art 7.0*. During calibration, the time series was not aligned to avoid interpolation of pixel intensities prior to analysis done with *MPO Canopus*.

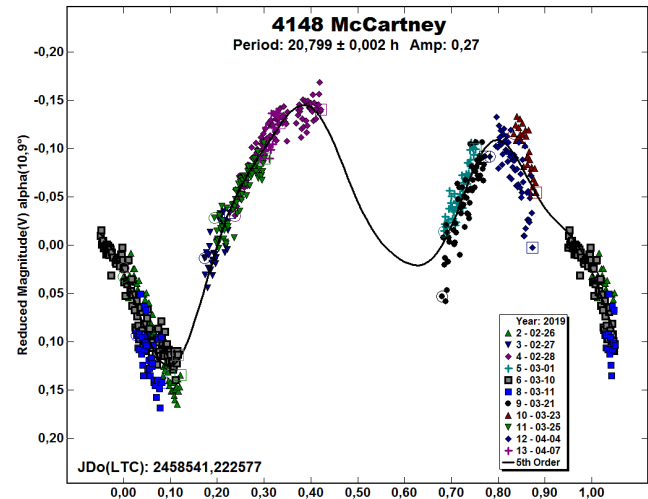
The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were taken from the APASS (Henden et al., 2009) or CMC-15 (Munos, 2017) catalogs, if possible. Otherwise the MPOSC3 catalog was used. The nightly zero points for the APASS and CMC-15 catalogs are generally consistent to about ± 0.05 mag or better, but occasionally reach >0.1 mag. There is a systematic offset between the two catalogs and so the same catalog is used for all observations of a given asteroid. Period analysis is done with *MPO Canopus*, which implements the FALC algorithm by Harris (Harris et al., 1989).

The observatory in Klokkeholm is controlled by *Sequence Generator Pro* software. In the handover of FITS-files between *MPO Canopus* and SG-Pro, there is an issue of switching the FITS keywords OBS-DATE and OBS-LOC. This software error was corrected in *MPO Canopus* using the Photometry Session Form during analysis.

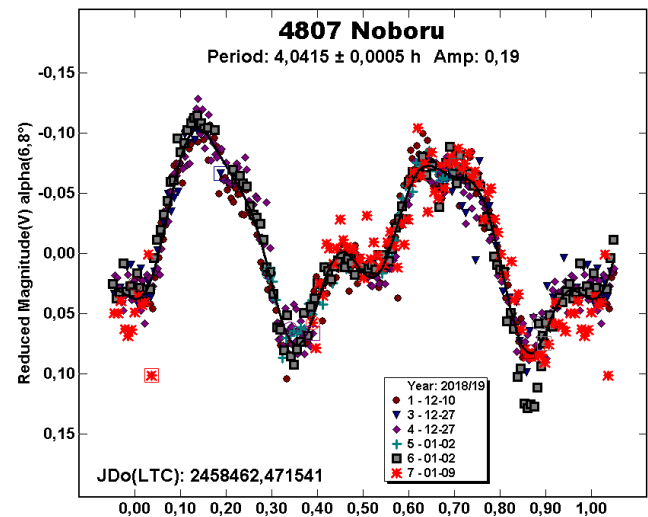
4148 *McCartney* is a member of the Flora family. In a period search between 10 and 21 h, the period spectrum revealed two significant minima at 10.2 h and 20.8 h; the first is a monomodal solution while the second is bimodal and gives the better fit. Using *MPO Canopus* 10.7.11.1, exclusively CMC15 comparison stars, and no zero-point adjustments, this data set can be pushed to 5 harmonic terms in the whole range of solutions between 10 and 21 h without creating fits by exclusion.

The best fit solution is for $P = 20.799 \pm 0.002$ h and amplitude $A = 0.27$ mag. The RMS is 20 mmag, some 10 mmag larger than the internal scatter of the individual lightcurves. The data set has no individual lightcurves longer than 4 h and parts of the phased

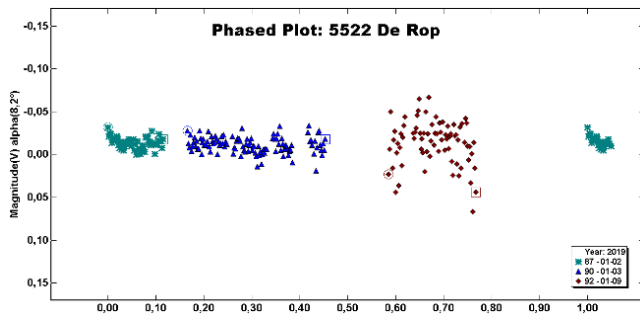
plot are without coverage. Therefore, the only merit of this study of 4148 is to support the period of $P = 20.748 \pm 0.003$ h by Odden et al. (2019). A search in the LCDB (2019 August) listed other observers finding a similar period.



4807 *Noboru* was observed on six nights between 2018 December 9 and 2019 January 9. Data were analyzed with *MPO Canopus* 10.4.3.21 (Warner, 2013). Two of the six sessions were longer than the period reported in this paper. Using six harmonic terms, a period of $P = 4.0415 \pm 0.0005$ h and amplitude of 0.19 mag were found. The fit has an RMS of 15 mmag. A search in the LCDB as of 2019 August found three recent papers with similar periods of 4.0415 h (Contreras, 2019), 4.044 h (Klinglesmith, 2019a), and 4.04 h (Zeigler et al., 2019).

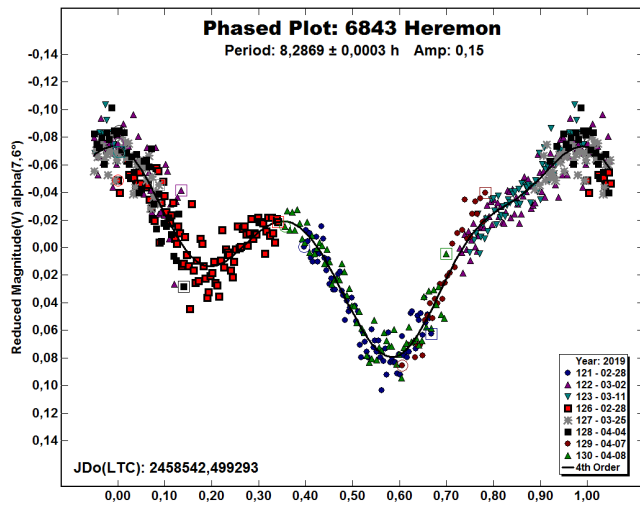


5522 *De Rop* is a member of the Nysa family and was by chance in the field of 4807 *Noboru* on 2019 January 2 and 9. The time series was analyzed with *MPO Canopus* 10.4 and, in each session, five solar-like comparison stars from the MPOSC3 catalog were selected. On both nights, there were no signs of changing magnitude. The two sessions (pre- and post-GEM flip) of January 2 lasted 6.5 h and of January 9 lasted 2.8 h. However, the last session required a zero-point offset of -0.40 mag to align the lightcurve with the two sessions starting 2019 January 2. The large offset might be explained if 5522 is a very slow rotator. A search in the LCDB updated 2019 August did not find any previous reported results for 5522 *De Rop*.



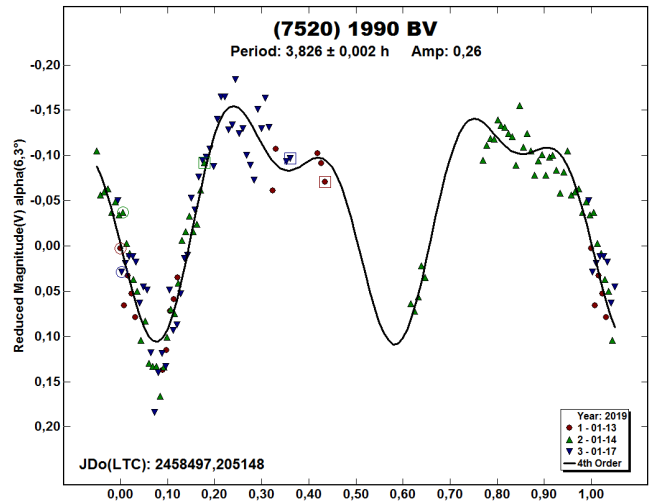
6843 *Heremon* is an inner main-belt asteroid. Observations were done between Feb 27 and Apr 8 in eight sessions of rather short duration, the longest being 3.9 h. Lightcurves were analyzed using *MPO Canopus* 10.7 (Warner, 2017). The CMC15 catalog was used with all sessions. Initial period searches with no zero-point adjustments yielded very poor fits. A search between 4 and 14 h periods showed only hints of solutions near 8 and 12 h, the latter being slightly favored. The last three sessions, those with the largest phase angles, were too bright by 0.15 mag and looked misplaced compared to all the other lightcurves.

The suspicion arose that the default slope parameter $G = 0.15$ was too low for this asteroid. A trial with $G = 0.3$ reduced zero-point adjustments by half and stayed within ± 0.04 mag. This led to a suspected period near 8 h. Pursuing this idea further, values of G up to 0.50 were tested. At $G = 0.40$, zero-point adjustments were in the range of $-0.029 < \text{Offset} < 0.009$ mag. This produced a period of $P = 8.2869 \pm 0.0003$ h and amplitude $A = 0.15$ mag; the RMS fit was 12 mmag. A search in the LCDB updated on 2019 Aug. 19 reports two previously determined periods by Mainzer et al. (2016) and Pravec (2019), both with $P = 8.2865$ h.

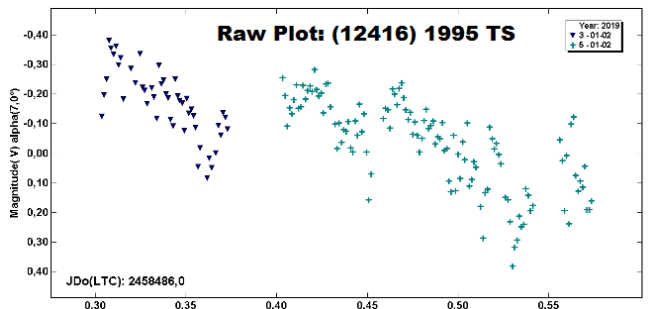
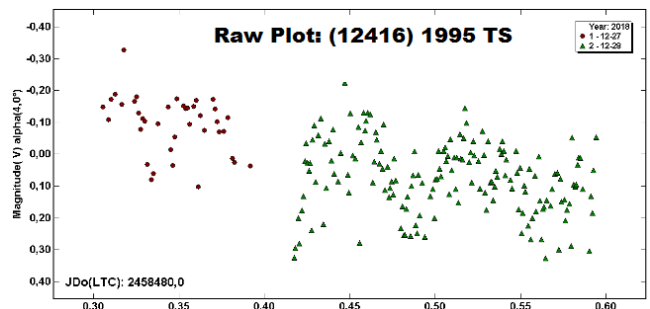


(7520) 1990 BV was observed on three nights in 2019 January. The lightcurves were analyzed with *MPO Canopus* 10.7 with up to five solar-like comparison stars from the MPOSC3 catalog. Too few data were obtained and only a monomodal lightcurve of $P = 1.792 \pm 0.001$ h, $A = 0.24$ mag could be determined with certainty. Around twice this period, a few alias periods showed up in the period spectrum at 3.1 h, 3.55 h, and 3.826 ± 0.002 h, all of which fit the data equally well. The longest solution had a bimodal lightcurve with amplitude of 0.32 mag.

Searching the LCDB listed four other papers where a synodic period close to 3.83 h was reported for this asteroid: Carreno (2019), KlingleSmith (2019b), Marchini (2019), and Zeigler (2019b). This paper supports – not convincingly – these findings.



(12416) 1995 TS happened to be in the field of 4807 Noboru for a short span of time. The asteroid was around magnitude $V = 17.8$ and with a low SNR. The lightcurves look saw-tooth, as if the flat fielding or tracking was bad. However, the telescope mount used has friction drive and runs very smoothly and does not need autoguiding. Using the same set of frames, the lightcurve for 4807 Noboru looked normal. A 4th-order period search between 1.5 and 6.5 h yielded only weak correlations in the period spectrum and the pre-flip lightcurves have significant magnitude offsets compared to the post-flip curves. Since no definitive conclusions can be made, only the two night's raw plots are shown instead of a phased plot. A search of the LCDB had no entries for this object.



Number	Name	yyyy mm/dd	Phase	L _{PAB}	B _{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
4148	McCartney	2019 02/26-04/07	10.9, 26.3	141	0	20.799	0.002	0.27	0.03	FLOR
4807	Noboru	2018 12/09-01/09	*6.8, 12.8	89	1	4.0415	0.0005	0.19	0.03	MB-I
5522	De Rop	2018 01/02-01/09	8.2, 12.0	90	1	-	-	-	-	NYSA
6843	Heremon	2019 02/28-04/08	*7.9, 16.6	169	9	8.2875	0.002	0.16	0.03	MB-I
7520	1990 BV	2019 01/12-01/17	6.3, 8.8	104	2	3.826	0.002	0.32	0.03	MB-I
12416	1995 TS	2018 12/27-01/03	4.0, 7.0	88	1	-	-	0.30	0.10	MB-I

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

Acknowledgements

This research was made possible in part based on data from CMC15 Data Access Service at CAB (INTA-CSIC) (<http://svo2.cab.inta-csic.es/vocats/cmcl5/>) and the AAVSO Photometric All-Sky Survey (APASS), funded by the Robert Martin Ayers Sciences Fund.

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LIGHTCURVE FOR ASTEROID 4717 KANEKO

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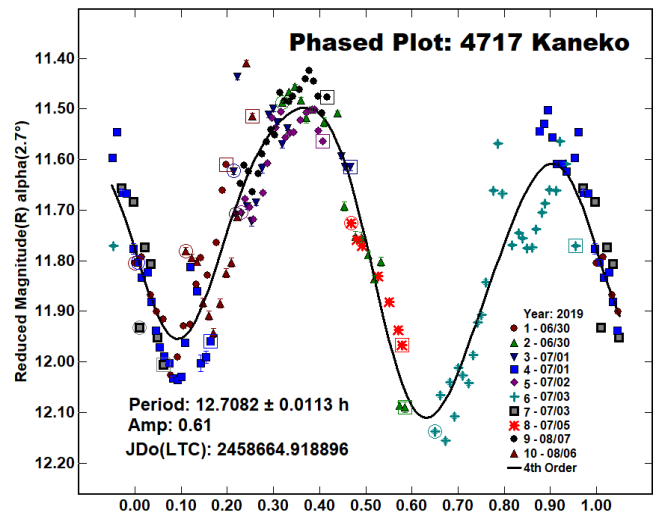
(Received: 2019 October 15)

A team of observers associated with the University of Maryland, College Park conducted observations to determine the rotation period of 4717 Kaneko. Lightcurve analysis using MPO Canopus on photometric data retrieved from multiple nights of observations was conducted in order to determine its rotation period. Using seven nights of data, 4717 Kaneko was found to have a rotation period of 12.7082 ± 0.0113 h and an amplitude of 0.61 mag.

Over the course of the summer, remote observations of 4717 Kaneko were made to determine its rotation period. The asteroid was observed using an online telescope-sharing website called itelescope.net. The T-17 telescope was used on June 30th, July 1st, 2nd, 3rd, 5th, August 6th and 7th in 2019, it is located in Coonabarabran, Australia at the Siding Spring Observatory (iTelescope.net) at coordinates $31^{\circ} 16' 24''$ S and $149^{\circ} 03' 52''$ E. The primary diameter of the telescope is 0.43 m, with a focal length of 2912mm, CCD pixel size of 13 micrometers x 13 micrometers, an array of 1024 x 1024, and a full well of 100,000 e. Each picture taken had an exposure of 300 seconds, and binning set to 1. All observations used a clear filter and images were processed with standard bias, dark, and flat calibrations. MPO Canopus (Warner) was used to determine differential magnitudes and search for a rotation period using Fourier analysis. The celestial coordinates of 4717 Kaneko placed the galactic center in the background of the images, causing the field to be very crowded. Performing accurate aperture photometry was extremely challenging and resulted in a rather noisy light curve.

No rotation period determinations were found prior to our analysis in the Asteroid Lightcurve Database (Warner et al., 2009).

4717 Kaneko is a main-belt asteroid that was discovered by Mizuno and Furuta at the Kani Observatory in Japan on 1989 November 20. The asteroid was named after a social education worker named Isao Kaneko (Minor Planet Center). The asteroid has an orbital period of 5.25 years, an absolute magnitude of 11.3, an albedo of 0.1808, and a diameter of 17.99 km (NASA, 2007). The observations of 4717 Kaneko were made across six days in which a total of 176 data points were collected. The period of 4717 Kaneko was determined to be 12.7082 ± 0.0113 h and an amplitude of 0.61 mag.



Acknowledgements

We thank the University of Maryland Astronomy Department and Dr. Melissa Hayes-Gehrke for partially funding this study as well as the T-17 telescope at the Siding Spring Observatory in Coonabarabran, Australia through iTelescope.net for allocating resources.

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	Grp
4717	Kaneko	2019 06/30-08/07	2.7, 14.1	279.3	-7	12.7082	0.0113	0.61	MB-M

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

ASTEROID PHOTOMETRY AT SOPOT ASTRONOMICAL OBSERVATORY: 2019 JUNE-OCTOBER

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(Received: 2019 October 15)

A summary on the lightcurve and synodic rotation period determinations for 29 asteroids observed at Sopot Astronomical Observatory from 2019 June-October is presented in this paper.

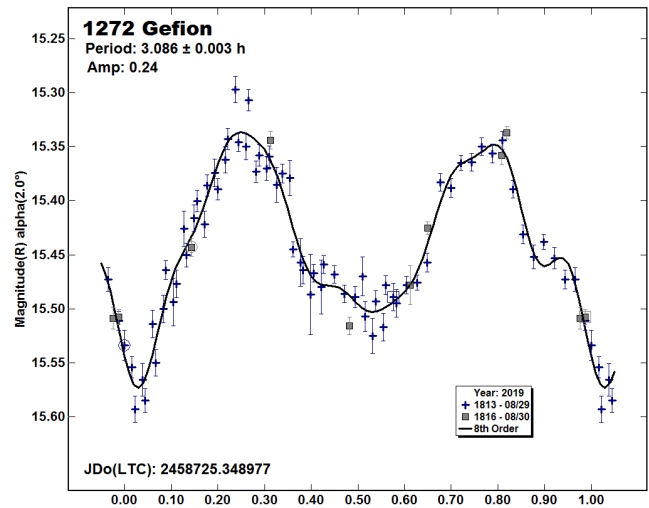
Photometric observations of 29 asteroids were conducted at Sopot Astronomical Observatory (SAO) between 2019 June-October in order to determine their synodic rotation period. For this purpose, two 0.35-m $f/6.3$ Meade LX200GPS Schmidt-Cassegrain telescopes were employed. The telescopes are equipped with a SBIG ST-8 XME or a SBIG ST-10 XME CCD camera. The exposures were unfiltered and unguided for all targets. Both cameras were operated in 2x2 binning mode, which produces image scales, respectively, of 1.66 arcsec/pixel and 1.25 arcsec/pixel for the ST-8 XME and ST-10 XME cameras. 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, 2018). Differential photometry with up to five comparison stars of near solar color ($0.5 \leq B-V \leq 0.9$) was performed using the Comparison 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. Field comparison stars were calibrated using standard Cousins R magnitudes derived from the Carlsberg Meridian Catalog 15 (VizieR, 2019) Sloan r' magnitudes using the formula $R = r' - 0.22$ in all cases presented in this paper. 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.

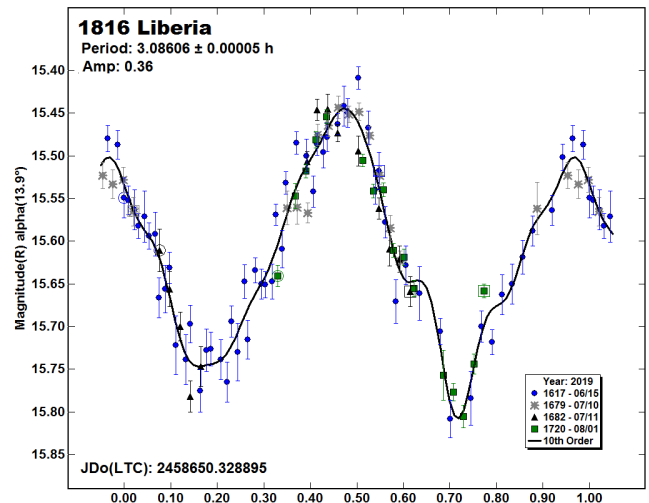
Some of the targets presented in this paper were observed within the Photometric Survey for Asynchronous Binary Asteroids (BinAstPhot Survey) under the leadership of Petr Pravec from Ondřejov Observatory, Czech Republic.

Table 1 gives the observing circumstances and results.

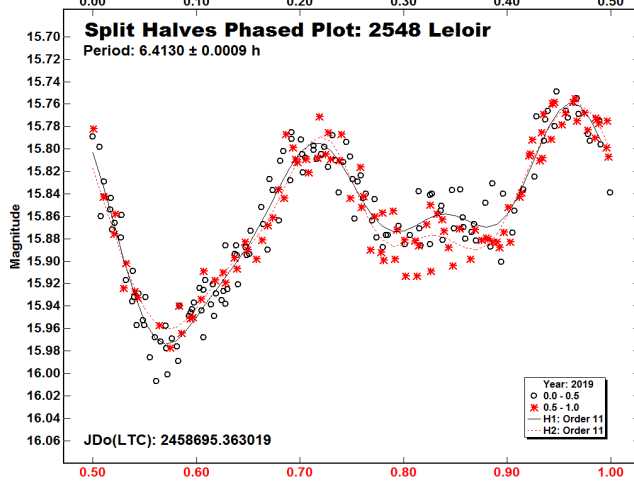
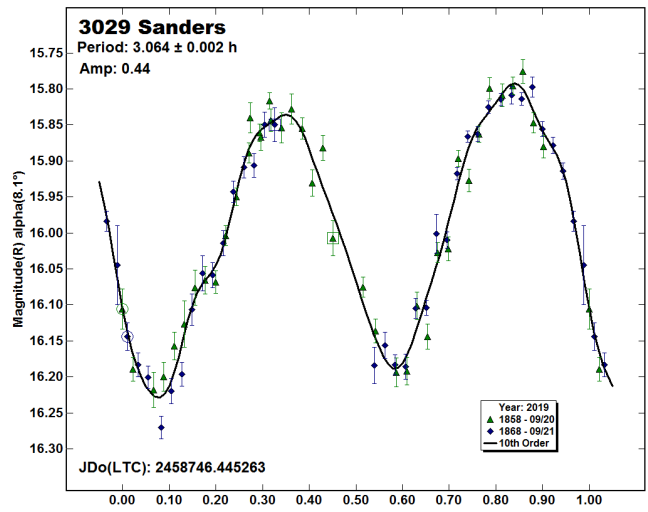
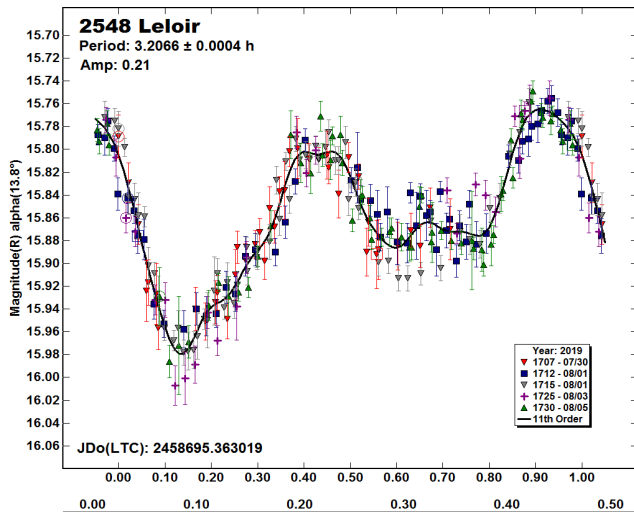
1272 Gefion. Two similar rotational periods were previously determined by Waszczak et al. (2015): 2.900 h and 3.087 h. An uncertainty flag of $U = 2$ was assigned to both of these results in the lightcurve database (LCDB; Warner et al., 2019). The SAO photometric observations were performed over two consecutive nights in late 2019 August. Period analysis indicates an equivocal bimodal solution of $P = 3.086 \pm 0.003$ h, which is consistent with one of the results determined by Waszczak et al (2015).



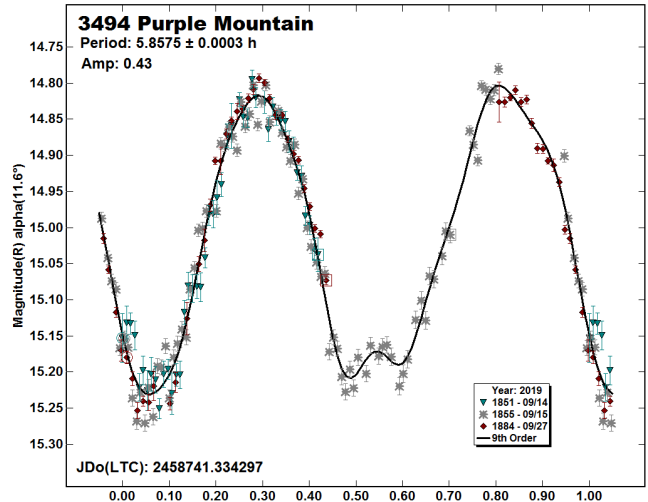
1816 Liberia. A search of the LCDB finds the following previously determined synodic rotation periods: 3.0861 h (Willis, 2004) and 3.02 h (Behrend, 2008), as well as the result for sidereal period by Hanus et al. (2016) of 3.086156 h. The SAO result of $P = 3.08606 \pm 0.00005$ h, determined from the observations carried out from 2019 June 15 through August 1, is in complete agreement with the previously determined period results.



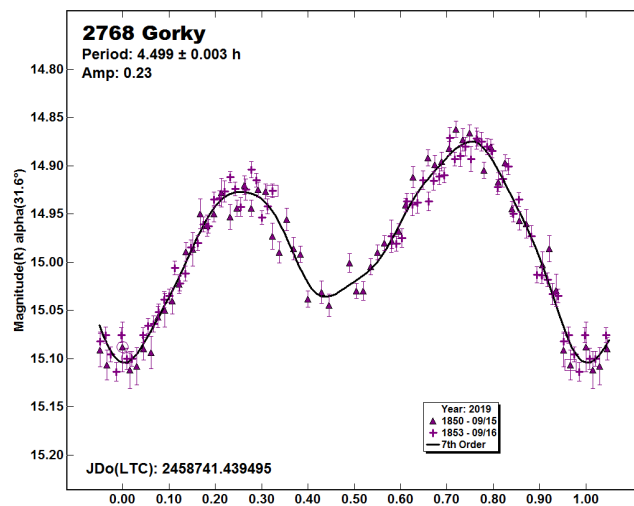
2548 Leloir. No previous period determinations were found in the LCDB. The data collected at SAO in 2019 from late July and early August indicate $P = 3.2066 \text{ h} \pm 0.0004 \text{ h}$ as the most likely value for period. Still, it should be noted that due to the slightly higher noise level in some individual lightcurves obtained on some nights with less favorable observing conditions, a double period of $P = 6.4130 \text{ h}$ cannot be formally ruled out. This is supported by the fact that the two halves of the lightcurve at the longer period are somewhat different and the amplitude of 0.21 mag still allows for different solutions besides a bimodal one (Harris et al., 2014). Based on the available data, it was difficult to discern whether such a double period is just a consequence of unstable observational conditions or is the correct solution.



3494 Purple Mountain. Cantu et al. (2016) and Kosiarek et al. (2017) found rotation periods of, respectively, 5.857 h and 2.928 h. The SAO data collected over three nights in 2019 September over a range of relatively low phase angles yields an equivocal bimodal solution of $P = 5.8575 \pm 0.0003$ h. The fairly large amplitude (0.43 mag) of the corresponding lightcurve strongly supports such a result (Harris et al., 2014).

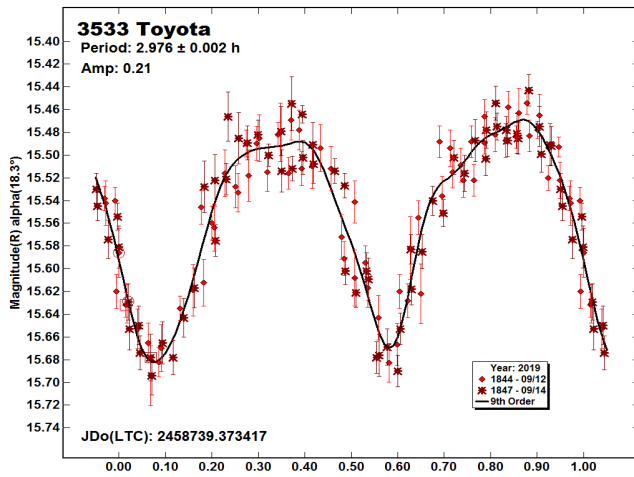


2768 Gorky. Pray et al. (2008) found a synodic period of 4.507 h. The SAO data obtained in 2019 September point to a bimodal solution of $P = 4.449 \pm 0.003$ h, which is only slightly different from the one found previously.

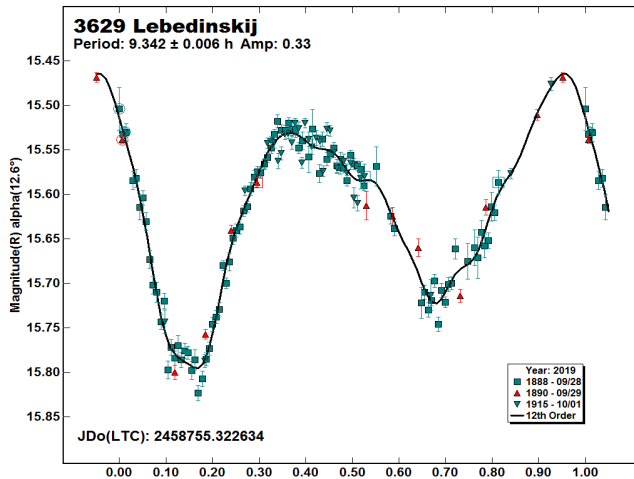


3533 Toyota. Several synodic rotation period determinations were known for this asteroid prior to the SAO observations in on two nights in 2019 September. These include Behrend (2006; 2.9814 h), Pray et al. (2007; 2.9807 h), and Pravec (2009; 2.98156 h). Analysis of the SAO data gave $P = 2.976 \pm 0.002$ h.

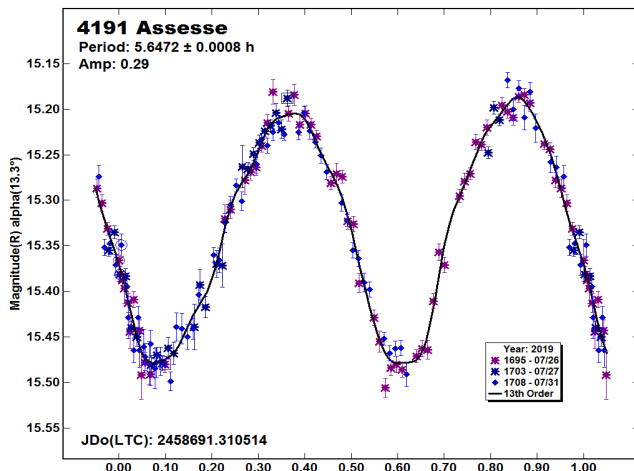
3029 Sanders. No records on previous period determinations were found prior to the SAO observations of this target. Period analysis conducted upon the SAO observations over two consecutive nights in 2019 September show an unambiguous bimodal period solution of $P = 3.064 \pm 0.002$ h.



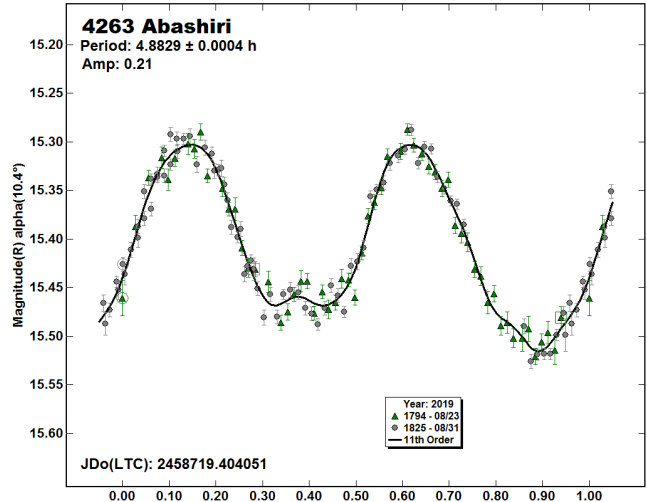
3629 Lebedinskij is a Vestoid type asteroid without a previously known rotation period. Observations undertaken over three nights from 2019 September 28 to October 1 revealed a bimodal lightcurve with a synodic rotation period of $P = 9.342 \pm 0.006$ h and amplitude of 0.33 mag.



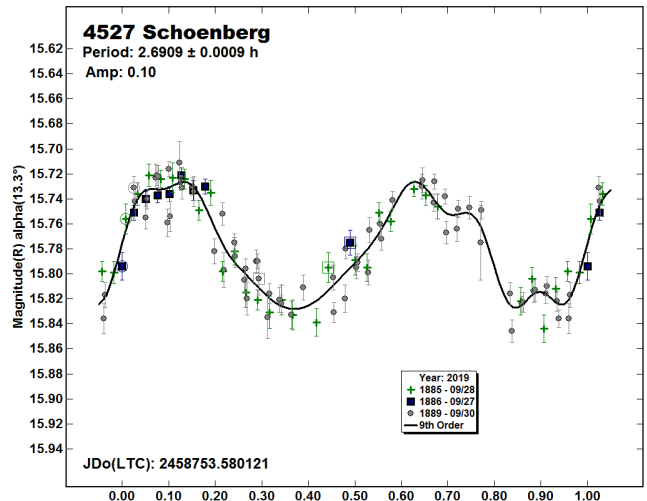
4191 Assesse. Previous rotation period determinations include Angeli et al. (2001; 5.4 h), Alvarez (2010; 5.6489 h), and Waszczak et al. (2015; 5.649 h). The bimodal solution for period of $P = 5.6472 \pm 0.0008$ h based on the data taken at SAO over three nights in 2019 July is consistent with the earlier results.



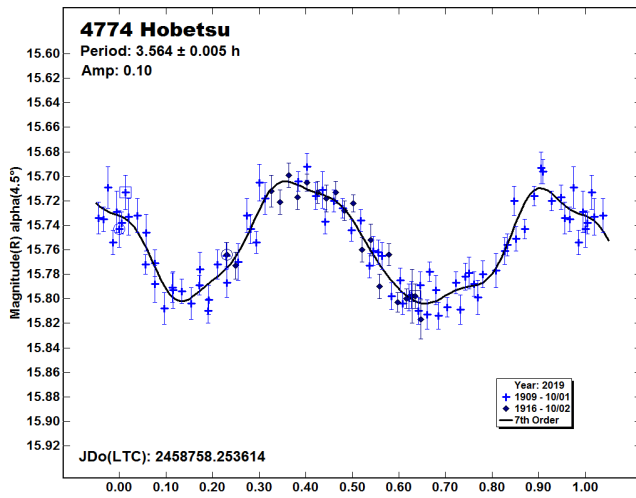
4263 Abashiri. This is a Binastphot Survey target that had been monitored three times previously within this Survey in 2008, 2012, and 2016. Those observations found periods of 4.8820 h (Pravec, 2008), 4.8817 h (Pravec, 2012), and 4.88230 h (Pravec, 2016). No other rotation period results were found. Observations at SAO made in 2019 under the same Survey led to an almost identical result of $P = 4.8829 \pm 0.0004$ h.



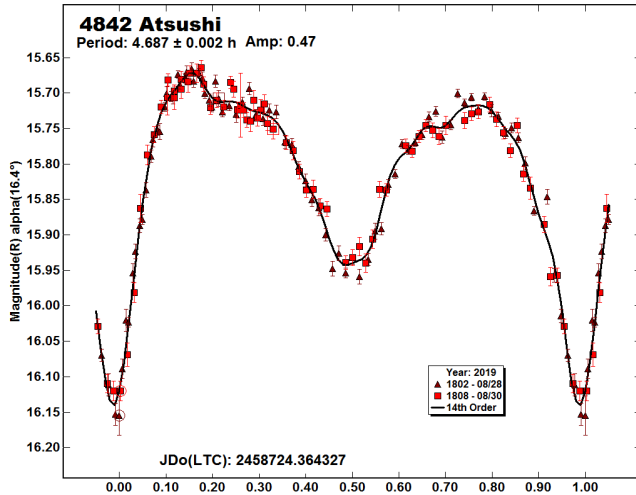
4527 Schoenberg. The rotational period of $P = 2.6909 \pm 0.0009$ h found on the basis of SAO data obtained in 2019 September confirms the only previous result (Burkxonov et al., 2013; 2.69 h).



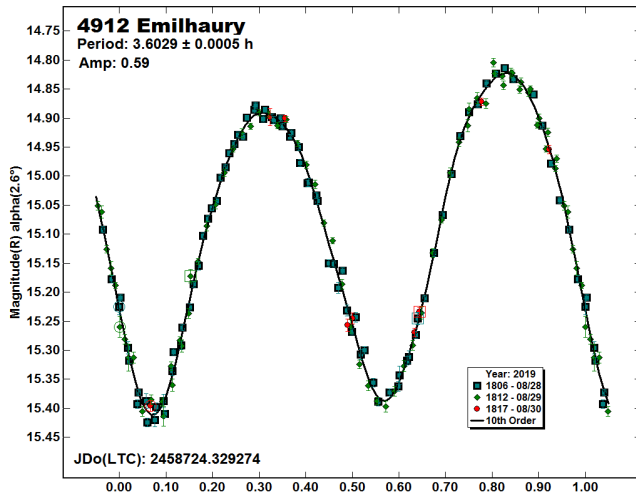
4774 Hobetsu. An analysis of SAO data taken on two consecutive nights in early 2019 October corroborate the only previous period result of 3.577 h (Pray, 2005), indicating the close result of $P = 3.564 \pm 0.005$ h as the most favorable one.



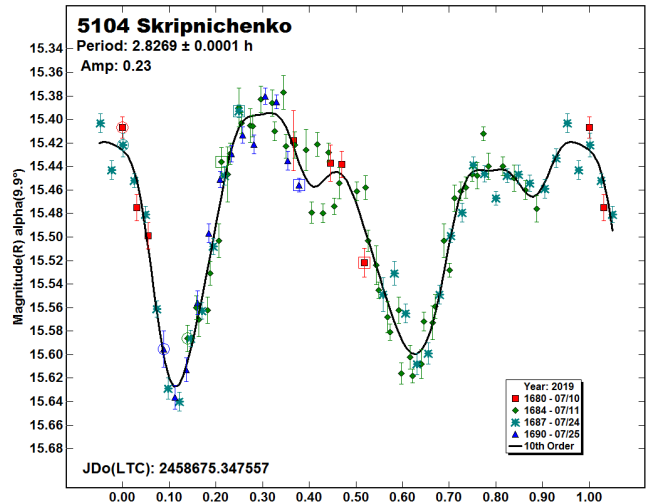
4842 Atsushi. No previous period determinations have been reported. A large amplitude (0.47 mag) bimodal lightcurve phased to a period of $P = 4.687 \pm 0.002$ h is based on SAO data obtained on two nights in 2019 August.



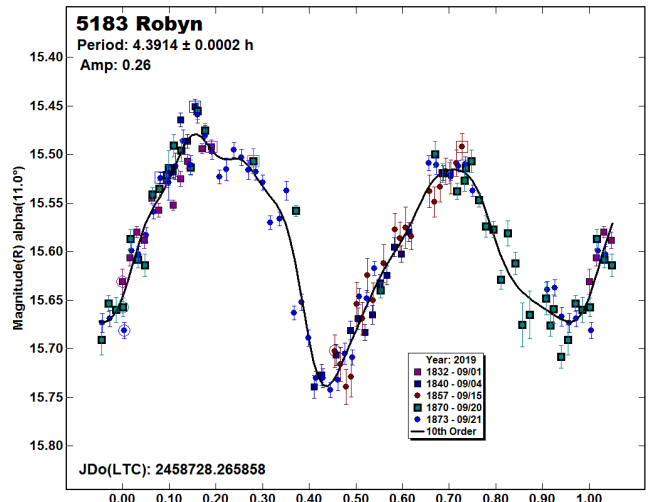
4912 Emilhaury. This is another asteroid without previously known rotation period. The low phase angle observations carried out at SAO over three nights in 2019 August show an unambiguous bimodal solution at $P = 3.6029 \pm 0.0005$ h.



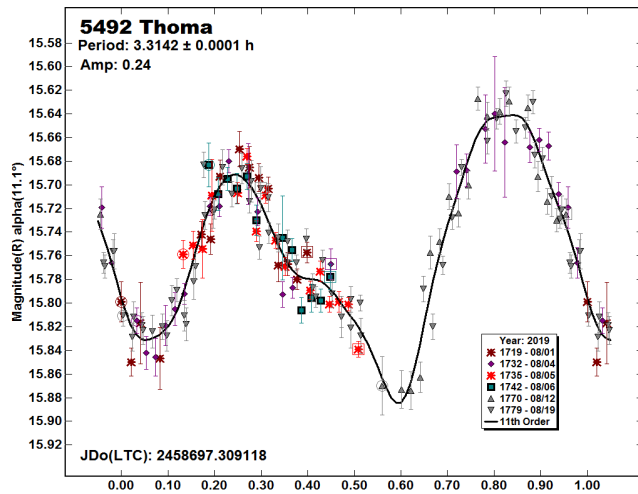
5104 Skripnichenko. Previous rotation period determinations for this Eunomia family asteroid are by Angeli and Barucci (1996, 6.14 h) and Behrend (2006, 2.82708 h; 2011, 2.8266 h; 2014, 2.83 h). The SAO data from 2019 July led to a period of $P = 2.8269 \pm 0.0001$ h, which is fully consistent with the results reported by Behrend.



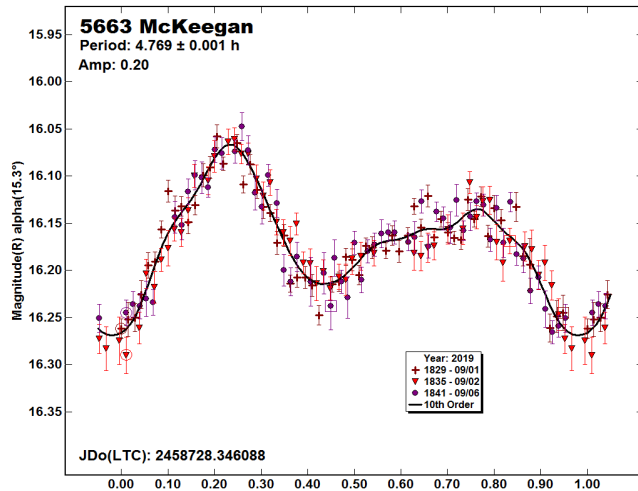
5183 Robyn. This seems to be the first rotation period determination for this Eunomia family asteroid. The observations were conducted on five nights in 2019 September. Period analysis yielded a bimodal lightcurve phased to a period of $P = 4.3914 \pm 0.0002$ h.



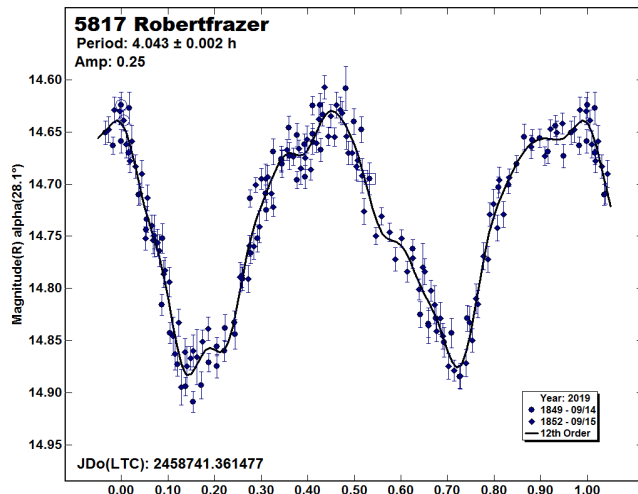
5492 Thoma. Klinglesmith et al. (2015) and Waszczak et al. (2015) found identical synodic rotation periods of 3.315 h. Period analysis of SAO data shows an almost identical result: $P = 3.3142 \pm 0.0001$ h.



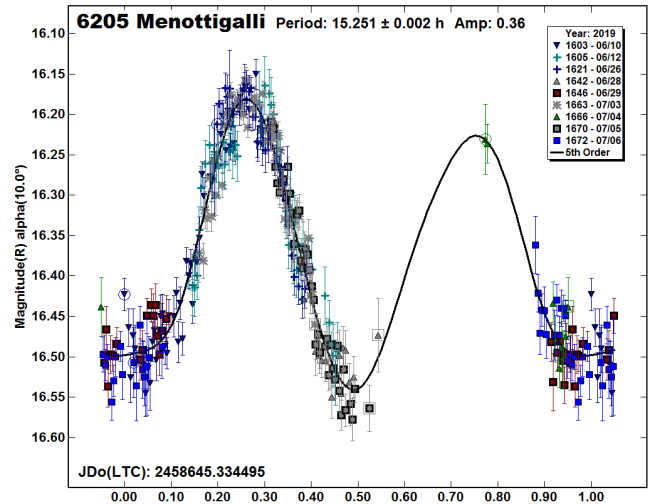
5663 McKeegan. This is another BinAstPhot Survey target with no previously known rotation period. The 2019 September SAO observations carried out as part of this Survey on three nights led to an unambiguous rotation period of $P = 4.769 \pm 0.001$ h.



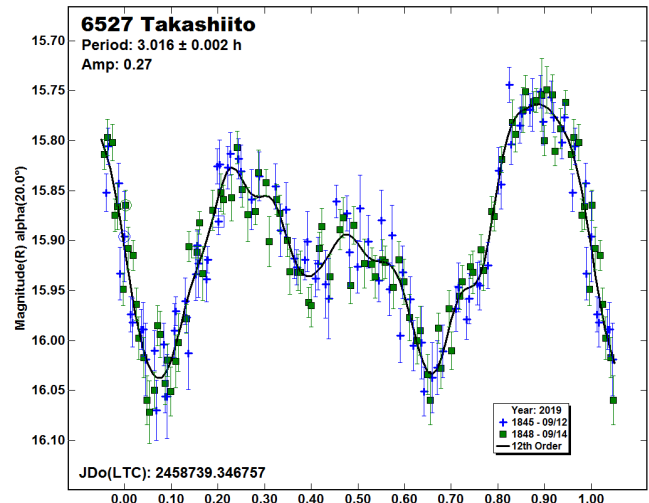
5817 Robertfraser. Consistent period values were determined previously by Behrend (2004, 4.0511 h) and Koff (2005, 4.051 h). There is no significant difference based on the SAO 2019 September data that led to $P = 4.043 \pm 0.002$ h.



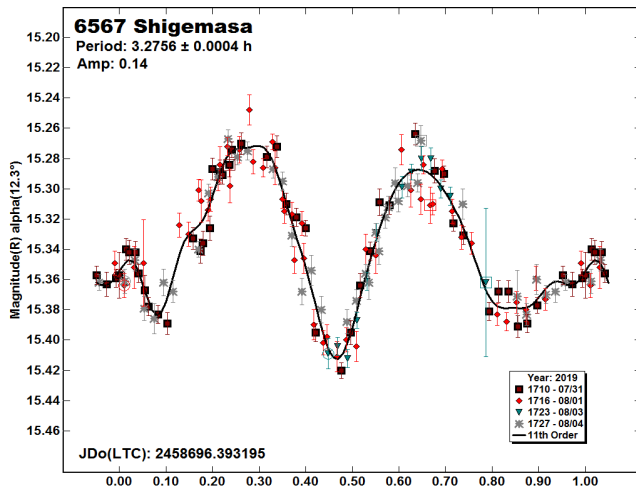
6205 Menottigalli. This is another BinAstPhot Survey program target with no previously known rotation period. Period analyses performed independently by Pravec and Benishek using the SAO observations indicate periods of 15.252 h (Pravec, 2019) and 15.251 h (this work) as the most favorable solutions despite the extremely scarce coverage of most of the second half of the rotational cycle. The advantage of such a bimodal solution over other possibilities is supported by the rather high amplitude of the bimodal lightcurve of 0.36 mag (Harris et al, 2014).



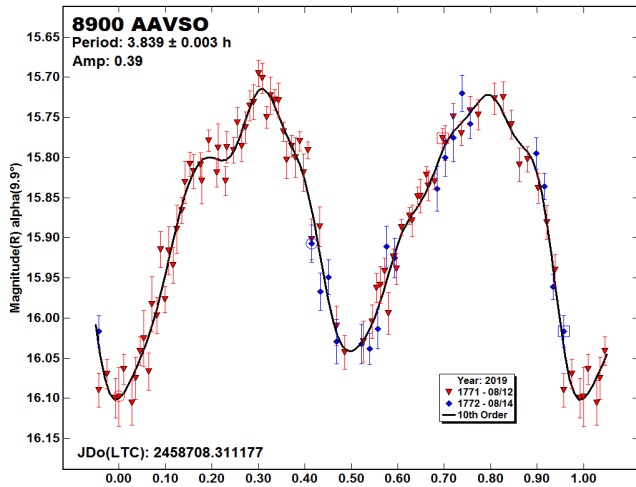
6527 Takashiito. A search of the LCDB found no previous rotation period results on this Flora family asteroid. A secure period of $P = 3.016 \pm 0.002$ h was found based two dense photometric data sets obtained in 2019 September.



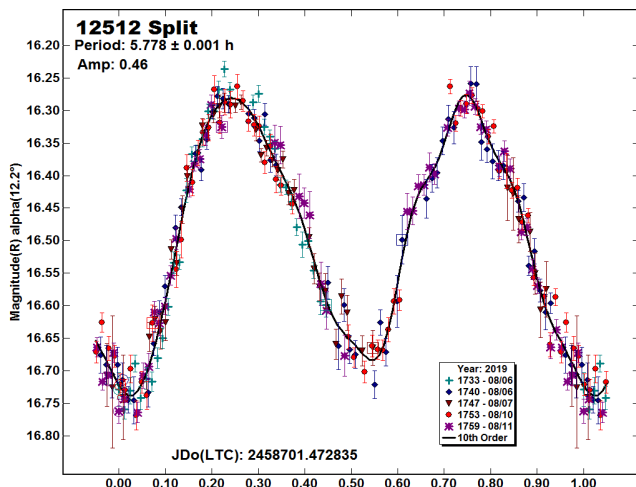
6567 Shigemasa. This was a BinAstPhot Survey target with no previously known rotation period. Period analyses conducted independently by Pravec and Benishek on SAO data from four nights in 2019 July-August converge to statistically equal periods of 3.2752 ± 0.0005 h (Pravec, 2019) and 3.2756 ± 0.0004 h (this work).



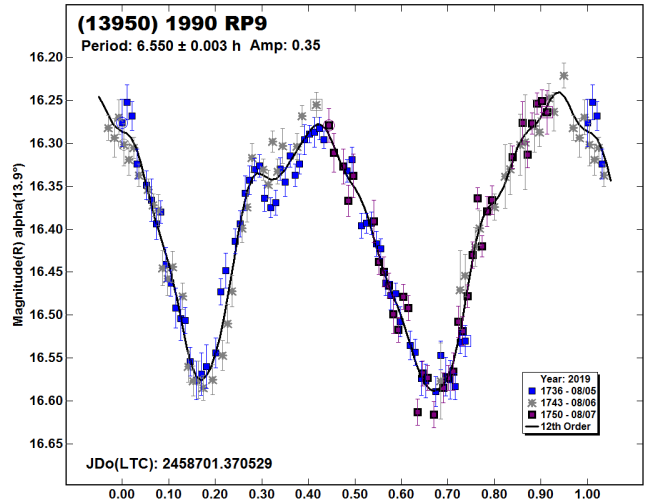
8900 AAVSO. The only previous result for a rotation period is by Waszczak (2015, 3.837 h). A bimodal lightcurve with an amplitude of 0.39 mag, phased to a period $P = 3.839 \pm 0.003$ h, was found based on data from two nights in 2019 August.



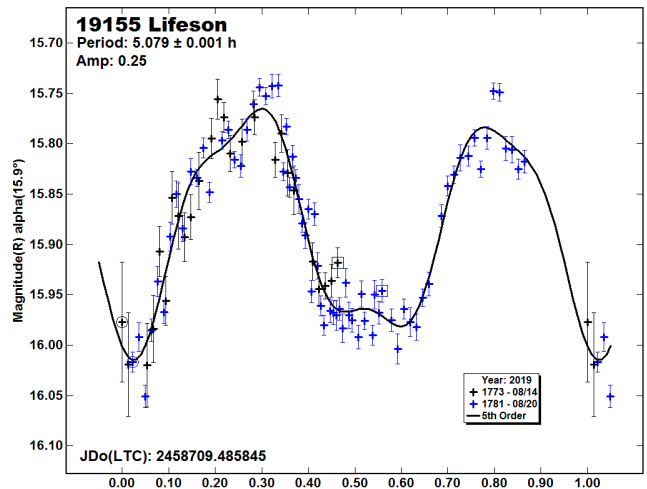
12512 Split. This Baptistina family asteroid was observed within the BinAstPhot Survey at SAO on five nights in 2019 August. Analysis found a large amplitude (0.46 mag.) bimodal lightcurve with a period of $P = 5.778 \pm 0.001$ h. Pravec (2019) used the same data independently to find $P = 5.7781 \pm 0.0006$ h



(13950) 1990 RP9. No previous period determinations were known for this Vestoid asteroid. A unique bimodal solution with $P = 6.550 \pm 0.003$ h was found using SAO data obtained on three nights in 2019 August.

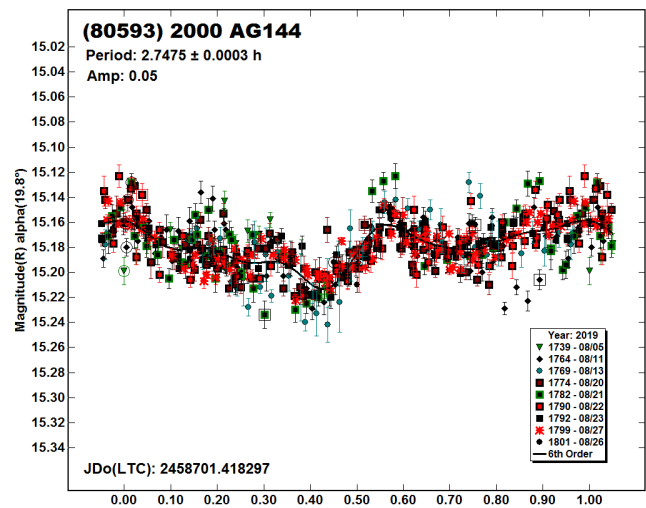
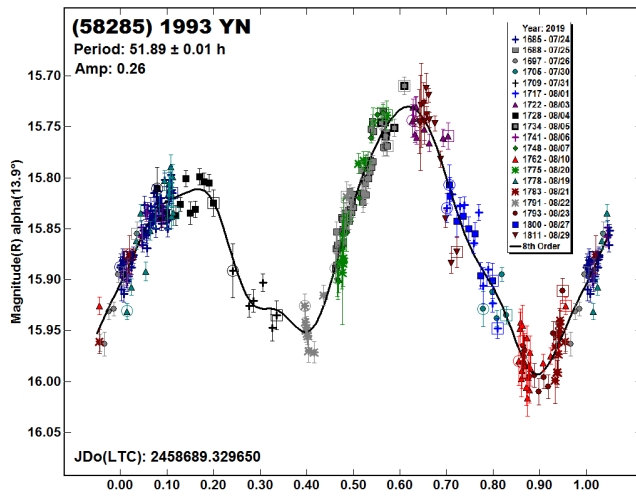


19155 Lifeson. No records on past period determinations were found prior to observations done at SAO in 2019 August. The rotation period of $P = 5.079 \pm 0.001$ h reported here, even though based on an incomplete bimodal lightcurve, represents the most likely solution, especially given the amplitude and relatively low phase angle (Harris et al., 2014). Future observations could increase the certainty of the result given here.



(58285) 1993 YN. This is a Mars-crossing BinAstPhot Survey asteroid with no previously known rotation period. Initial observations indicated a slow-spinning asteroid. The target was monitored systematically for more than a month (2019 late July - late August) on 19 nights.

A sparse photometric data set was created by obtaining several separate groups of a few data points on each night. A bimodal lightcurve with an amplitude of 0.26 mag phased to a period of $P = 51.89 \pm 0.01$ h was found as a result of period analysis. Pravec (2019), independently using the same data set, found 51.92 h for the period



(80593) 2000 AG144. This Mars-crossing asteroid was included in the BinAstPhot Survey observing program. No prior rotation period determinations were known. The photometric observations within the survey were made in 2019 August at SAO on nine nights, as well as on two nights by V. Chiorny using a 0.7-m telescope of the Kharkiv University Observatory, Ukraine.

Despite a low lightcurve amplitude, Pravec used the full data set to find a nearly unambiguous solution of $P = 2.7476$ h and assign an uncertainty flag on the LCDB system of $U = 2+$ (Pravec, 2019). In an independent period analysis based solely on the SAO data, an almost identical result of $P = 2.7475 \pm 0.0003$ h was found.

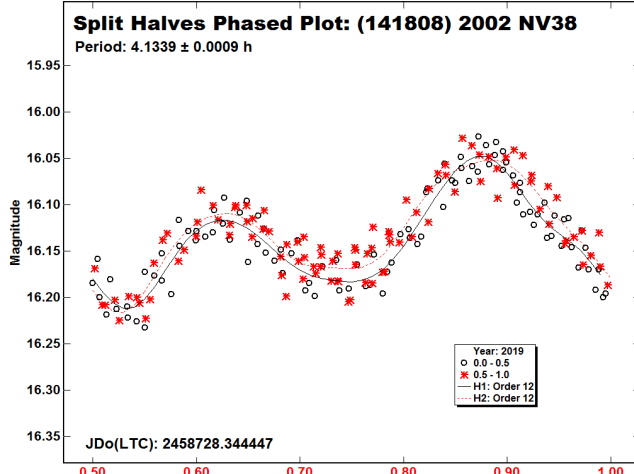
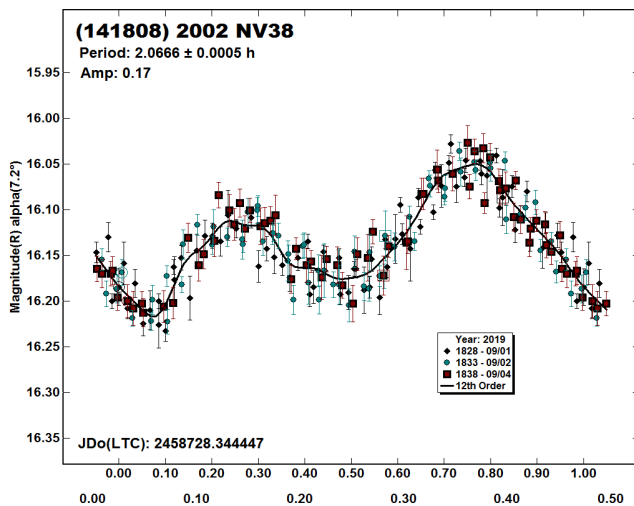
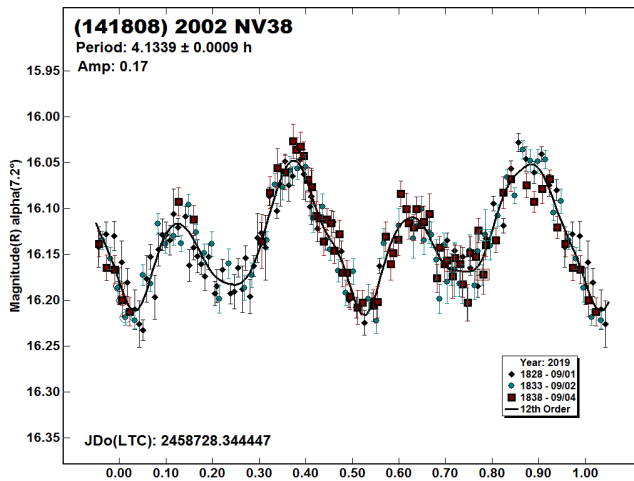
(141808) 2002 NV38. This Mars-crossing asteroid was a BinAstPhot Survey program target without a known prior rotation period determination. Analysis of the dense photometric data acquired at SAO on three nights in early 2019 September shows two distinctly pronounced, harmonically related solutions: the longer period is exactly twice the shorter one (4.133 h vs. 2.066 h).

The possibility of a shorter period below the 2.2 h “spin-barrier” for “rubble-pile” asteroids could indicate either a small monolithic asteroid ($D < \sim 200$ m) or a strongly cohesive “rubble-pile” structure. Given that the absolute magnitude is estimated to be $H = 16.0$ (JPL, 2019), it is more likely not a small-sized asteroid, which would require $H > 22$ (Pravec and Harris, 2000).

Number	Name	2019/mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
1272	Gefion	08/29-08/31	2.0, 1.8	338	3	3.086	0.003	0.24	0.02	MB-O
1816	Liberia	06/15-08/01	13.9, 17.8	271	29	3.08606	0.00005	0.36	0.02	PHO
2548	Leloir	07/30-08/05	13.8, 12.2	337	12	3.2066	0.0004	0.21	0.03	MB-M
2768	Gorky	09/14-09/16	31.6, 31.5	51	-2	4.499	0.0003	0.23	0.01	FLOR
3029	Sanders	09/19-09/21	8.1, 7.6	12	4	3.064	0.002	0.44	0.01	FLOR
3494	Purple Mountain	09/14-09/27	11.5, 17.0	335	8	5.8575	0.0003	0.43	0.01	FLOR
3533	Toyota	09/12-09/14	18.4, 17.9	21	1	2.976	0.002	0.21	0.02	FLOR
3629	Lebedinskiy	09/28-10/02	12.7, 11.1	27	4	9.342	0.006	0.33	0.01	V
4191	Assesse	07/26-07/31	13.4, 12.0	323	16	5.6472	0.0008	0.29	0.01	EUN
4263	Abashiri	08/23-09/01	10.5, 6.6	348	6	4.8829	0.0004	0.21	0.01	FLOR
4527	Schoenberg	09/27-09/30	13.8, 12.1	23	-5	2.6909	0.0009	0.10	0.02	FLOR
4774	Hobetsu	10/01-10/02	4.5, 5.0	1	5	3.564	0.005	0.10	0.02	FLOR
4842	Atsushi	08/28-08/30	16.5, 15.9	1	3	4.687	0.002	0.47	0.01	FLOR
4912	Emilhaury	08/28-08/31	2.7, 2.0	338	3	3.6029	0.0005	0.59	0.01	FLOR
5104	Skripnichenko	07/10-07/25	9.9, 13.1	281	19	2.8269	0.0001	0.23	0.02	EUN
5183	Robyn	09/01-09/21	*11.0, 10.2	350	20	4.3914	0.0002	0.26	0.02	EUN
5492	Thoma	08/01-08/20	11.1, 8.1	325	17	3.3142	0.0001	0.24	0.02	MB-O
5663	McKeegan	09/01-09/06	15.3, 13.2	356	10	4.769	0.001	0.20	0.02	MB-I
5817	Robertfrazier	09/14-09/16	28.1, 27.9	28	18	4.043	0.002	0.25	0.02	MC
6205	Menottigalli	06/10-07/06	9.9, 18.3	253	15	15.251	0.002	0.36	0.03	MB-I
6527	Takashiito	09/12-09/14	20.1, 19.5	20	7	3.016	0.002	0.27	0.03	FLOR
6567	Shigemasa	07/31-08/05	12.3, 10.3	324	7	3.2756	0.0004	0.14	0.02	BAP
8900	AAVSO	08/12-08/14	9.9, 9.5	331	12	3.839	0.003	0.39	0.02	MB-I
12512	Split	08/05-08/11	12.2, 9.6	328	8	5.778	0.001	0.46	0.02	BAP
13950	1990 RP9	08/05-08/08	13.9, 13.0	335	8	6.550	0.003	0.35	0.02	V
19155	Lifeson	08/13-08/21	15.9, 13.1	346	9	5.079	0.001	0.25	0.03	EUN
58285	1993 YN	07/24-08/29	*14.0, 16.9	316	12	51.89	0.01	0.26	0.02	MC
80593	2000 AG144	08/05-08/26	19.8, 13.0	339	9	2.7475	0.0003	0.05	0.02	MC
141808	2002 NV38	09/01-09/05	7.2, 6.6	343	7	4.1339	0.0009	0.17	0.02	MC

Table I. Observing circumstances and results. Phase is the solar phase angle given at the start and end of the date range. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the average phase angle bisector longitude and latitude. Grp is the asteroid family/group (Warner et al., 2009): BAP = Baptistina, EUN = Eunomia, FLOR = Flora, MB-I/M/O = main-belt inner/middle/outer, MC = Mars Crosser, PHO = Phocaea, V = Vestoid.

On the other hand, the “split halves” at the double period shows noticeable differences in the two halves of the lightcurve. This favors the longer period solution and a gravity-dominated “rubble-pile” structure for this asteroid. The solution of $P = 4.1339 \pm 0.0009$ h is adopted here as being more likely correct. An independent period analysis by Pravec (2019) resulted in a period of 4.1333 ± 0.0008 h. Given the unknown basic physical parameters for this asteroid, a conclusive period cannot be given. Further study of other physical parameters is highly desirable as it would likely lead to the true rotation period.



Acknowledgements

Observational work at Sopot Astronomical Observatory is supported by a 2018 Gene Shoemaker NEO Grant from the Planetary Society.

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2020 JANUARY-MARCH

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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 using lightcurve inversion. We also include lists of objects that will or might be radar targets. 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 2020 January-March

In the first three sets of tables, "Dec" is the declination and "U" is the quality code of the lightcurve. See the latest asteroid lightcurve data base (LCDB; Warner et al., 2009; *Icarus* **202**, 134-146.) 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 $V \leq 18.0$ during any month in the current year and up to five years in the future, e.g., limiting the results by magnitude and declination, family, and more.

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 database. This can be accessed for uploading and downloading data at

<http://www.alcdef.org>

Containing almost 3.6 million observations for 14840 objects (2019 Oct 6), we believe this to be the largest publicly available database of raw asteroid time-series lightcurve data.

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 $V = 15.5$ and brighter (sometimes 15.0 when the list has too many potential targets).

Lightcurve/Photometry Opportunities

Objects with $U = 3-$ or 3 are excluded from this list since they will likely appear in the list 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, *do 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 highly-rated result have been proven wrong at times. Note that the lightcurve amplitude in the tables could be more or less than what's given. Use the listing only as a guide.

An entry in bold italics is a near-Earth asteroid (NEA).

Number	Name	Brightest			LCDB Data			U
		Date	Mag	Dec	Period	Amp		
3467	Bernheim	01 05.9	15.1	+23				
4750	Mukai	01 06.5	15.5	+24	38.3	0.40	2	
87135	2000 NU5	01 09.5	15.5	+13		0.76		
4540	Oriani	01 13.2	15.2	+14				
64163	2001 TB49	01 15.3	15.3	+17				
946	Poesia	01 16.4	13.8	+23	108.5	0.24-0.32	2+	
18172	2000 QL7	01 20.6	15.4	+68				
3759	Piironen	01 21.0	14.7	+17	409.848	0.09-0.56	2	
7118	Kuklov	01 21.2	15.5	-1		0.45		
437316	2013 OS3	01 21.5	14.8	+25				
2075	Martinez	01 21.6	14.2	+30	4.755	0.28	2	
1932	Jansky	01 29.5	15.3	+15				
6141	Durda	01 30.1	15.4	-2	460.	0.50	2+	
3999	Aristarchus	01 30.4	14.8	+17	12.58	0.30	2+	
1579	Herrick	01 30.7	15.0	+8				
46875	1998 QD104	01 31.4	15.5	+16	88.734	0.47	2	
5626	1991 FE	02 02.3	15.1	+11	133.6	0.07-0.44	2	
3118	Claytonsmith	02 03.1	14.9	+14	15.794	0.40	2	
1678	Hveen	02 04.1	14.9	+26	5.987	0.07	2	
2859	Paganini	02 06.7	14.9	+13				
5824	Inagaki	02 08.7	15.1	+7				
4931	Tomsk	02 11.0	14.8	+4	7.02	0.46	2	
3566	Levitani	02 12.0	14.9	+12				
163373	2002 PZ39	02 12.0	14.3	+29				
4904	Makio	02 15.8	14.9	-5	7.83	0.08	2	
2361	Gogol	02 19.0	15.5	+14				
4194	Sweitzer	02 20.6	15.3	+10				
4705	Secchi	02 20.8	15.2	+10				
10419	1998 XB4	02 23.1	15.3	+9				
10143	Kamogawa	02 23.8	15.2	-1		0.09		
3088	Jinxuzhonghua	02 26.3	15.4	+5	6.005	0.31	2	
3471	Amelin	02 28.9	15.5	+6				
2452	Lytot	03 02.8	15.3	+13				
1389	Onnie	03 02.9	15.3	+6	22.5	0.34	2	
5377	Komori	03 05.1	15.5	+5				
5972	Harryatkinson	03 05.7	15.1	+10				
1415	Malautra	03 11.2	14.1	+1	>12.	0.03	1	
1755	Lorbach	03 11.2	14.8	+7				
5070	Arai	03 12.3	15.4	+1	53.	0.30	2	
4227	Kaali	03 14.7	15.3	+5				
16704	1995 ED8	03 15.1	15.1	-1				
1628	Strobel	03 16.7	13.9	-1	9.52	0.20-0.22	2	
4570	Runcorn	03 16.9	14.8	+0	>20.	0.12	2-	
2905	Plaskett	03 19.7	15.3	+3				
38079	1999 HF	03 21.2	15.5	-2				
7717	Tabeisshi	03 24.0	15.4	-8				
7084	1991 BR	03 27.9	15.4	+0	5.308	0.19	2	
1179	Mally	03 29.6	15.3	-4	46.692	0.08	1	
331471	1984 QY1	03 29.7	15.3	+6	45.5	0.46-0.65	2	
949	Hel	03 31.0	13.0	-17	8.215	0.13-0.14	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 to get more details about a specific asteroid.

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

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 significantly different values 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-G₁₂, introduced by Muinonen *et al.* (2010; *Icarus* **209**, 542-555). It will be some years before H-G₁₂ becomes widely used. Furthermore, it still needs refinement. That can be done mostly by having data for more asteroids, but only if at very low and moderate phase angles. We strongly encourage obtaining data every degree between 0° to 7°, the non-linear part of the curve that is due to the opposition effect. At angles $\alpha > 7^\circ$, well-calibrated data every 2° or so out to about 25-30°, if possible, should be sufficient. Coverage beyond about 50° is not generally helpful since the H-G system is best defined with data from 0-30°.

Num	Name	Date	α	V	Dec	Period	Amp	U
389	Industria	01 02.3	0.18	11.0	+23	8.53	0.18-0.34	3
1196	Sheba	01 02.9	0.18	13.5	+23	6.319	0.21-0.28	3
412	Elisabetha	01 04.5	0.44	12.8	+22	19.635	0.08-0.20	3
1292	Luce	01 04.7	0.33	14.1	+22	6.954	0.17-0.26	3
1010	Marlene	01 04.9	0.18	14.4	+23	31.06	0.17-0.32	2+
222	Lucia	01 06.7	0.36	14.0	+24	7.837	0.25-0.41	3
498	Tokio	01 06.9	0.73	12.8	+25	41.85	0.23-0.23	3
407	Arachne	01 13.0	0.21	12.1	+22	22.627	0.30-0.31	3
946	Poesia	01 16.4	0.61	13.8	+23	108.5	0.24-0.32	2+
274	Philagoria	01 20.0	0.79	14.1	+23	17.938	0.37-0.51	3
863	Benkoela	01 20.9	0.69	13.4	+22	8.20	0.05-0.27	3-
537	Pauly	01 21.1	0.04	13.9	+20	16.168	0.14-0.20	3
112	Iphigenia	01 30.9	0.35	13.2	+19	31.466	0.30	3
816	Juliana	02 01.6	0.62	13.8	+19	10.557	0.22-0.53	3
860	Ursina	02 02.3	0.38	14.4	+16	9.386	0.22-0.50	3
1274	Delportia	02 03.6	0.86	14.0	+18	5.615	0.05-0.26	3
1503	Kuopio	02 04.1	0.41	13.1	+17	9.957	0.65-0.90	3
622	Esther	02 08.0	0.38	12.9	+14	47.5	0.30-0.6	2
1266	Tone	02 08.1	0.26	14.1	+16	7.40	0.06-0.12	2
90	Antiope	02 17.0	0.80	13.3	+15	16.509	0.05-0.88	3
227	Philosophia	02 20.1	0.36	13.0	+10	26.468	0.06-0.20	3
231	Vindobona	02 20.4	0.84	13.6	+14	14.245	0.20-0.29	3
46	Hestia	02 21.6	0.59	12.2	+09	21.040	0.09-0.12	3
602	Marianna	02 22.2	0.17	13.1	+10	35.195	0.07-0.17	3
591	Irmgard	02 24.7	0.24	12.8	+09	7.35	0.23-0.26	3
582	Olympia	02 25.2	0.19	11.2	+09	36.312	0.05-0.6	3
101	Helena	02 25.6	0.67	12.2	+11	23.080	0.09-0.13	3
839	Valborg	02 27.9	0.05	14.5	+08	10.366	0.14-0.19	3
30	Urania	02 29.6	0.74	10.6	+06	13.686	0.11-0.45	3
66	Maja	03 01.3	0.78	12.9	+09	9.735	0.21-0.45	3
538	Friederike	03 04.0	0.94	14.5	+10	46.728	0.25-0.25	3
184	Dejopeja	03 06.4	0.20	12.2	+05	6.442	0.22-0.3	3
358	Apollonia	03 08.8	0.16	13.0	+04	50.6	0.15-0.15	3-
124	Alkeste	03 09.5	0.61	11.3	+03	9.906	0.08-0.30	3
122	Gerda	03 09.8	0.15	12.1	+04	10.685	0.10-0.26	3
477	Italia	03 16.0	0.75	13.9	+04	19.413	0.15-0.32	3

Num Name	Date	α	V	Dec	Period	Amp	U
271 Penthesilea	03 16.2	0.55	14.2	+00	18.787	0.23-0.33	3
1628 Strobil	03 16.8	0.91	13.9	-01	9.52	0.20-0.22	2
569 Misa	03 19.7	0.68	13.4	-01	11.595	0.09-0.25	3
277 Elvira	03 24.5	0.41	14.1	-03	29.69	0.34-0.59	3
1225 Ariane	03 28.8	0.22	14.1	-03	5.507	0.30-0.36	3
2616 Lesya	03 31.0	0.76	14.9	-03	9.217	0.43-0.51	3
300 Geraldina	03 31.1	0.17	14.4	-04	6.842	0.04-0.32	3
671 Carnegia	03 31.7	0.71	14.4	-06	8.332	0.24	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>

Additional lightcurves 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 \geq 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.

Favorable apparitions are in bold text. NEAs are in italics.

Num Name	Brightest			LCDB Data		U
	Date	Mag	Dec	Period	Amp	
118 Peitho	01 02.7	11.3	+35	7.8055	0.11-0.33	3
1292 Luce	01 04.8	14.1	+22	6.9541	0.17-0.26	3
4374 Tadamori	01 05.6	14.8	+15	4.5047	0.77-0.94	3
81 Terpsichore	01 12.6	11.7	+33	10.943	0.06-0.10	3
545 Messalina	01 13.1	14.2	+32	7.2	0.22-0.27	3
368 Haidea	01 14.8	15.1	+11	9.823	0.15-0.23	3
1670 Minnaert	01 15.2	15.0	+35	3.528	0.23-0.25	3
198 Ampella	01 15.5	11.8	+14	10.379	0.11-0.22	3
755 Quintilla	01 16.9	14.3	+17	4.552	0.08-0.45	3
131 Vala	01 18.1	13.1	+27	5.1812	0.08-0.32	3
6084 Bascom	01 18.4	15.2	-2	2.7454	0.14-0.23	3
815 Coppelia	01 19.9	14.2	+40	4.421	0.17-0.24	3
766 Moguntia	01 20.0	14.1	+34	4.8164	0.06-0.23	3
2105 Gudy	01 25.7	14.4	-15	15.795	0.18-0.52	3-
598 Octavia	01 28.6	13.4	+29	10.8903	0.05-0.28	3
456 Abnoba	01 29.8	13.4	-2	18.281	0.2-0.32	3
643 Scheherezade	01 30.5	14.4	+1	14.161	0.23-0.37	3
1845 Helewalda	01 30.5	14.8	+14	7.2786	0.15-0.34	3-
481 Emita	01 31.8	12.3	+31	14.412	0.16-0.30	3
1052 Belgica	02 02.1	14.4	+21	2.7097	0.08-0.10	3
860 Ursina	02 02.3	14.4	+16	9.386	0.22-0.50	3
76818 2000 RG79	02 02.9	15.4	+1	3.1664	0.14-0.15	3
1689 Floris-Jan	02 07.8	14.9	+18	145.	0.02- 0.4	3
3511 Tsvetaeva	02 08.0	15.0	+0	6.2279	0.80-0.92	3
503 Evelyn	02 10.4	12.0	+22	38.78	0.30- 0.5	3-
195 Eurykleia	02 11.5	12.7	+22	16.521	0.10-0.24	3
40267 1999 GJ4	02 13.4	14.3	-25	4.9567	0.67-1.11	3
267 Tirza	02 13.7	14.3	+22	7.648	0.18- 0.4	3
35107 1991 VH	02 15.5	15.2	+19	2.6236	0.08-0.15	3
4031 Mueller	02 16.4	15.0	+32	2.942	0.14-0.19	3
205 Martha	02 17.0	13.3	-2	14.911	0.10-0.50	3
1308 Halleria	02 19.2	14.6	+15	6.028	0.14-0.17	3
782 Montefiore	02 19.4	13.5	+20	4.0728	0.31-0.54	3
1967 Menzel	02 19.6	14.7	+18	2.835	0.24-0.39	3
2151 Hadwiger	02 24.2	14.4	+29	5.872	0.07-0.38	3
101 Helena	02 25.6	12.2	+11	23.08	0.09-0.13	3
1604 Tombaugh	02 27.4	15.1	+2	7.24	0.16-0.35	3-

Num Name	Date	Brightest		LCDB Data		
		Mag	Dec	Period	Amp	U
839 Valborg	02 28.0	14.5	+8	10.366	0.14-0.19	3
619 Triberga	03 02.7	13.6	-2	29.311	0.30-0.45	3
5175 Ables	03 04.8	15.5	-22	2.798	0.06-0.10	3
1016 Anitra	03 05.6	14.4	+10	5.9295	0.26-0.50	3
3497 Innanen	03 07.9	14.8	+7	7.181	0.39-0.60	3
7132 Casulli	03 08.3	15.1	+0	3.524	0.15-0.25	3-
987 Wallia	03 08.8	14.9	+0	10.0813	0.11-0.36	3
124 Alkeste	03 09.6	11.3	+3	9.906	0.08-0.30	3
2903 Zhuhai	03 12.8	15.0	-16	5.263	0.32-0.54	3
1139 Atami	03 13.6	14.7	-13	27.446	0.15-0.45	3
78 Diana	03 15.8	10.6	-4	7.2991	0.02-0.30	3
477 Italia	03 16.1	13.9	+4	19.413	0.15-0.32	3
3223 Forsius	03 17.5	14.3	+4	2.343	0.20-0.28	3
4175 Billbaum	03 19.1	15.2	+6	2.73	0.08-0.15	3-
939 Isberga	03 21.0	15.3	-2	2.9173	0.20-0.25	3
651 Antikleia	03 22.5	14.7	+8	20.299	0.13-0.41	3
6382 1988 EL	03 23.4	14.8	-12	2.895	0.06-0.20	3
901 Brunzia	03 25.8	14.7	-7	3.1363	0.09-0.28	3
217 Eudora	03 27.5	14.4	+3	25.272	0.08-0.31	3
1225 Ariane	03 28.8	14.1	-3	5.5068	0.30-0.36	3
909 Ulla	03 30.1	14.6	+12	8.73	0.08-0.24	3
300 Geraldina	03 31.1	14.4	-4	6.8423	0.04-0.32	3
850 Altona	03 31.6	13.7	+17	11.1913	0.09-0.17	3
420 Bertholda	03 31.8	13.1	-11	11.04	0.24-0.29	3

Radar-Optical Opportunities

Past radar targets:

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

Arecibo targets:

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

<http://www.naic.edu/~pradar/ephemfuture.txt>

Goldstone targets:

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

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 the Minor Planet Center observing tools

In particular, monitor NEAs 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 or their Facebook or Twitter accounts) 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 circle 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 rotation rate is changing under the influence of YORP. This is why observing asteroids that already have well-known periods remains a valuable use of telescope time. It is even more so when considering the BYORP (binary-YORP) effect among binary asteroids that 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.

To help focus efforts in YORP detection, Table I gives a quick summary of this quarter’s radar-optical targets. The family or group for the asteroid is given under the number name. Also under the name will be additional flags such as “PHA” for Potentially Hazardous Asteroid, NPAR for a tumbler, and/or “BIN” to indicate the asteroid is a binary (or multiple) system. “BIN?” means that the asteroid is a suspected but not confirmed binary. The period is in hours and, in the case of binary, for the primary. The Amp column gives the known range of lightcurve amplitudes. 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 R SNR column indicates the estimated radar SNR using the tool at

<http://www.naic.edu/~eriverav/scripts/index.php>

The “A” is for Arecibo; “G” is for Goldstone.

Asteroid	Period	Amp	App	Last	R SNR
(437316) 2013 OS3	-	-	-	-	A 32
NEA					G -
2012 RK15	-	-	-	-	A 260
NEA					G 90
(163373) 2002 PZ39	-	-	-	-	A 800
NEA					G 270
(35107) 1991 VH	2.623	0.08	5	2014	A -
NEA BIN		0.15			G -
2011 EH	-	-	-	-	A 890
NEA					G 300
2017 BM123	2.150	0.37	1	2017	A 105
NEA NHATS					G 35
2015 RH2	-	-	-	-	A 7
NEA NHATS					G -
(65690) 1991 DG	-	-	-	-	A 35
NEA					G -

Table I. Summary of radar-optical opportunities for the current quarter. Period and amplitude data are from the asteroid lightcurve database (Warner et al., 2009; *Icarus* **202**, 134-146). SNR values are *estimates* that are affected by radar power output along with rotation period, size, and distance. They are given for relative comparisons among the objects in the list.

The SNRs were calculated using the current MPCORB absolute magnitude (H), a period of 4 hours (2 hours if $D \leq 200$ m) if it’s not known, and the approximate minimum Earth distance during the current quarter. These are estimates only and assume that the radars are fully functional.

If the SNR value is in bold text, the object was found on the radar planning pages listed above. Otherwise, the planning 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 is usually placed on the list only if the estimated Arecibo SNR > 10 when using the SNR calculator mentioned above.

It’s rarely the case, especially when shape/spin axis modeling, that there are too much data. Remember that the best set for modeling includes data not just from multiple apparitions but from as wide a range of phase angles during each apparition as well.

(437316) 2013 OS3 (H = 18.4)

There are no periods reported in the LCDB. The estimated diameter is about 600 meters, so the rotation period will likely be > 2 hours. The asteroid starts the year not far from the North Celestial Pole but quickly moves south and crosses the equator towards the end of January.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	08 17.0	+67 08	0.27	1.18	17.4	37.1	134	116	+0.30	+33
01/05	07 53.9	+64 50	0.23	1.16	16.9	35.4	137	80	+0.67	+31
01/09	07 26.7	+60 53	0.19	1.14	16.4	32.7	141	43	+0.96	+28
01/13	06 57.3	+54 09	0.15	1.11	15.8	29.0	147	48	-0.93	+23
01/17	06 27.9	+42 50	0.12	1.09	15.2	25.1	152	101	-0.56	+14
01/21	06 00.6	+24 59	0.10	1.07	14.8	27.3	150	164	-0.15	+1
01/25	05 36.6	+01 52	0.10	1.06	15.1	41.2	135	133	+0.00	-16
01/29	05 16.3	-19 34	0.11	1.04	15.8	57.8	117	81	+0.15	-29
02/02	04 59.5	-34 49	0.13	1.02	16.5	69.7	103	56	+0.50	-37
02/06	04 45.3	-44 46	0.16	1.01	17.2	76.8	94	71	+0.86	-41

2012 RK15 (H = 23.4)

The observing window for those with modest telescopes is just more than a week for this 60-m NEA. The rotation period is unknown but keep in mind that the chances are good that the period is < 2 hours.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/28	02 20.3	+33 09	0.02	0.99	18.1	82.2	96	65	+0.09	-26
01/29	04 10.6	+38 52	0.02	1.00	17.5	60.5	118	76	+0.15	-9
01/30	05 45.9	+38 20	0.03	1.01	17.4	43.0	136	83	+0.23	+5
01/31	06 48.0	+35 16	0.04	1.01	17.5	31.3	148	84	+0.31	+15
02/01	07 26.4	+32 10	0.04	1.02	17.7	23.8	155	80	+0.40	+21
02/02	07 51.2	+29 38	0.05	1.03	18.0	19.0	160	73	+0.50	+25
02/03	08 08.2	+27 39	0.06	1.04	18.2	15.7	163	65	+0.59	+28
02/04	08 20.4	+26 05	0.07	1.05	18.5	13.5	166	55	+0.69	+30
02/05	08 29.6	+24 50	0.08	1.06	18.7	12.0	167	45	+0.78	+32
02/06	08 36.8	+23 50	0.09	1.07	18.9	11.0	168	33	+0.86	+33

(163373) 2002 PZ39 (H = 18.9)

The diameter is ~ 500 m, but the close approach of 0.04 AU or 16 LD (lunar distances) allows it to be worked with modest telescopes. It brightens slowly the second half of January but then, after closest approach on Feb 12, the viewing circumstances soon become unfavorable. The period should be > 2 hours.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/10	09 12.4	+19 41	0.36	1.31	18.2	19.1	154	36	+0.99	+40
01/15	09 10.3	+20 01	0.30	1.27	17.7	15.6	160	36	-0.78	+39
01/20	09 05.9	+20 32	0.25	1.23	17.0	11.4	166	108	-0.24	+38
01/25	08 58.0	+21 19	0.20	1.18	16.3	6.5	172	174	+0.00	+37
01/30	08 44.2	+22 30	0.15	1.14	15.5	4.0	175	122	+0.23	+34
02/04	08 18.3	+24 23	0.11	1.09	15.0	12.5	166	55	+0.69	+29
02/09	07 19.4	+27 20	0.07	1.05	14.5	30.1	148	28	+1.00	+18
02/14	04 29.6	+26 42	0.04	1.00	14.5	72.4	105	139	-0.71	-15

(35107) 1991 VH (H = 16.7; Binary/Trinary)

Pravec et al. (1997; *IAUC* **6607**) reported this as a binary asteroid with a primary period of 2.624 h and orbital period of 32.69 h. Reanalysis of data from 2003 (Pravec et al., 2006; *Icarus* **181**, 63-93) found three periods, indicating the possibility of a second satellite. This is a prime target for a coordinated campaign with observers well-spaced around the globe. Also required will be high-quality data with < 0.02 mag accuracy and precision. There is good news: 1991 VH is within easy reach throughout the first quarter of 2020.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
01/01	10 40.4	-07 25	0.44	1.23	17.1	46.7	114	160	+0.30	+43
01/11	10 46.5	-04 43	0.39	1.25	16.7	40.7	124	53	-1.00	+46
01/21	10 47.0	-00 16	0.35	1.26	16.3	32.6	136	91	-0.15	+49
01/31	10 40.6	+06 11	0.32	1.27	15.8	22.1	151	141	+0.31	+53
02/10	10 27.5	+14 17	0.30	1.28	15.3	10.4	166	3	-0.99	+54
02/20	10 09.7	+22 40	0.31	1.29	15.3	8.7	169	142	-0.12	+53
03/01	09 51.4	+29 39	0.33	1.30	15.9	19.4	154	91	+0.33	+51
03/11	09 37.6	+34 25	0.37	1.30	16.4	29.1	140	54	-0.97	+48
03/21	09 30.8	+37 07	0.42	1.30	16.9	36.6	129	160	-0.10	+47
03/31	09 31.3	+38 16	0.47	1.30	17.3	42.0	119	53	+0.36	+47

2011 EH (H = 25.5)

The estimated diameter is only 25 meters, meaning that there is a good chance of 2011 EH being a super-fast rotator. Sky motion will be fast, reaching 107"/min around Feb 18 at 00:00 UT.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/17	18 56.2	+24 53	0.01	0.98	20.5	121.3	58	56	-0.38	+10
02/18	15 45.3	+32 24	0.01	0.99	18.1	79.2	100	61	-0.28	+52
02/19	13 13.1	+25 08	0.01	1.00	17.8	45.3	134	91	-0.20	+85
02/20	12 09.8	+18 28	0.02	1.00	18.2	29.1	150	114	-0.12	+77
02/21	11 40.0	+14 38	0.03	1.01	18.6	20.7	159	132	-0.06	+69
02/22	11 23.2	+12 19	0.03	1.02	19.0	15.5	164	148	-0.03	+65
02/23	11 12.5	+10 47	0.04	1.03	19.3	12.0	168	162	+0.00	+62
02/24	11 05.1	+09 42	0.05	1.04	19.5	9.3	170	175	+0.00	+59

2017 BM123 (H = 23.7; NHATS)

Warner (*MPB* 44, 223-237) reported a secure period of 2.150 h for this 50-meter NEA based on observations in 2017. That is the only entry in the LCDB. The observing window is only about 10 days. Fortunately, the moon won't be much of a problem.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/20	09 45.9	+10 01	0.06	1.05	18.0	5.8	174	144	-0.12	+43
02/22	09 53.7	+14 57	0.05	1.04	17.7	7.0	173	169	-0.03	+47
02/24	10 05.3	+21 48	0.04	1.03	17.6	12.4	167	166	+0.00	+52
02/26	10 24.1	+31 23	0.03	1.02	17.5	21.6	158	142	+0.05	+58
02/28	10 58.5	+44 23	0.03	1.01	17.5	35.2	144	118	+0.17	+62
03/01	12 12.7	+59 18	0.03	1.01	17.8	52.8	126	98	+0.33	+57
03/03	14 56.9	+68 31	0.03	1.00	18.4	71.5	107	88	+0.52	+45

2015 RH2 (H = 21.9; NHATS)

The main reason this asteroid is included is because it's a potential target for a human mission. Visit <https://ceneos.jpl.nasa.gov/nhats/> for information and observing tools under the Near-Earth Object Human Space Flight Accessible Targets Study (NHATS) program. The estimated size is only 12 meters, so be alert for this being a super-fast rotator. Keep in mind the rule of thumb that exposures must be $< 0.187P$ (period) to avoid *rotational smearing*.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/20	14 22.1	-17 22	0.09	1.03	19.1	63.5	112	71	-0.12	+40
02/23	14 05.0	-18 52	0.10	1.04	19.0	57.3	118	110	+0.00	+41
02/26	13 48.5	-20 05	0.10	1.05	19.0	51.4	124	147	+0.05	+41
02/29	13 32.7	-21 00	0.11	1.06	19.0	45.8	130	163	+0.24	+41
03/03	13 17.6	-21 38	0.12	1.08	19.0	40.5	135	130	+0.52	+41
03/06	13 03.3	-22 01	0.12	1.09	19.0	35.6	140	89	+0.81	+41
03/09	12 50.0	-22 10	0.13	1.10	19.0	31.0	145	46	+0.99	+41
03/12	12 37.7	-22 07	0.14	1.12	19.0	26.9	150	22	-0.92	+41
03/15	12 26.4	-21 54	0.15	1.13	19.1	23.2	153	55	-0.65	+41
03/18	12 16.2	-21 32	0.16	1.14	19.2	20.2	157	94	-0.34	+41

(65690) 1991 DG (H = 19.0)

At 470 meters, this NEA is a "giant" compared to some others this quarter. The observing window extends from mid-February to early April. Weather permitting, it should be possible to get data at more than one lunation, which will be a great help for modeling.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
02/10	10 18.7	-14 54	0.36	1.31	18.5	23.5	148	30	-0.99	+34
02/20	10 10.9	-14 11	0.28	1.25	17.7	19.9	155	125	-0.12	+33
03/01	09 58.1	-11 12	0.22	1.19	17.0	18.6	157	103	+0.33	+33
03/11	09 40.2	-04 28	0.16	1.14	16.4	23.8	152	45	-0.97	+34
03/21	09 15.8	+08 48	0.12	1.09	16.1	38.2	138	168	-0.10	+36
03/31	08 37.3	+32 26	0.09	1.04	16.1	63.1	112	42	+0.36	+35
04/10	06 58.5	+62 23	0.09	0.99	17.0	94.0	81	116	-0.94	+25

IN THIS ISSUE

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

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855	Newcombina	50	50
855	Newcombina	75	75
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2100	Ra-Shalom	23	23	4868	Knushevia	50	50
2131	Mayall	61	61	4868	Knushevia	75	75
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2150	Nyctimene	75	75	5104	Skripnichenko	18	18
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2548	Leloir	64	64	6485	Wendeesther	75	75
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2595	Gudiachvili	7	7	6558	Norizuki	50	50
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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, <http://www.alpo-astronomy.org>). Current and most recent issues of the *MPB* are available on line, free of charge from: <http://www.minorplanet.info/MPB>

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The deadline for the next issue (47-2) is January 15, 2020. The deadline for issue 47-3 is April 15, 2020.