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LIGHTCURVE BASED ROTATIONAL PERIOD DETERMINATION FOR ASTEROIDS 2070 HUMASON AND 3122 FLORENCE

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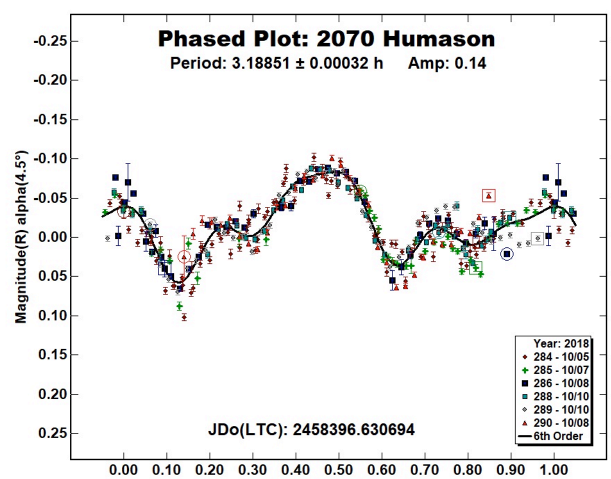
We report photometric analysis of two asteroids observed at the Carl Sagan Observatory (OCS in Spanish) of the Universidad de Sonora in Hermosillo, Sonora, México. For 2070 Humason, our derived intrinsic rotation period is P = 3.18851 ± 0.00032 h and A = 0.14 mag. For 3122 Florence, our derived intrinsic rotation period is P = 2.3589 ± 0.0005 h and A = 0.24 mag. In both cases, we found good agreement with previously reported values.

The Mexican Asteroid Photometry Campaign (CMFA in Spanish) began in 2015 as an effort to study asteroids and to establish a collaborative network among researchers from different Mexican institutions (Sada et al, 2016). In 2017, the asteroid research team at the Universidad de Sonora (UNISON), which is part of the CMFA, decided to undertake a local program to study a sample of asteroids in addition to those selected for the CMFA runs (Contreras et al. 2018).

Here we report results from seven observing nights. Observations of the analyzed asteroids were carried out at our local facility, the Carl Sagan Observatory of the Universidad de Sonora (UNISON) in Hermosillo, Sonora, México. This observatory operates a Meade LX-200GPS 0.41-m f/10 telescope equipped with a 3056 × 3056 × 12 µm Apogee Alta F9000 CCD for imaging. The image frame was trimmed to a subframe of 2000 × 2000 pix and then binned to 2 × 2 pixels yielding an effective 1000 × 1000 pix, ~20 × 20 arcmin FOV with an image scale of about 1.2 arcsec/pix. Images were obtained unguided and unfiltered.

All images were reduced in the standard manner using nightly flat-field files as well as dark-current and bias images using CCDSoft v5.00.071. Photometric measurements and lightcurve analysis were performed using MPO Canopus (version 10.7.3.0, Warner 2017). Although all observations were unfiltered, differential magnitudes were calculated based on R band stellar magnitudes.

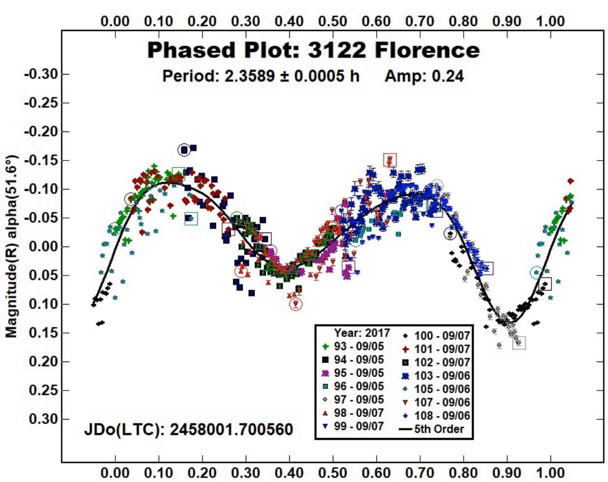
2070 Humason. This main-belt asteroid (MBA) pertaining to the Flora family, is named in memory of Milton L. Humason (Schmadel 2003). It was discovered on 1964 Oct 14 at Goethe Link Observatory at Brooklyn, Indiana. Mainzer et al. (2016) reported an absolute magnitude of H = 13.30, an albedo of 0.405 and a diameter of 4.570 km for this object. 2070 Humason was reported by Benishek et al. (2019) to have a rotation period of 3.1883 ± 0.0005 h with an amplitude of 0.15 mag. In this work, this asteroid was observed on four nights (2018 Oct 5, 7, 8 and 10). A total of 322 data points were used to construct its lightcurve. Based on this lightcurve, we derived an intrinsic rotation period of 3.18851 ± 0.00032 h with an amplitude of 0.14 mag when using a 6th order fit.



Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
3122	Florence	2017 09/05-07	49.8,59.8	335.7	30.8	2.3589	0.0005	0.24	0.07	NEA
2070	Humason	2018 10/05-10	4.6, 1.1	18.2	1.1	3.18851	0.00032	0.14	0.03	MBO

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/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

3122 Florence. This near-Earth asteroid (NEA) was discovered at Siding Spring, Australia by J.S. Bus on 1981 Mar 2. It was named in memory of Florence Nightingale, English nurse and hospital reformer (Schmadel 2003). It belongs to the Amor family and is classified as a potentially hazardous asteroid (PHA). Radar observations during its 2017 close approach to Earth showed that 3122 Florence has two moons (Benner et al. 2017). Mainzer et al. (2016) reported an absolute magnitude of H = 14.00, an albedo of 0.231 and a diameter of 4.401 km for this object. There are many previously published rotation periods values reported in the Asteroid Lightcurve Data Base (LCDB; Warner et al., 2009). Values range from P = 2.3568 ± 0.0002 h with an amplitude of 0.19 ± 0.03 mag (Franco et al. 2018) to P = 5 ± 1 h with an amplitude of 0.15 ± 0.02 mag (Wisniewski et al. 1997). Warner (2016) found a main period of 2.358 h and a second period of 10.36 h. Data for this object were collected during 3 nights (2017 Sep 5, 6, and 7) compiling a total of 577 data points. Since the asteroid´s path across the sky goes very close to bright stars, all observation nights were split up into several sessions. A period of P = 2.3589 ± 0.0005 h with an amplitude of A = 0.24 mag was found, when using a 5th order fit. This value is in good agreement with most of those previously reported periods. We have no evidence for the presence of satellites in our photometry data.



Acknowledgements

We would like to thank the Departamento de Agricultura y Ganadería of the Universidad de Sonora for hosting Carl Sagan Observatory and for their support. MEC acknowledges support from CONACyT Fellowship C-841/2018. LO, PLG, JCS acknowledge support from UNISON project USO315003483.

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LIGHTCURVE-BASED PERIOD DETERMINATION FOR APOLLO PHA (162082) 1998 HL1

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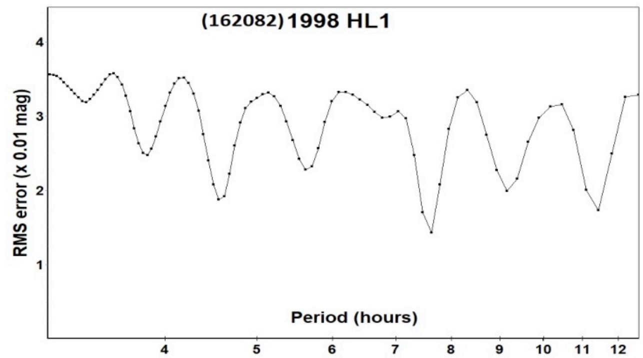
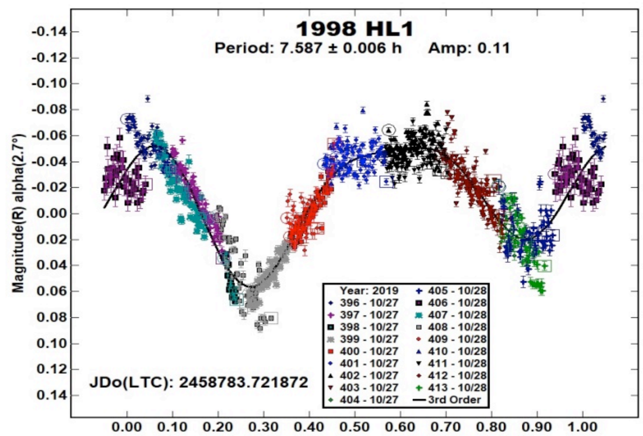
Asteroid (162082) 1998 HL1 was observed during October 2019 at the Observatorio Estelar Carl Sagan from the Universidad de Sonora. Photometric data were collected during two nights that showed a period P = 7.587 ± 0.006 h and amplitude of A= 0.11 ± 0.03 mags.

Near-Earth asteroid (162082) 1998 HL1 is classified as a potentially hazardous asteroid (PHA) and a member of the Apollo group. It was discovered on 1998 April 18 by LINEAR at Socorro (JPL, 2016). As a PHA this object is of considerable interest but unfortunately little is known beyond its orbital parameters. Hence we considered devoting observatory time to the study of 1998 HL1 during its recent close approach.

In total, for two nights (October 27 & 28, 2019) data were recorded at the Carl Sagan Observatory belonging to the Universidad de Sonora (UNISON) in Hermosillo, Mexico. This observatory operates a Meade LX-200GPS 0.41-m $f/10$ telescope equipped with a 3056 x 3056 x 12 μm Apogee Alta F9000 CCD for imaging. The image frame was trimmed to a subframe of 2000 x 2000 pixels and then binned 3x3, yielding an effective 666 x 666 pixel array and a 20 x 20 arcmin FOV with and image scale of about 1.8 arcsec/pix. Images were unguided and unfiltered. Exposure time was 40 s during the first night and 50 s for the second. Images from the observatory were reduced in the standard manner using nightly flat-field files as well as dark-current and bias images using *CCDSoft* v 5.00.071. Photometric measurements and lightcurve analysis were performed using *MPO Canopus* (version 10.7.3.0; Warner 2017). Although all observations were unfiltered, differential magnitudes were calculated based on R band stellar magnitudes.

A total of 15.1 h of data were taken. The first night seeing was considerably good and resulted in a very low scattering of the lightcurve. On the second night conditions deteriorated causing an increase in scattering. Due to the object's considerable angular velocity the field of view had to be adjusted nine times per night during both nights. This resulted in nine different sessions per night once the data were loaded into MPO Canopus for analysis. Using a 3rd order Fourier fit we derived a period of P = 7.587 ± 0.006 h and amplitude A = 0.11 ± 0.03 mag. Below we include both the period spectrum and phased lightcurve. At the time of writing no other published results were found in the literature. Considering the importance of PHAs we hope more observatories will have the opportunity to study the same object in order to confirm our results.





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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
162082	1998 HL1	2019 10/27-28	*2.8,7.2	34	2.2	7.587	0.006	0.11	0.03	Apollo

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).

ROTATION PERIOD AND AMPLITUDE DETERMINATION OF (18172) 2000 QL7: A FAST ROTATOR

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Photometric observations of (18172) 2000 QL7, a fast-rotator Amor/Mars-crosser asteroid, were made over three consecutive nights: 2019 October 29 through November 1. A synodic rotation period of 2.3767 ± 0.0005 h and lightcurve amplitude of 0.11 ± 0.01 mag were determined. The result significantly differs from the one published by Warner and Stephens (2020). Additional observations were made in January 2020. Initial results have been examined and confirmed.

The minor planet (18172) 2000 QL7 is an Amor-family asteroid crossing Mars' orbit with a MOID 0.05895 AU and Earth MOID of 0.36528 AU. With absolute magnitude H = 15.6, it belongs to NEO 1+ KM group (MPC, 2019). During the apparition in 2019/2020, formal opposition was on Dec 9.9 and closest approach Jan 8.9 (JPL, 2019), however due to orbit geometry, phase angles were relatively large at those two events, 41° and 50°, respectively.

The first set of observations were made at Lusowko Platanus Observatory (IAU code K80), Lusowko, Poland, over three consecutive nights: 2019 Oct 29 - Nov 1. The instrumentation included a 0.28-m *f*/2.2 Rowe-Ackermann Schmidt Astrograph mounted on NEQ-6 mount, ASI290MM CMOS camera with FOV 31′×18′ and DreamFocuser. The image scale is 0.96 arcsec/pix. A clear filter was used for all observations.

A total of 6141 light frames were collected, each with an exposure time of 10 s. The observing schedule and conditions are summarized in Table I. All frames were astrometrically solved and corrected for bias, dark, and flat-field frames obtained during the same night. An in-house pipeline software was used to reduce frames, do aperture photometry, and create the lightcurve that includes the uncertainty for each data point. Using an outliner elimination process, 5717 data points were selected for further analysis.

Night 2019 Oct	Num of Data Points	Obs arc h	Airmass	V mag
29	763	2.355	1.261 - 1.517	15.9
30	2736	9.815	1.044 - 1.519	15.9
31	2642	9.339	1.047 - 1.309	15.9

Table I. Observing schedule and conditions of first observations set. Column "Night" means a night starting at a given date.

Fourth-order Fourier series analysis on weighted data points was used to create a periodogram and determine a period. A period spectrum for trial periods from 0.3 h to 11.1 h in steps of 1 s is shown in Fig. 1. Four potential solutions were identified and inspected on phase/magnitude diagrams. The best fit synodic rotational period is P = 2.3767 ± 0.0005 h and amplitude 0.11 ± 0.01 mag (Fig. 2; see Figs. 5, 7). The bimodal lightcurve shows the slightly different first maximum seen on every cycle. The period uncertainty was determined using a Monte Carlo method.

Warner and Stephens (2020), obtained P = 2.509 h ± 0.001 h, or ≅ 9032 s, for the asteroid. Their observations were made in 2019 August. The closest local minimum on my periodogram is at P = 2.518 h. Fig. 3 shows my data forced to this period. The RMSE value is about 0.013 mag larger than the fit to the shorter period.

To try to resolve the ambiguities, additional observations were made in 2020 January in Lusowko Platanus Observatory ("second set") and with a robotic telescope in Nerpio (Spain, IAU code I89, "third set"). The Nerpio setup was a 0.43-m *f*/4.5 CDK and ProLine 16803 CCD camera. Observations in Nerpio were made with a Sloan r′ filter. Exposures were 75 s. Tables II and III summarize the additional observations.

Night 2020 Jan	Num of Data Points	Obs arc h	Airmass	V mag
15	2650	8.298	1.066 - 1.205	15.5
16	1030	3.003	1.201 - 1.459	15.5

Table II. Observing schedule and conditions of second observations set made in Lusowko Platanus Observatory in January 2020. 3305 of 3680 data points were selected for further analysis.

Night 2020	Num of Data Points	Obs arc h	Airmass	V mag
Jan 08	100	2.771	1.316 - 1.413	15.5
Jan 09	79	3.246	1.305 - 1.460	15.5
Jan 14	102	3.860	1.248 - 1.568	15.5
Jan 15	135	4.943	1.214 - 1.552	15.5
Feb 01	30	1.405	1.050 - 1.087	15.6

Table III. Nerpio ("third set") schedule and conditions. 432 of 446 data points were used for analysis.

The additional data sets were analyzed independently. The "second set" found P = 2.37571 ± 0.00051 h (Figs. 4, 5) and, for the "third set", P = 2.3750 ± 0.0072 h (Figs. 6, 7). Both results are consistent with those using the first set. Neither of the additional periodograms shows a strong feature near 2.509 h (9032 s) and the lightcurves forced to the longer period are much less convincing than those to 2.3767 h.

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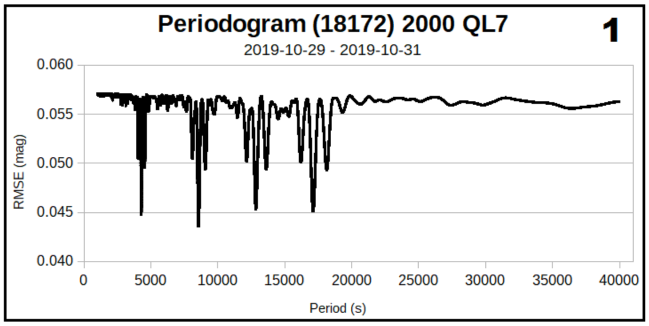
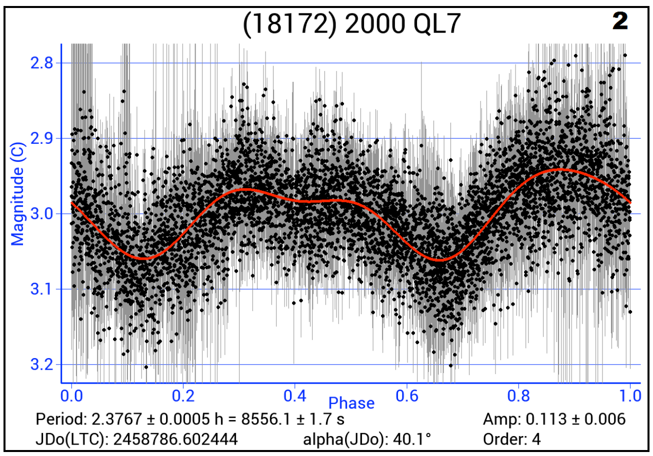
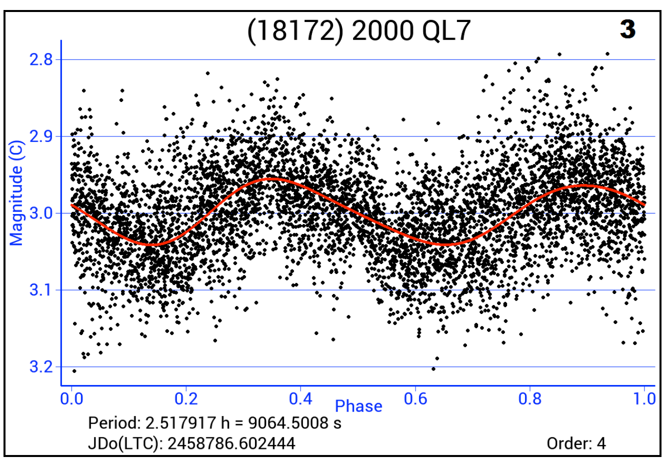
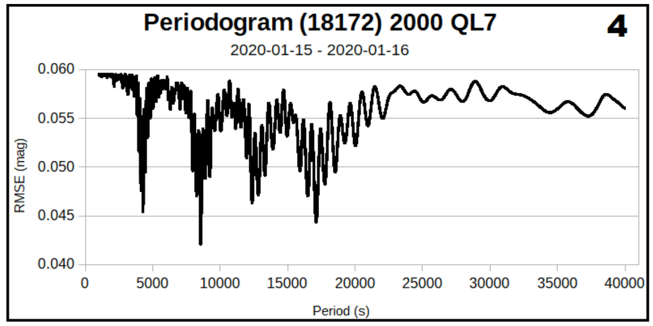
Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
18172	2000 QL7	2019 10/29-11/01	39.7,40.9	45	36	2.3767	0.0005	0.14	0.01	AMOR

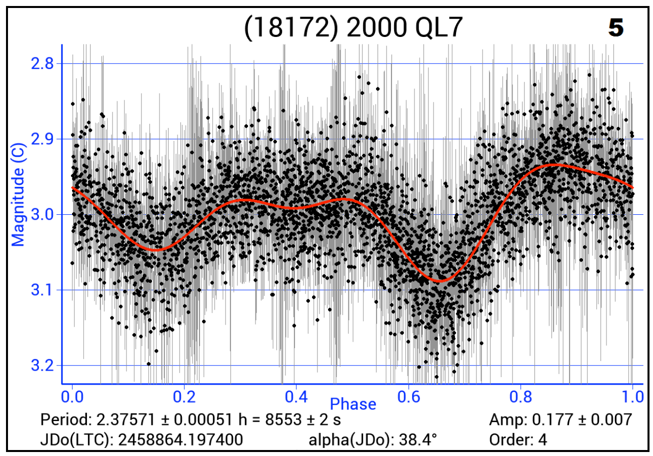
Table IV. Observing circumstances and results. The phase angle is given for the first and last date. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

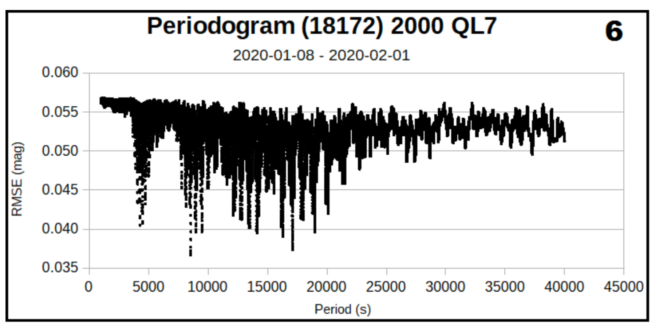


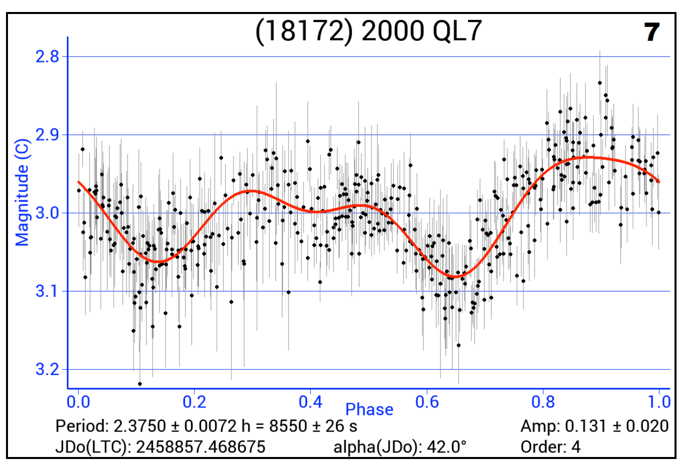












PHOTOMETRIC OBSERVATIONS OF TWENTY-THREE MINOR PLANETS

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Phased lightcurves and synodic rotation periods for 23 main-belt asteroids are presented, based on CCD observations made from 2019 September through 2019 November. All the data have been submitted to the ALCDEF database.

CCD photometric observations of 23 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 23 asteroids were obtained between 2019 September and November.

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.

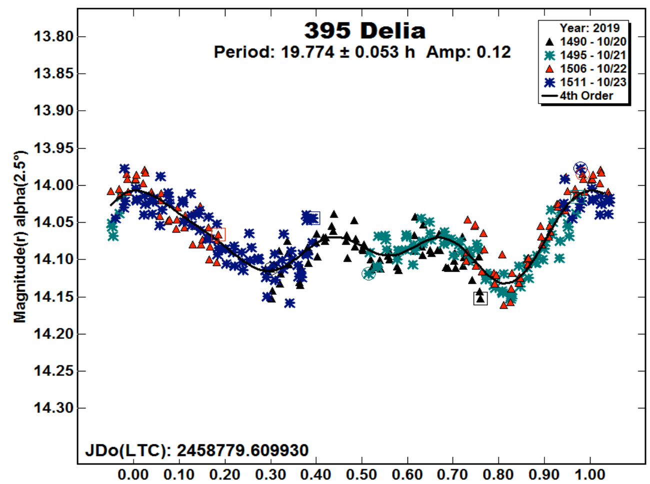
The data reduction and period analysis were done using *MPO Canopus* (Warner, 2019). The 45′x30′ field of the CCD typically enables the use of the same field center for three consecutive nights. In these fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected 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 with respect to a color term. Comparison 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. The consistency of the ATLAS 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.

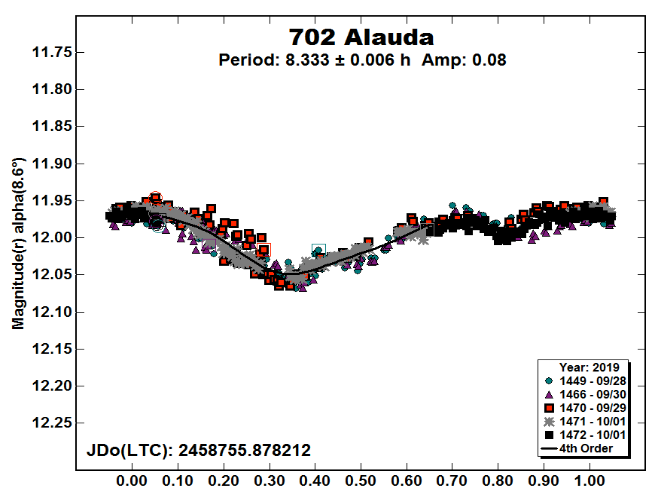
A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars. It was typically necessary to employ star subtraction to remove contamination by field stars. For the asteroids described here, I note the RMS scatter on the phased lightcurves, which gives an indication of the overall 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, 2011a) using the criteria of magnitude greater than 15.0 and quality of results, U, less than 2+. In this set of observations, 8 of the 23 asteroids had no previous period analysis and 15 had U = 2. 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.

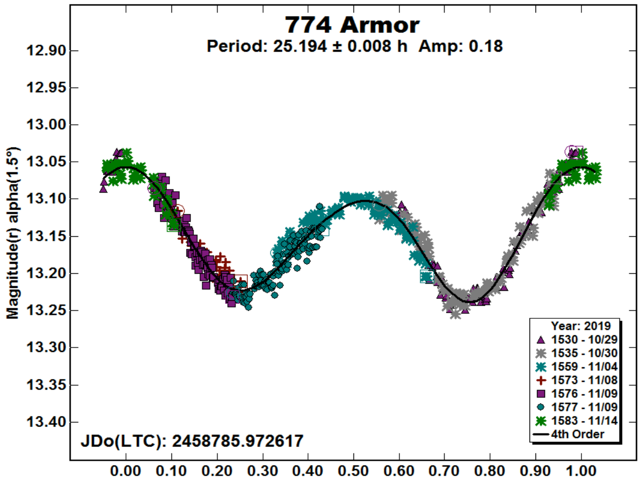
<u>395 Delia.</u> This outer-belt asteroid was discovered in 1894 by Auguste Charlois at Nice. Marciniak (2015) shows a period of 19.680 ± 0.0005 h, and Ditteon (2018) computed 18.98 ± 0.02 h. A total of 296 data points were gathered during four observing nights, resulting in a synodic period of 19.774 ± 0.053 h and agreeing with Marciniak's value. The amplitude is 0.12 mag, and the RMS scatter on the fit shown in the phased plot is 0.025 mag.



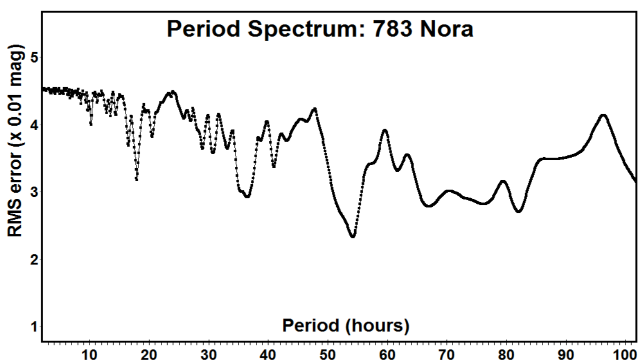
<u>702 Alauda</u> resides in a highly inclined orbit in the outer belt. It was discovered in 1910 at Heidelberg by Joseph Helffrich. Several period solutions appear in the LCDB. Fauerbach and Bennett (2005) obtained a period of 8.348 ± 0.001 h, Benishek and Protitch-Benishek (2008) showed 8.3539 ± 0.0007 h, and Alkema (2014) calculated 8.3531 ± 0.0004 h. Observations were carried out on four nights, during which 554 images were gathered. The resulting solution is 8.333 ± 0.006 h agrees with previous assessments. The amplitude of the lightcurve is small, 0.08 mag, and the RMS error is 0.011 mag.

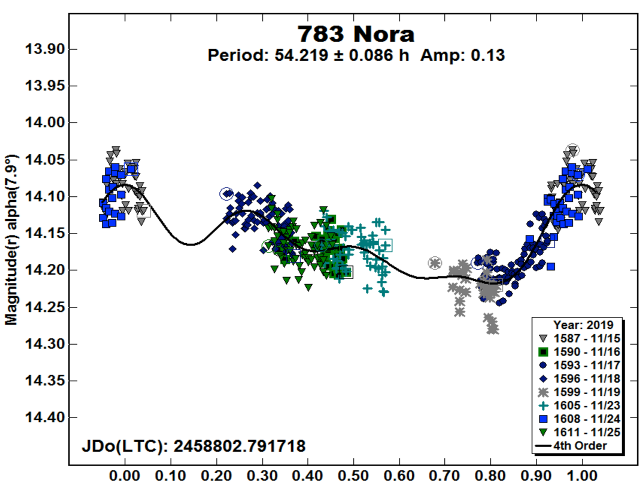


774 Armor was discovered by Charles Le Morvan at Paris in 1913. Three consistent period solutions appear in the LCDB: Warner et al. (2006), 25.162 ± 0.002 h; Behrend (2005), 26.2 ± 0.2 h; and Oey et al. (2013), 25.107 ± 0.005 h. After seven nights, 555 images were obtained, yielding a period of 25.194 ± 0.008 h, in agreement with the earlier results. The amplitude and RMS error of the lightcurve are 0.18 mag and 0.012 mag, respectively.

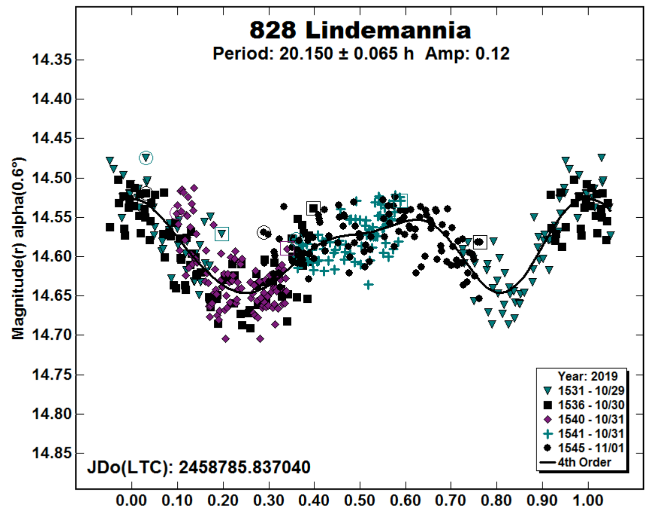


783 Nora is an inner-belt minor planet in an eccentric orbit. LCDB entries include those by Florczak et al. (1997; 34.4 ± 0.5 h) and Polakis (2018; 55.53 ± 0.08 h). This challenging lightcurve was the result of 414 observations gathered over eight nights. The period spectrum shows a signal at 54.219 ± 0.086 h, or about the period published by Polakis. The RMS error is 0.024 mag, which is large relative to the amplitude of 0.13 mag.

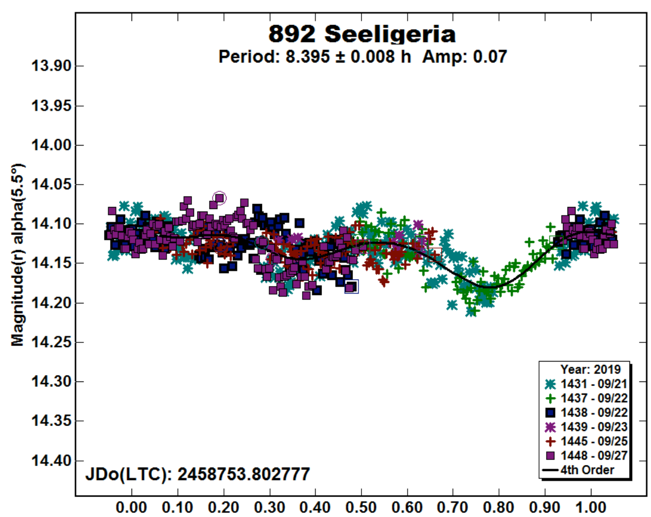




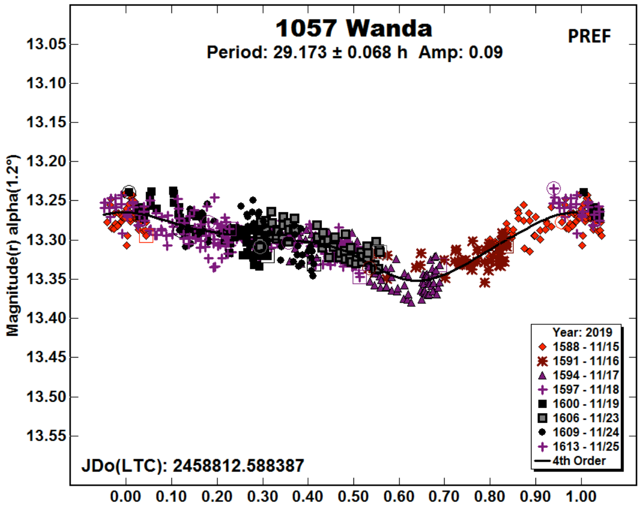
828 Lindemannia. Johann Palisa's 1916 discovery while at Vienna was named after Adolph Friedrich Lindemann, a British amateur astronomer and engineer. Only one period solution is published, that of Buchheim (2014), who derived a period of 20.52 ± 0.02 h. A total of 479 observations were made during four nights, producing a synodic period of 20.150 ± 0.065 h, agreeing with Buchheim's result. The amplitude is 0.12 mag, and the RMS error is 0.029 mag.

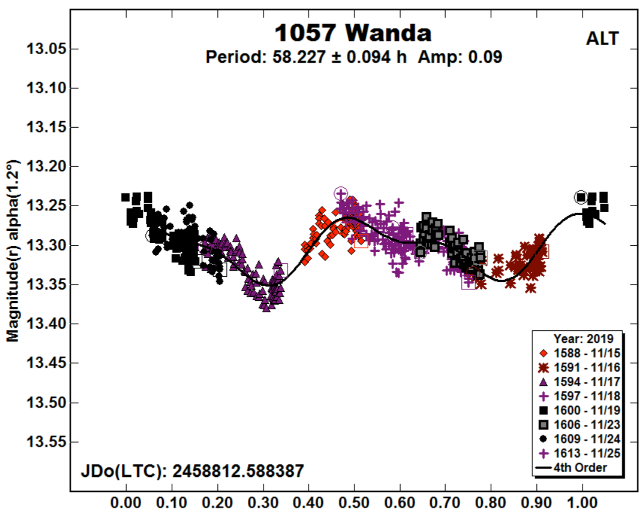


892 Seelgeria is one of Max Wolf's 228 discoveries, made from Heidelberg in 1918. Shipley et al. (2008) calculated a period of 15.78 ± 0.04 h, while Behrend (2017) obtained 41.4 ± 0.5 h. The author gathered 621 images in five nights to create the binned lightcurve with very small amplitude. The period is 8.395 ± 0.008 h, but the RMS error of 0.019 mag is significant relative to the amplitude of 0.07 mag.

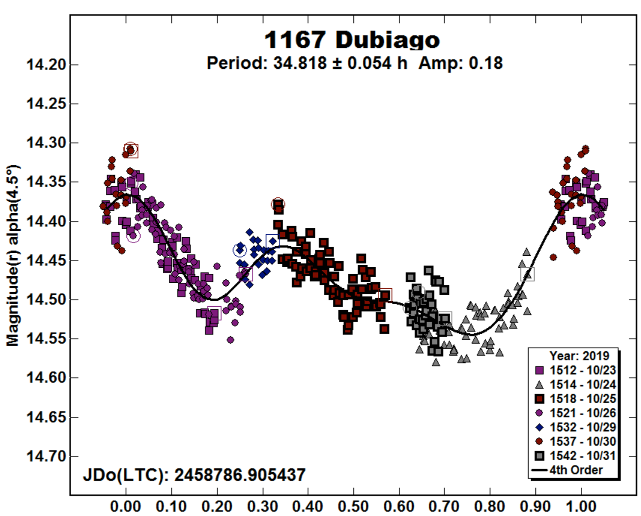


1057 Wanda. Grigory Shajn discovered this minor planet in 1925 at Simeis. Binzel (1987) published a period of 28.8 h, while Pray (2005) computed 28.49 ± 0.03 h. Its eccentric orbit brought it to a perihelic opposition in 2019, during which 593 images were obtained in eight nights. A monomodal lightcurve has a period of 29.173 ± 0.068 h, but the bimodal solution of 58.227 ± 0.094 h is possible. The amplitude for the monomodal solution is 0.09 mag, and the RMS error is 0.016 mag.

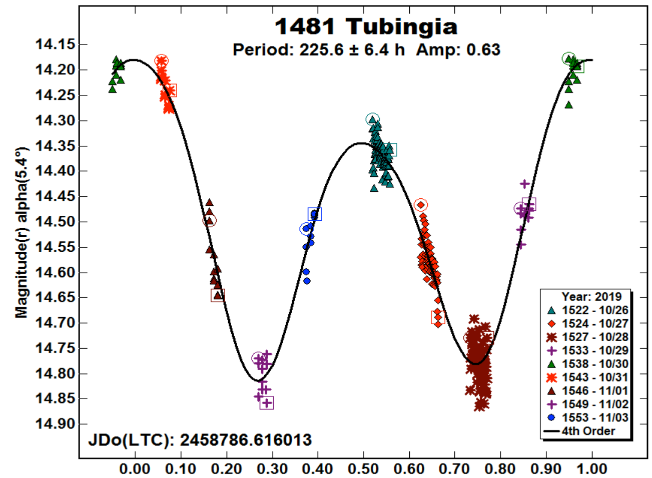




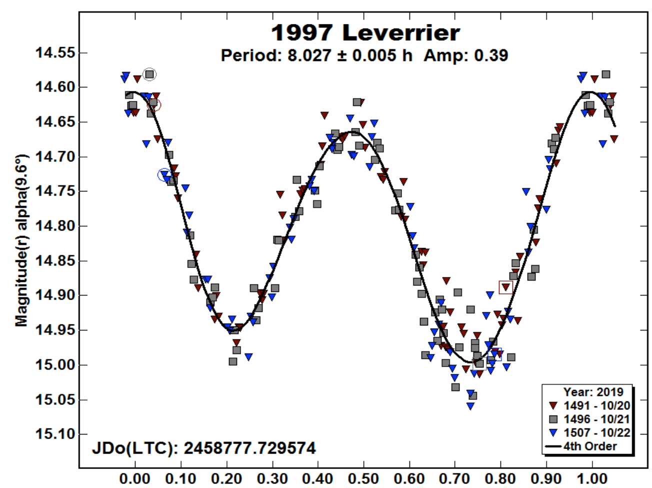
1167 Dubiago was found by Evgenii Skvortsov at Simeis in 1930. The two solutions in the LCDB are by Dahlgren et al. (1991; 14.3 h) and Waszczak et al. (2015; 34.837 ± 0.0990 h). During seven nights, 349 images were taken. The derived period is 34.818 ± 0.054 h, agreeing with Waszczak. The amplitude and RMS error are 0.18 mag and 0.025 mag, respectively.



1481 Tubingia is named after Tübingen, Germany, the city of Johannes Kepler's birth. Its discovery was made by Karl Reinmuth at Heidelberg in 1938. Binzel (1987) published an uncertain period of 160 ± 20 h. Sparse observations during nine nights were made until 278 data points were acquired, producing a synodic period of 225.6 ± 6.4 h. The lightcurve amplitude is 0.63 mag with an RMS error of 0.032 mag.

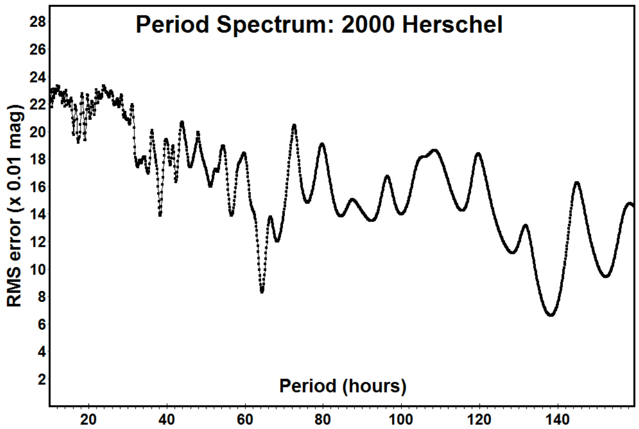


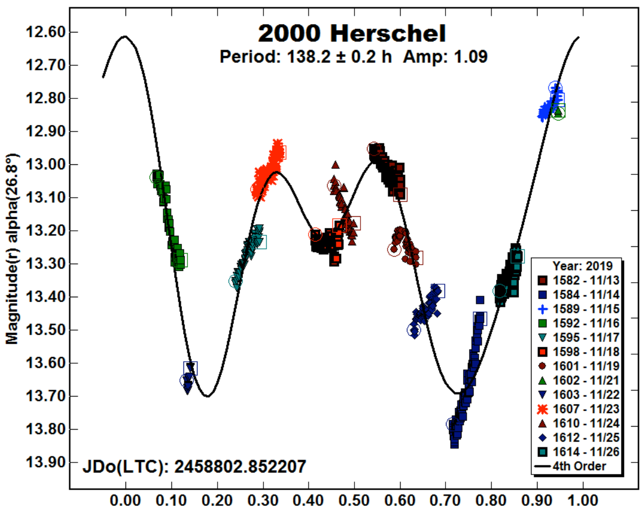
1997 Leverrier, a Flora-family minor planet, was discovered at Goethe Link observatory in Brooklyn in 1963. The lone published period is by Durech et al. (2016), who found 8.01532 ± 0.00001 h. During the favorable 2019 October opposition, 214 images were obtained in three nights. These resulted in a solution of 8.027 ± 0.005 h, in agreement with Durech's period. The amplitude is 0.39 mag with an RMS error of 0.032 mag.



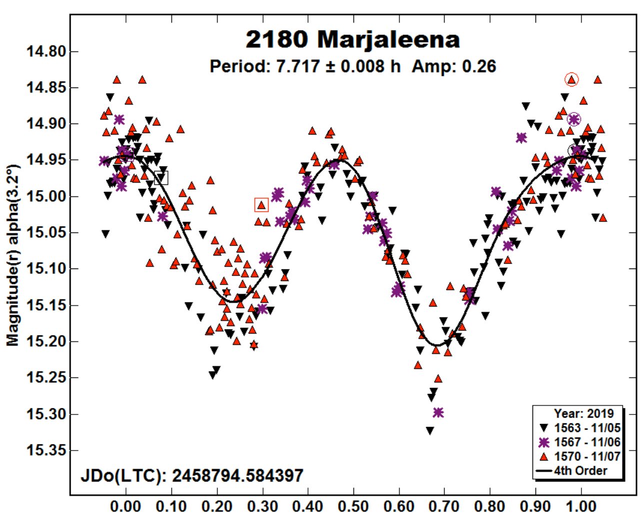
2000 Herschel. Theodor von Schubart found this asteroid in 1960 at Sonneberg. The prolific visual observer William Herschel is familiar to amateur astronomers. Warner (2011b) revisited observations made and published in 2009 to obtain a period of 130 ± 3 h, with a strong indication of tumbling. Pilcher et al. (2020) found a primary rotation of 133.6 h and a second tumbling period of 344 h, the latter being one of multiple possible solutions.

The asteroid's highly inclined and eccentric orbit brought it to closer than 1 au from the earth during the 2019 apparition. A total of 802 images obtained during 13 nights resulted in a period solution of 138.2 ± 0.2 h, somewhat in line with Warner's result. Similarly, the phased lightcurve shows prominent signs of tumbling. The amplitude is 1.09 ± 0.067 mag, but the actual error likely exceeds the formal error. Both the period spectrum and phased lightcurve are provided.



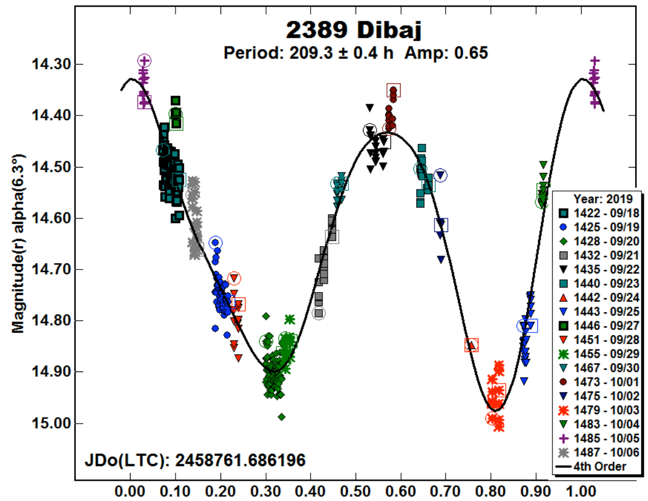


2180 Marjaleena is an Eos-family asteroid discovered by Finnish astronomer Heikki Alikoski at Turku in 1940. Behrend (2014) shows a period of 7.396 ± 0.002 h, while Wasczak (2015) published 7.703 ± 0.0015 h, and Hanus et al. (2018) obtained 8.34626 ± 0.0004 h.

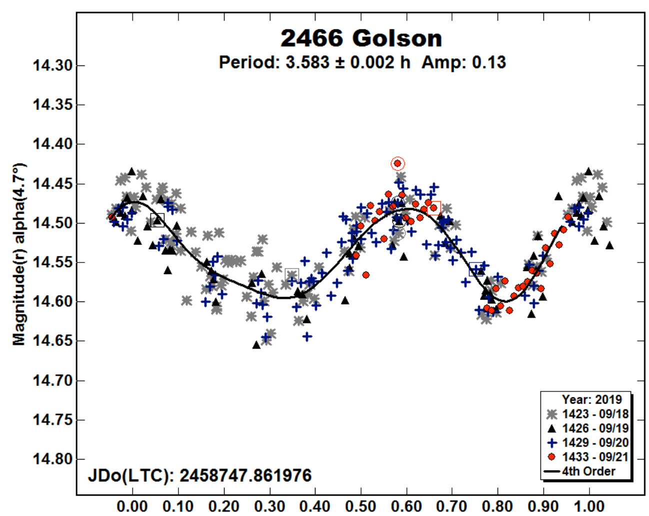


After three nights of dense data, 306 points were enough to produce a clean period solution of 7.717 ± 0.008 h, agreeing with Waszczak's value. The amplitude of the lightcurve is 0.26 mag and the RMS error is 0.046 mag.

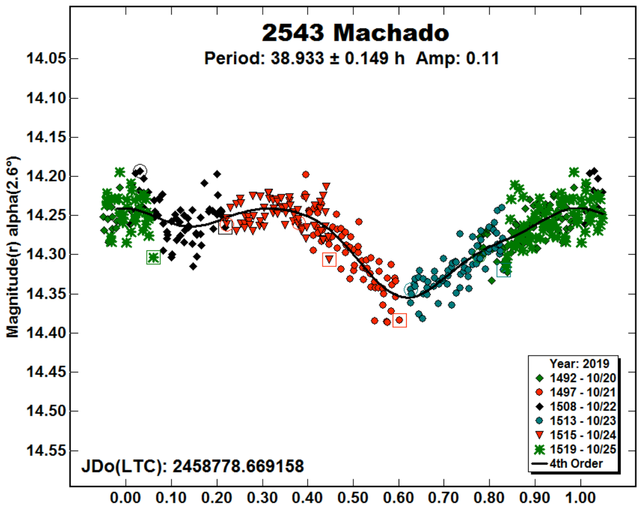
2389 Dibaj is an inner-belt asteroid, discovered in 1977 by Lyudmila Chernykh at Nauchnyj. Likely owing to its eccentric orbit, there are no periods published in the LCDB. It was observed during a favorable apparition during 18 nights, in which 381 images were acquired. The synodic period is 209.3 ± 0.4 h. The lightcurve amplitude is 0.65 mag with an RMS error of 0.04 mag.



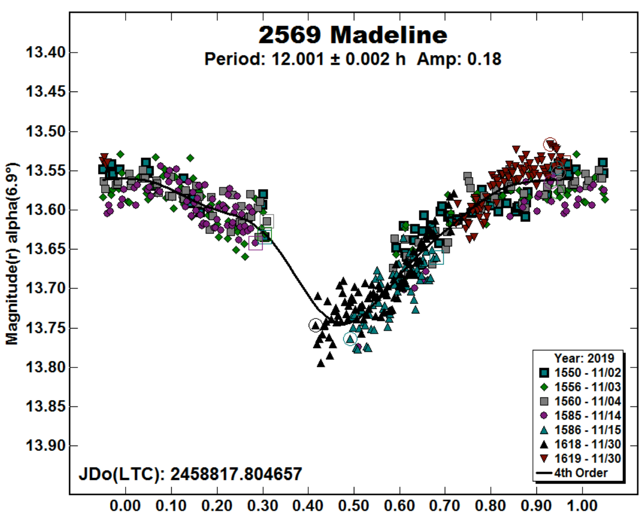
2466 Golson. In 1959, this minor planet was found at Goethe Link Observatory in Brooklyn. The LCDB shows no period solutions for it. During four nights in 2019 October, 280 data points were used to create a phased lightcurve with a period of 3.583 ± 0.002 h and amplitude of 0.13 mag with an RMS error of 0.026 mag.



2543 Machado. Henri Debehogne discovered this asteroid in 1980 at La Silla. Its orbit has a high eccentricity and moderately high inclination. The one solution in the LCDB is that of Oey (2011), who shows 31.72 ± 0.03 h. A total of 411 images were obtained in six nights, yielding a rotation period of 38.933 ± 0.149 h, disagreeing with Oey's result. An amplitude of 0.11 mag was found, with an RMS error of 0.021 mag.

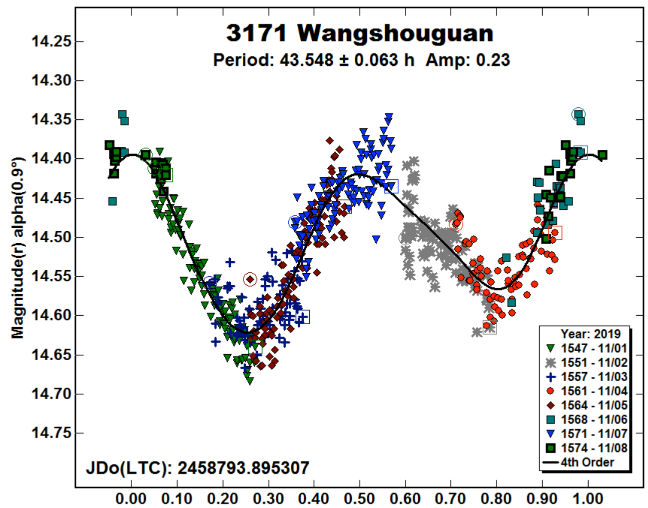


2569 Madeline is a Eunomia-family asteroid that was discovered by Edward Bowell in 1980 at Flagstaff. No period solutions appear in the LCDB. The asteroid was observed during six nights in 2019 November, and 529 data points were secured. After the fifth night, the period was found to be roughly 12 hours, and so nearly commensurate with earth's rotation. A wait of ten nights for the next observing run moved that period solution even closer to a half day, at 12.001 ± 0.002 h.

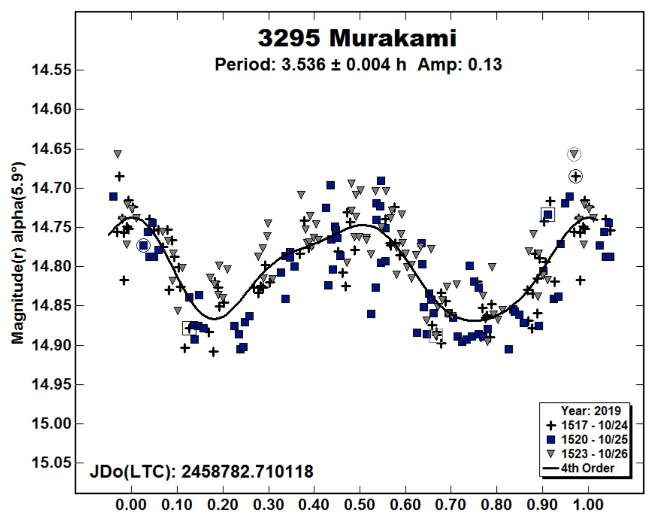


This is a monomodal solution, and it is entirely possible that the correct period is double this value. The amplitude is 0.18 mag, and the fit is good, with an RMS error of 0.022 mag.

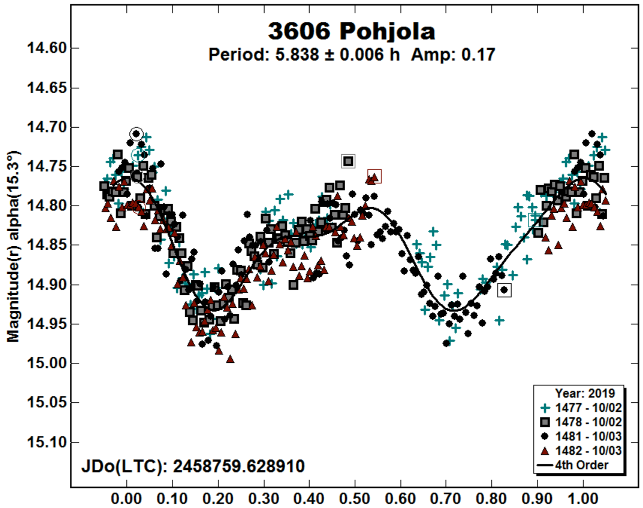
3171 Wangshouguan was discovered at Purple Mountain Observatory at Nankink in 1979. The LCDB contains no period solutions for it. Over the course of eight nights, 621 images were taken, resulting in a phased lightcurve with a synodic period of 43.548 ± 0.063 h. An amplitude of 0.23 mag was determined, with an RMS error of 0.031 mag.



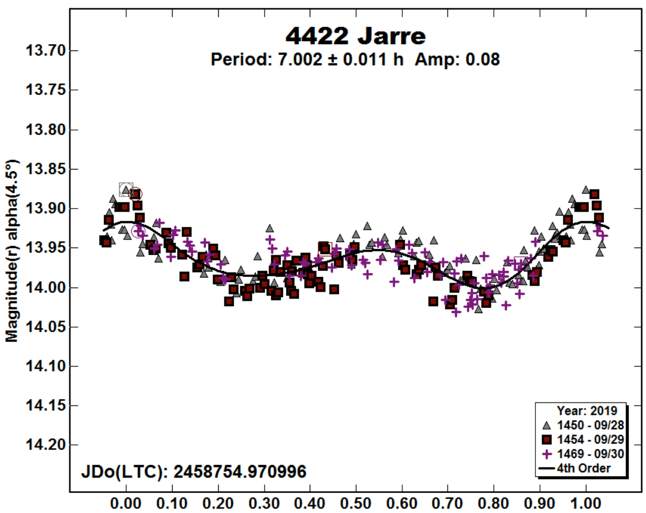
3295 Murakami was discovered by Karl Reinmuth at Heidelberg in 1950. Its rotation period does not appear in the LCDB. The asteroid was observed on three nights during a perihelic opposition in 2019 October, during which 229 images were acquired. The synodic period is 3.536 ± 0.004 h, with lightcurve amplitude of 0.13 mag, and an RMS error of 0.035 mag. Due to its eccentric orbit, it will be 2 magnitudes fainter during the 2021 February opposition.



3606 Pohjola. Yrjö Vaisala discovered this minor planet in 1939 at Turku. Aznar et al. (2016) showed a period of 2.92 ± 0.01 h. Dense data were taken during two nights, producing 425 images. The derived rotation period is 5.838 ± 0.006 h, which is twice Aznar's result. The amplitude and RMS error on the fit are 0.17 mag and 0.029 mag, respectively.

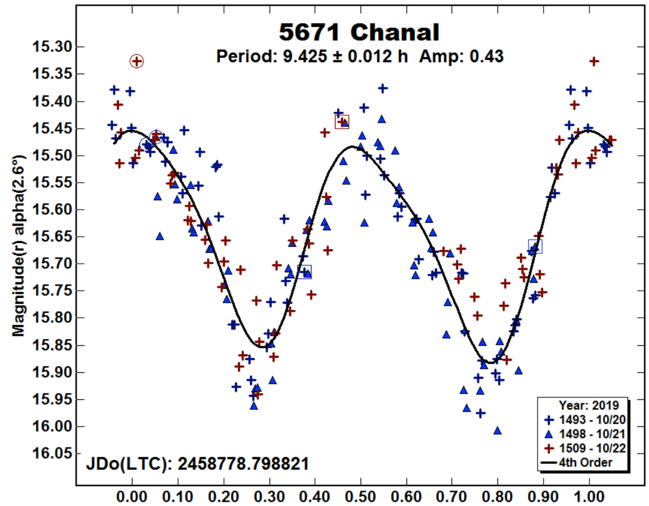


4422 Jarre was discovered by Louis Boyer at Algiers in 1942 and is named after French composer Jean Michel Jarre. The only period shown in the LCDB is that of Behrend (2002), who computed 5.428 ± 0.004 h.

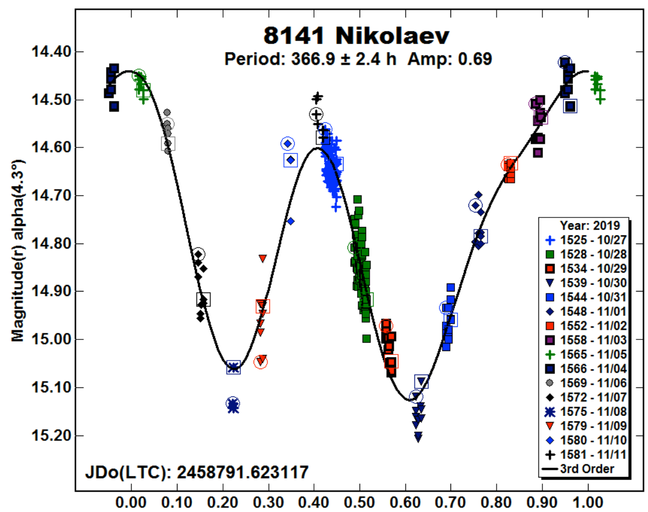


During three nights, 259 observations were made, resulting in a period solution of 7.002 ± 0.011 h, disagreeing with Behrend's value. The amplitude is 0.08 mag, and the RMS error is 0.018 mag.

5671 Chanal. This asteroid was discovered in 1985 by CERGA Observatory at Caussols, France. Behrend (2017) shows the only rotation period in the LCDB: 9.425 ± 0.012 h. In 2019 October, 191 images were taken in three nights to arrive at a synodic period of 9.425 ± 0.012 h. The amplitude of the phased lightcurve is 0.43 mag, and the RMS error of the Fourier fit is 0.067 mag.



8141 Nikolaev is an inner-belt asteroid in a very eccentric orbit. It was discovered by Lyudmila Chernykh in 1982 at the Crimean Astrophysical Observatory. There are no period solutions in the LCDB.

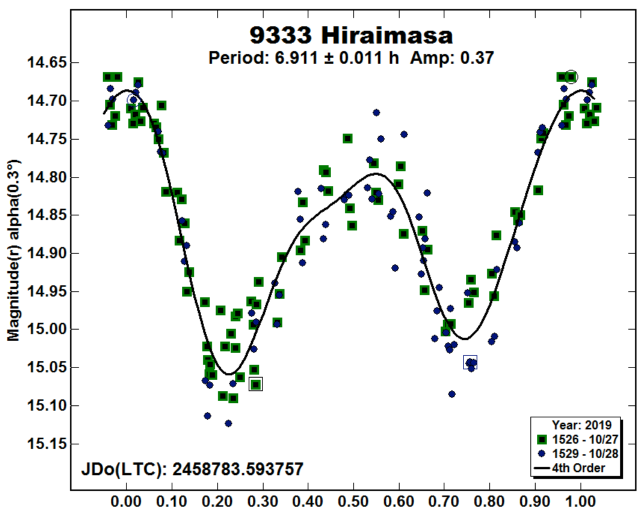


Due to its long period, 280 sparse observations were carried out during 16 consecutive nights. The resulting solution is a period of 366.9 ± 2.4 h, with an amplitude of 0.69 mag, and an RMS error of 0.042 mag. It will be near aphelion, and nearly three magnitudes fainter at the next opposition in 2021 April.

9333 Hiramaisa. Kin Endate and Kazuro Watanabe made the discovery of this minor planet at Kitami in 1990. The LCDB shows no period solutions. It was observed for two nights, and 151 data points were acquired. The phased lightcurve has a period of 6.911 ± 0.011 h. The amplitude is 0.37 mag, and the RMS error is 0.040 mag.

Number	Name	2019 /mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
395	Delia	10/10-10/23	2.4,3.6	22	4	19.774	0.053	0.12	0.03	MB-O
702	Alauda	09/28-10/01	8.6,8.8	1	24	8.333	0.006	0.08	0.01	MB-O
774	Armor	10/29-11/14	1.5,5.2	37	4	25.194	0.008	0.18	0.01	MB-O
783	Nora	11/15-11/25	7.8,11.0	43	-12	54.219	0.086	0.13	0.02	MB-I
828	Lindemannia	10/29-11/01	*0.6,0.7	37	1	20.150	0.065	0.12	0.03	MB-O
892	Seeligeria	09/21-09/27	5.3,3.8	12	-6	8.395	0.008	0.07	0.02	MB-O
1057	Wanda	11/15-11/25	*1.2,5.0	53	2	29.173	0.068	0.09	0.02	MB-O
1167	Dubiago	10/23-10/31	4.5,7.0	16	3	34.818	0.054	0.18	0.03	MB-O
1481	Tubingia	10/26-11/03	5.4,8.3	19	2	225.6	6.4	0.63	0.03	MB-O
1997	Leverrier	10/20-10/22	9.5,8.5	38	6	8.027	0.005	0.39	0.03	FLOR
2000	Herschel	11/13-11/26	26.7,28.6	34	33	138.2	0.2	1.09	0.07	MB-I
2180	Marjaleena	11/05-11/07	3.2,2.4	50	1	7.717	0.008	0.26	0.05	EOS
2389	Dibaj	09/18-10/06	6.3,15.6	347	4	209.3	0.4	0.65	0.04	MB-I
2466	Golson	09/18-09/21	4.6,3.2	3	-3	3.583	0.002	0.13	0.03	MB-M
2543	Machado	10/20-10/25	2.5,3.3	27	-5	38.933	0.149	0.11	0.02	MB-O
2569	Madeline	11/02-11/15	*7.0,8.1	49	-7	12.001	0.002	0.18	0.02	EUN
3171	Wangshouguan	11/01-11/08	0.9,2.9	39	2	43.548	0.063	0.23	0.03	MB-O
3295	Murakami	10/24-10/26	5.9,6.5	27	-8	3.536	0.004	0.13	0.04	MB-M
3606	Pohjola	10/02-10/03	15.3,14.8	30	13	5.838	0.006	0.17	0.03	MB-M
4422	Jarre	09/28-09/30	4.5,3.9	9	-5	7.002	0.011	0.08	0.02	MB-I
5671	Chanal	10/20-10/22	2.6,2.7	26	-5	9.425	0.012	0.43	0.07	MB-M
8141	Nikolaev	10/27-11/11	4.2,13.6	30	4	366.9	2.4	0.69	0.04	MB-I
9333	Hiraimasa	10/27-10/28	0.3,0.6	34	1	6.911	0.011	0.37	0.04	MB-M

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).



Acknowledgments

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LIGHTCURVE ANALYSIS OF LONG-PERIOD MINOR PLANET 2580 SMILEVSKIA

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2580 Smilevskia is a main-belt asteroid with no prior rotational period determinations. Data were acquired from two observatories spanning five weeks near a perihelic opposition. A synodic rotation period of 658.4 ± 1.2 h was computed. Data have been submitted to the ALCDEF database.

CCD photometric observations of 2580 Smilevskia were performed at Command Module Observatory (MPC V02) in Tempe and the Lowell Observatory Anderson Mesa Station (MPC 688) outside Flagstaff. Images at V02 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. Images taken at 688 employed the 0.7-m *f*/8 telescope, which has a CCD camera system designed and built in the Lowell instrument shop (Buie, 2010). The image scale was 0.91 arcsec/pixel with 2x2 binning. Exposure time was 5 minutes through a Cousins R filter. Table I shows the observing circumstances and results. All the images were obtained during 2019 September and October.

The V02 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 688 data made use of 20 full-frame biases and 15 or more twilight flats taken each night under an automated exposure routine with the telescope aimed at the 'Chromey spot' (Chromey and Hasselbacher, 1996), tracked at the sidereal rate but dithered 30" between frames. The thinned, back-illuminated e2v CCD was kept at roughly –110° C using a Cryotiger chiller and so had negligible dark current.

The data reduction and period analysis were done using *MPO Canopus* (Warner, 2017). In the imaged fields, the asteroid and three to five comparison stars were measured. Comparison stars were selected with colors within the range of $0.5 < B\text{-}V < 0.95$ 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 comparison 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 with respect to a color term. Comparison star magnitudes were derived from a combination of CMC15 (Muiñoz and Evans, 2014), APASS DR9 (Munari et al. 2015), and GAIA2 G (Sloan r´ = G for stars of asteroidal color) catalogues to set the zero-points

Number	Name	2019/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
2580	Smilevskia	09/18-10/24	462	3.4,13.9	352	-265	8.4	1.2	0.75	0.05	MB-I

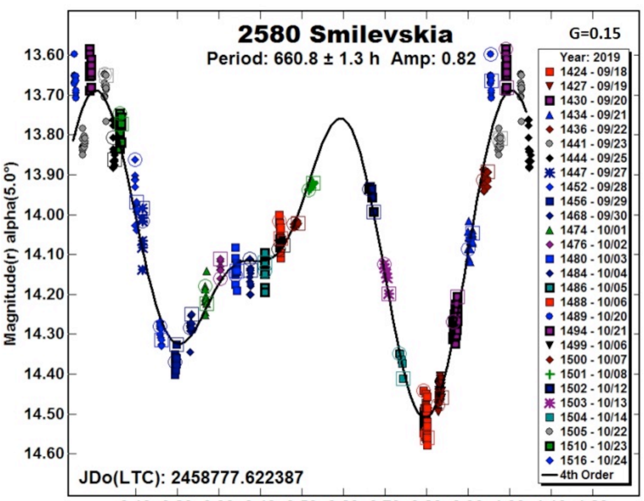
Table I. Observing circumstances and results. The phase angle (α) is given at the start and end of each date range, unless it reached a minimum or maximum, which is then the second of three values. LPAB and BPAB are each the average phase angle bisector longitude and latitude (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

each night. In most regions the Sloan r´ data sources for brighter stars yielded very similar magnitudes (within about 0.05 mag total range), so mean values rounded to 0.01 mag precision were used. This careful adjustment of the comparison star magnitudes and color-indices allowed the separate nightly runs to be linked with no zero-point offset required.

A 9-pixel (16 arcsec) diameter measuring aperture was used for asteroids and comp stars for the V02 data. The apertures used on the 0.7-m data varied depending on seeing but were typically 13 or 15 pixels (12 or 14 arcsec) diameter. It was typically necessary to employ star subtraction to remove contamination by field stars. We note the RMS scatter on the phased lightcurve, which gives an indication of the overall data quality including errors from the calibration of the frames, measurement of the comparison 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). The phased lightcurve shows the maximum at phase zero. Magnitudes in the phased plot are apparent and scaled by *MPO Canopus* to the first night.

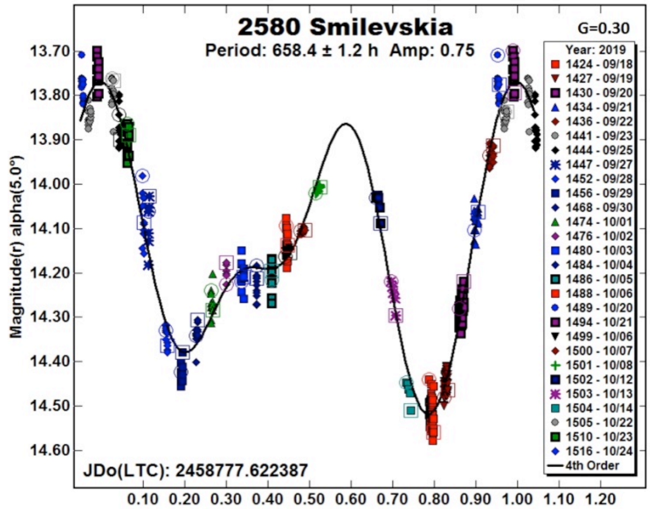
The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results. The new data for this asteroid may be found in the ALCDEF database.

2580 Smilevskia was discovered in 1977 by Lyudmila Chernykh at the Crimean Astrophysical Observatory at Nauchnyj. The LCDB shows no published rotation periods.



The first 16 nights of observations were conducted only at V02. Between October 6 and 14, the asteroid was observed at 688, with one night of overlap. Observations at V02 were resumed on October 20. In all, 462 images were acquired.

Using the default value of 0.15 for the phase-slope parameter, the period solution produced a result of 660.8 ± 1.3 h. We noticed that scatter between overlapping points on the phased curve is rather high, and not convincingly due to tumbling. The phase-slope parameter was adjusted upward to 0.30, resulting in the tighter fit and a synodic period of 658.4 ± 1.2 h, as shown in the second figure. The amplitude is 0.75 ± 0.05 mag, and the RMS scatter on the fit shown in the phased plot is 0.048 mag.



Acknowledgments

The authors would like to express their gratitude to Brian Warner for support of his *MPO Canopus* software package.

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LIGHTCURVE AND PERIOD OF THE NEA PHA 2019 GT3

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The authors report on the results of photometric observations of near-Earth asteroid (NEA) 2019 GT3. The most probable synodic rotation period is 0.73 ± 0.03 h with an amplitude of 1.3 ± 0.2 mag. The body appears to be rather elongated with a lower limit a/b ≈ 1.4 ± 0.3 (if S-type) and strength-bound.

The asteroid 2019 GT3 was discovered by Pan-STARRS 1 on 2019, April 3.3916 and announced on MPEC 2019-G100. The asteroid is classified as a near-Earth object by NASA's Centre for Near-Earth Object Studies (CNEOS) and by JPL Small-Body Database: with a MOID of about 0.017 AU and a diameter of about 200 m, falls under the Potentially Hazardous category.

Here we present some lightcurves obtained in 2019 Sep 4 and 6 with the astrometric images taken from G. V. Schiaparelli Astronomical Observatory (MPC 204) and from Magdalena Ridge Observatory (MPC H21). The images were analyzed in OAS.

From Schiaparelli, 55 images, each of 6 seconds exposure, were taken on Sept 4 with a 0.36-m *f*/11 Schmidt-Cassegrain and CCD SBIG STX-16803 (4096×4096 pixels, 9 microns). No filter was used. The camera was binned 3×3 and only the central part of the FOV was taken to avoid off-axis aberrations. This gave a field-of-view of 15′×15′ and a pixel scale of 1.42 arcsec/pixel.

From Astronomical Research Institute, 310 images, each of 7 seconds exposure, were taken on Sept 4 and 6 with a 0.61-m *f*/5.2 reflector and CCD Apogee Alta F6 (1024×1024 pixels, 24 microns) binned 1×1 with no filter. This gave a field-of-view of 26.4′×26.4′ and a pixel scale of 1.55 arcsec/pixel.

During the observations, the asteroid was about 0.05 au from the Earth and 1 au from the Sun, with phase angle decreasing from 88° to 73°. The mean sky motion was about 21-22″/minute, which required short exposures to have point-like images useful for astrometry. All images were calibrated by applying flat field and dark frame.

Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2019 GT3	09/04-09/06	88.1,73.1	310	31	[A]0.7332	0.0001	1.32	0.20	NEA
						0.3533	0.0001	1.24	0.20	NEA

Table I. Observing circumstances and results. [A]Preferred period for an ambiguous solution. 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.

In OAS we used *MPO Canopus* v10.7 (Warner, 2009) to measure the images and do the period analysis of the lightcurves. A first analysis shows a monomodal lightcurve with a best rotation period of about 0.35 ± 0.03 h with an amplitude of 1.24 ± 0.20 mag (Fig. 1). The amplitude uncertainty was estimated as in Carbognani, (2011). The large amplitude helped overcome the low signal-to-noise ratio. If we correct the amplitude to zero phase angle using the empirical formula by Zappala et al. (1990), using m = 0.03/deg, the mean value for S-type asteroids, we have A(0°) ≈ 0.4 mag. In the case of a type C or M asteroid, the amplitude at zero phase angle would be about 0.6 mag. For such large amplitudes, an elongated asteroid shape is very common, so we think that the real period value is the double one, i.e. 0.73 ± 0.03 h (about 44 minutes), with an observed amplitude of 1.32 ± 0.20 mag (Harris et al., 2014). Fig. 2 shows the resulting bimodal and symmetric lightcurves. If we correct the observed amplitude to zero phase angle as before, assuming S-type, we have A(0°) = 0.39 ± 0.20 mag. Assuming a triaxial ellipsoid (major axis a, b, c), then we found a lower limit for the ratio (a/b) using $a/b = 10^{(A/2.5)} = 1.4 \pm 0.3$ (Warner, 2006).

The rotation period of this asteroid is under the spin barrier value of about 2.2 h, which is consistent with its small size (Pravec and Harris, 2000). The period and the lower limit for the a/b ratio provide constraints on the internal structure of the asteroid, i.e. it is most likely an elongated body that is strength-bound rather than gravity-bound (rubble-pile).

A summary of the observations and results is given in Table I.

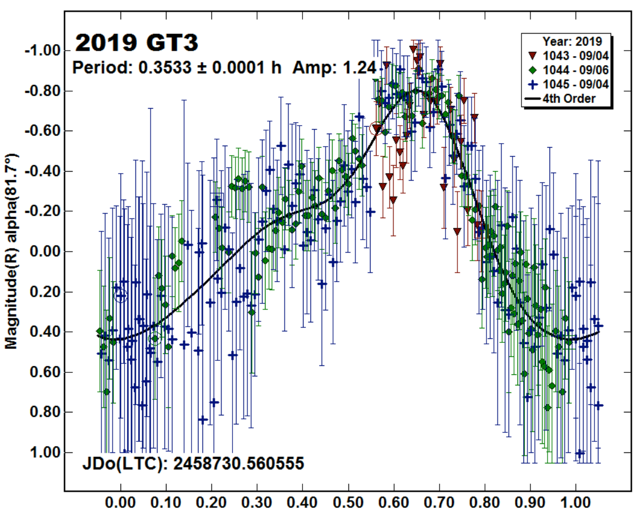

Figure 1. The monomodal lightcurve solution of 2019 GT3. It is interesting to note the larger photometric uncertainty near the lightcurve minimums with respect to the maximums.

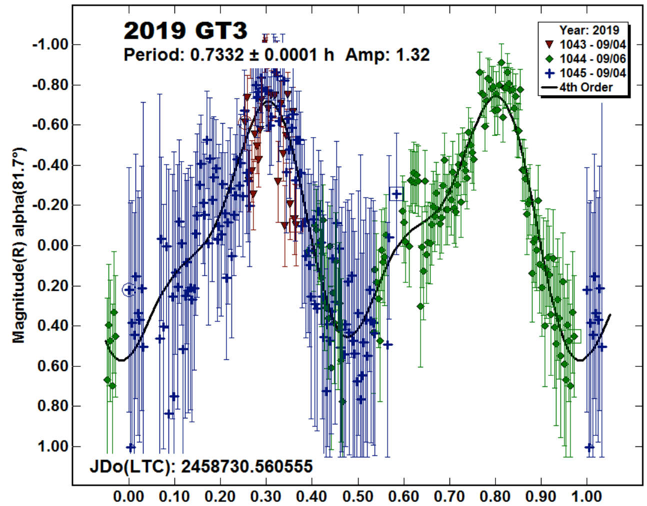

Figure 2. The preferred period fit to a bimodal lightcurve.

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NEAR-EARTH ASTEROID LIGHTCURVE ANALYSIS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2019 SEPTEMBER - 2020 JANUARY

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Lightcurves for 33 near-Earth asteroids (NEAs) obtained at the Center for Solar System Studies (CS3) from 2019 September to early 2020 January were analyzed for rotation period, peak-to-peak amplitude, and signs of satellites or tumbling. Some objects are good candidates for being members of the class of very wide binary asteroids. Others show signs of being "ordinary" binary asteroids, while others proved to be difficult to categorize as one or the other or if their behavior was due to tumbling. There were few easy answers.

CCD photometric observations of 33 near-Earth asteroids (NEAs) were made at the Center for Solar System Studies (CS3) from 2019 September to early 2020 January. 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.

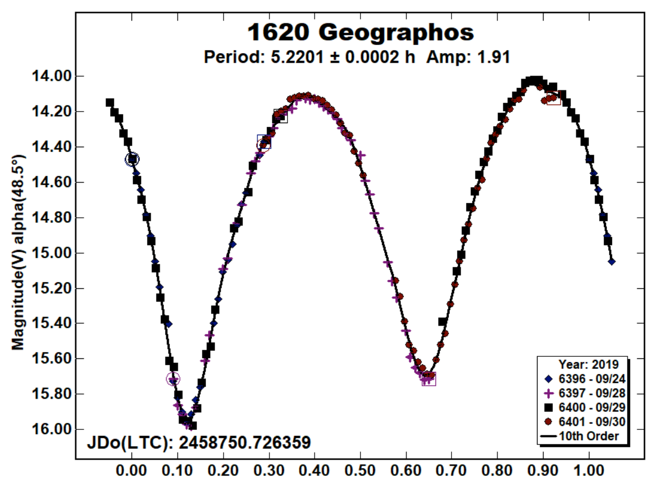
Even so, we found in most cases that nightly zero-point adjustments of no more than 0.02-0.03 mag were required during period analysis. There were occasional exceptions that required up to 0.10 mag. These may have been related in part to using unfiltered observations, poor centroiding of the reference 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 $-5*\log(r\Delta)$, 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*.

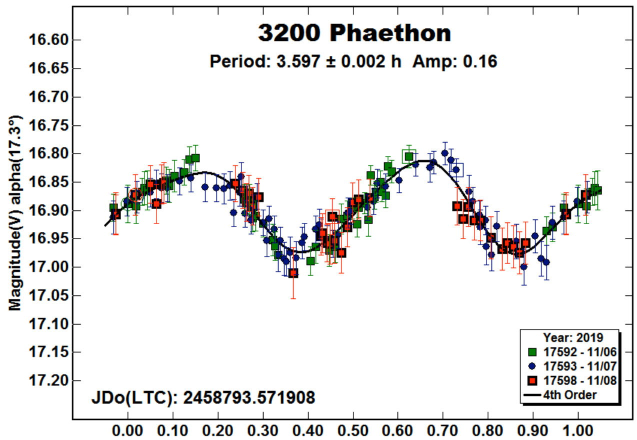
Our initial search for previous results started with the asteroid lightcurve database (LCDB; Warner *et al.,* 2009) found on-line at *http://www.minorplanet.info/lightcurvedatabase.html*. Readers are strongly encouraged to obtain, when possible, the original references listed in the LCDB.

<u>1620 Geographos.</u> The rotation period of about 5.223 h for this 2.5 km NEA was established by Dunlap (1974). Durech et al. (2008) found that the rotation period was decreasing due to the YORP effect (Rubincam, 2000). The amplitude of 1.91 mag is near the maximum reported (2.03 mag), indicating the view was nearly equatorial during the 2019 apparition.



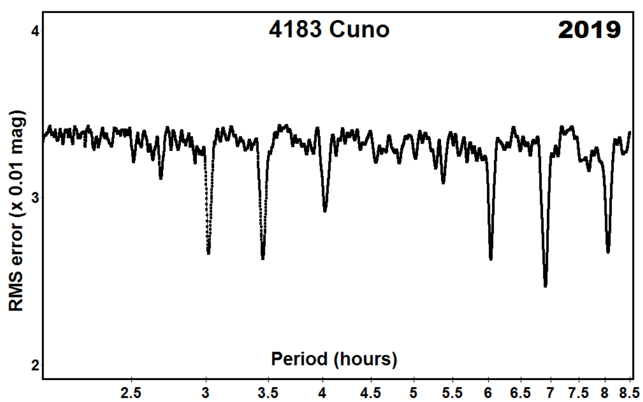
<u>3200 Phaethon.</u> This 5.8 km NEA has been well-studied over the years, e.g., Pravec et al. (2004, 3.6048 h), Warner (2015a, 3.6039 h), and Hanuš et al. (2018), who found a spin axis of (λ, β) = (318°, –47°). Our period is within the error bars and/or sidereal-synodic period correction of previous results.

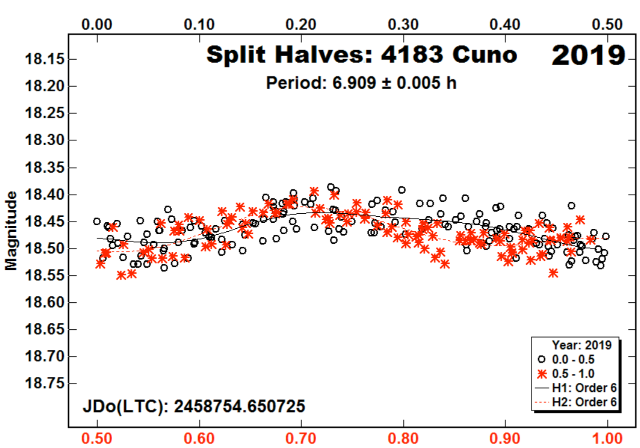
The amplitude 0.16 mag is about mid-range of the amplitudes given in the LCDB (0.05- 0.34 mag).



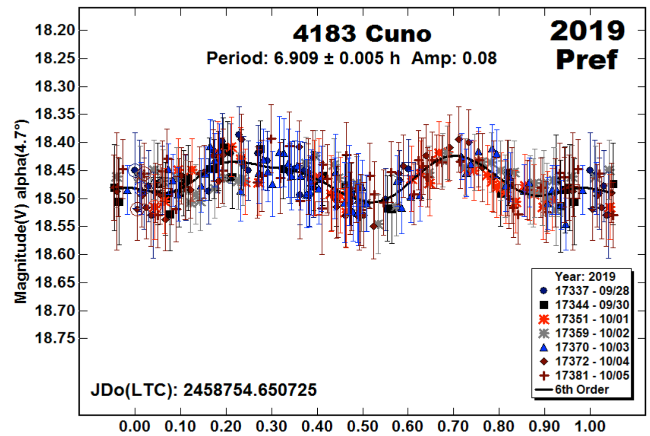
4183 Cuno. Pravec et al. (1997, 1998, 2000) studied this 3.9 km asteroid extensively, finding periods close to 3.56 h and lightcurve amplitudes ranging from 0.69-0.84 mag. It's noteworthy that the observations were at phase angles of 34°-65°. At larger phase angles, shadowing effects can affect lightcurve shapes that lead to unexpected results. However, 34° should not be so severe as to raise significant concerns.

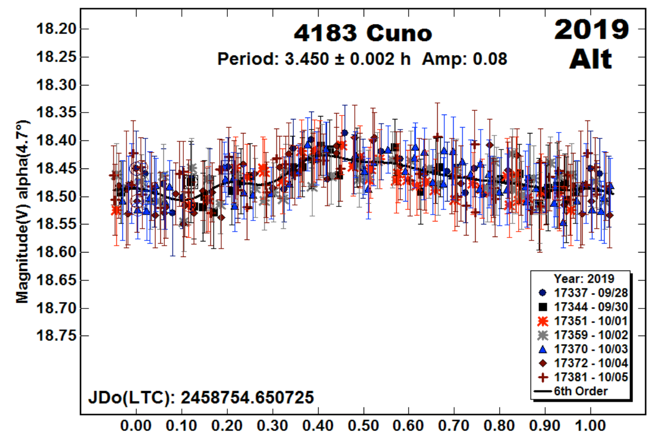
We raise this point because our observations in 2019 were at a phase angle of about 4° and, as expected, the amplitude was significantly lower (0.08 mag). As noted by Harris et al. (2014), bimodal lightcurves shapes cannot be assumed at low phase angles and low amplitudes. Keeping this in mind, our analysis took a look at solutions from 2-8.5 h. The period spectrum showed two strong groups, one centered near 3.45 h and the other near 6.9 h. We could not get a good fit to the 3.56 h found by Pravec et al.





We reviewed the favored period of 6.909 h, which produced an asymmetrical lightcurve (the maximums had different shapes). A split-halves plot (see Harris et al., 2014) seems to confirm the asymmetry since the two halves differ by more than the noise. Even so, the half-period of 3.450 h cannot be formally excluded.

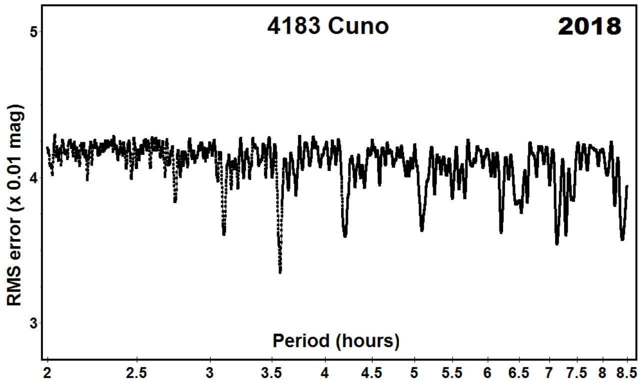


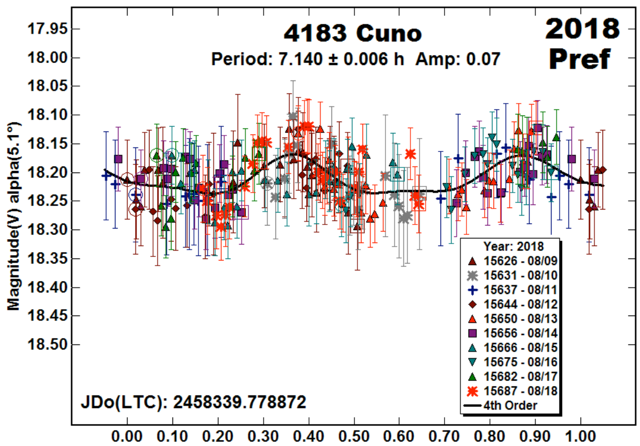


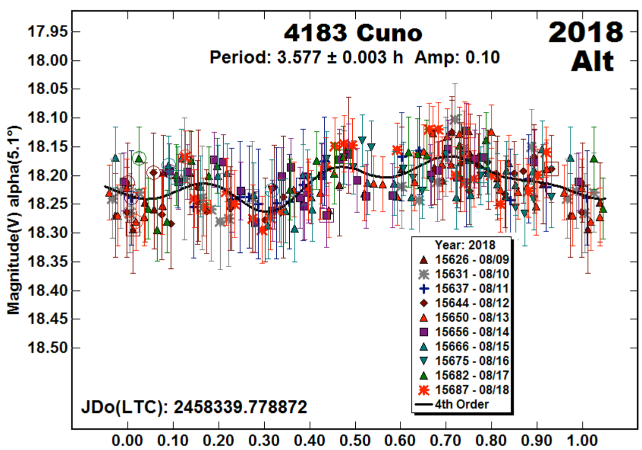
The results from 2019 prompted a review of earlier data from Warner (2015a) and Warner and Stephens (2019). The data obtained in 2018 seem to favor the results from Pravec et al. Our results from 2019 appear in the period spectrum but with significantly larger RMS values.

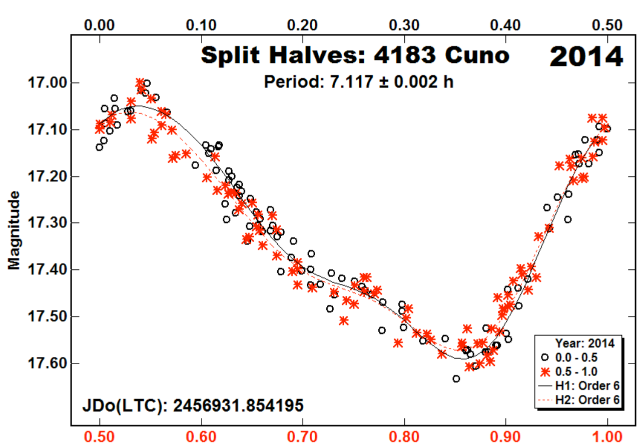
The fit of the 2018 data to 3.577 h maximizes overlapping data points. The unusual shape is not unreasonable given the low phase angle of about 4°. We prefer the longer period of 7.140 h mostly because it's close to the 2019 preferred result and the review of the 2014 data that produced a lightcurve with an amplitude of 0.53 mag. Here again, at a somewhat large phase angle of 38°. The period spectrum is nearly identical to the one from 2019. The split-halves plot for 7.117 h shows the two halves to be very similar. Despite the caveats of lightcurve shapes at small and large phase angles, the 2014 data seem to make a strong case for the bimodal lightcurve solution of 7.117 h.

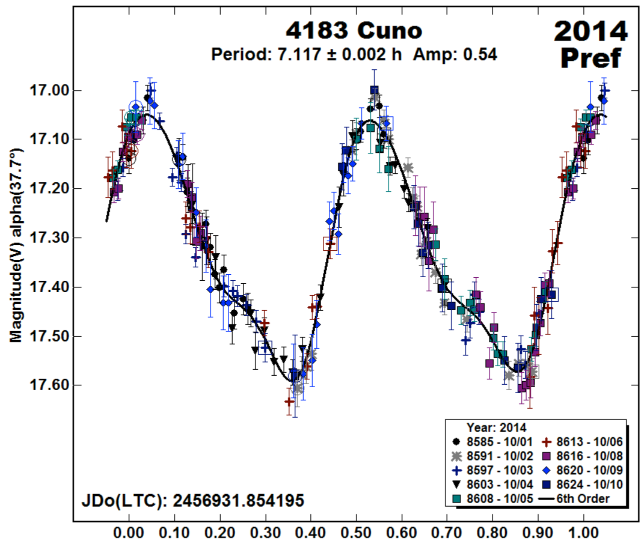
Still to be explained are 1) the significant difference in the periods for the bimodal solutions from 2019 and 2014 and 2) if the 2014 data half-period of 3.558 h is valid despite the large amplitude. Unfortunately, the only observations found in the LCDB are from Pravec et al. and our three apparitions. Independent work is needed. The asteroid will reach V ~15.5 in 2020 July. We strongly encourage observations, especially if part of a coordinated campaign involving two or more observers at well-separated longitudes.

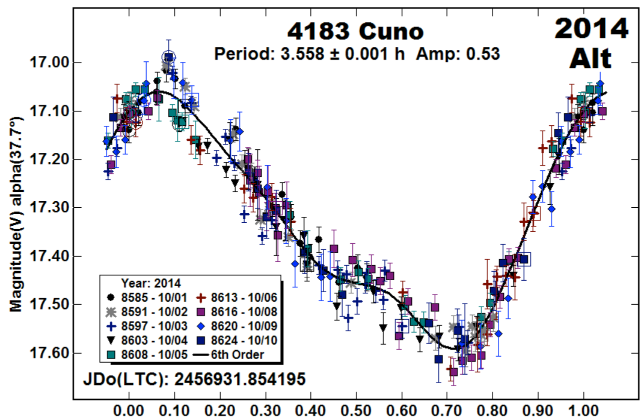






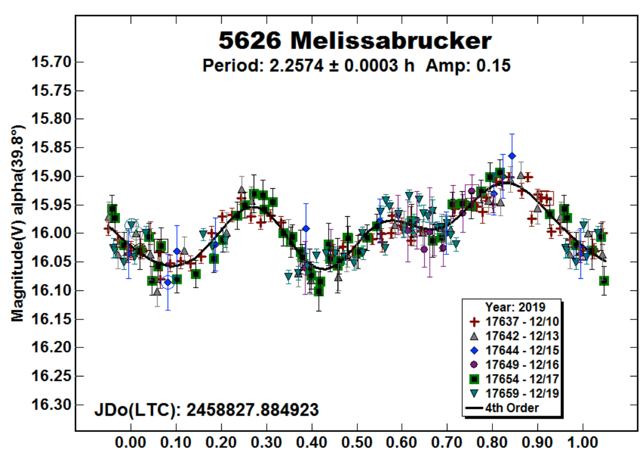




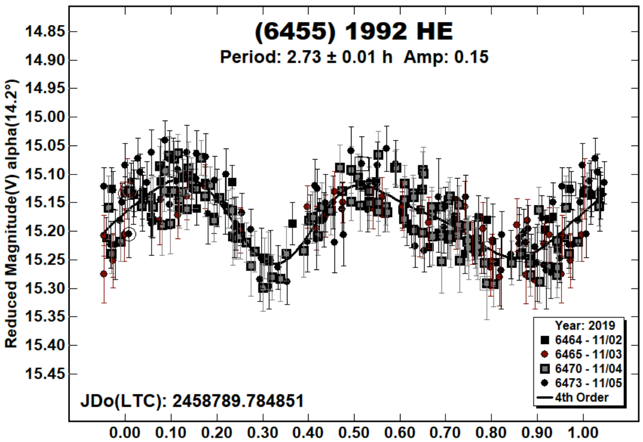


5626 Melissabrucker. Krugly et al. (2002) reported 2.4606 h. Warner (2017b) reported a period of 133.6 h with a secondary period of 2.735 h, making the object a candidate for the class of *very wide binary asteroids* (Warner, 2016b).

There was no obvious long-period signal in the data from 2019. However, we did find a secure period of 2.2574 h. This is in keeping with the very wide binary model. The viewing aspect (phase angle bisector longitude) differed by 50° between 2017 and 2019. It's possible this was enough to hide, or at least substantially reduce, the long-period component.

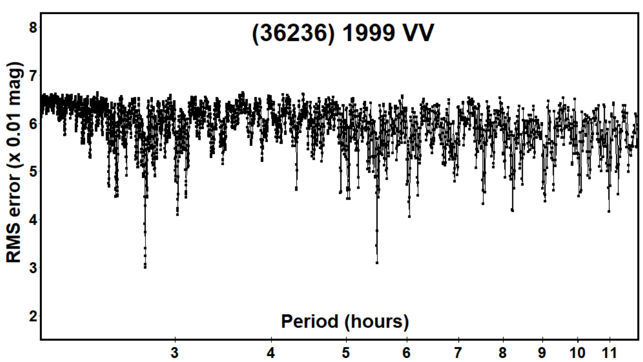


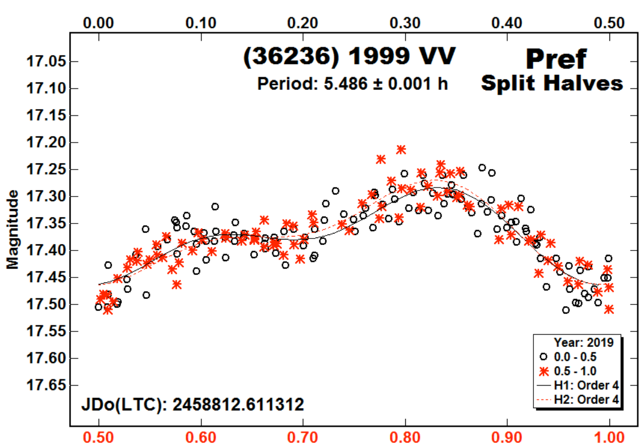
(6455) 1992 HE. Pravec et al. (2002) reported an ambiguous solution of 5.471 h or 2.739 h. The latter is very close to the result we obtained from our 2019 data. Given the relatively low phase angle and asymmetry of the lightcurve, we believe the shorter period, i.e., about 2.73 h, is more likely, as do Wolters et al. (2005) and Linder et al. (2013).

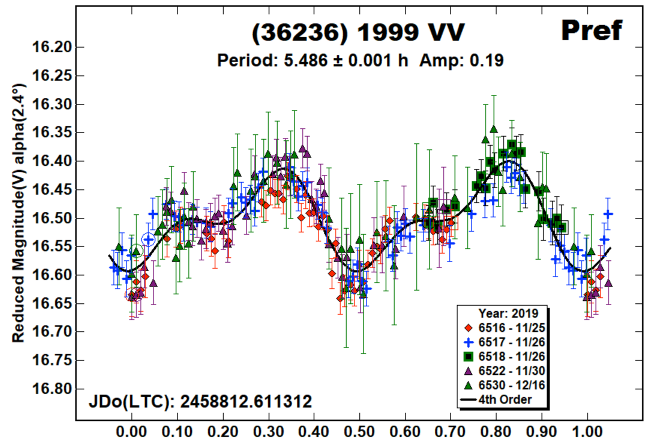


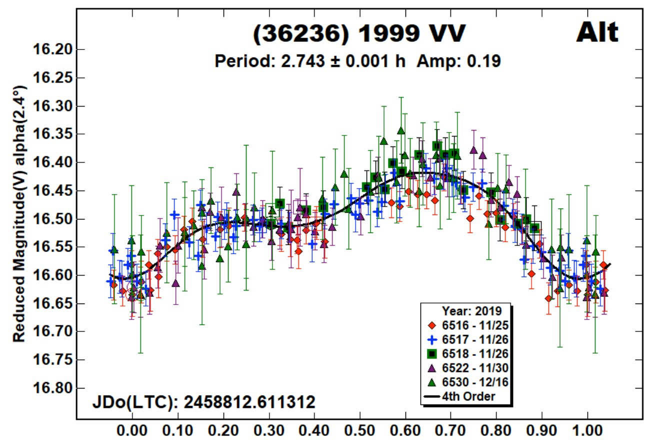
(36236) 1999 VV. The only previous result is from Warner (2017a) where a period of 6.19 h was reported based on data obtained in 2016 November. The 2019 data do not support that result; they also do not lead to a definitive answer.

Looking at the split-halves plot for the longer solution of 5.486 h, the two halves are nearly symmetrical: any deviations are below or at the noise level. Still, the lightcurve does show hints of two maximums, the first at about 0.15 rotation phase being much lower than the second one near 0.65 rotation phase.

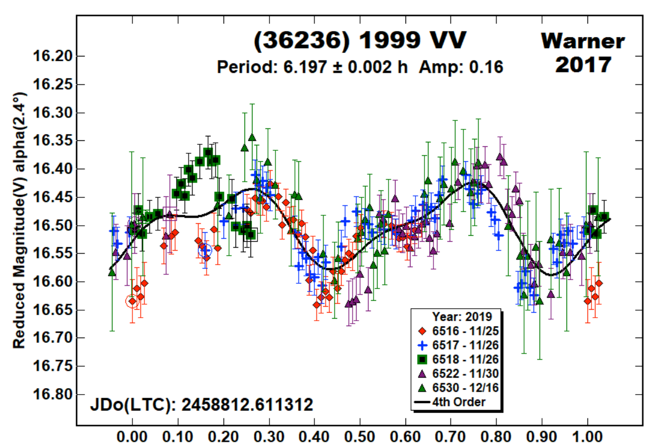






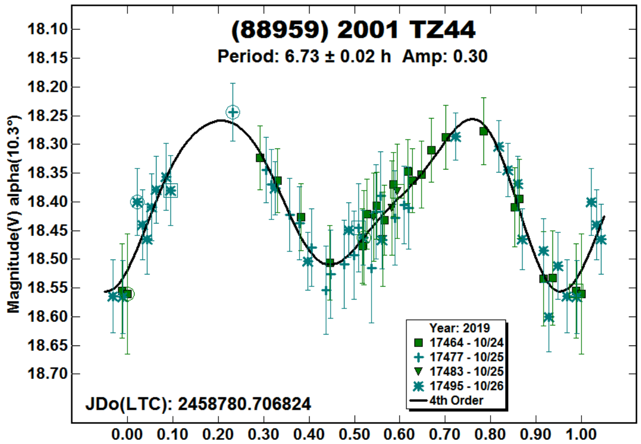


As noted before and shown in the “2017” plot, the 2019 data do not support a period of 6.197 h. A closer but still noisy fit occurs when forcing the 2016 data to the 2019 result of 5.486 h. Fitting to the half-period of 2.743 h is even less satisfying.

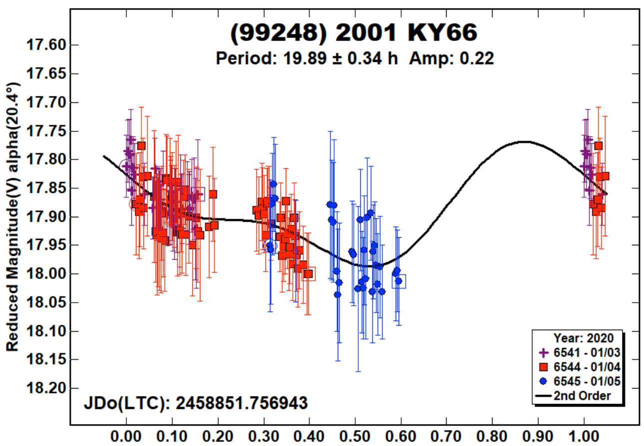


While Harris et al. (2014) caution against assuming a bimodal lightcurve at low amplitudes and phase angles, the amplitude of 0.19 mag in 2019 data starts to approach the point where a bimodal solution becomes more likely than not, though still not assured. Given the assumption of a bimodal lightcurve in this case, we have adopted the longer period of 5.486 h, but acknowledge that the half-period cannot be formally excluded.

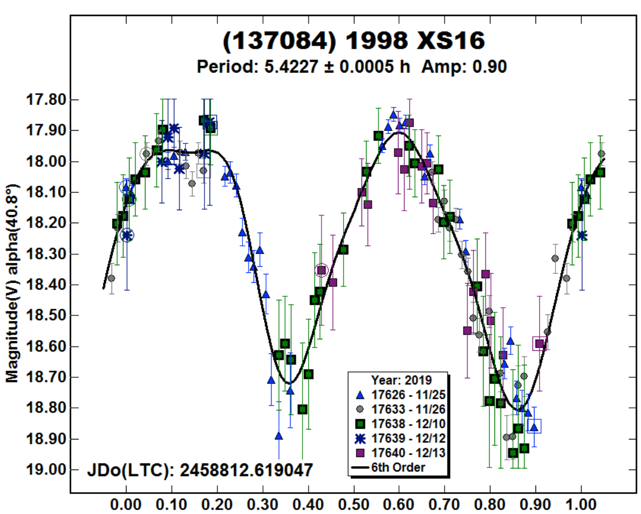
(88959) 2001 TZ44. There was no rotation period reported in the LCDB for this 1.3 km. NEA. Circumstances did not allow getting full coverage of the lightcurve.



(99248) 2001 KY66. This 1.6 km has proved to be difficult when trying to find the rotation period. Warner (2015b) found an insecure period of 19.7 h. In 2019 poor observing conditions led to noisy data. By the time conditions improved, the asteroid was too faint. Our result, such as it is, is close to the one in Warner (2015b).

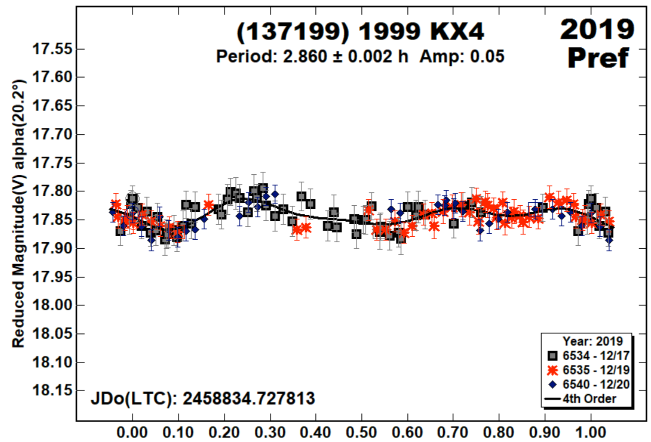


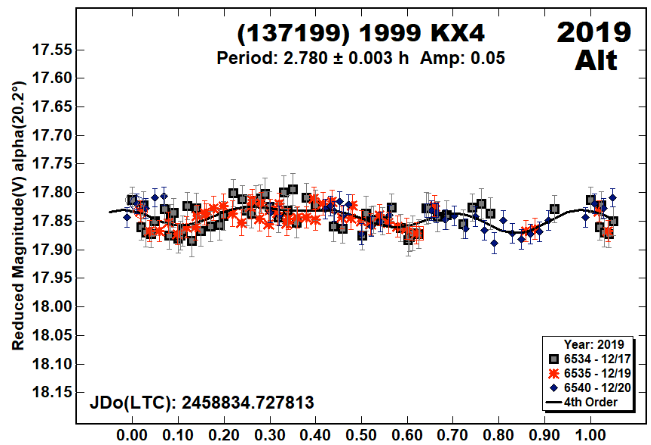
(137084) 1998 XS16. Pravec et al. (1999) found a period of 5.4211 h. Our result is in good agreement with theirs.



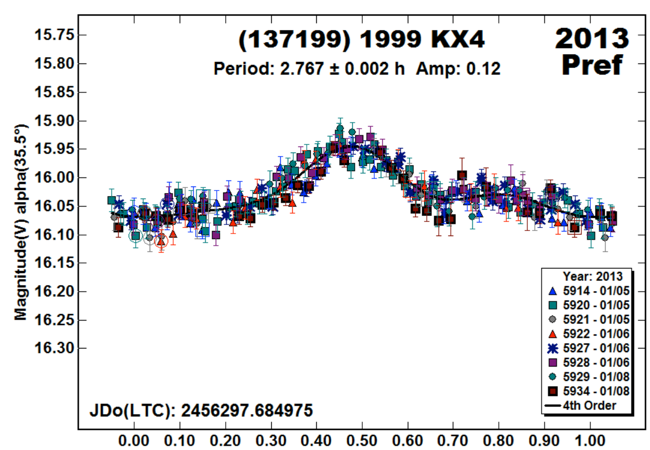
(137199) 1999 KX4. The estimated diameter of this NEA is 1.2 km. Previous results include Warner (2013; 2.767 h) and Carbognani (2014), who reported periods of 2.797-2.976 h when using subsets of data obtained in 2013 Feb-Mar.

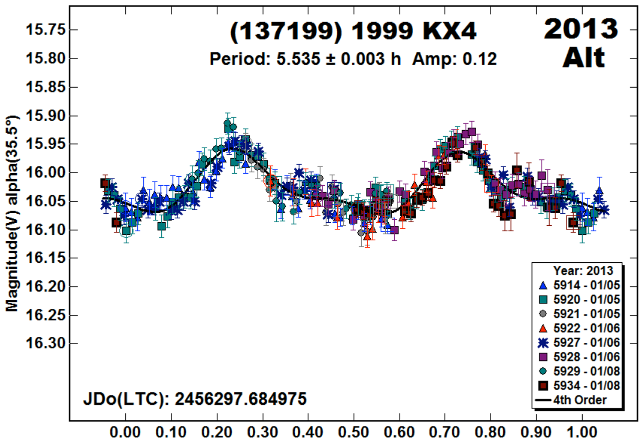
We observed the asteroid for three nights in 2019 December. The best fit to our data was 2.860 h. Forcing the data to a period of 2.7-2.8 h, found 2.780 h, but the fit is noticeably of lower quality.



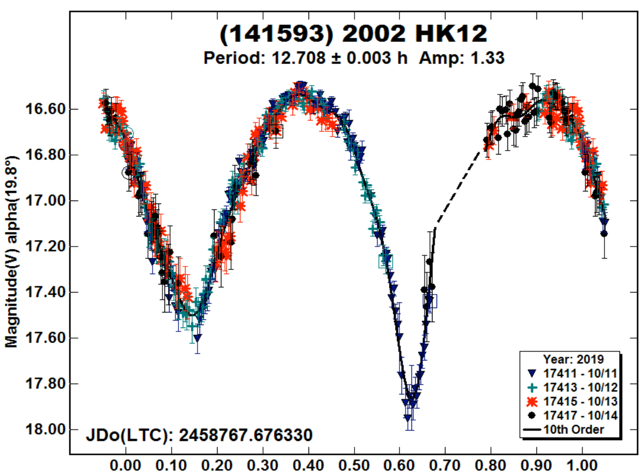


We took another look at the data from Warner (2013), which were obtained about two months before those from Carbognani et al. We could not get a reasonable fit to 2.860 h and still found a period of 2.767 h, which is our preferred solution. However, the double period of 5.535 h cannot be formally excluded.

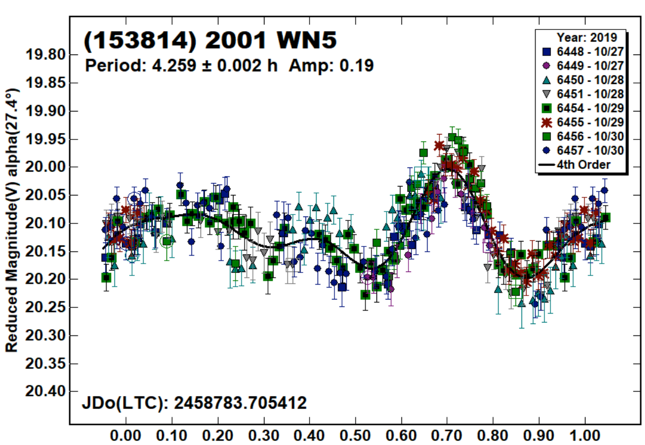




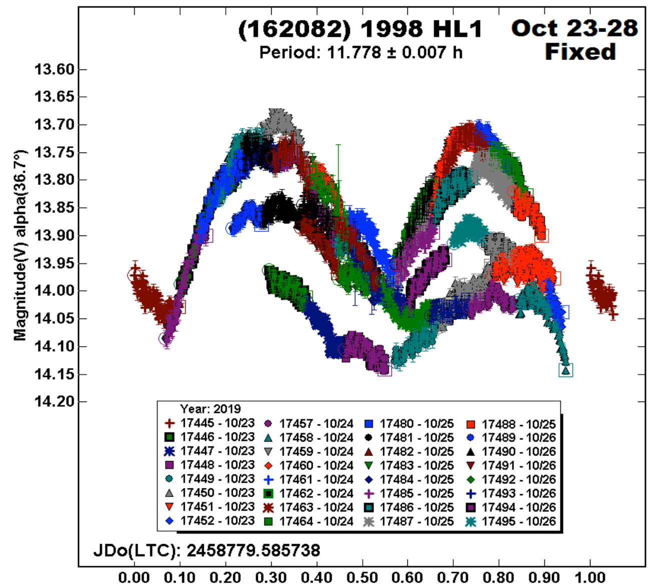
(141593) 2002 HK12. Pravec et al. (2002) and Wolters et al. (2005) reported nearly identical periods of 12.690 h and 12.691 h. We found a similar result of 12.708 h. The slight difference may be attributable to the incomplete coverage of the 2019 lightcurve. The dashed line in the plot at 0.65-0.80 rotation phase estimates the part of the lightcurve that our data did not cover. The sharp change in slope is unlikely caused by the asteroid being highly bifurcated. In such cases, the lightcurve should show "shoulders" on both sides of a minimum.



(153814) 2001 WN5. Using data from 2010, Skiff et al. (2019), found a period of 4.253 h. Our result is in good agreement.

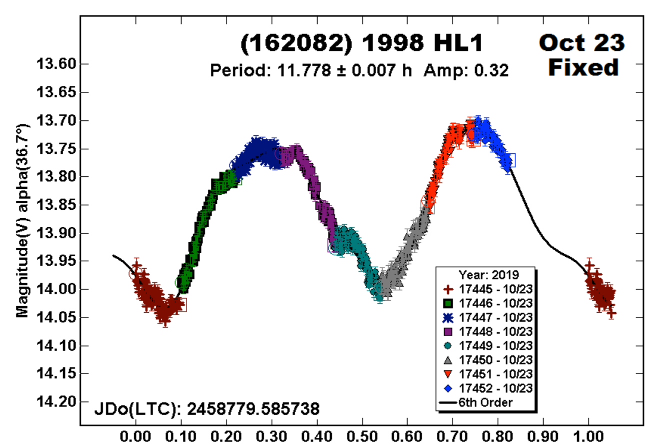


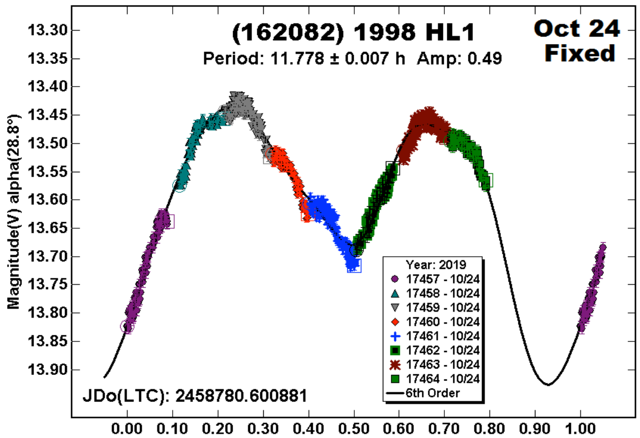
(162082) 1998 HL1. This 500-m NEA made a close approach (0.042 AU) to Earth in 2019 October. The viewing aspect and phase angle changed dramatically over the four nights we observed the asteroid. As expected, this led to significant changes in the lightcurve shape and amplitude, which are clearly seen in the composite lightcurve.

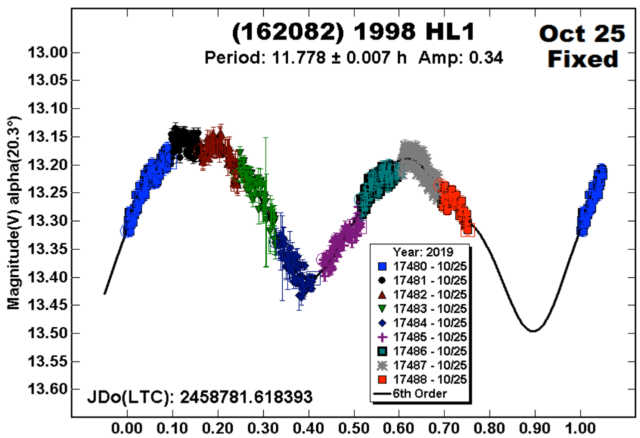


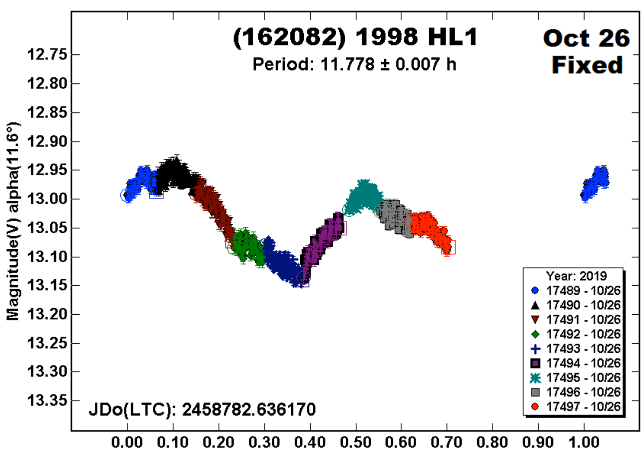
Using the data from individual nights, we found periods ranging from 9-12 hours, but these were inaccurate due to large gaps in lightcurve coverage. In the plots for the individual nights, the period was forced to 11.778 h, the period derived from the entire data set and the one adopted for this paper. The plot for Oct 26 does not include the Fourier curve because it went to unreasonable heights as the analysis tried to fill in the gap. Regardless, the evolution of the lightcurve is clearly seen.

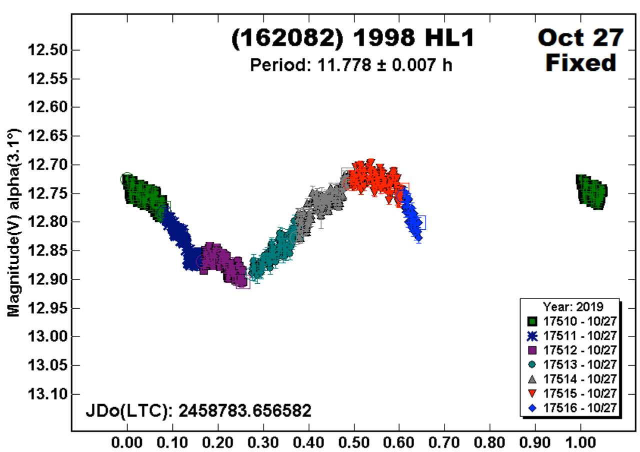
The phase angle dropped from 37.5° to 3.9° over the four nights. It actually reached a minimum of 1.2° near Oct 27 at 12:00 UT. This allowed us to find the absolute magnitude and phase slope parameters: H = 19.355 ± 0.043 and G = 0.296 ± 0.044. The MPCORB file gives H = 19.1. The value for G is consistent with type S asteroids (Warner et al., 2009). Spectroscopic observations would be needed to confirm this.

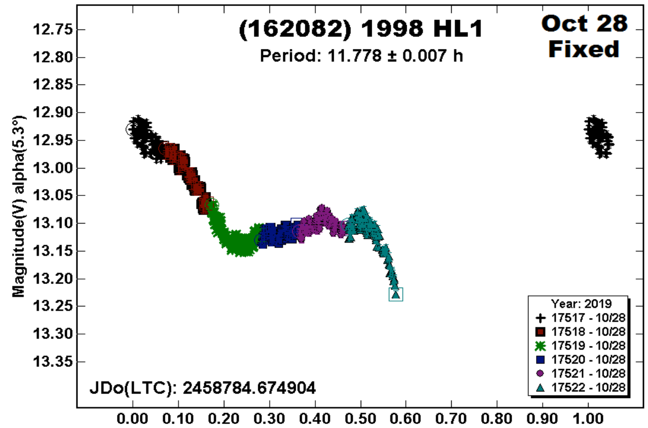


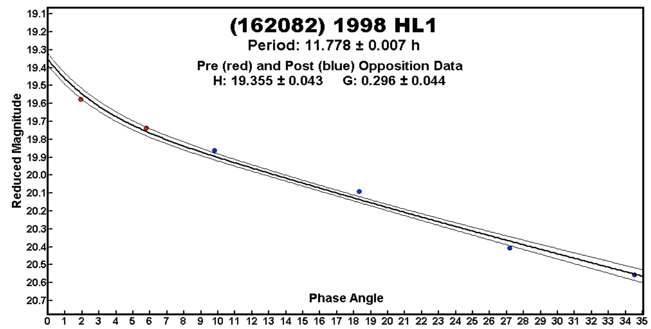




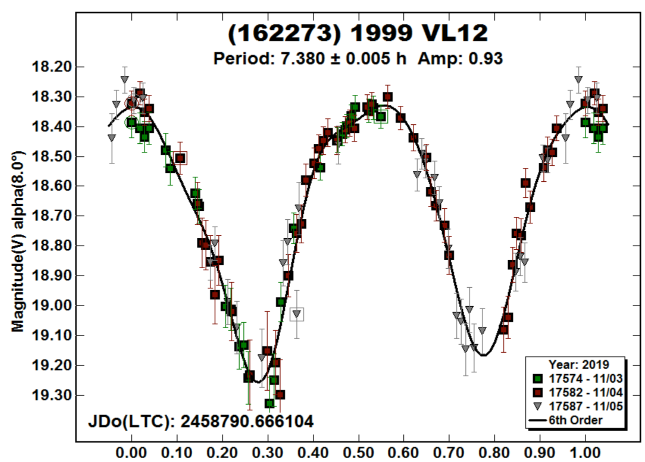


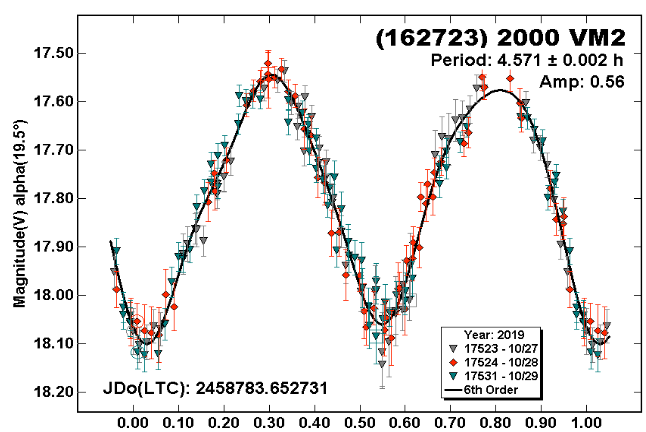




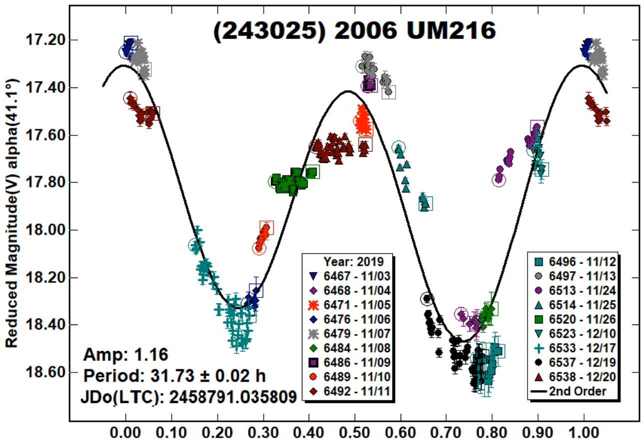


(162273) 1999 VL12, (162723) 2000 VM2. These appear to be the first reported rotation periods for the two NEAs. The estimated sizes are, respectively, 1.1 and 1.0 km.

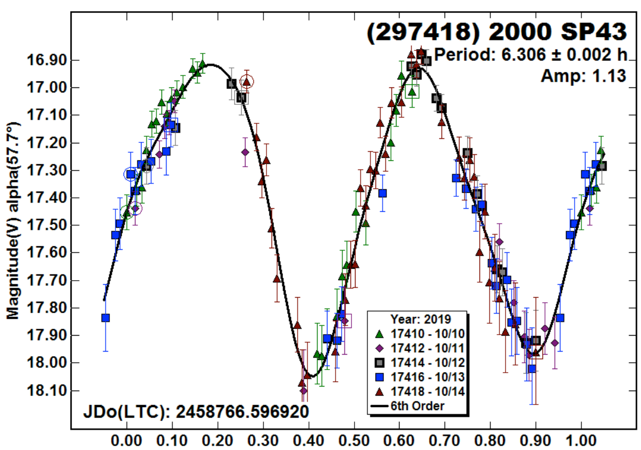




(243025) 2006 UM216. There was no reported rotation period in the LCDB for this 2 km NEA. The data could not be fit to a single period and appear to show the asteroid being in non-principal axis rotation (NPAR; Pravec et al., 2014; 2005). The period given here is the most dominant of those found when searching in the range of 10-100 hours. Subtracting that from the data set to find a secondary period was fruitless.

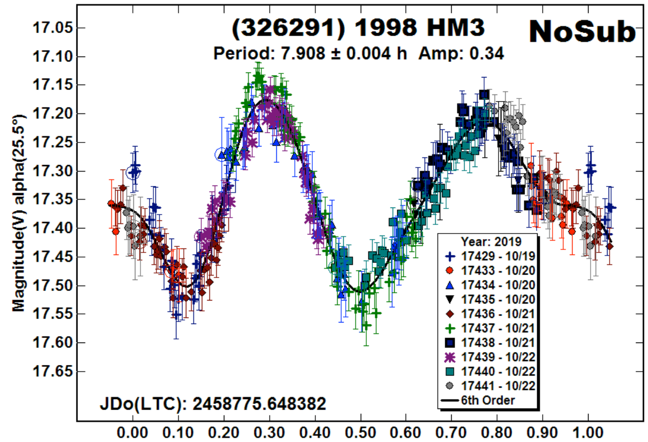


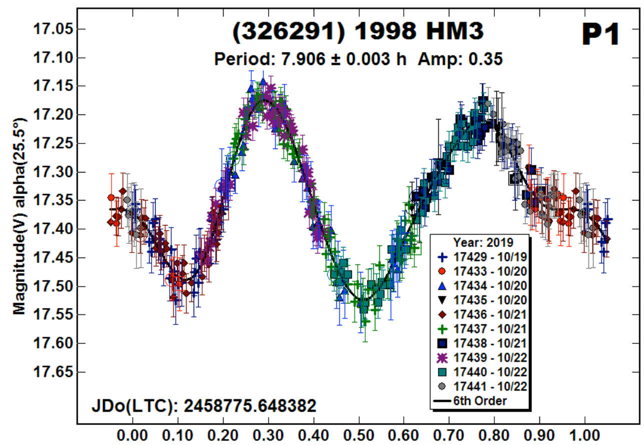
(297418) 2000 SP43. Hergenrother (2018) found a period of 6.314 h and amplitude 0.98 mag at phase angle 33°. The L_{PAB} differed by ~30°, so our amplitude of 1.13 mag might be explained by the larger phase angle (57°) and/or a viewing aspect that was a little closer to equatorial.

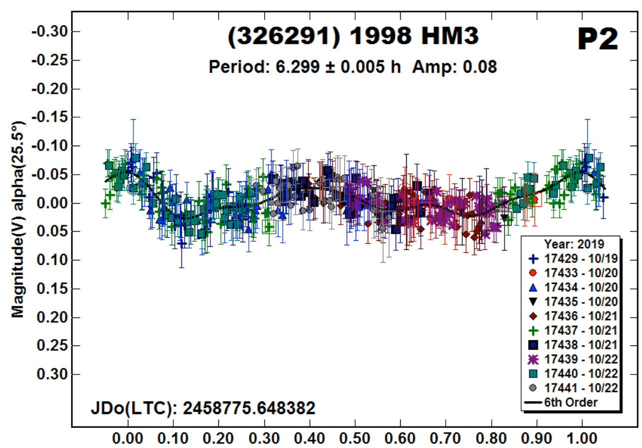


(326291) 1998 HM3. There were no rotation periods given in the LCDB for the 500-m 1998 HM3. Our data obtained on four consecutive nights, 2019 Oct 19-22, could not be cleanly fit to a single period.

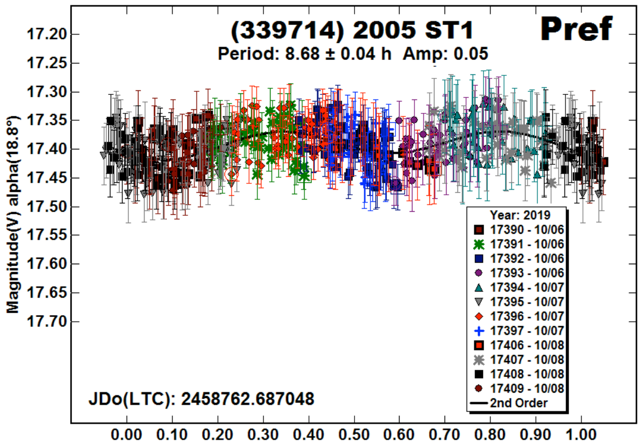
This prompted a dual-period search using an iterative instead of simultaneous method in *MPO Canopus*, which produced a significantly better fit to a period of 7.906 h. Subtracting that result from the dataset leads to a secondary period of 6.299 h with amplitude 0.08 mag. This could be due to a satellite with a rotation period independent of its orbital period (no mutual events were seen that would confirm this) or that the asteroid is a low-level tumbler and the two periods are the dominant solutions for rotation and precession. If so, the true periods may be the sum of integral multiples of the corresponding rotation frequencies.

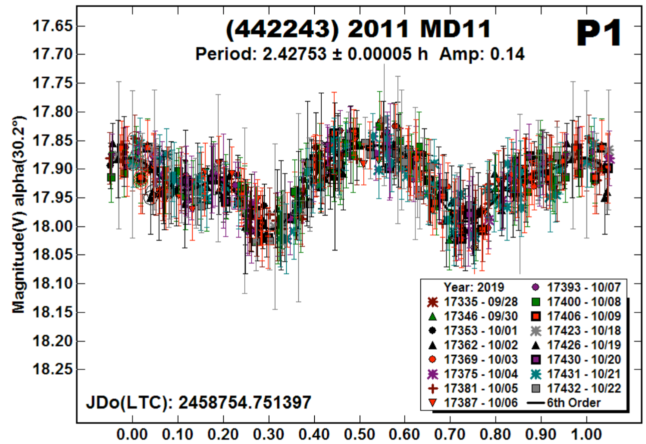


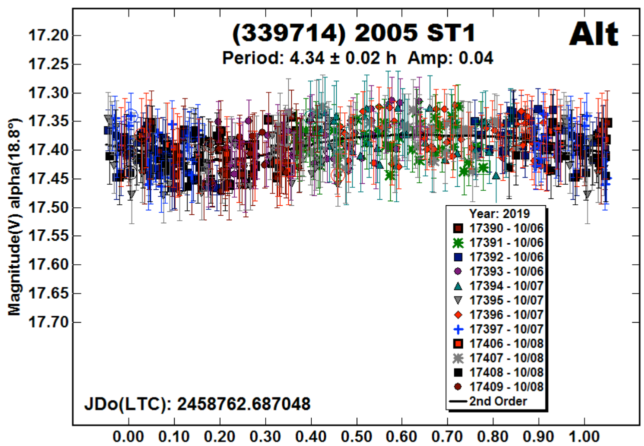


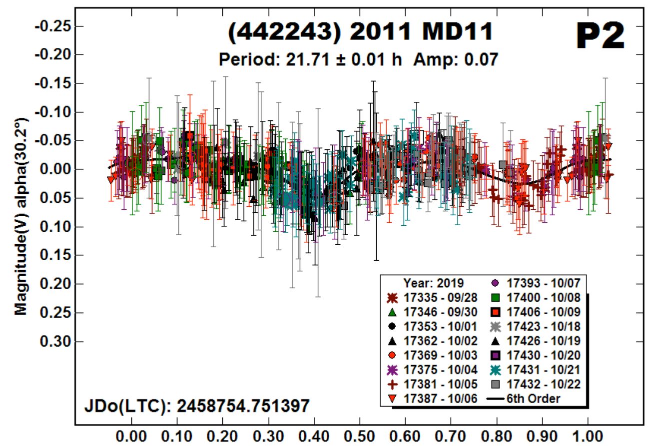


(339714) 2005 ST1. The estimated diameter of this NEA is 250 m. There were no other rotation periods given in the LCDB. Because of the noisy data and low amplitude, it's not safe to presume that the lightcurve should be bimodal. We have adopted a period that corresponds to such a lightcurve, but the half-period, monomodal lightcurve cannot be formally excluded.



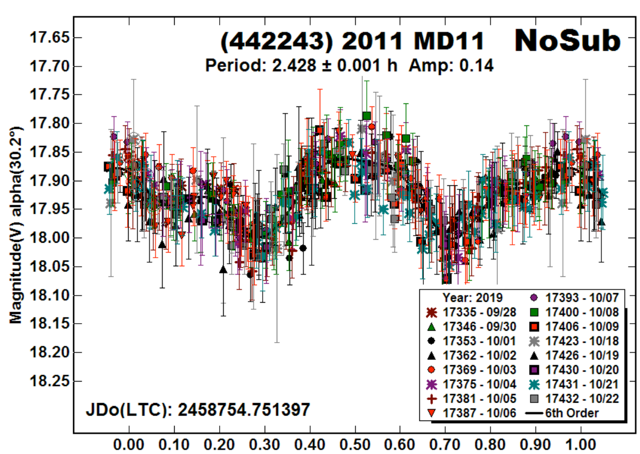






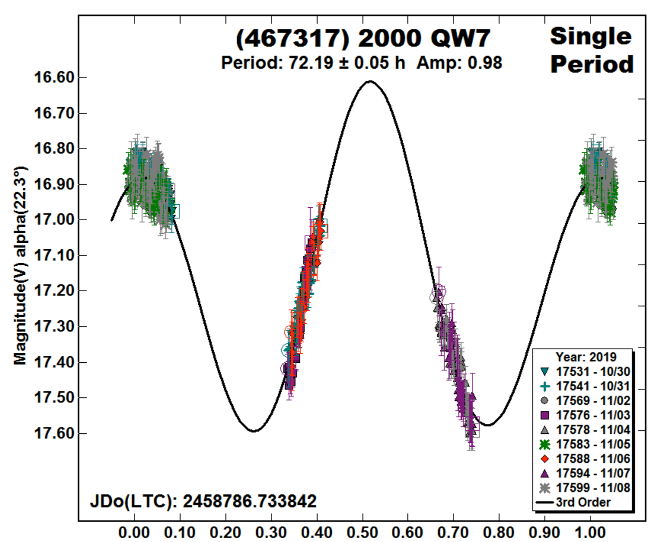
<u>(442243) 2011 MD11</u>. Warner (2016a) was first to report a rotation period for this 700-m NEA: 2.430 h. Our data, noisy as they were, found a similar period of 2.42753 h. We considered that some of the "noise" might be due to a secondary period and so did a dual-period search in *MPO Canopus*. This led to a bimodal lightcurve with P_2 = 21.71 h and amplitude 0.07 mag. These are consistent with the primary and satellite of a binary system with the satellite rotation tidally locked to its orbital period.

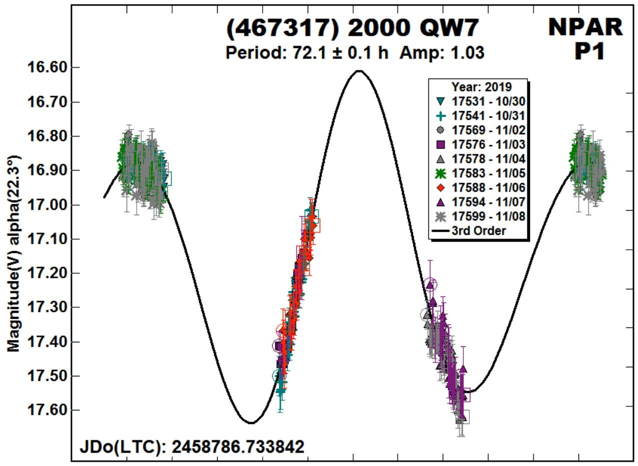
Since there were no mutual events (occultations and/or eclipses) seen (or they were below the noise level) this can be considered only as a suspected binary.

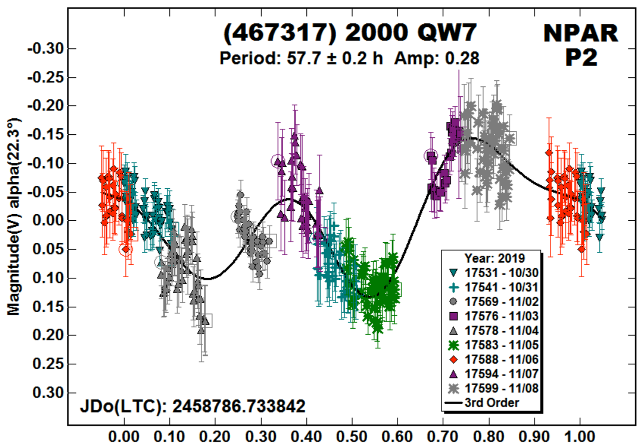


<u>(467317) 2000 QW7</u>. Pravec et al. (2000) reported a period of 71.3 h based on data obtained in 2010. Our data from 2019 could be interpreted more than one way. Assuming a single period with bimodal lightcurve, we found 72.19 h. However, when plotting the raw data from each night, almost every set showed some signs of a secondary period. This prompted another dual-period search.

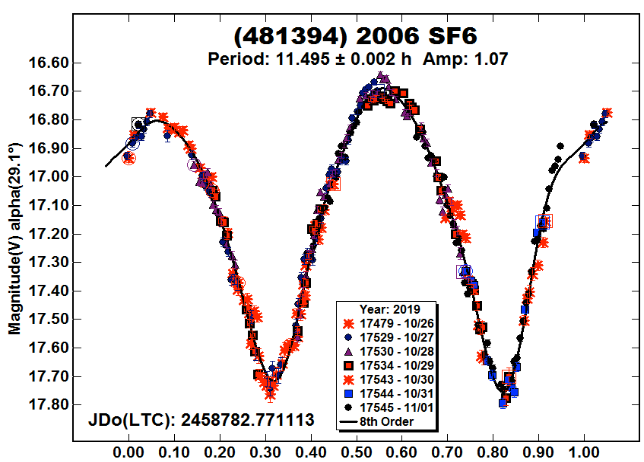
This led to periods of 72.1 h and 57.7 h. Presumably these are due to tumbling but are just the dominant ones found in our search. As happens with most long-period tumblers, the data set was too sparse and from a single station. This makes finding the true periods of rotation and precession almost impossible.





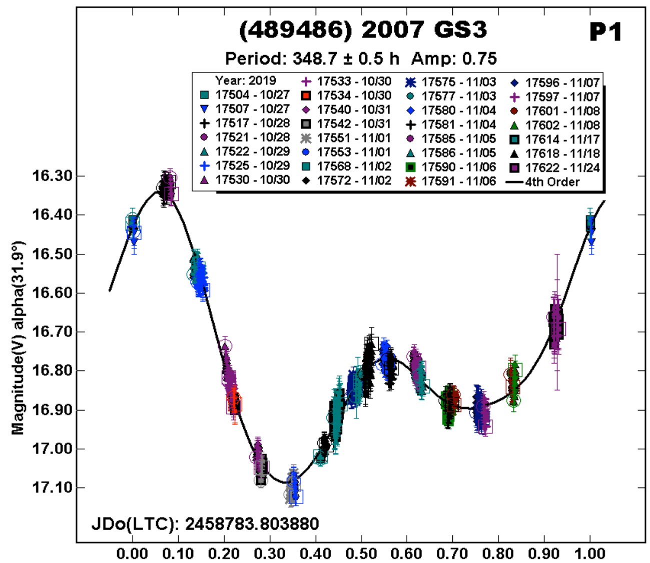


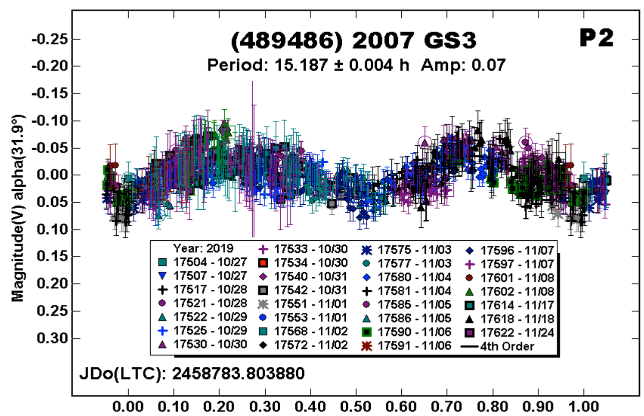
(481394) 2006 SF6. We reported a period of 11.517 h using data from 2018 September (Warner and Stephens, 2019). The data from the 2019 October-November sessions give a nearly identical solution of 11.495 h. The L_{PAB} differed by 298° (or 118° if assuming the opposite pole was being seen). The phase angles were similar, 23° and 26°. Given these circumstances, it would seem likely that the lightcurve amplitudes would be about the same, and they were: 0.97 mag and 1.07 mag.



(489486) 2007 GS3. The estimated size of this NEA is 400 m. These appear to be the first reported periods for the asteroid. A raw plot of the data using the full data set showed a clear long-period trend. The resulting shape of the lightcurve with a period of 348.7 h is a bit suspicious. Give the amplitude of 0.75, a more symmetrical body might be expected.

Assuming the solution was valid, the search for a secondary period found 15.187 h; it seems reasonably secure despite the noisy data. This potentially makes 2007 GS3 a member of the class of *very wide binary asteroids* (see Warner, 2016b for a more detailed discussion of this class).

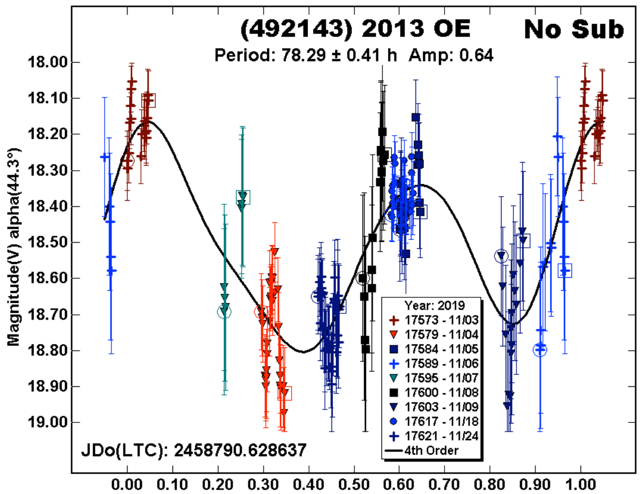


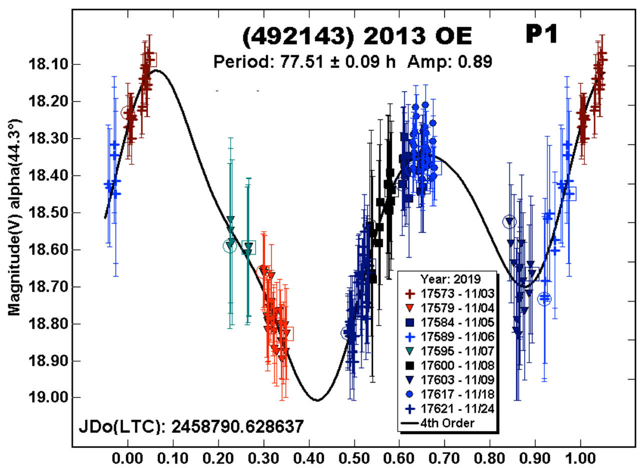


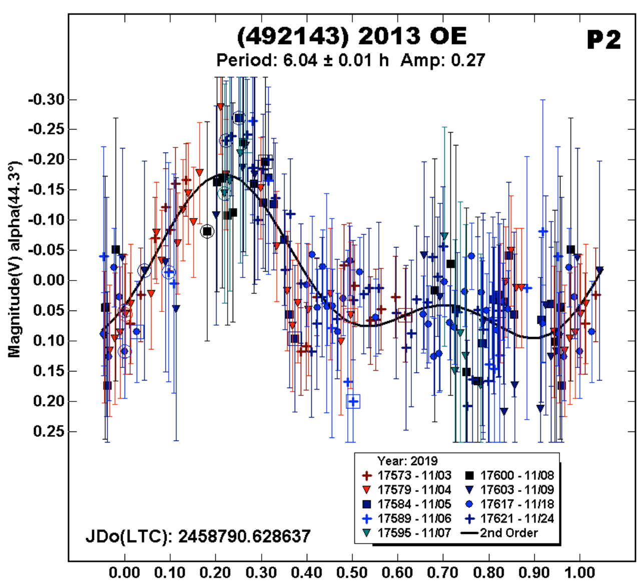
(492143) 2013 OE. The estimated size is 850 m; there were no other rotation periods in the LCDB. Given the noisy and sparse data set, it seemed that even a single period solution would be difficult to find. However, plots from individual nights seemed to show at least one additional period was possible. A dual-period search confirmed the suspicion. Comparing the "No Sub" plot to "P1" (P = 77.51 h) shows that "P1" has a much better fit to the data when subtracting the two additional periods that were found.

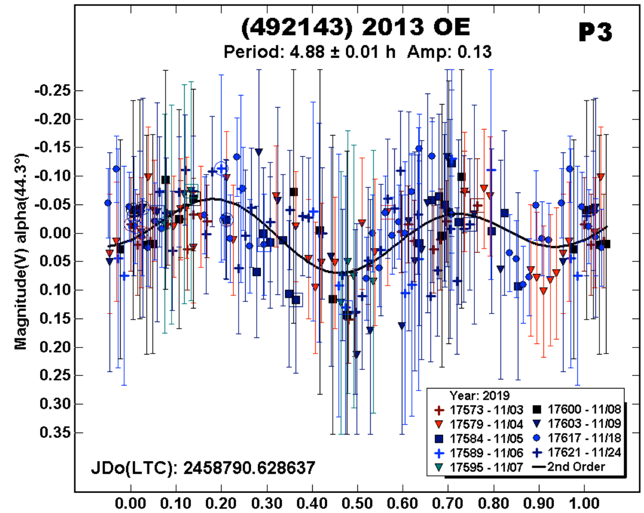
Removing the long period from the data found P_2 = 6.04 h with a lightcurve that could be loosely called bimodal. Subtracting this did not fully bring "P1" into line and so the two periods were subtracted in yet another period search, which led to a more reasonably shaped bimodal lightcurve with an amplitude of 0.13 mag ("P3"). Since this is less than the error bars, the solution is suspect. However, subtracting the two additional periods finally gave a good fit of the data to the "P1" period.

Given the noisy data and low amplitudes for the additional periods, there was the possibility that they were residuals (higher-order harmonics) found in the period searches. This is supported by noting that P_2 and P_3 have a nearly integral ratio of 5:4. Such "coincidences" are often a sign that the Fourier analysis is being misled. The available data set does not allow determining which of the two additional periods, if either, is valid and the other just harmonically related to the others. Even so, subtracting P_2 and P_3 gives a more reliable value for P_1.

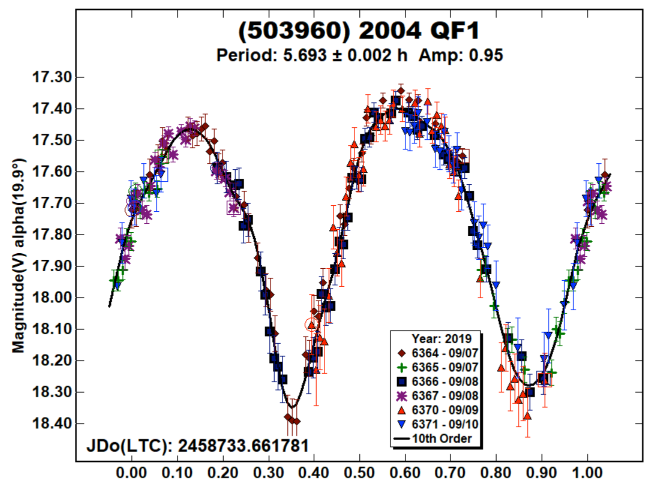




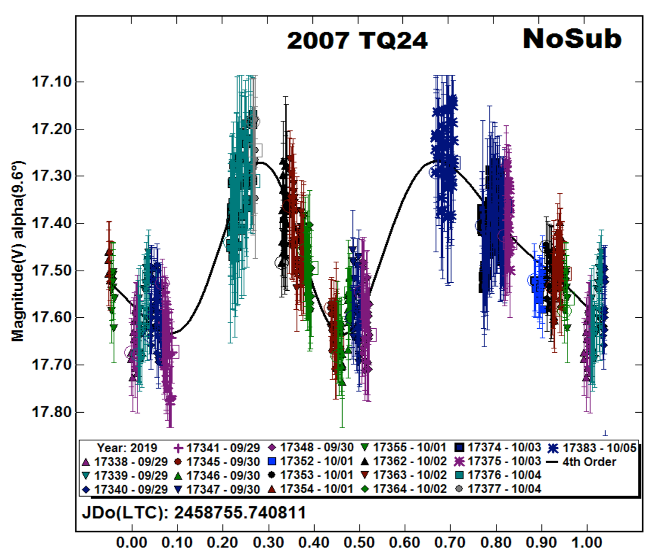




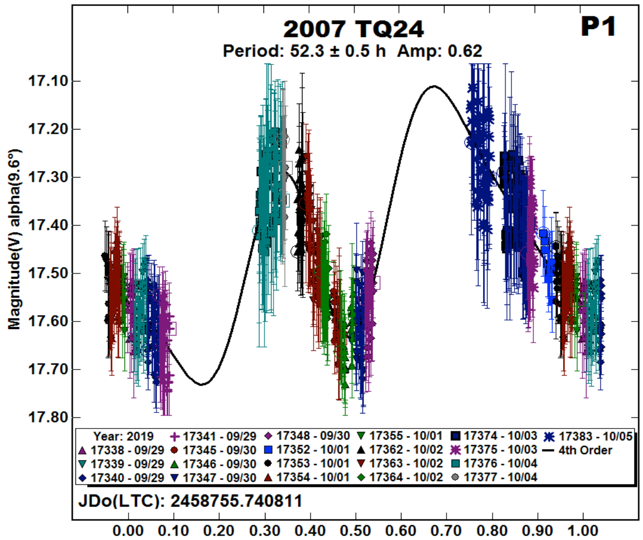
<u>(503960) 2004 QF1</u>. There were no other rotation periods found in the LCDB for this 650-m NEA. This is one of the few examples in this collection that led to a quick and definitive solution.

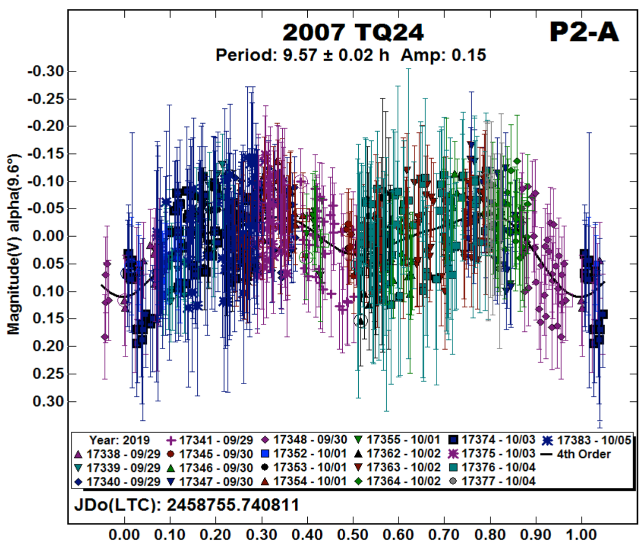


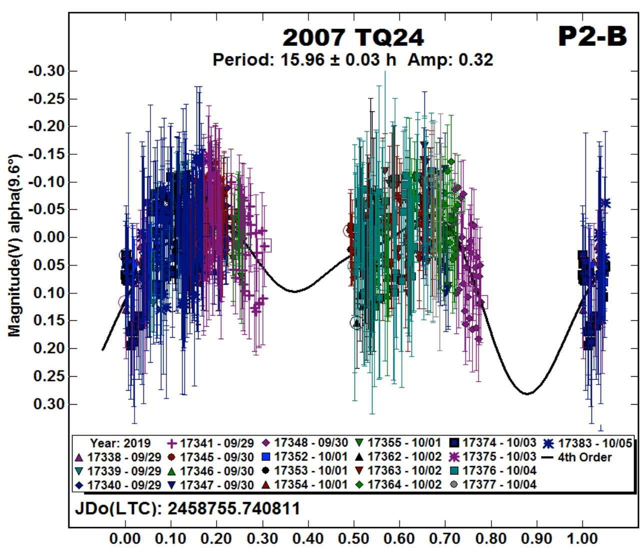
<u>2007 TQ24</u>. The raw plot of the data obtained from 2019 Sep 29 - Oct 5 left little doubt of a long period. Eventually, this proved to be true but only after subtracting one of two secondary periods.



In the "NoSub" plot (with a period of ~52h), some of the sessions have poor fits. We looked to see if a secondary period could produce something better. The result was a lightcurve with P_1 = 52.3 h, which – despite the noise – shows the slope for each session closely matching the slope of the Fourier curve.

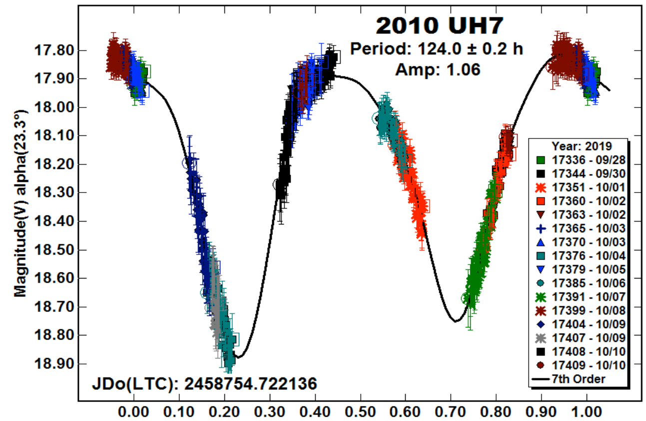


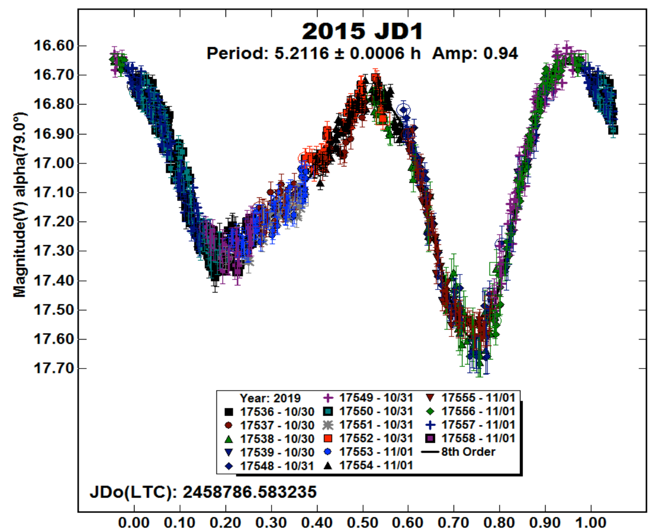


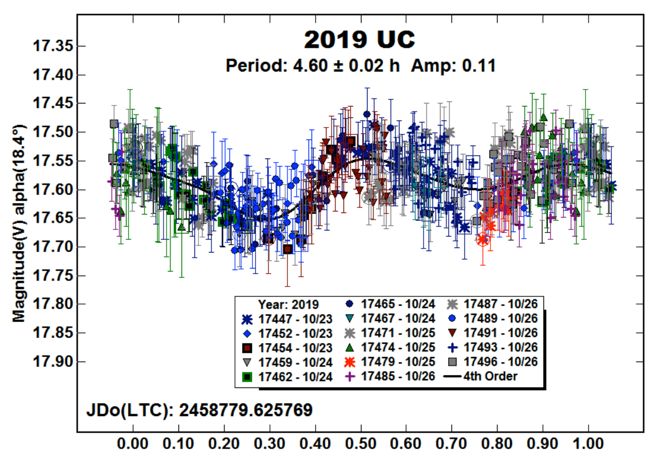


This "P1" fit was achieved by subtracting one of two secondary periods: $P_{2\text{-}A}$ = 9.57 h or $P_{2\text{-}B}$ = 15.96 h, which have a nearly integral ratio of 5:3. Of the two, the longer period is more likely based on the larger amplitude and nearly symmetrical shape of the lightcurve as well as being more plausible for one of the two periods of tumbling.

2010 UH7, 2015 JD1, 2019 UC. These appear to be the first reported rotation periods for these three NEAs.

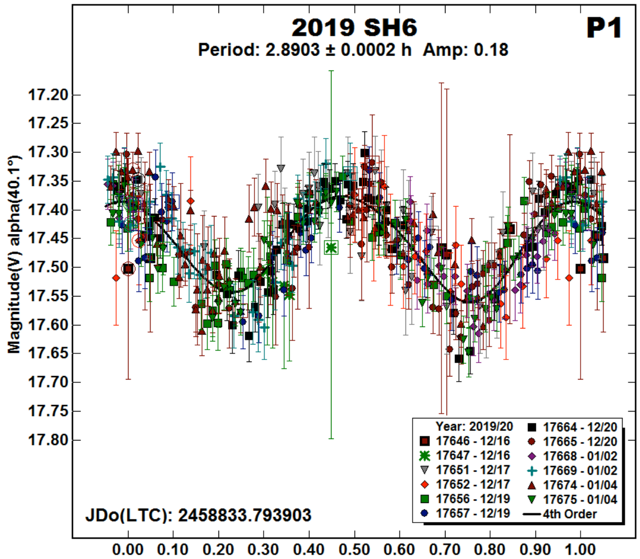


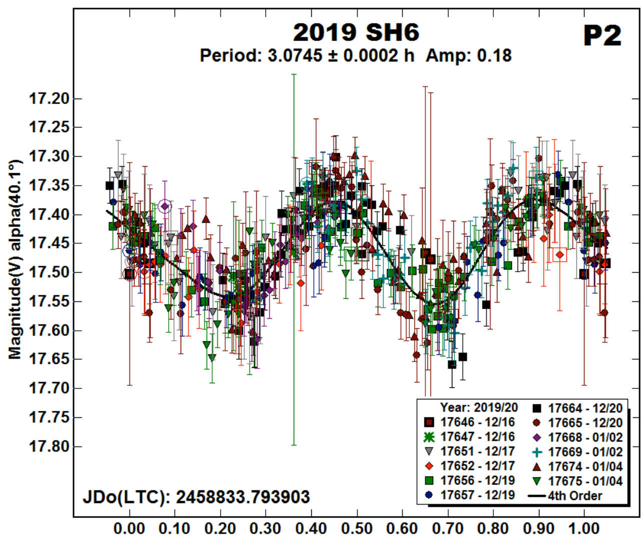


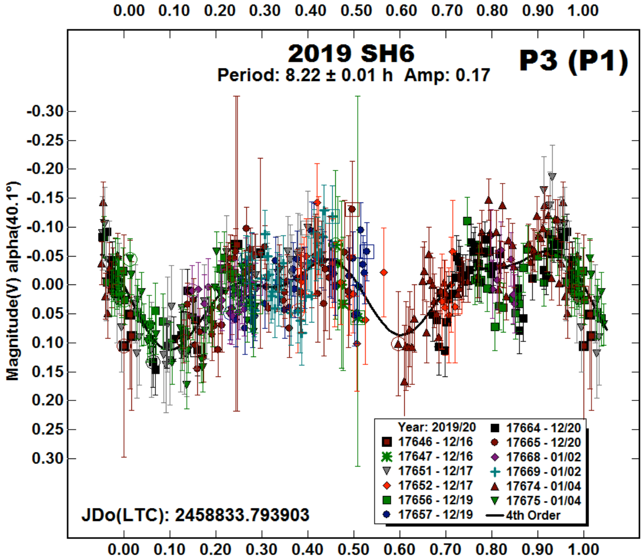


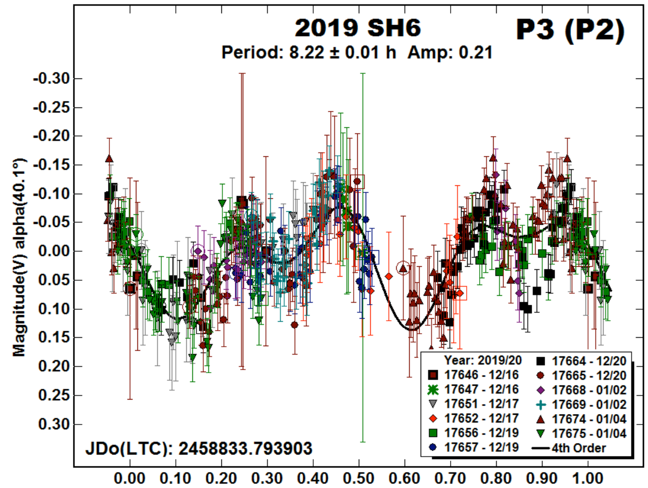
2019 SH6. This 300-m NEA is almost certainly tumbling (Petr Pravec, private communications). The two periods given here are the dominant ones using the dual-period search of *MPO Canopus*.

The software does not do simultaneous two-period searches, which is required to get an accurate estimate of the periods of rotation and precession. However, even well-equipped software can be challenged with noisy or insufficient data.









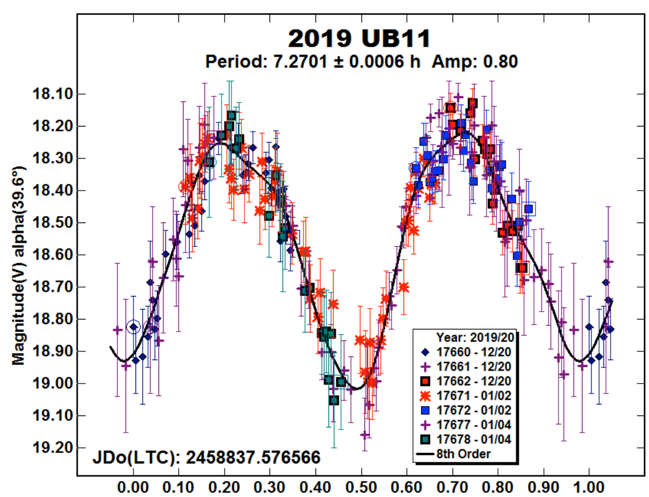
The relatively good fits to the two periods was possible only by subtracting a third period, which – while the same – produced significantly different lightcurve shapes. The "P3 (P1)" plot was produced using a dual period search that subtracted only P_1 while the "P3 (P2)" lightcurve is the result of subtracting only P_2.

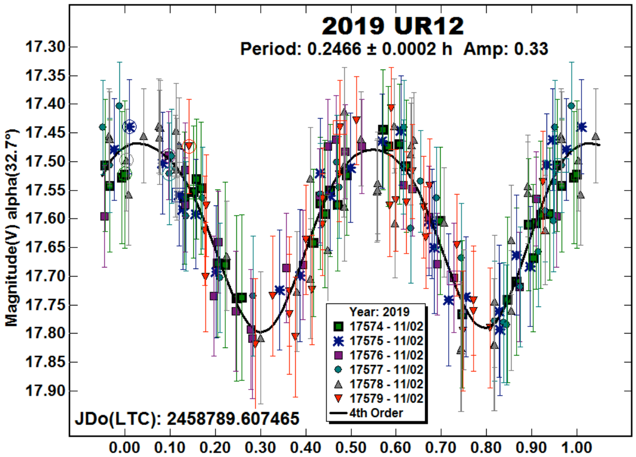
P_3 is unlikely to have physical origins. Instead, it is possibly a "beat frequency" (1/*P*), which is created when the two periods nearly repeat against each other after a set number of cycles. An excellent example of this is seen in Harris et al. (2014).

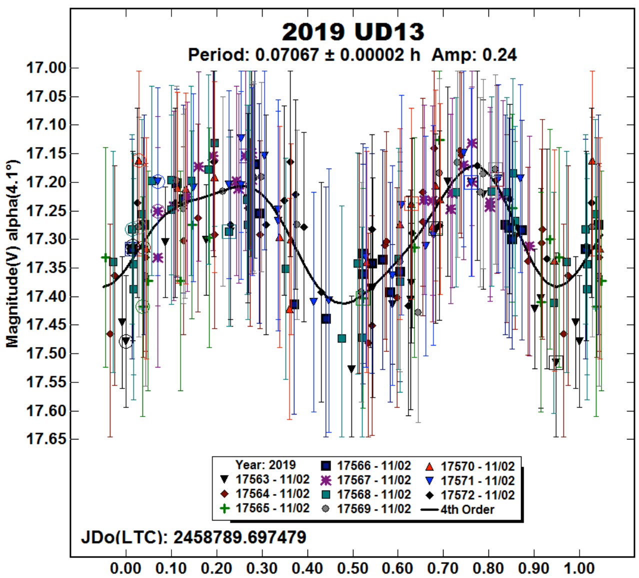
2019 UB11, 2019 UR12, 2019 UD13. The LCDB had no other rotation periods listed at the time of this writing. The respective estimated diameters are 215 m, 40 m, and 60 m.

2019 UB11 was a relatively easy target despite its period being nearly commensurate with an Earth day. This was by virtue of the long observing runs that encompassed more than 3/4 of the rotation period.

It's little surprise that, because of their size, 2019 UR12 and 2019 UD13 are super-fast rotators. Both proved to be challenging because the rate of sky motion and potentially very fast rotation required using short exposures and dealing with the subsequent large SNR values.







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. 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	2019 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	0.02
3200	Phaethon	11/06-11/08	17.3,17.6	32	25	3.597	0.002	0.16	0.02
4183	Cuno	09/28-10/05	4.7,3.4	12	8	[A1]6.909	0.005	0.08	0.02
						[A2]3.450	0.002	0.08	0.02
4183	Cuno	2018/08/09-08/18	5.0,2.0	326	4	[A1]7.140	0.006	0.07	0.02
						[A2]3.577	0.003	0.10	0.02
4183	Cuno	2014/10/01-10/10	37.6,39.8	76	7	[A1]7.117	0.002	0.54	0.03
						[A2]3.558	0.001	0.53	0.03
5626	Melissabrucker	12/10-12/19	39.8,19.5	126	-6	2.2574	0.0003	0.15	0.02
6455	1992 HE	11/02-11/05	14.3,13.6	54	23	2.73	0.01	0.15	0.02
36236	1999 VV	11/25-12/16	2.5,20.1	58	-1	[A1]5.486	0.001	0.19	0.02
						[A2]2.743	0.001	0.19	0.02
88959	2001 TZ44	10/24-10/26	10.3,8.5	38	-9	6.73	0.02	0.30	0.03
99248	2001 KY66	01/03-01/05	20.4,21.3	79	5	19.92	0.34	0.22	0.05
137084	1998 XS16	11/25-12/13	40.8,37.9	35	30	5.4227	0.0005	0.90	0.05
137199	1999 KX4	12/17-12/20	20.2,17.8	101	-8	[A1]2.860	0.002	0.05	0.01
						[A2]2.780	0.003	0.05	0.01
137199	1999 KX4	2013/01/05-01/08	35.5,35.7	132	8	[A1]2.767	0.002	0.12	0.01
						[A2]5.535	0.003	0.12	0.01
141593	2002 HK12	10/11-10/14	19.9,16.4	31	6	12.708	0.003	1.33	0.03
153814	2001 WN5	10/27-10/30	27.4,23.2	54	5	4.259	0.002	0.19	0.03
162082	1998 HL1	[1]10/23-10/28	*35.0,6.2	34	8	11.778	0.007	0.38	0.03
162082	1998 HL1	10/23	34.9	33	18	11.32	0.05	0.32	0.03
162082	1998 HL1	10/24	27.1	33	14	9.97	0.04	0.38	0.03
162082	1998 HL1	10/25	18.6	34	10	10.7	0.5	0.24	0.02
162082	1998 HL1	10/26	10.0	34	5	10.0	0.4	0.26	0.03
162082	1998 HL1	10/27	2.0	34	1	11.5	0.3	0.17	0.02
162082	1998 HL1	10/28	6.3	34	-3	8.3	0.2	0.36	0.05
162273	1999 VL12	11/03-11/05	8.0,8.3	37	9	7.380	0.005	0.93	0.05
162723	2000 VM2	10/27-10/29	19.5,19.1	46	13	4.571	0.002	0.56	0.03
243025	2006 UM216	11/04-12/20	40.7,12.6	86	0	[T1]31.73	0.02	1.3	0.1
297418	2000 SP43	10/10-10/14	57.7,56.1	342	12	6.306	0.002	1.13	0.04
326291	1998 HM3	10/19-10/22	25.2,20.4	22	15	[T1]7.906	0.003	0.35	0.02
						[T2]6.299	0.005	0.08	0.01
339714	2005 ST1	10/06-10/08	19.0,23.0	19	12	[A1]8.68	0.04	0.05	0.02
						[A2]4.34	0.02	0.04	0.02
442243	2011 MD11	09/28-10/22	30.1,15.4	34	5	[P1]2.42753	0.00005	0.14	0.02
						[P2]21.71	0.01	0.07	0.02
467317	2000 QW7	10/30-11/08	22.3,17.0	46	-13	72.19	0.05	0.98	0.05
						[T1]72.1	0.1	1.03	0.10
						[T2]57.7	0.2	0.28	0.03
481394	2006 SF6	10/26-11/01	29.1,22.1	50	5	11.495	0.002	1.07	0.03
489486	2007 GS3	10/27-11/24	*32.1,32.0	53	-10	[P1]348.7	0.5	0.75	0.03
						[P2]15.187	0.004	0.07	0.02
492143	2013 OE	11/03-11/18	44.4,54.7	155	8	[P1]77.51	0.09	0.89	0.04
						[P2]6.04	0.01	0.27	0.04
						[P3]4.88	0.01	0.13	0.03
503960	2004 QF1	09/07-09/10	19.9,19.2	355	13	5.693	0.002	0.95	0.02
	2007 TQ24	09/29-10/05	*9.4,17.8	5	-5	52.3	0.5	0.62	0.05
						[P2]15.96	0.03	0.32	0.04
						[P2]9.57	0.02	0.15	0.04
	2010 UH7	09/28-10/10	23.3,19.6	26	6	124.0	0.2	1.06	0.05
	2015 JD1	10/30-11/01	78.1,66.7	12	30	5.2116	0.0006	0.94	0.04
	2019 UC	10/23-10/26	18.7,28.8	20	-5	4.60	0.02	0.11	0.03
	2019 SH6	[2]12/16-01/04	40.1,52.9	120	-6	[T1]2.8903	0.0002	0.18	0.03
						[T2]3.0745	0.0002	0.18	0.03
						[BF]8.22	0.01	0.17	0.03
	2019 UB11	01/02-01/04	29.5,28.6	82	-4	7.2701	0.0006	0.80	0.06
	2019 UR12	11/02-11/02	31.9	23	-4	0.2466	0.0002	0.33	0.04
	2019 UD13	11/02-11/02	6.1	39	3	0.07067	0.00002	0.24	0.05

Table II. Observing circumstances. [1]The first line for (162082) 1998 HL1 is for the combined data set; the additional lines are for individual nights (see text). [2]The observations ended in 2020 January. 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). [A1,A2]Preferred and alternate periods of an ambiguous solution. [P1,P2,P3]Primary, secondary (and trinary) periods of a (suspected) binary. [T1,T2(,BF)]Dominate periods (and beat frequency period) of a (suspected) tumbler. See text for specific details.

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SPIN-SHAPE MODEL FOR 33 POLYHYMNIA

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We present a shape and spin axis model for main-belt asteroid 33 Polyhymnia. The model was achieved with the lightcurve inversion process, using combined dense photometric data acquired from five apparitions, between 2008-2019 and sparse data from USNO Flagstaff. Analysis of the resulting data found a sidereal period P = 18.60888 ± 0.00029 hours and two mirrored pole solutions at (λ = 19°, β = -65°) and (λ = 185°, β = -61°) with an uncertainty of ± 15 degrees.

The minor planet 33 Polyhymnia has been observed extensively by the authors in the past oppositions, covering a wide range of phase angle bisectors, essential condition for starting a lightcurve inversion work. Dense photometric data were downloaded from ALCDEF (ALCDEF, 2019) and, in order to improve the solution, we have also used sparse data from USNO Flagstaff Station (MPC Code 689), taken from the Asteroids Dynamic Site (AstDyS-2, 2019).

The observational details of the dense data used are reported in Table I with the mid-date of the apparition, longitude and latitude of phase angle bisector (L_{PAB}, B_{PAB}).

Reference	Mid date	L_{PAB}°	B_{PAB}°
Pilcher (2009)	2008-04-15	203	-1
Pilcher (2011)	2011-01-15	112	2
Audejean (2012) Web	2012-03-13	163	1
Ferrero (2012)	2012-03-17	162	1
Pilcher (2018)	2018-04-28	221	-1
Pilcher (2020)	2019-08-31	14	0

Table I. Observational details for the data used in the lightcurve inversion process for 33 Polyhymnia.

Lightcurve inversion was performed using MPO LCInvert v.11.7.5.1 (BDW Publishing, 2016). For a description of the modeling process see LCInvert Operating Instructions Manual, Durech et al. (2010) and references therein.

Figure 1 shows the PAB longitude/latitude distribution for dense/sparse data used in the lightcurve inversion process. Figure 2 (top panel) shows the sparse photometric data distribution (intensities vs JD) and (bottom panel) the corresponding phase curve (reduced magnitudes vs phase angle).

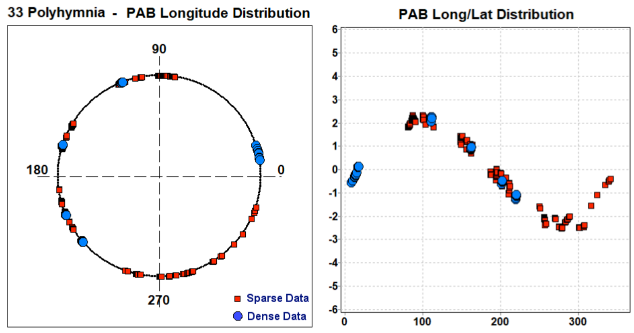

Figure 1: PAB longitude and latitude distribution of the data used for the lightcurve inversion model.

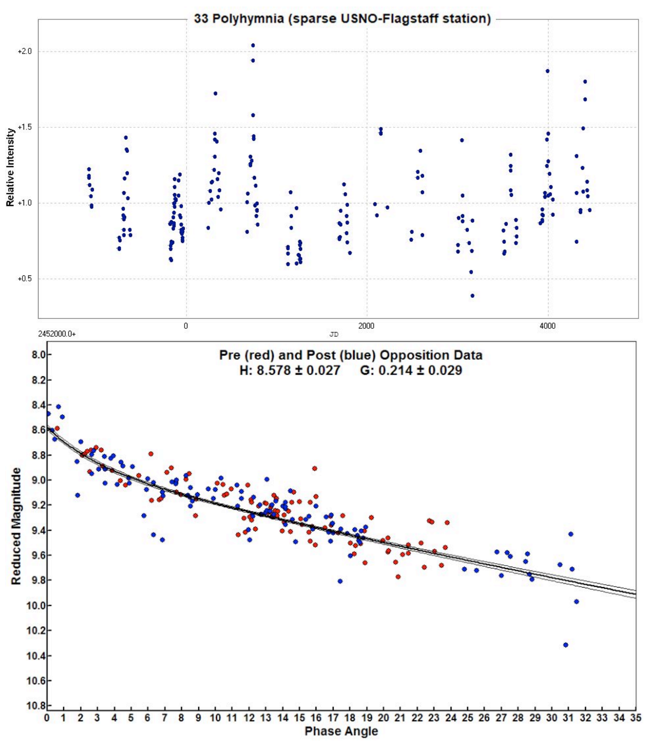

Figure. 2: Top: sparse photometric data point distribution from (689) USNO Flagstaff station (relative intensity of the asteroid's brightness vs Julian Day). Bottom: phase curve obtained from sparse data (reduced magnitude vs phase angle).

In the analysis, the processing weighting factor was set to 1.0 for dense data and to 0.3 for sparse data. The "dark facet" weighting factor was set to 0.5 to keep the dark facet area below 1% of total area and the number of iterations was set to 50.

The sidereal period search was started around the average of the synodic periods found in the asteroid lightcurve database (LCDB; Warner et al., 2009). We found one isolated sidereal periods with a Chi-Sq value within 10% of the lowest Chi-Sq (Figure 3).

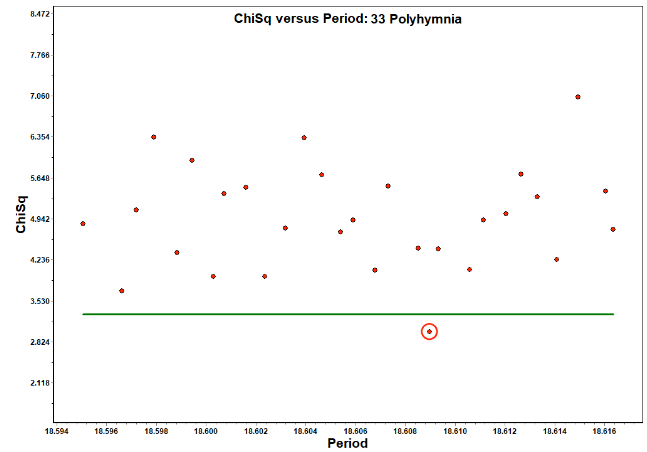

Figure 3: The period search for 33 Polyhymnia shows one isolated sidereal periods with Chi-Sq values within 10% of the lowest value.

The pole search was started using the "medium" option with the previously found sidereal period set to "float". From this step we found two roughly mirrored lower Chi-Sq solutions (Figure 4) separated by 180° in longitude at ecliptic longitude-latitude pairs (15°, -60°) and (195°, -60°).

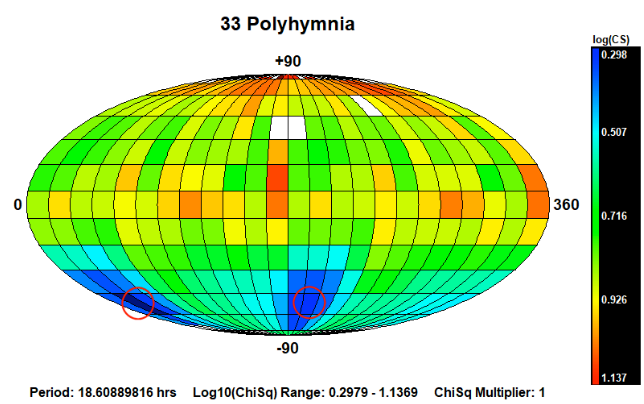

Figure 4: Pole search distribution. The dark blue indicates the better solutions (lower Chi-Sq), while maroon the worst ones.

The subsequent "fine" search, centered on these rough positions, allowed us to refine the position of the pole (Figure 5). The analysis shows two set of clustered solutions within 15° of radius that had Chi-Sq values within 10% of the lowest value, centered at ecliptic longitude-latitude (17°, -64°) and (191°, -65°).

The two best solutions (lower Chi-Sq) are reported in Table II. The sidereal period was obtained by averaging the two solutions found in the pole search process. Typical errors in the pole solution are ± 15° and the uncertainty in sidereal period has been evaluated as a rotational error of 30° over the total time span of the dense data set. Figure 6 shows the shape model (first solution) while Figure 7 shows the fit between the model (black line) and some observed lightcurves (red points).

λ °	β °	Sidereal Period (hours)	RMS
19	-65	18.60888 ± 0.00029	0.0127
185	-61		0.0133

Table II. The two spin axis solutions for 33 Polyhymnia (ecliptic coordinates) with an uncertainty of ± 15 degrees. The sidereal period is the average of the two solutions found in the pole search process.

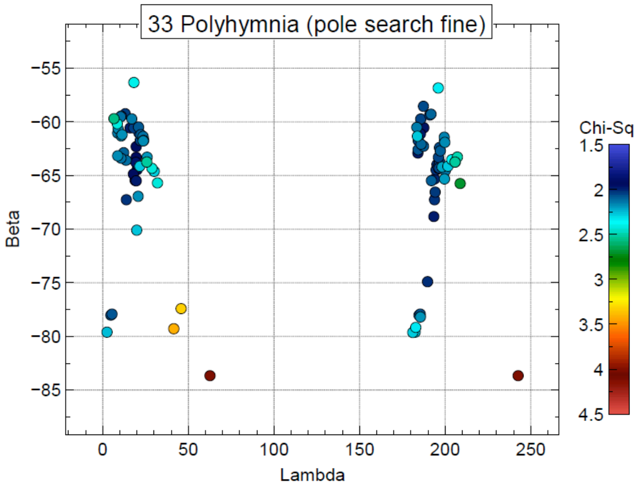

Figure 5: The "fine" pole search shows two clustered solutions centered at the ecliptic longitude / latitude (17°, -64°) and (191°, -65°) with radius approximately of 15° and Chi-Sq values within 10% of the lowest value.

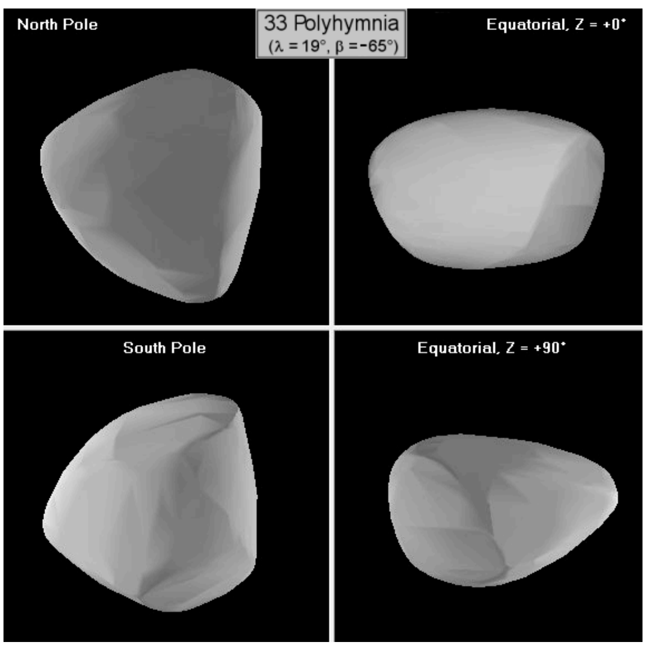

Figure 6: The shape model for 33 Polyhymnia (λ = 19°, β = -65°).

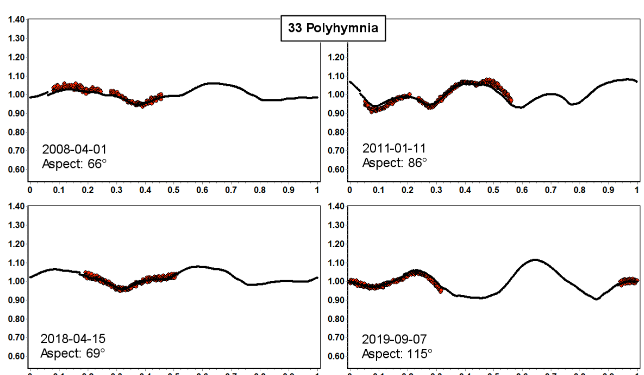

Figure 7: Model fit (black line) versus observed lightcurves (red points) for (λ = 19°, β = -65°) solution.

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CALL FOR OBSERVATIONS

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Observers who have made visual, photographic, or CCD measurements of positions of minor planets in calendar year 2019 are encouraged to report them to this author on or before 2020 April 1. This will be the deadline for receipt of reports, for which results can be included in the "General Report of Position Observations for 2019," to be published in *MPB* Vol. 47, No. 3.

LIGHTCURVE ANALYSIS OF HILDA ASTEROIDS AT THE CENTER FOR SOLAR SYSTEM STUDIES: 2019 NOVEMBER

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(Received: 2020 January 9)

CCD photometric observations of three Hilda asteroids were made at the Center for Solar System Studies (CS3) in 2019 November to provide additional lightcurves for modeling.

CCD photometric observations of three Hilda asteroids were made at the Center for Solar System Studies (CS3) in 2019 November. 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.

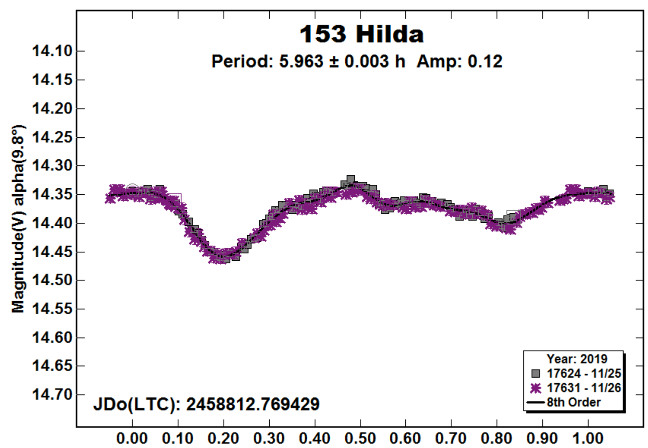
Measurements were made using *MPO Canopus*. The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Comp star magnitudes were taken from ATLAS catalog (Tonry et al., 2018), which has Sloan griz magnitudes that were derived from 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 mag.

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 sky (catalog) magnitude of the asteroid (V is Johnson V, SR is Sloan r´). 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.

153 Hilda. This is the largest member (170 km) of the Hilda group. Shevchenko et al. (2009) used data from 2002 observations to find a period of 5.9587 h. Our period of 5.963 h is in good agreement.

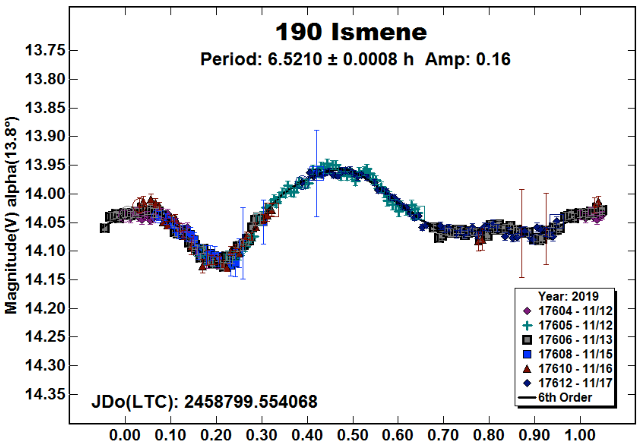


190 Ismene. Binzel and Sauter (1992) are the earliest entry in the LCDB with a result (6.51 h) that is near the adopted period of 6.5210 h given in the LCDB. Dahlgren et al. (1998) found a period of 6.52 h. Shevchenko et al. (2008) found a period of 6.5192 h using data from 1999. Since then, only two other references in the LCDB have a result near the adopted period: Dunckel (2011; a web posting) and this work.

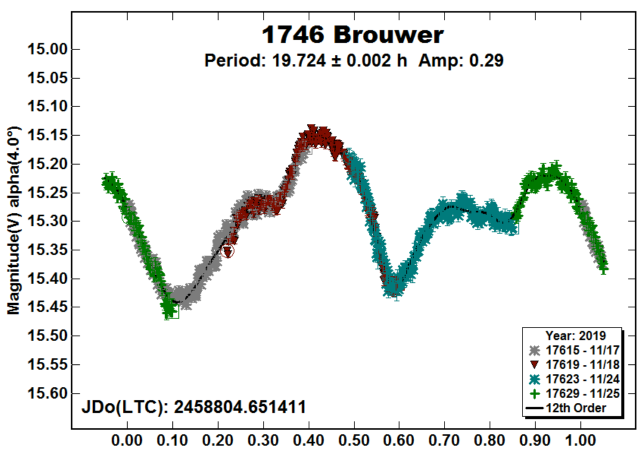
Number	Name	2019/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
153	Hilda	11/25-11/26	9.8,9.7	108	-7	5.963	0.003	0.12	0.01
190	Ismene	11/12-11/17	13.8,14.2	345	0	6.5210	0.0008	0.16	0.01
1746	Brouwer	11/17-11/25	4.0,3.5	60	10	19.724	0.002	0.29	0.02

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).

For the second largest member of the Hilda family (158 km) this seems a sparse sampling. It may be that observers seeing an accurate period and U = 3 in the LCDB believe that no other observations are required. It's a rare occasion when there are too many observations of an asteroid. In this case, the new data contributed to developing an accurate shape and spin axis model.



1746 Brouwer. Dahlgren et al. (1998) found P = 19.8 h for Brouwer. Hanus et al. (2016) derived a shape and spin axis model with two possible poles: (λ, β) = (21°, –67°) or (158°, –71°). The sidereal period was 19.7255 h for both models.



The result from the 2019 observations at CS3 led to an asymmetric bimodal lightcurve with a period of 19.724 h and amplitude of 0.29 mag.

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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MAIN-BELT ASTEROIDS OBSERVED FROM CS3: 2019 OCTOBER TO DECEMBER

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(Received: 2020 January 9)

CCD photometric observations of 21 main-belt asteroids were obtained at the Center for Solar System Studies (CS3) from 2019 October to December.

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.

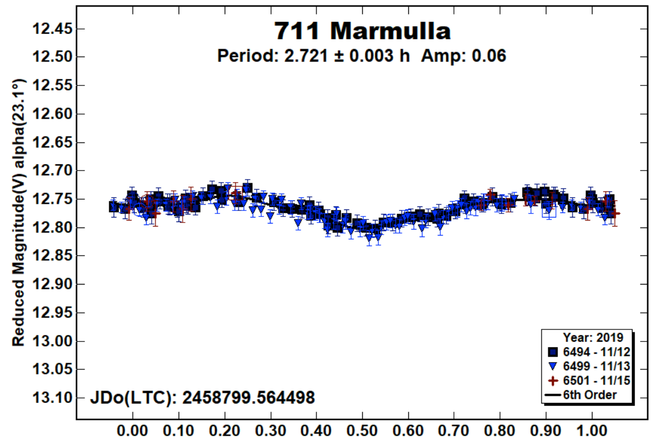
Image processing, measurement, and period analysis were done using *MPO Canopus* (Bdw Publishing), which incorporates the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector feature in *MPO Canopus* was used to limit the comparison stars to near solar color. Night-to-night calibration was done using field stars from the 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.

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 $-5*\log(r\Delta)$ 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.

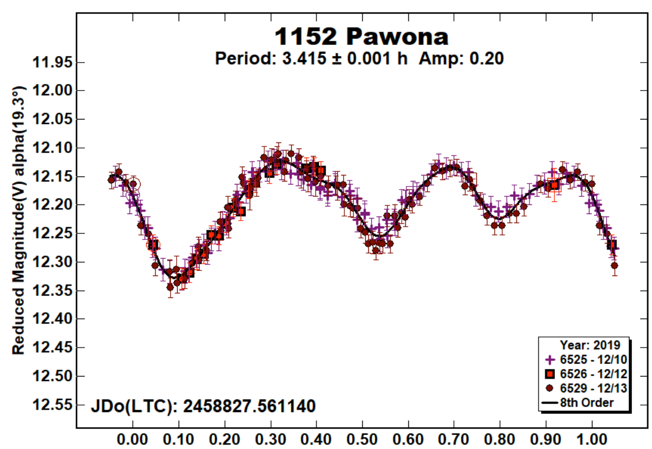
The amplitude indicated in the plots (e.g. Amp. 0.23) is the amplitude of the Fourier model curve and not necessarily the adopted amplitude of the lightcurve.

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).

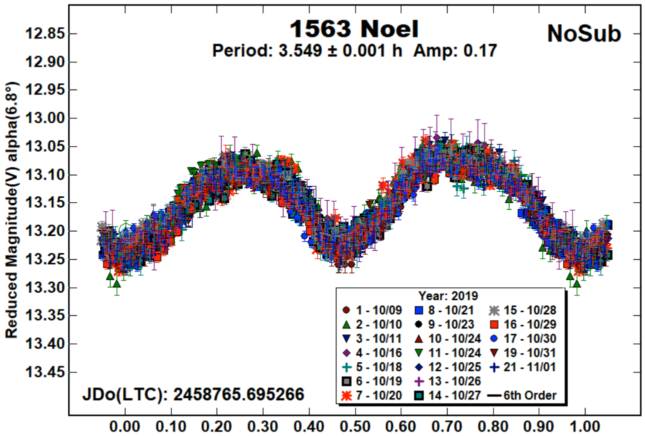
711 Marmulla. This member of the Flora family has had two reported rotational periods in the past. Kryszczyńska et al. (2012) reported a period of 2.88 h and Skiff et al. (2019) reported a period of 2.7216 h. Our result agrees with the Skiff period.

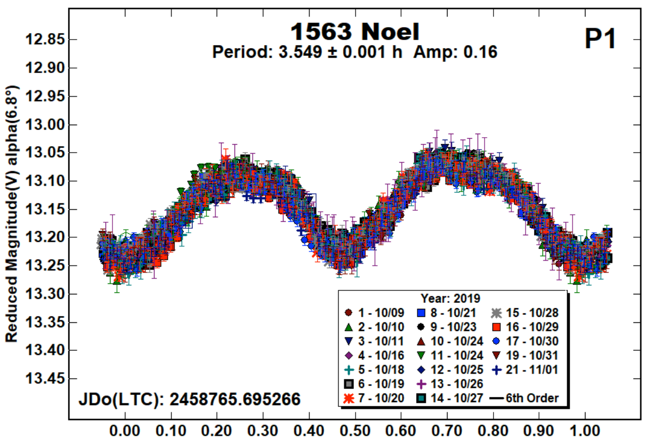


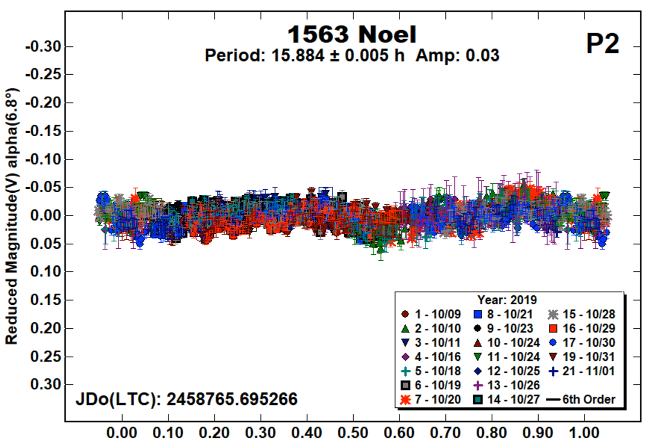
1152 Pawona. This Vestoid has been observed several times in the past. Koff and Clark (2002), Behrend (2019), Schmidt (2017), and Klinglesmith et al. (2017) all reported periods near 3.42 h. Our period agrees with those prior results.



1563 Noel. This member of the Flora family has been observed in 2008, 2013 and 2015 by the Photometric Survey for Asynchronous Binary Asteroids (Pravec 2019) as being a 'Prime Suspect' of being a binary asteroid. At each opposition the survey and individual members (Oey et al. 2017, Apostolovska et al. 2017) found rotational periods near 3.549 h. At the 2019 opposition, sings of a weak secondary period signal was detected (NoSub). Several values for that period, all commensurate with an Earth day, were found. The solution of 15.9 h best fit the data. With such a small amplitude, observations at stations at different longitudes have the best chance of confirming this suspected binary.

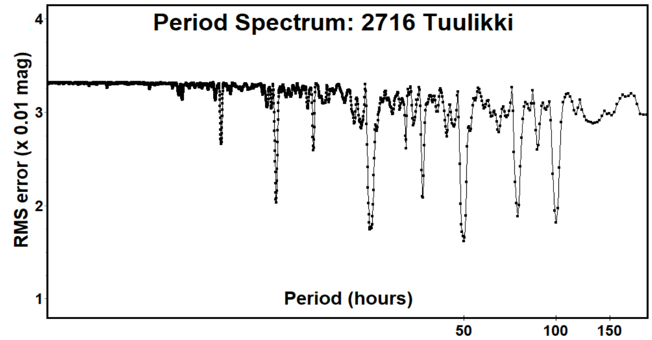


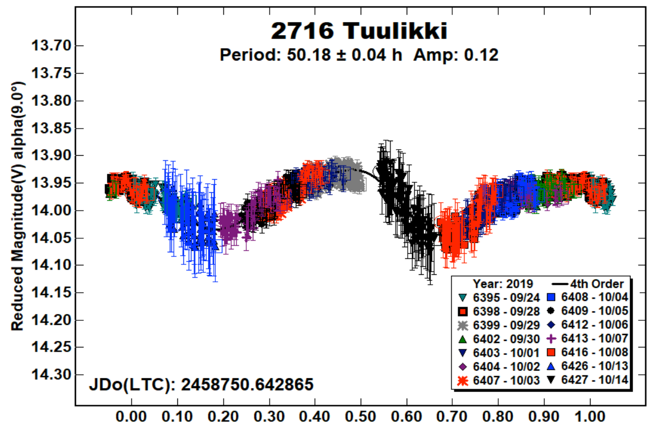




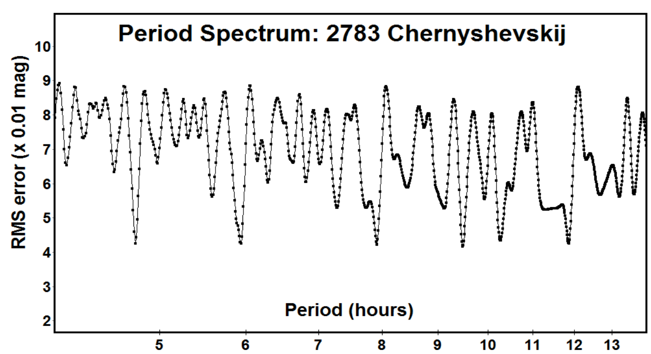
2716 Tuulikki. This appears to be the first reported lightcurve period for Tuulikki, which is a Vestoid member with an estimated diameter of 5.2 km. Per the period spectrum, the period with the best fit is nearly commensurate with two Earth days. This requires an extended observing campaign to construct a complete lightcurve.

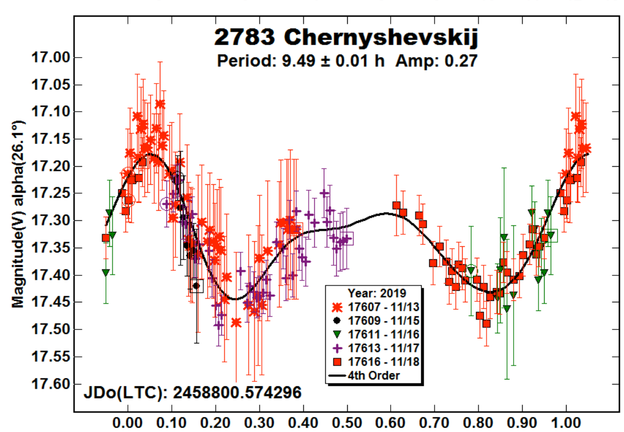
Other solutions created monomodal or trimodal lightcurves, which are possible due to the low amplitude (Harris et al., 2014), and cannot be formally excluded.



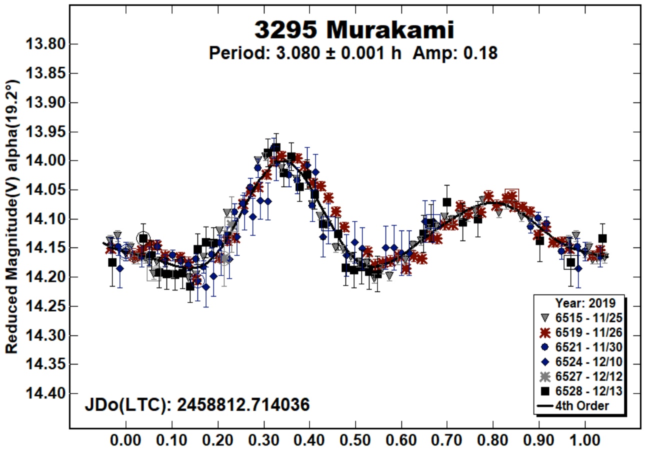


2783 Chernyshevskij. From observations obtained in 2011, Behrend (2019) reported a period of 9.455 h. Our data at the 2019 opposition was incomplete and noisy. They showed several possible periods of equal probability, including one near 12 h that is a 4:5 alias of the Behrend result. Given the high quality Behrend lightcurve, we have adopted the 9.49 h period is the probable correct period.

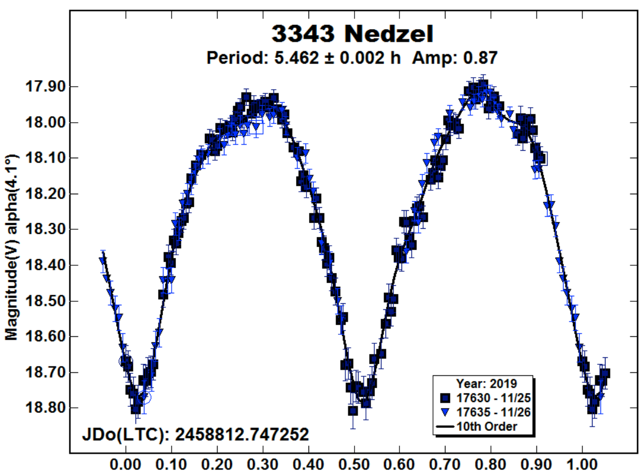




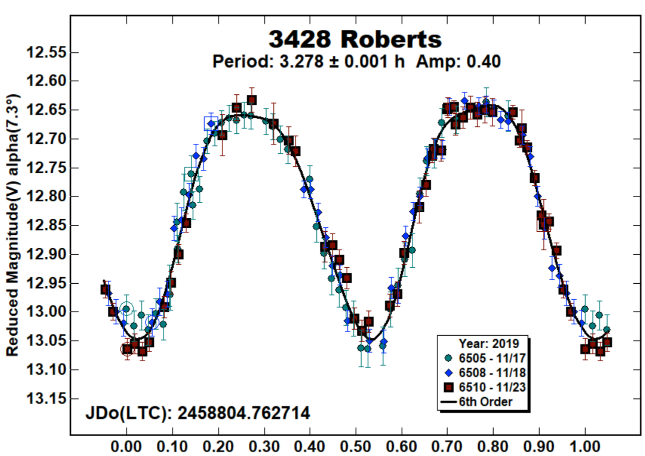
3295 Murakami. This is the first reported lightcurve period in the LCDB for this middle main-belt asteroid.



3343 Nedzel. We worked this Mars crosser twice in the past (Stephens 2018 and Warner 2018b), finding periods of 5.46 h. In addition, Folberth et al. (2012) found a period of 5.462 h. Using sparse data from the Lowell Observatory Database, Ďurech et al. (2018) found a sidereal period of 5.463570 h. Our solution is in good agreement.

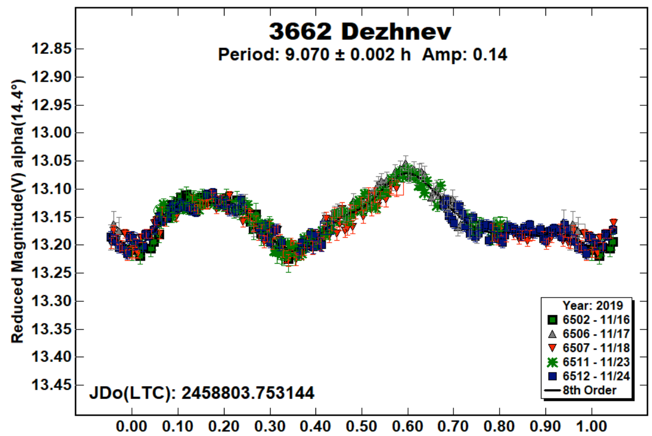


3428 Roberts. Oliver et al. (2008) observed this main-belt object and found a synodic rotational period of 3.278 h. Our period is in good agreement with those results.

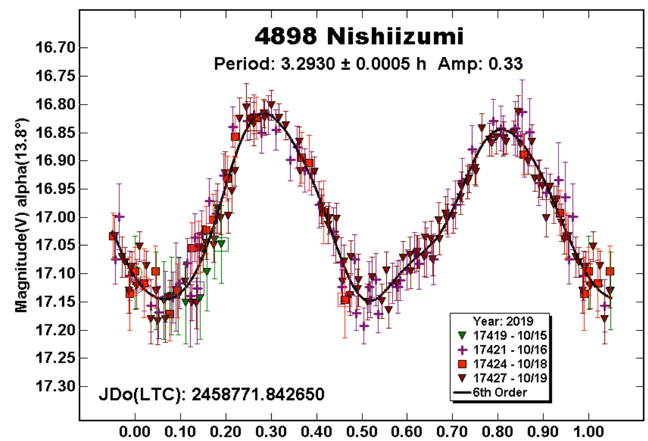


Hanuš et al. (2016), using only sparse data, found a pole solution with ecliptic coordinates of (λ, β) = (63°, +49°) and a sidereal period of 3.27835 h. They also found an alternate pole solution of (231°, +49°). Our observations were done to provide a dense data set to help improve the pole in future modeling.

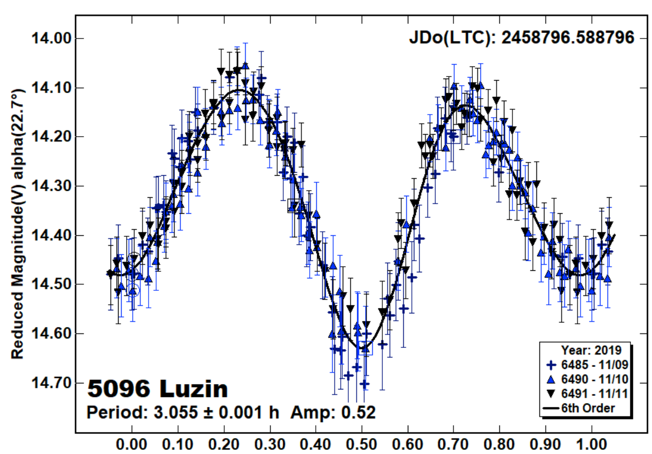
3662 Dezhnev. There were no previous entries in the LCDB for this 9.4 km member of the Eunomia group/family.



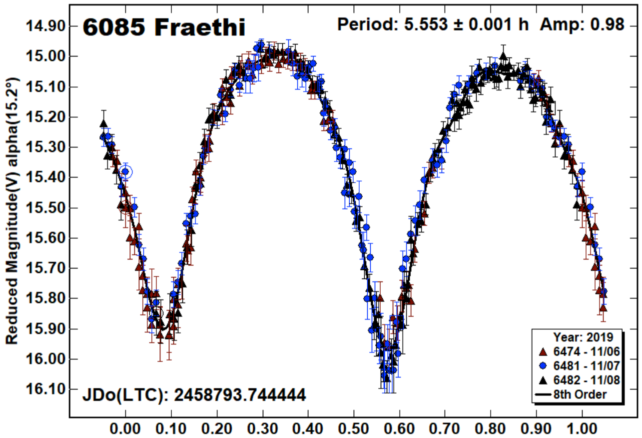
4898 Nishiizumi. Previous results for this 2 km Hungaria (Warner 2007; 2012; 2015; 2018a) were close to our result of 3.2930 h.



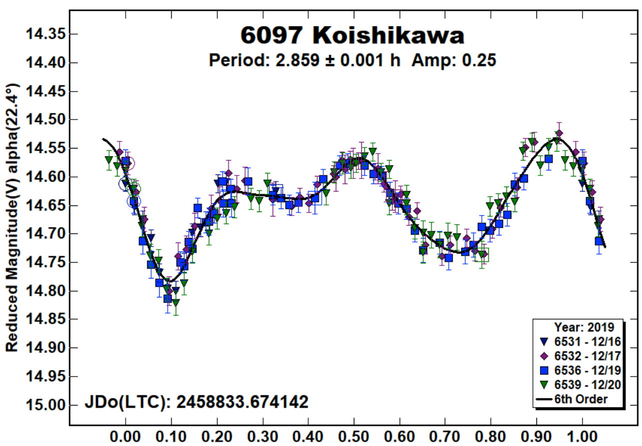
5096 Luzin. Klinglesmith et al. (2013) observed this Vestoid in 2012 and determined the rotational period to be 3.054 h. Our result is in good agreement with their period.



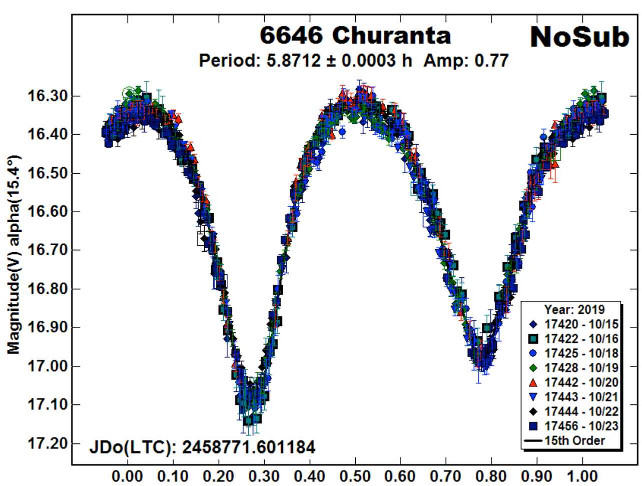
6085 Fraethi. We found a period of 5.556 h in 2015 (Stephens 2016). The 2019 result agrees with that prior result.

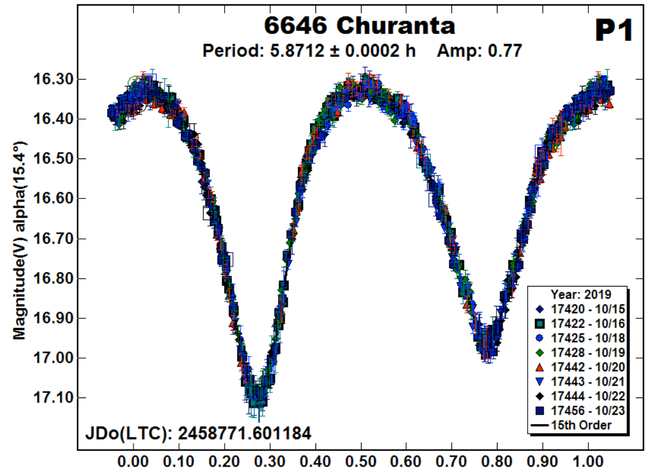


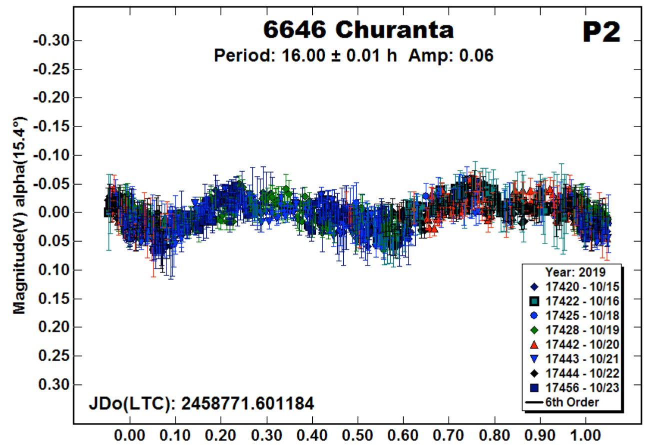
6097 Koishikawa. This member of the Flora group/family was observed in 2010 and 2017 by the Photometric Survey for Asynchronous Binary Asteroids (Pravec, 2019; Oey and Groom 2019). Both groups reported P = 2.8598 h. Our result is in good agreement.



6646 Churanta. We worked this Hungaria three times in the past (Warner 2007, 2012, 2015), each time finding a rotational period of 5.87 h. Since the amplitude at all four oppositions is consistent, the spin axis must be close to one of the ecliptic poles. During the 2019 apparition, slight deviations in the lightcurve suggested a secondary period (NoSub).

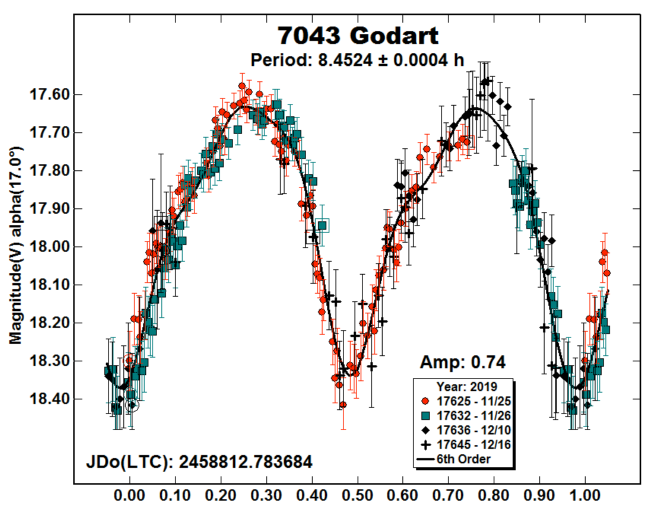






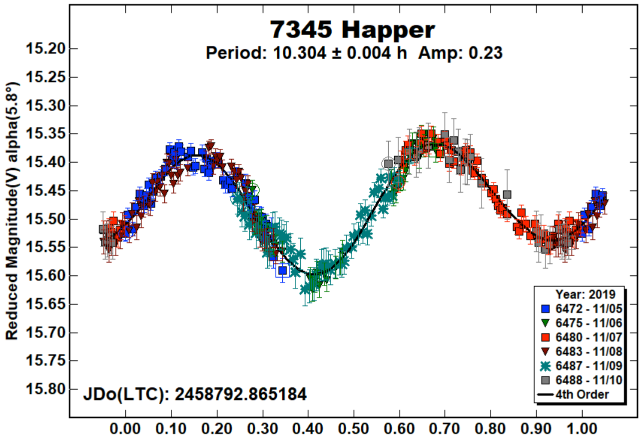
We did a dual-period search and found a secondary period of 16.00 h with no mutual events (P2). We are concerned that the P2 is exactly 2/3 day, so that the two nearly symmetrical halves alternate each night, but there is *almost* enough asymmetry in the P2 curve to overcome these doubts. The next opportunity for northern observers is 2023 February.

7043 Godart. This member of the Flora group/family has been well studied in the past as part of the Photometric Survey for Asynchronous Binary Asteroids (Pravec et al. 2019) and by Waszczak et al. (2005).

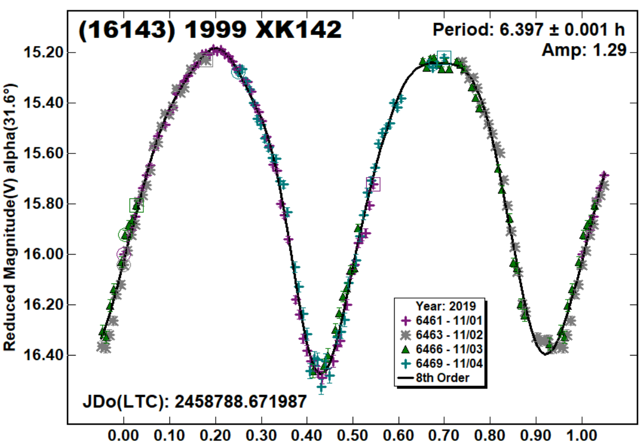


Both groups reported periods near 8.45 h. Our solution is in good agreement. Hanuš et al. (2013) reported ecliptic coordinates ($\lambda,\beta,P_{SIDERAL}$) = (73°, +62°, 8.4518 h) and a weaker, competing solution of (235°, 80°, 8.4518 h).

7345 Happer. No records were found in the LCDB for this Mars crosser, so this is another new discovery of an asteroid rotational period.



(16143) 1999 XK142. Per the LCDB, this Mars crosser has been observed twice by the Palomar Transient Factor survey (Waszczak et al. 2015; Chang et al. 2015). We also observed it in 2016 (Stephens 2016). Each time, a period near 6.4 h was found. Our result is in agreement with the periods in those prior works.



The Waszczak data were available on the ALCDEF asteroid photometry database (*http://www.alcdef.org/*), so we attempted a pole and shape model.

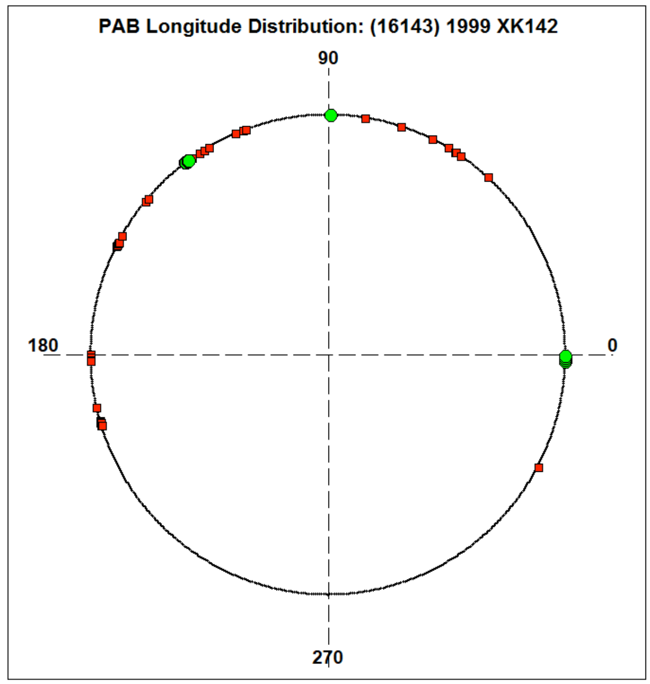
Sparse data observations were obtained from the Catalina Sky Survey and USNO-Flagstaff survey using the AstDyS-3 site (*https://newton.spacedys.com/astdys/*). These sparse data were combined with our dense data using *MPO LCInvert*, (Bdw Publishing). This Windows-based program incorporates the algorithms developed by Kassalainen et al. (2001a, 2001b) and converted by Josef Ďurech 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.

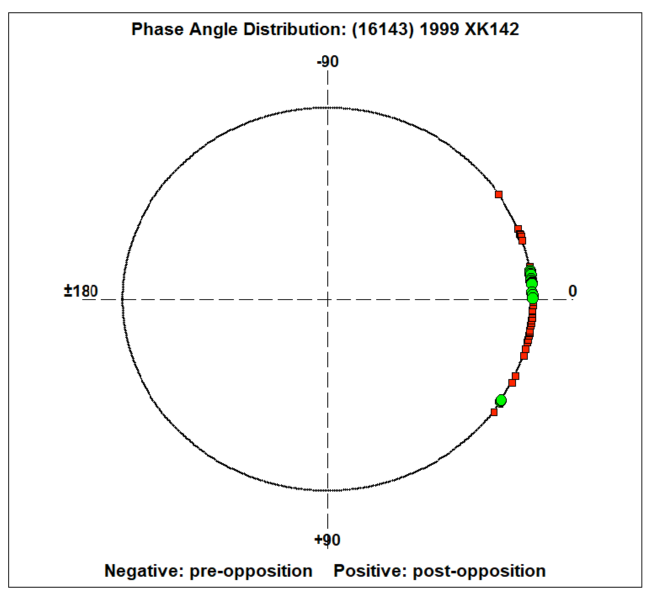
The modeling processing using lightcurve inversion has been detailed previously (e.g., Warner 2017, and references therein). The idea is to find a shape and its orientation such that its modeled lightcurves closely match the original data. Main-belt asteroids usually require data from at least three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

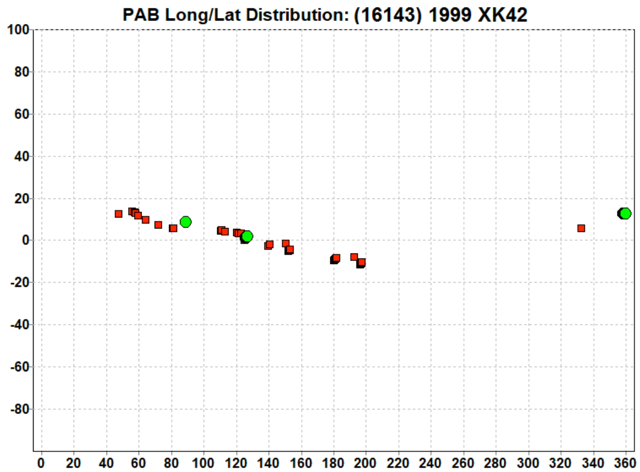
In the PAB longitude plot, green circles represent dense lightcurves while red squares represent sparse data from one or more of the surveys. The green line in the period plot lies 10% above the lowest χ^2 value. This was an ideal solution since it has a well-defined shape with only one data point below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

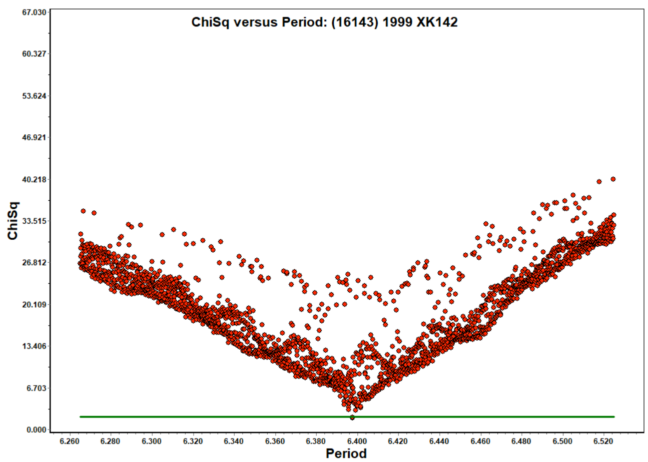
855 Newcombia	Eclipitic Long/Lat	Sidereal Period (hours)
Preferred	(197°, -91°)	6.397446 ± 0.000001
Alternate	(17°, -89°)	

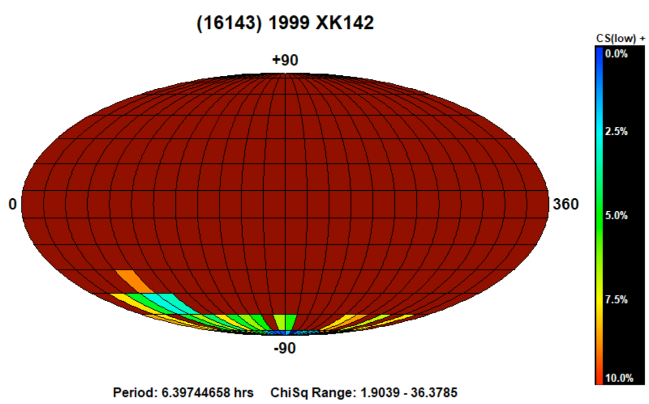
Table II. The two pole solutions for (1643) 1999 XK142. It is common in lightcurve inversion to get two solutions that differ by about 180° in longitude.







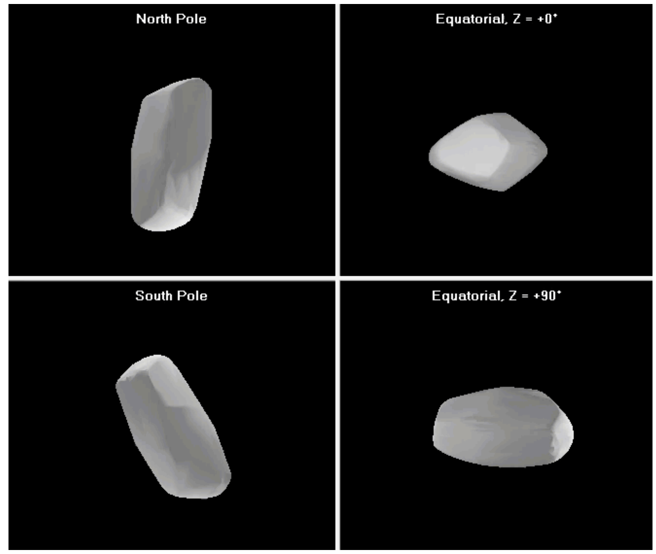


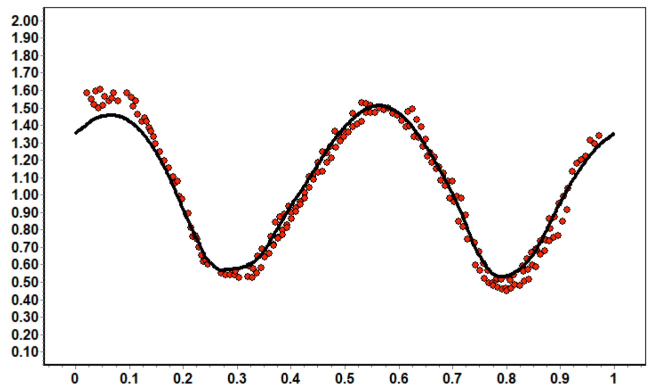


In the pole plot, dark red represents a solution that is more than 10% above the lowest χ^2 value. A "perfect" solution is when there is only one dark blue region and all the others are dark red. The result of our search was (λ, β, P) = (17°, –89°, 6.397446 h), which indicates that the asteroid is in retrograde rotation. The estimated error in the pole position is a circle with radius of 10° and 1-2 units in the last decimal place of the period.

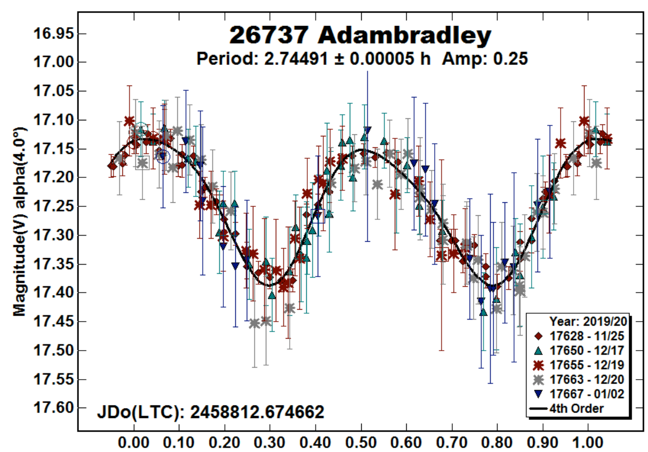
When the spin axis pole is |β| ~ 90°, the longitude becomes almost meaningless since even a small shift in the pole direction can put the longitude 0° ≤ λ < 360°.

To check the quality of the solution, the original data (red dots) are plotted against the model (black line) for a given date. This particular comparison shows that the model is close but needs further refinement, i.e., more data!





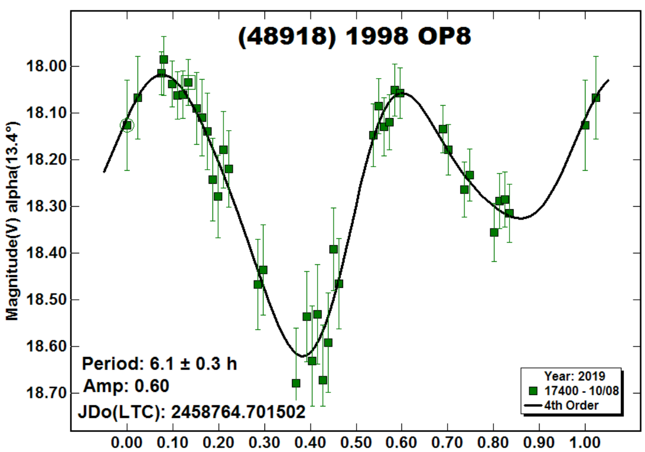
26737 Adambradley, (48918) 1998 OP8. There was no rotation period posted in the LCDB for either of these two presumptive members of the Baptistina family.



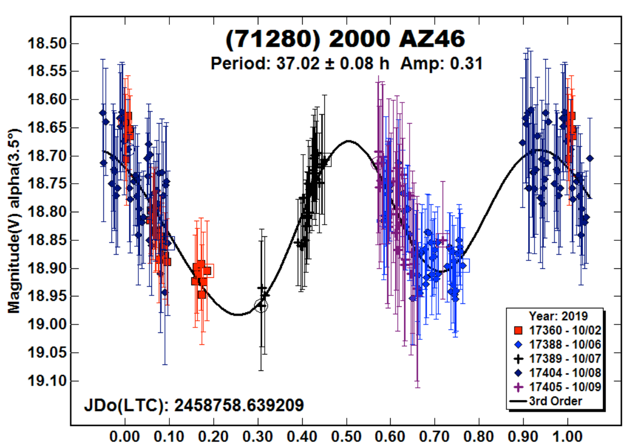
Mainzer et al. (2016) used WISE data to find a diameter and albedo for both asteroids. For 26737, they used H = 14.50 to derive D = 3.643 ± 0.363 km and p_V = 0.211 ± 0.037. The values for 48918 when using H = 14.70 were D = 2.674 ± 0.126 km and p_V = 0.326 ± 0.043. Generally, Baptistina members have an albedo around p_V = 0.057 (Warner et al., 2009), making these two asteroids somewhat on the bright side. Spectroscopic observations or detailed orbital analysis will be needed to confirm Baptistina family membership.

Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
711	Marmulla	11/12-11/15	23.1,23.8	6	3	2.721	0.003	0.06	0.01	FLOR
1152	Pawona	12/10-12/13	19.3,20.0	30	6	3.415	0.001	0.20	0.02	V
1563	Noel	10/09-11/01	*6.8,6.0	28	-4	3.549	0.001	0.16	0.01	FLOR
						15.884	0.005	0.03	0.01	
2716	Tuulikki	09/24-10/14	9.0,17.8	348	6	50.18	0.04	0.12	0.02	V
2783	Chernyshevskij	11/13-11/24	26.1,27.1	352	0	9.49	0.01	0.27	0.03	MB-I
3295	Murakami	11/25-12/13	19.2,24.4	33	-10	3.080	0.001	0.18	0.02	MB-M
3343	Nedzel	11/25-11/26	4.1,4.3	60	10	5.462	0.002	0.87	0.03	MC
3428	Roberts	11/17-11/23	7.3,9.5	36	2	3.278	0.001	0.40	0.02	MB-M
3662	Dezhnev	11/16-11/24	14.4,16.9	26	12	9.070	0.002	0.14	0.01	MB-M
4898	Nishiizumi	10/15-10/19	13.8,15.8	359	1	3.2930	0.0005	0.33	0.02	H
5096	Luzin	12/31-12/31	*13.8,15.8	0	0	3.055	0.001	0.52	0.03	V
6085	Fraethi	11/06-11/08	15.2,14.3	71	-6	5.553	0.001	0.98	0.02	FLOR
6097	Koishikawa	12/16-12/20	22.4,23.5	41	-4	2.859	0.001	0.25	0.02	V
6646	Churanta	10/15-10/23	*15.4,15.4	29	21	5.8712	0.0002	0.77	0.01	H
						16.00	0.01	0.06	0.01	
7043	Godart	12/31-12/31	*15.4,15.4	0	0	8.4524	0.0004	0.74	0.05	FLOR
7345	Happer	11/05-11/10	5.9,2.7	50	-2	10.304	0.004	0.23	0.02	MC
16143	1999 XK142	11/01-11/04	31.6,32.1	359	13	6.397	0.001	1.29	0.01	MC
26737	Adambradley	11/25-01/02	4.0,20.6	58	1	2.74491	0.00005	0.25	0.03	BAP
48918	1998 OP8	12/31-12/31	*31.6,32.1	0	0	6.1	0.3	0.60	0.05	BAP
71280	2000 AZ46	10/02-10/09	*3.5,3.4	13	8	37.02	0.08	0.31	0.04	MB-O
100935	1998 MA42	10/02-10/26	*8.1,13.9	14	8	411	1	0.85	0.10	MC

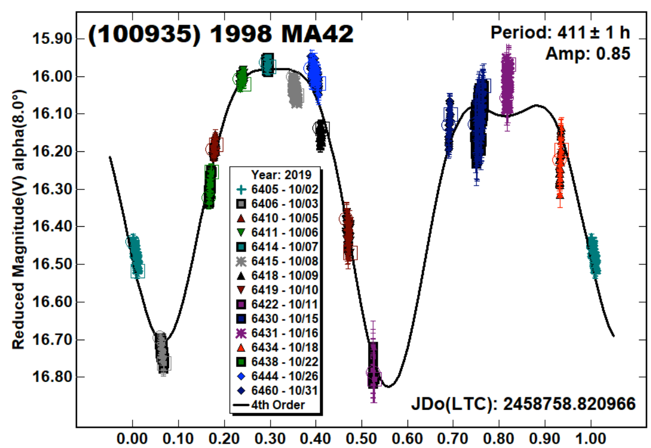
Table III. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al.,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



(71280) 2000 AZ46. There were no previously reported periods in the LCDB for this outer main-belt member to guide the analysis of the 2019 data. Despite the noise in the data, the amplitude of 0.31 mag, the repeating coverage on four nights, and covering a minima and maxima gives some confidence to the solution.



(100935) 1998 MA42. Given the long rotational period, it is not surprising that there are no previously reported lightcurves in the LCDB for this Mars crosser. After nearly a month of observations, there was sufficient double coverage of the lightcurve to have confidence in the primary rotational period, which is longer than the period where tumbling would be more likely than not (Pravec et al., 2005). This seems to be confirmed by several nights showing obvious signs of not matching the Fourier curve.



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.

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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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LIGHTCURVES AND ROTATION PERIODS OF 10 HYGIEA, 47 AGLAJA, 455 BRUCHSALIA, 463 LOLA, AND 576 EMANUELA

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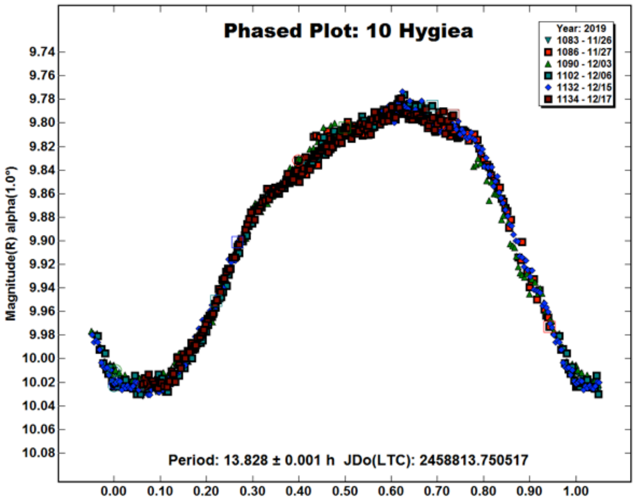
Synodic rotation periods and amplitudes are found for 10 Hygiea 13.828 ± 0.001 h, 0.23 ± 0.01 magnitudes with one maximum and minimum per rotational cycle; 47 Aglaja 13.173 ± 0.001 h, 0.21 ± 0.02 magnitudes; 455 Bruchsalia 11.839 ± 0.001 h, 0.50 ± 0.03 magnitudes; 463 Lola 6.2071 ± 0.0001 h, maximum amplitude 0.50 ± 0.03 magnitudes; 576 Emanuela 20.372 ± 0.001 h, 0.12 ± 0.01 magnitudes.

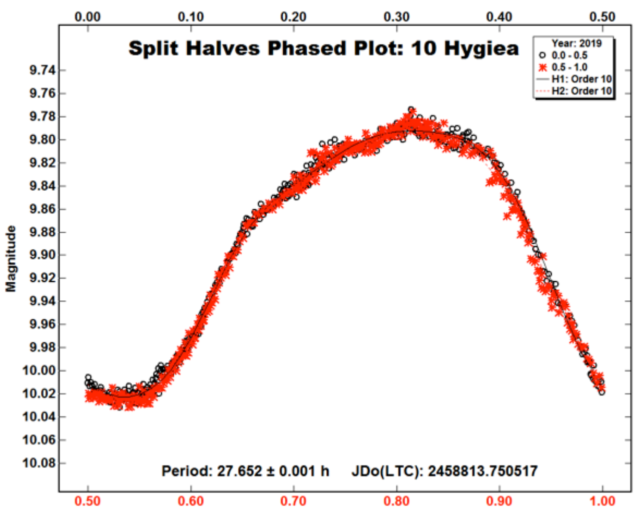
Observations to produce the results reported in this paper were made at the Organ Mesa Observatory with a Meade 35 cm LX200 GPS Schmidt-Cassegrain, SBIG STL-1001E CCD, unguided. For the bright targets 10 Hygiea and 47 Aglaja exposure times were 30 seconds with R filter for 10 Hygiea and clear filter for 47 Aglaja. For all other targets reported here images were obtained with 60 second exposure times, clear filter. To reduce the number of data points on the lightcurves and make them easier to read, data points have been binned in sets of 3 with maximum time difference 5 minutes.

10 Hygiea. The Lightcurve Data Base (Warner et al. 2009, updated 2019 August) lists 8 previously published rotation periods with supporting lightcurves for 10 Hygiea. Five of the periods are near 27.630 hours, with amplitudes between 0.09 and 0.33 magnitudes, based on lightcurves showing the usual two maxima and minima per rotational cycle. This value was considered reliable for many years. Vernazza et al. (2019) obtained disk resolved images of 10 Hygiea in 2017 and 2018 with the SPHERE (Spectro-Polarimetric High contrast Exoplanet Research) instrument on the 8 meter VLT at the European Southern Observatory. These images reveal Hygiea to be very nearly spherical with hemispheric albedo variegation. There is only one maximum and minimum per rotational cycle, and a sidereal period of 13.82559 hours is included in the publication. New photometric observations on 6 nights 2019 Nov. 26 – Dec. 17 provide a good fit to a lightcurve with synodic period 13.828 ± 0.001 hours, amplitude 0.23 magnitudes, with one maximum and minimum per rotational cycle. This is compatible with the period by Vernazza et al. The split halves plot to the double period of 27.652 hours shows that the two halves are almost identical and confirms by a different observational technique the shorter period.

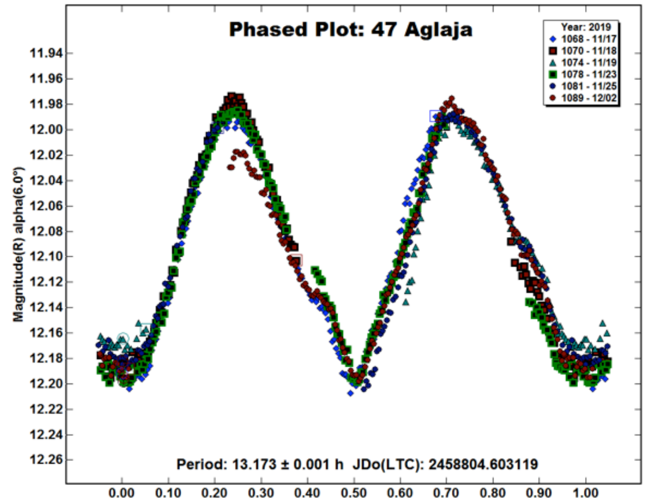
Number	Name	yyyy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
10	Hygiea	2019/11/26-2019/12/17	1.0, 6.9	63	3	13.828	0.001	0.23	0.01
47	Aglaja	2019/11/17-2019/12/02	6.0, 2.3	68	5	13.173	0.001	0.21	0.02
455	Bruchsalia	2019/12/11-2020/01/08	17.2, 14.3	156	12	11.839	0.001	0.50	0.03
463	Lola	2019/10/08-2019/11/24	24.1, 5.3	58	5	6.2071	0.0001	0.50	0.03
576	Emanuela	2019/09/25-2019/11/06	16.5, 5.5	42	13	20.372	0.001	0.12	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, unless a minimum (second value) was reached. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984).

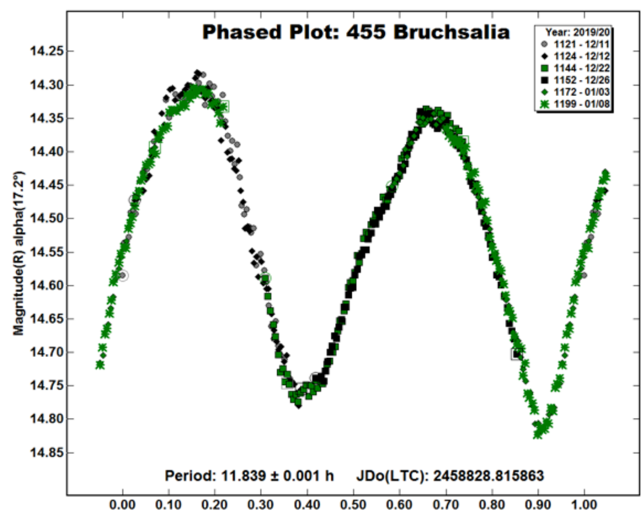




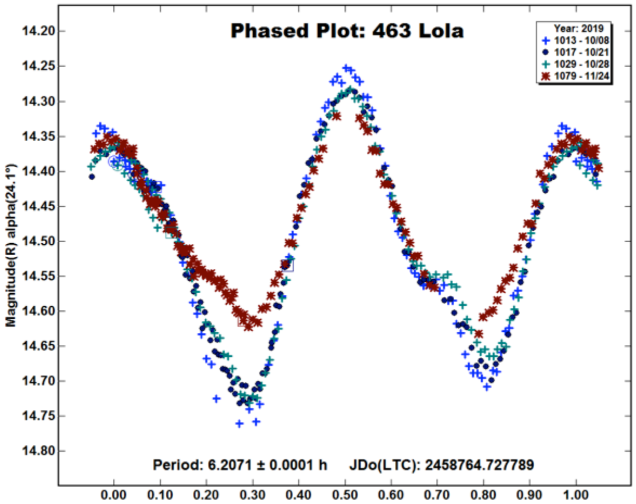
47 Aglaja. The Lightcurve Data Base (Warner et al. 2009, updated 2019 August) lists 8 previously published rotation periods with supporting lightcurves for 47 Aglaja, seven of which are near 13.178 hours. New observations on 6 nights 2019 Nov. 17 – Dec. 2 can be fit to a slightly asymmetric bimodal lightcurve with period 13.173 ± 0.001 h, amplitude 0.21 ± 0.02 magnitudes. The period is consistent with previously published periods.



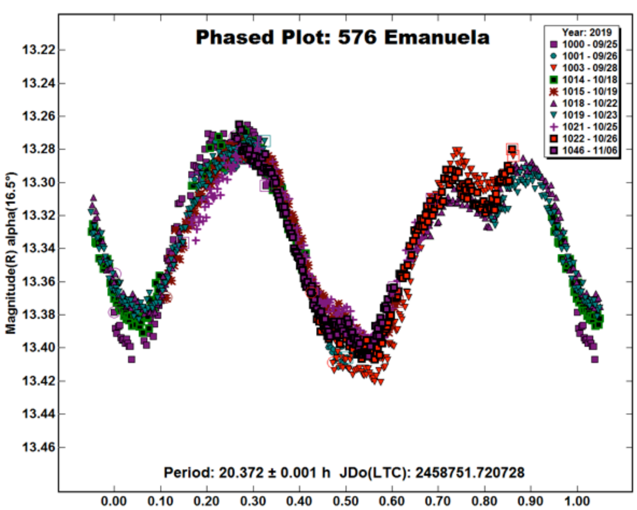
455 Bruchsalia. The Lightcurve Data Base (Warner et al. 2009, updated 2019 August) lists 8 previously published rotation periods, 6 with supporting lightcurves, and seven of which are near 11.85 hours, amplitudes in the range 0.10 - 0.40 magnitudes. New observations on 6 nights 2019 Dec. 11 to 2020 Jan. 8 provide a good fit to a lightcurve with period 11.839 ± 0.001 hours, amplitude 0.50 ± 0.03 magnitudes. The period is consistent with other values and the amplitude is the largest yet found.

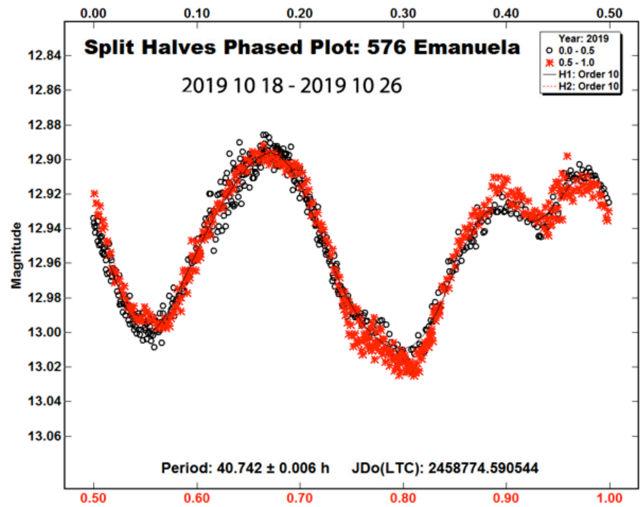


463 Lola. Previously, the only published rotation periods have been three parallel studies made in the interval 2004 Oct. 7 – Nov. 14. near celestial longitude 28 degrees. These are by Bembrick (2005), 6.206 h; Le Crone et al. (2005); 6.20 h; Menke (2005), 6.212 h, all with amplitude near 0.22 magnitude. New observations on 4 nights 2019 Oct. 8 – Nov. 24 near celestial longitude 58 degrees can be fit to a synodic rotation period 6.2071 ± 0.0001 h. The amplitude decreased monotonically from 0.50 ± 0.02 magnitudes Oct. 8 at phase angle 24 degrees to 0.44 ± 0.02 magnitudes Oct. 28 at phase angle 15.5 degrees to 0.30 ± 0.02 magnitudes Nov. 24 at phase angle 5.3 degrees. The period is consistent with the previously published values and the amplitude is considerably greater at a different celestial longitude.



576 Emanuela. Early published periods based on sparse lightcurves include Wetterer et al. (1999), >26 h; Behrend (2003), 14 h; CALL (2011), 8.192 h. The first dense lightcurve was by this author (Pilcher, 2017), who found a good fit to a symmetric bimodal lightcurve with a period of 40.812 hours. The author thanks B. Warner (private communication) for suggesting that the symmetry of the bimodal lightcurve might indicate the period is only half as great with one maximum and minimum per rotational cycle. A reexamination (Pilcher, 2018) showed that the data obtained in 2017 were equally consistent with periods of 40.812 hours and 20.404 hours, the latter based upon a lightcurve with one maximum and minimum per cycle. New data were obtained on 10 nights 2019 Sept. 25 – Nov. 6 with the specific goal of resolving the ambiguity. They provide a good fit to an unsymmetric bimodal lightcurve with period 20.372 ± 0.001 hours and amplitude 0.12 ± 0.01 magnitudes. Sessions obtained on six nights 2019 Oct. 18 – 26 were sufficient to cover the complete double period of 40.742 hours. A split halves plot to the double period over this interval shows that the two halves are almost identical. A rotation period of 20.372 hours may now be considered secure.





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LIGHTCURVE ANALYSIS OF NEAR-EARTH ASTEROIDS IN 2017 FROM BMO AND JBL

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Photometric observations of a selection of Near-Earth Asteroids were done from Blue Mountains Observatory (BMO), JBL Observatory (JBL). The observations were made during the favorable apparition for each asteroid. Most of these objects were selected from The Asteroid Lightcurve Database and the data was collected using multiple instruments across Australia.

CCD photometric observations were made in 2017 from Blue Mountains Observatory (BMO) and remotely at JBL Observatory by Oey.

Table I describes the equipment that was used. Further information of the instruments used at BMO can be found at its website (BMO, 2017).

Obs	Scope	Ap (m)	*f*	Camera	Pixel	Bin	Scale
JBL	J12	0.30	7.4	ST-10XME	7.4	1x1	0.84
JBL	J16	0.45	8.4	STL11000	9.0	2x2	0.80
BMO	B14	0.35	6.0	ST-8XME	9.0	1x1	0.88
BMO	B24	0.61	6.8	U42	13.5	1x1	0.70
BMO	B14E	0.35	11.0	U6	24.0	1X1	1.28

Table I. Equipment specifications. The Scope column gives the code used in Table II. Pixel sizes are in microns. Scale is arcsec/pixel. BMO = Blue Mountains Observatory.

Images taken with all telescopes were unfiltered with exposures ranging from 60 to 180 s to prevent trails due to the fast-apparent motion of NEA during the close approach.

The raw data from BMO (B14) were reduced with a library of flats, darks, and bias frames using *CCDSoft V5*. The raw images from BMO (B24 and B14E) and JBL observatory were processed using *Maxim DL V6* using a respective library of flats, darks and bias frames.

All data measurements and reductions were done using *MPO Canopus V10*. The period analysis used was the Fourier analysis algorithm (FALC) developed by Harris (Harris et al., 1989). The Comp Star Selector utility in *MPO Canopus* found up to five comparison stars of near solar-color for differential photometry. Catalog magnitudes were usually taken from the CMC-15 (*http://svo2.cab.inta-csic.es/vocats/cmc15/)* or APASS (Henden *et al.*, 2009) catalogs. 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 among the catalogs so, whenever possible, the same catalog is used for all observations of a given asteroid.

All future apparitions used the data provided by the JPL small body Database browser (*https://ssd.jpl.nasa.gov/sbdb.cgi#top*).

The favorably observed NEA was selected from The Asteroid Lightcurve Database (Warner, 2009).

The favorability in terms of asteroid apparent brightness and visibility from the Southern Hemisphere used the MP and Comet Ephemeris Service at MPC for its prediction and planning (*https://minorplanetcenter.net/iau/MPEph/MPEph.html*).

Multiple plots were used to illustrate changes in amplitude during the observing campaign when a large variation in the lightcurve shape made it inaccurate to plot the total data in a single lightcurve.

Table II shows the absolute magnitude (*H*), the asteroid family, and the instruments used for each asteroid.

Number	Name	H	Group	Comment
5189	1990 UQ	17.8	Apollo	B24
66146	1998 TU3	14.5	Aten	B14E, J12
65679	1989 UQ	19.5	Aten	B14E, P14, J16
99907	1989 VA	17.9	Aten	B24, J12
310560	2001 QL142	17.8	Apollo	B14, B24
496817	1989 VB	19.9	Apollo	B24
	2015 FO124	21.3	Apollo	B24
138925	2001 AU43	15.9	Amor	B24, J12
	2017 OP68	21.1	Amor	B24, B14

Table II. The H values are from the MPC. The orbital groups are from the LCDB (Warner et al., 2009). MB-I/O: Main-belt Inner/Outer, FLOR: Flora, MC: = Mars-crossing, PHO: Phocaea

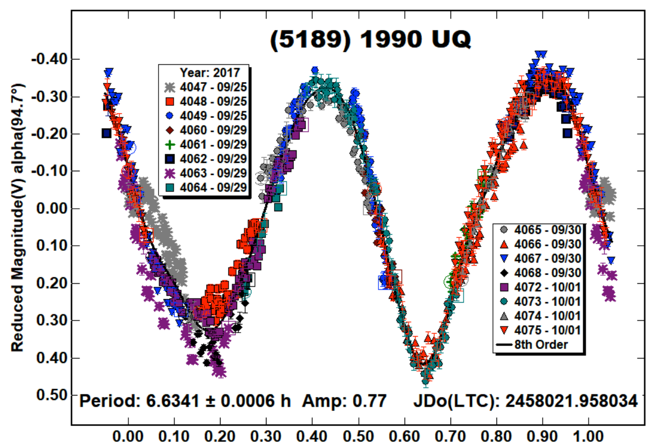


Fig 1. The Primary period of the lightcurve assuming the asteroid to be a possible binary.

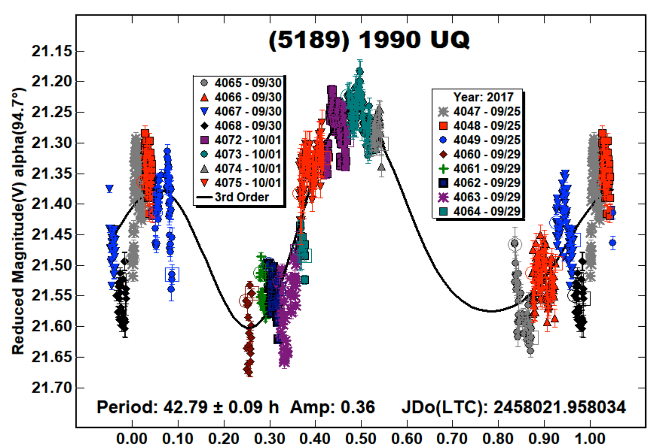


Fig. 2. Secondary lightcurve of the possible binary.

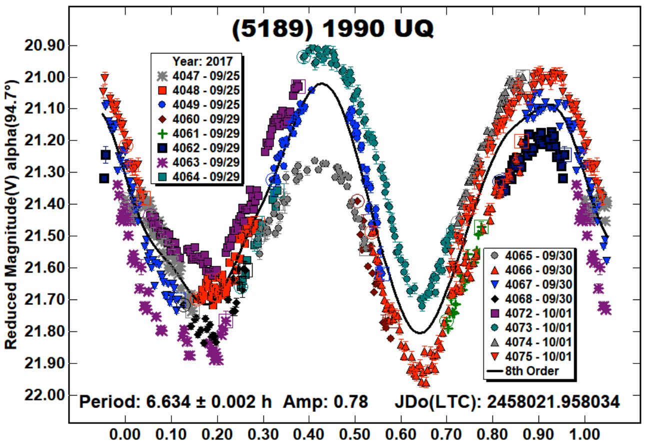


Fig. 3. Original lightcurve without dual period data reduction.

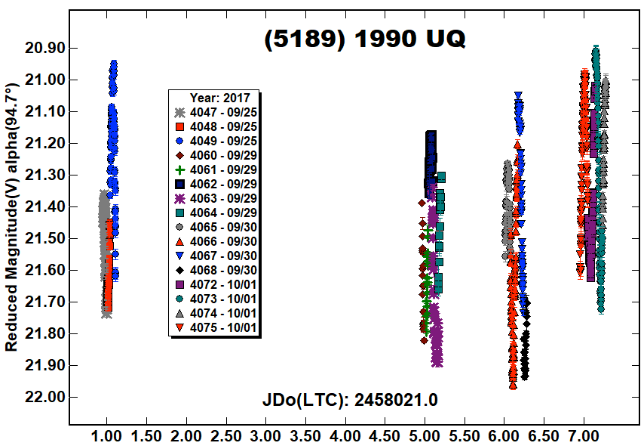


Fig. 4. Raw data of all 4 nights.

<u>(5189) 1990 UQ:</u> This Apollo NEA approached from southern declinations. The large amplitude allowed the accurate period to be determined very quickly. An overlapping lightcurve is obtained from the combination of 4 long nights resulting in a rotation period of 6.634 $\pm$ 0.002 h at U = 3 (Fig 3).

Due to the rapid approach and its occurrence within a few days of opposition, the well-known opposition effect should have caused a rapid brightening of the light curve but instead it was the reverse that occurred (Fig 4). Further investigation using Dual Period Search method in Canopus V10 revealed that the lightcurve consists of a Primary and Secondary period suggesting the presence of a satellite (Fig.1 and Fig 2). It was unclear if eclipse event was also detected. The additive nature of this lightcurve was apparent but it was prudent to be careful in the interpretation from a small quantity of data.

Most primaries of Near-Earth Asynchronous binaries were small, spheroidal and concentrating just below the strengthless rubble pile rotation limit of 2.2 h suggesting a rotational fission formation as described in Pravec et al. (2006). Despite the large solar Phase Angle during the encounter, we can safely assume that the primary was a significantly elongated object and it did not fit into this rotational fission model. Should 5189 1990 UQ be a binary, another possible model was one that formed from the disruptive encounters with major planets (Merline, 2002).

The observations were obtained past the close approach date on Sept 26. The next favorable apparition will be in May 2021. A search on the database show observation was done by Warner (2018b) showing a synodic rotation period of 6.676 $\pm$ 0.007 h with an amplitude of 1.02 mag.

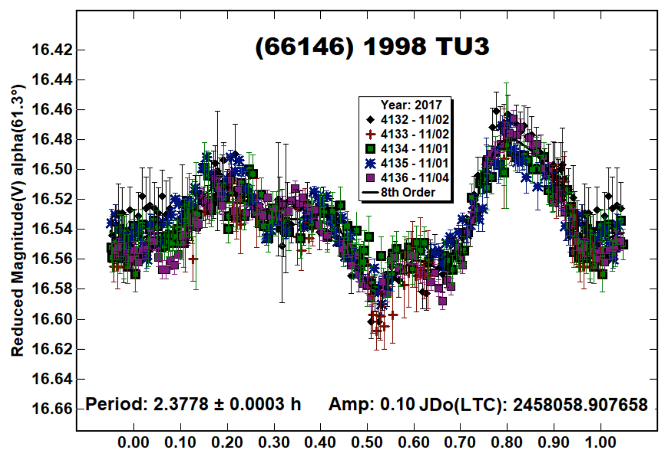


Fig 5. Plot during the month October 2017

Number	Name	2017/ mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
5189	1990 UQ	09/25-10/01	803	69,57	342	-28	6.6425^{P}	0.0009	0.77	0.02
5189	1990 UQ	09/25-10/01	803	69,57	342	-28	42.79^{S}	0.09	0.36	0.05
66146	1998 TU3	10/02-10/07	582	43,40	77	-18	2.3774	0.0003	0.08	0.02
66146	1998 TU3	11/01-11/04	511	60,66	16	-26	2.3778	0.0003	0.10	0.02
65679	1989 UQ	10/12-10/13	94	4,3	21	-2	7.75	0.02	0.36	0.02
99907	1989 VA	11/08-11/29	244	20,16,42	50	-12	2.5231	0.0002	0.24	0.02
138925	2001 AU43	08/14-09/02	199	48,39	295	-28	5.2561	0.0004	0.50	0.02
310560	2001 QL142	09/24-09/25	210	64,60	337	-30	5.97	0.01	0.11	0.02
310560	2001 QL142	09/28-10/01	575	57,54	341	-29	5.970	0.003	0.25	0.02
496817	1989 VB	08/13-09/22	853	33,78	328	-28	14.533	0.002	1.21	0.05
	2015 FO124	08/17-08/23	402	14,25	319	-8	7.8235	0.0008	1.16	0.03
	2017 OP68	09/02-09/21	485	68,12,23	345	-22	3.399	0.002	0.14	0.04

Table III. Observing circumstances and results. Pts is the number of data points. The phase angle is given for the first and last date. If there are three values, the middle value is for the minimum during the range. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris *et al.*, 1984). ^{P} and ^{S} represent Primary and Secondary rotational period of the possible binary.

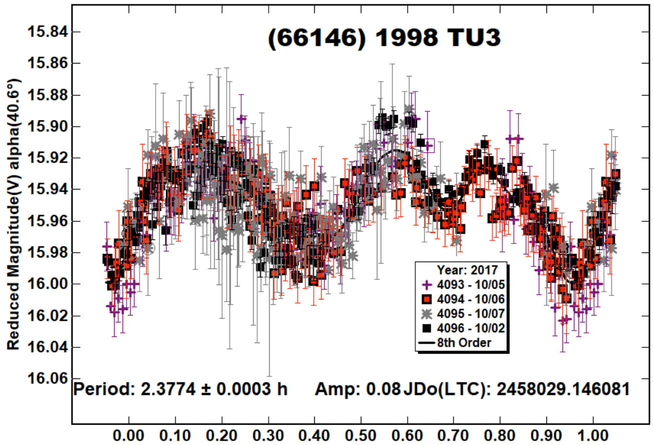
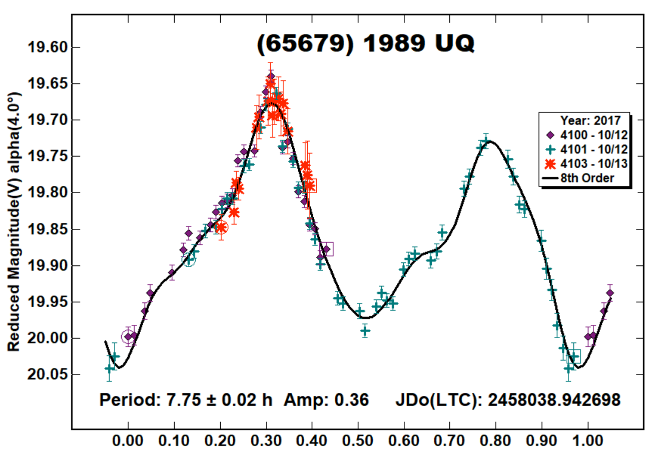


Fig 6. Plot during the month November 2017

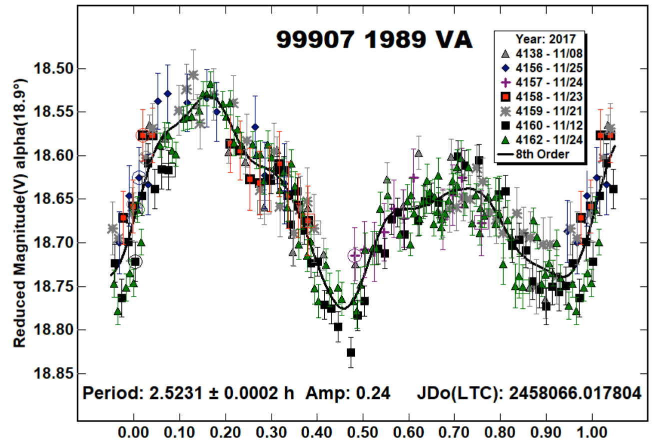
(66146) 1998 TU3: An Aten asteroid favorably placed for observation from the southern hemisphere during the month of October (Fig. 5) and November 2017 (Fig. 6). The close approach date is Oct 31.

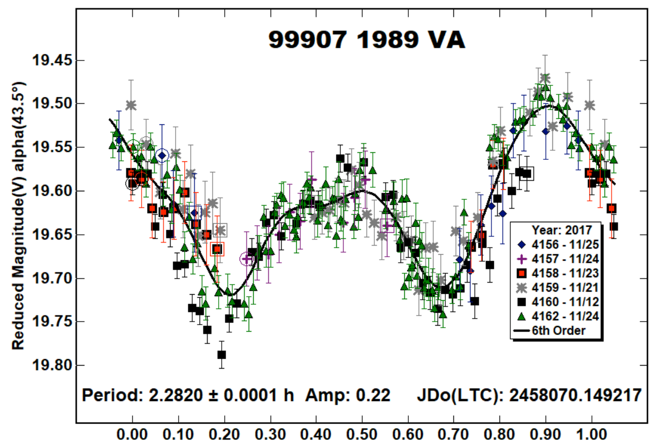
The large PA shift from 61 to 40 deg only showed a small amplitude change in the light curve despite the large change in PAB (Harris et al., 1984)

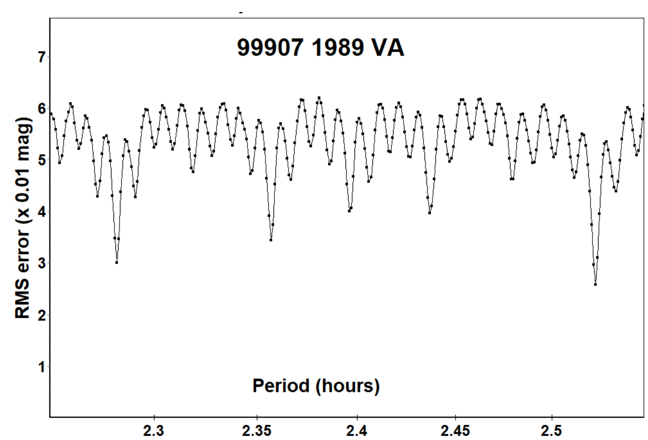
Previous work was done by many authors in the past but most notably was work performed by Warner (2018a) who suggested the presence of a binary signature in September, nearly 2 months prior to the close approach and after careful analysis using dual period methods in *Canopus V10*, there were no signs of binary events captured at BMO.



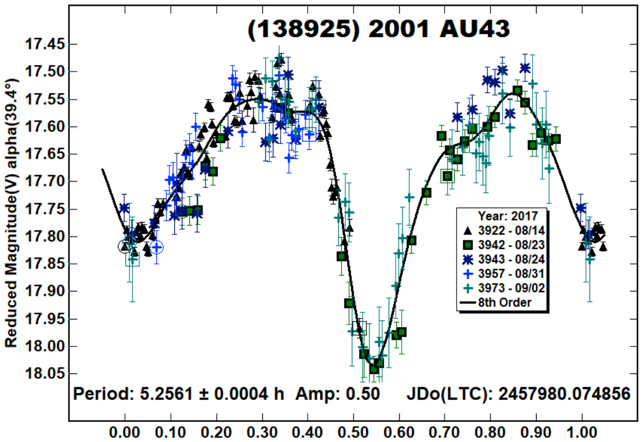
(65679) 1989 UQ: A Potentially Hazardous Asteroid (PHA), 1898 UQ was observed prior to the closest approach on the Oct 16. The observation was made during this apparition when the object was approaching from the deep southern celestial hemisphere before the observing circumstances negatively impacting the data collected. These data are to supplement a more complete data set obtained by Pravec (2017). The next favorable apparition will be in Oct 2024 ideally observed from both hemispheres.



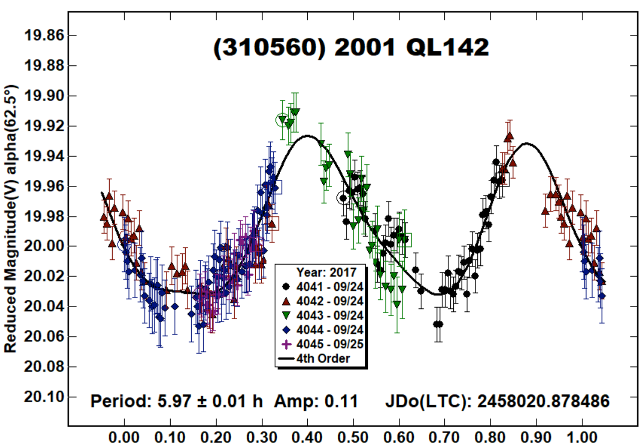


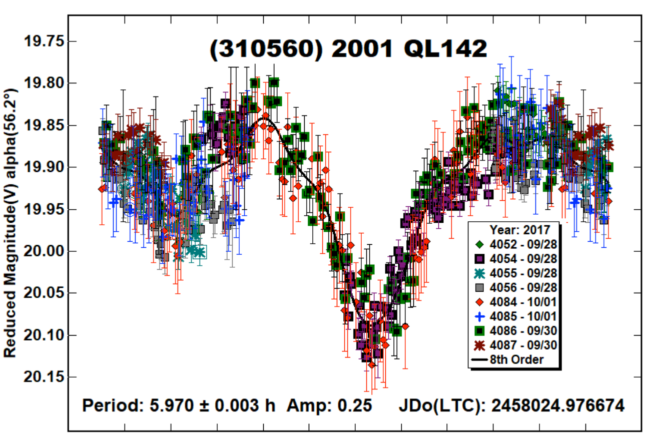


(99907) 1989 VA: An Aten asteroid previously observed by Pravec (1997) with the rotation period is consistent with this study. However, there was a probability of a shorter period of 2.2820 ± 0.0001 h, as shown in the period spectrum. A longer observing session that covers a double period of more than 5 hours would resolve this (Pravec, 2017a). Unfortunately, with fast moving NEA close to Summer in the Southern hemisphere, such observing window opportunity was quite rare. Most of the observations were done past close approach on Nov 12. The next better apparition where V= 16.1 mag will be in Nov 2022 and it will also be a southern target.

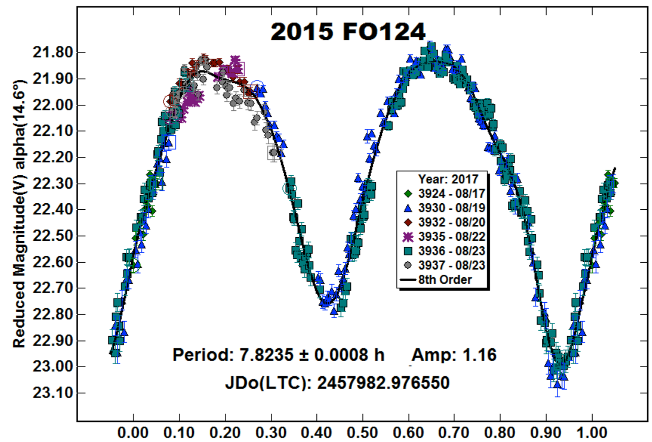


(138925) 2001 AU43: This Amor was observed past the close approach on Aug 1 due to its southerly observing opportunity for our southern hemisphere location. The object receded rapidly but the data obtained was more than double coverage providing unique bimodal light curve of U=3 quality. The next opportunity to observe it will not be until 2030. The previous paper published was by Mollica (2018) during the approach that provided a period of 5.251 ± 0.001 h using high quality data but did not obtain a double coverage. The final period is likely to be somewhere in between since combining the data is not going to improve the solution due to the large amplitude variation during the fly-by.

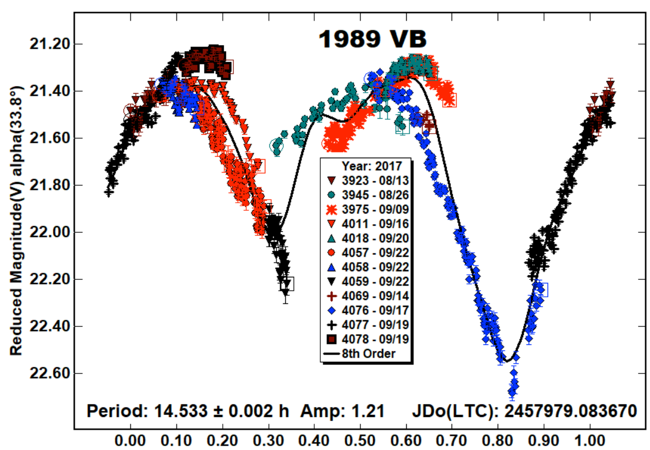




(310560) 2001 QL142: There has been no lightcurve observation done on this Apollo (PHA) asteroid previously. The data was obtained after the close approach on Sept 14. The lightcurve plot for the Sept 28 to Oct 1 data is unique with more than double coverage to get a U = 3 quality. Two plots are presented to illustrate the dramatic change in amplitude and shape of the lightcurve at different phase angles as it moves away from the Earth (Zappala et al., 1990). The next favorable close approach will not be until 2031.

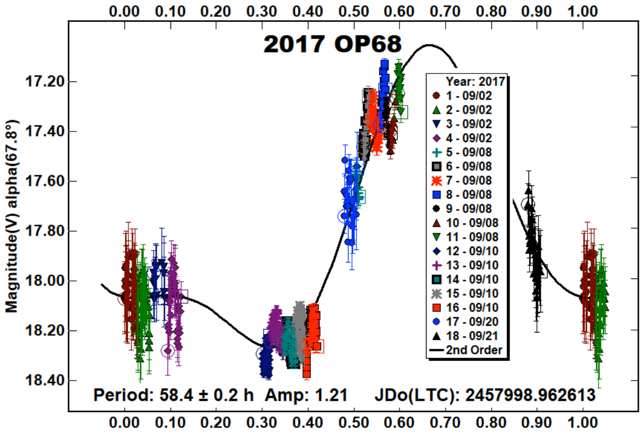


2015 FO124: The observations were obtained prior to the closest approach on Sept 9 of this Apollo asteroid. The opportunity to observe it again will not be until 2031. Previous study done by Monteiro (2018) indicated that the lightcurve period at the same apparition between Aug 18 - Aug 22 was 5.997 ± 0.002 h based on a partial light curve. A more accurate double coverage was obtained here to get a U = 3 lightcurve with a period of 7.8235 ± 0.0008 h and an amplitude of 1.16 mag.



(496817) 1989 VB: An Apollo (PHA) asteroid was observed before its close approach on Sept 29. Despite the limited data, this is an improvement from the U=2- result obtained in a single-night data in 1989-11-19 by Wisniewski et al. (1997) where the rotation period of about 16 h was quoted. There have been no other observations done since. The favorable return apparition will not be until Oct 2050 where V=16 mag.

The plot shows a non-unique bimodal lightcurve with characteristic tumbling feature in the light curve as described in Pravec (2005) or it could also be due to the large shift in solar phase (PA) and viewing aspect during the observing period. (Pravec, 2017a).



2017 OP68: A small Amor was observed during its closest approach on Sept 10. Multiple sessions were required to stitch up the lightcurve. The challenge with small object and fast apparent motion is the ability for the telescope system to track it in one single night while trying to keep the zero point as accurate as possible with complete different sets of comparison stars required for each session.

Studies done by Warner (2018b) of the same apparition show a period of 51.70 h and amplitude of 0.57 mag at Phase Angle (PA) of 13 deg. The study conducted was also incomplete, but the closest period found was 58.4 $\pm$ 0.2 h and a much larger amplitude of 1.21 mag that was consistent with a light curve at a larger PA of 67 deg. The correct rotational period was likely to be somewhere in between. Unfortunately, there will be no favourable apparition in the near future and combining both data will not improve the value due to the large amplitude discrepancy between the pre and post close approach.

Acknowledgements

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ROTATION PERIOD DETERMINATION FOR ASTEROID 8323 KRIMIGIS

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Photometric observations of main-belt asteroid 8323 Krimigis were made at the Filzi School Observatory (Laives - Italy). Results of lightcurve analysis are presented.

CCD photometric observations of 8323 Krimigis asteroid were made at the Filzi School Observatory (MPC code D12) over six nights in 2019 December. We used a 0.35-m reflector telescope reduced to *f*/8.0, a QHY9 CCD camera. The pixel scale was 1.56 arcsec when binned at 4x4 pixels. The computer clock was synchronized with an Internet time server before each session. All images were taken with an R filter and had an exposure time of 120 s.

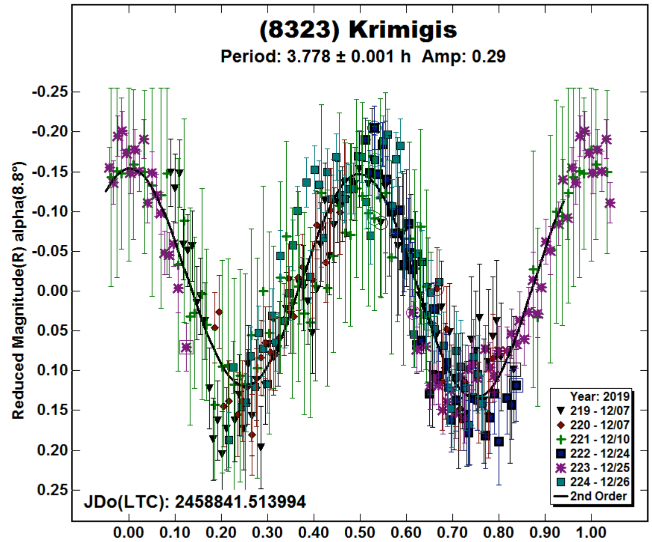
After being calibrated with dark and flat-field frames, the images were measured using *MPO Canopus* v10.7.12.9 (Warner, 2018) using aperture differential photometry. Solar-colored stars from CMC15 catalog in R band were used as the comparison stars. After the measurements, M*PO Canopus* was used for period analysis using the FALC algorithm developed by Harris (Harris et al., 1989).

8323 Krimigis. This main-belt asteroid was reported as a lightcurve photometry opportunity for 2019 December on the MinorPlanet.Info web site (MPI, 2019).

The asteroid was discovered on 1979 Oct 17 by E. Bowell at the Anderson Mesa Station of the Lowell Observatory. It is named in honor of Stamatios M. (Tom) Krimigis (b. 1938), head of the Space Department of the Applied Physics Laboratory of Johns Hopkins University and a specialist in solar, interplanetary and magnetospheric physics.

It is a middle main-belt asteroid with a semi-major axis of 2.69 au, eccentricity 0.297, inclination 9.79 deg, and orbital period of 4.43 yr. Its absolute magnitude is $H = 13.30$.

We did not find previous period data in the asteroid lightcurve database (LCDB; Warner et al., 2009). Our analysis found a synodic period of $P = 3.778 \pm 0.001$ h and lightcurve amplitude of $A = 0.29 \pm 0.10$ mag.



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Number	Name	2019/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
8323	Krimigis	12/07-12/26	8.7,12.2	77	79	3.778	0.001	0.29	0.10	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).

2000 HERSCHEL
A TUMBLING ASTEROID

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Minor planet 2000 Herschel is tumbling with a principal period of 133.6 h. A secondary period of 344 h is suggested, although other secondary periods are possible. The maximum amplitude is 1.1 magnitudes.

Several previously published rotation periods of 2000 Herschel are incompatible with each other. Warner (2009) published a period of 64 hours, amplitude 0.4 magnitudes, based on 9 sessions 2008 Dec. 11 to 2009 Jan. 13. Warner (2011) reexamined these data with comparison star magnitudes calibrated to the Johnson R system and found a period 130 hours with maximum amplitude 1.16 magnitudes and strong evidence of tumbling. Durkee (2011) obtained a period of 32 hours. Behrend (2019), from many sessions 2019 July 30 to Oct. 26, published an Earth commensurate period of 95.82 hours, amplitude 0.5 magnitudes, based on a slightly irregular bimodal lightcurve with gaps corresponding to longitudes from which no observations were obtained.

The six authors collaborated to obtain a much more comprehensive series of observations than in any of the previous studies. The equipment and the number of sessions by each author are reported on Table II.

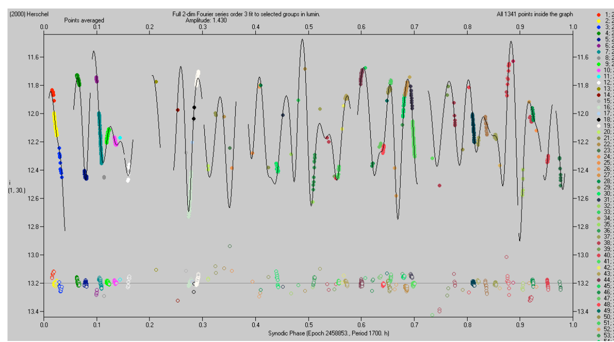
Calibration stars for all sessions are solar colored stars whose g´, r´, and i´ magnitudes were obtained from the APASS catalog on the VizieR web site. For each star the Rc magnitude was computed from the Munari relation (Munari, 2012).

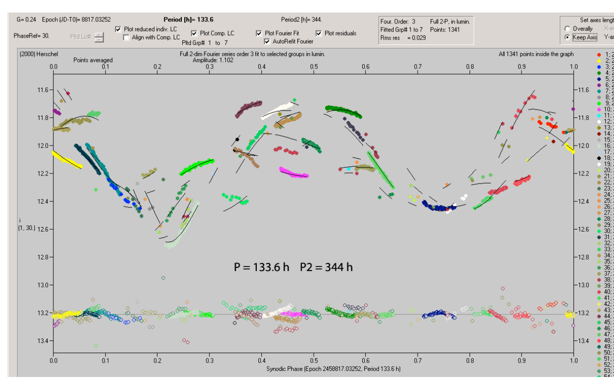
$$Rc = r' - (0.065*(g'-i')) - 0.174$$

In the APASS catalog, the magnitude consistency over the whole sky is consistent within a few x 0.01 magnitudes. For single period lightcurves that repeat from one cycle to the next, adjustment of the instrumental magnitudes by a few x 0.01 compensates for the inconsistency and improves the fit between sessions. For tumbling asteroids, the shape of the lightcurve changes from one cycle to the next and adjustment to best fit is not feasible. In this study all data points are plotted as calibrated with no adjustments.

The dual period algorithm procedure in *MPO Canopus* software is to find first one period and then the other. This is effective for satellite events in which rotation and revolution terms are independent. With tumbling, terms involving sums, differences, and integer multiples of sums and differences of two periods also contribute to the lightcurve and cannot be handled by *MPO Canopus* software.

Petr Pravec (personal communication) used simultaneous dual-period software to search for tumbling parameters. A principal period of 133.6 hours was found. Tumbling was confirmed, with a second period 344 hours one of multiple possible solutions. The procedure is described by Pravec et al. (2005). In this paper we include both the lightcurve phased to 133.6 hours and a raw lightcurve produced by the simultaneous dual period procedure. These plots show both the individual data points and the sum of the several Fourier terms that provide a best fit. The data points at the foot of both lightcurves plot the residuals between data and best fit Fourier terms.





Acknowledgments

The authors thank Petr Pravec for analyzing the data with simultaneous dual period software and producing the lightcurves that are included in this paper.

Number	Name	2019-20/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
2000	Herschel	10/26-01/02	25.2,33.9	37	30	133.6 344	0.5 5	1.10	0.05

Table I. Observing circumstances and results. The first line is the primary period; the second line is secondary period of tumbling. 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).

Observer Observatory (MPC code)	Telescope	CCD	Filter	Sessions
Pilcher Organ Mesa Observatory (G50)	0.35-m SCT *f*/10.0	SBIG STL-1001E	C	17
Franco Balzaretto Observatory (A81)	0.20-m SCT *f*/5.0	SBIG ST7-XME	C	3
Marchini Siena Observatory (K54)	0.30-m MCT *f*/5.6	SBIG STL-6303e (bin 2x2)	Rc	7
Papini Wild Boar Remote Observatory (K49)	0.23 cm SCT *f*/10.0	SBIG ST8-XME	Rc	4
Gao and Tan Ningbo Bureau of Education and Xinjiang Observatory Telescope (NEXT), Urumqi, Xinjiang, PRC	0.60-m RCT *f*/8.0	Scientific CCD230-42 Back Illuminated	C	43

Table II. Observing equipment and sessions. MCT: Maksutov-Cassegrain, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain. All sessions, except those from Gao and Tan, were dense data sets.

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COLLABORATIVE ASTEROID PHOTOMETRY FROM UAI: 2019 OCTOBER-DECEMBER

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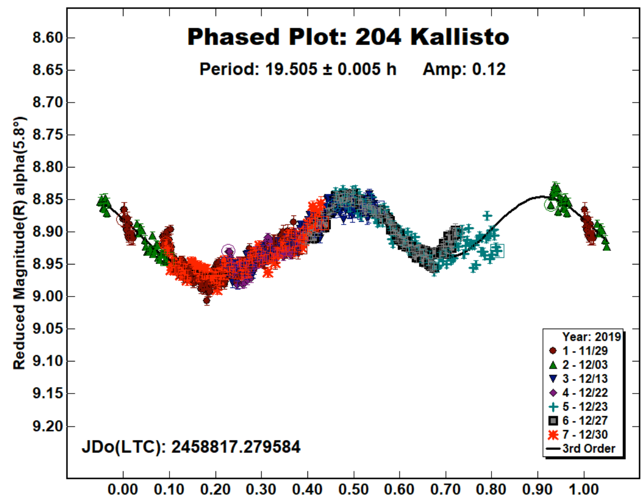
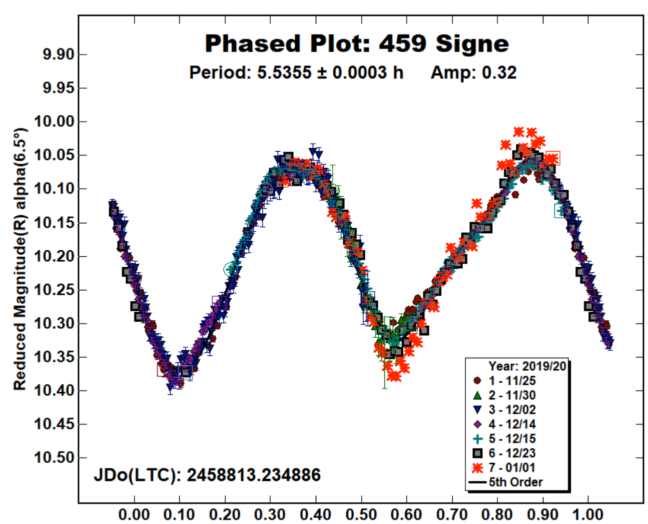
Photometric observations of seven asteroids, six main-belt and one near-Earth, were made in order to acquire lightcurves for shape/spin axis models. The synodic period and lightcurve amplitude were found for: 204 Kallisto: 19.505 ± 0.005 h, 0.12 mag; 459 Signe: 5.3555 ± 0.0003 h, 0.32 mag; 563 Suleika: 5.6656 ± 0.0004 h, 0.13 mag; 773 Irmintraud: 6.7484 ± 0.0008 h, 0.05 mag; 1060 Magnolia: 2.9102 ± 0.0006 h, 0.11 mag; 3533 Toyota: 2.9816 ± 0.0004 h, 0.15 mag; (162082) 1998 HL1: 11.60 ± 0.01 h, 0.21 mag.

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 October through early 2020 January using the instrumentation described in the 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 distributed with *MPO Canopus*. Table II shows the observing circumstances and results.

204 Kallisto is an S-type middle main-belt asteroid discovered on 1879 October 8 by J. Palisa at Pola. Observations were made over seven nights by G. Scarfi. We found a synodic period of P = 19.505 ± 0.005 h and amplitude A = 0.12 ± 0.03 mag. The period is close to the result published by Pilcher (2010).



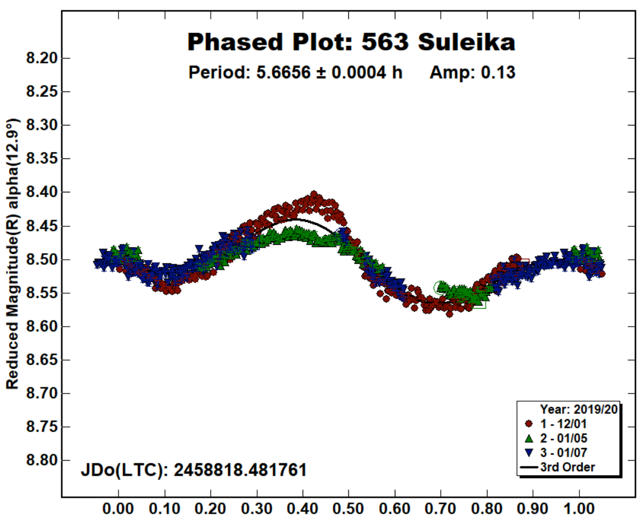
459 Signe is an S-type middle main-belt asteroid discovered on 1900 October 22 by M. Wolf at Heidelberg. Collaborative observations were made over seven nights. We found a synodic period of P = 5.3555 ± 0.0003 h and amplitude A = 0.32 ± 0.03 mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



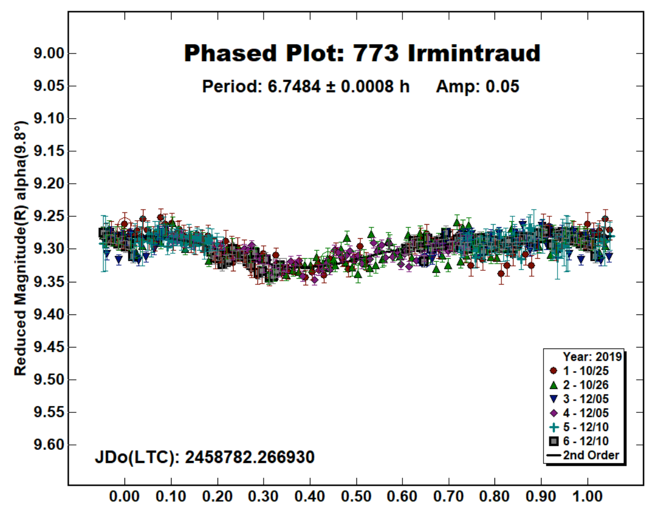
Observatory (MPC code)	Telescope	CCD	Filter	Observed Asteroids
Balzaretto Observatory (A81)	0.20-m SCT *f/5.0*	SBIG ST8-XME	C	563
Siena University (K54)	0.30-m MCT *f/5.6*	SBIG STL-6303e(bin 2x2)	Rc, C	459, 563, 1060, 3533, 162082
Iota Scorpii(K78)	0.40-m RCT *f/8.0*	SBIG STXL-6303e(bin 2x2)	Rc	204, 773, 3533
GAMP(104)	0.60-m NRT *f/4.0*	Apogee Alta	C	773, 162082
El Sauce Observatory (X02)	0.60-m CDK *f/6.5*	FLI PL 9000 (bin 2x2)	C	162082
GiaGa Observatory (203)	0.36-m SCT *f/5.8*	Moravian G2-3200	Rc	459
Filzi School Observatory (D12)	0.35-m RCT *f/8.0*	QHY9 (KAF8300)	Rc	459
M57 (K38)	0.30-m RCT *f/5.5*	SBIG STT-1603	C	773
WBRO (K49)	0.235-m SCT *f/10*	SBIG ST8-XME	Rc	773
G.Pascoli (K63)	0.40-m NRT *f/3.2*	QHY22 C 1318	C	162082
GAV	0.20-m SCT *f/6.3*	SXV-H9	Rc	459
Hypatia Observatory	0.25-m NRT *f/4.9*	SBIG ST8-XE	C	563
Cherryvalley Observatory (I83)	0.20-m SCT *f/7.1*	SBIG STL-1301	Rc	162082

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

563 Suleika is a type Sl (Bus & Binzel, 2002) outer main-belt asteroid discovered on 1905 April 6 by P. Gotz, at Heidelberg. Collaborative observations were made over three nights. We found a synodic period of $P = 5.6656 \pm 0.0004$ h and amplitude $A = 0.13 \pm 0.04$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



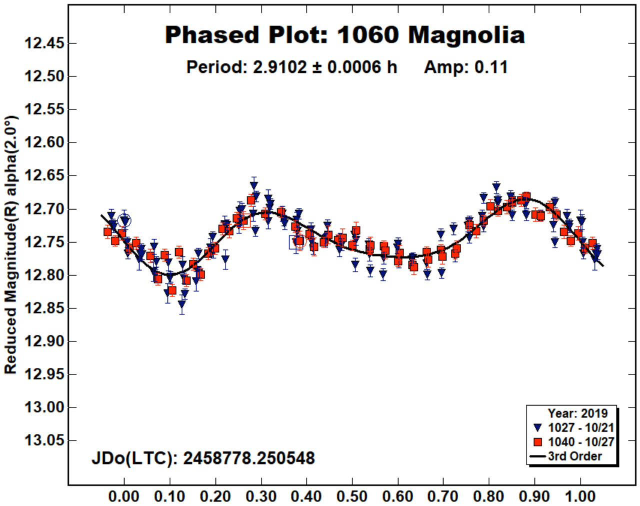
773 Irmintraud is a T-type (Bus & Binzel, 2002) outer main-belt asteroid discovered on 1913 December 22 by F. Kaiser at Heidelberg. Collaborative observations were made over four nights. We found a synodic period of $P = 6.7484 \pm 0.0008$ h and low amplitude $A = 0.05 \pm 0.02$ mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



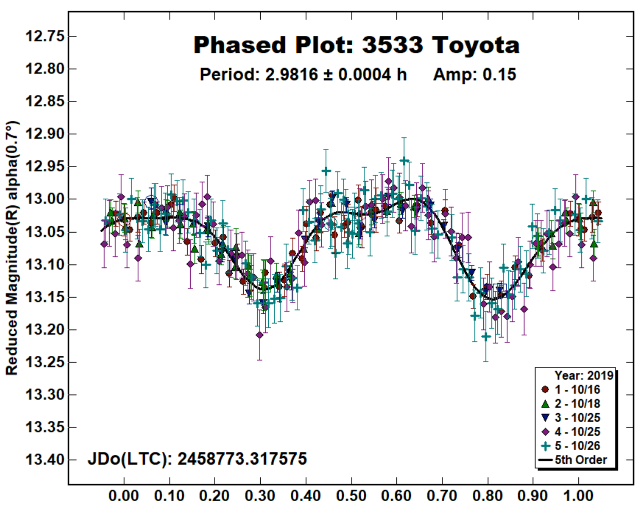
Number	Name	20yy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
204	Kallisto	19/11/29-19/12/30	5.5,14.5	52	-5	19.505	0.005	0.12	0.03	MB-M
459	Signe	19/11/25-20/01/01	6.7,16.7	70	10	5.3555	0.0003	0.32	0.03	MB-M
563	Suleika	19/12/01-20/01/07	*12.9,7.9	92	1	5.6656	0.0004	0.13	0.04	MB-O
773	Irmintraud	19/10/25-19/12/10	*10.0,12.9	47	21	6.7484	0.0008	0.05	0.02	MB-O
1060	Magnolia	19/10/21-19/10/27	*2.5,1.6	31	2	2.9102	0.0006	0.11	0.03	FLOR
3533	Toyota	19/10/16-19/10/26	*1.1,5.1	24	-1	2.9816	0.0004	0.15	0.03	FLOR
162082	1998 HL1	19/10/25-19/11/08	*14.5,44.8	36	-16	11.60	0.02	0.21	0.07	NEA

Table II. 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).

1060 Magnolia is a medium albedo member of the Flora family. It was discovered on 1925 August 13 by K. Reinmuth at Heidelberg. Observations by A. Marchini were made over two nights at DSFTA (2019). We found a synodic period of P = 2.9102 ± 0.0006 h and amplitude A = 0.11 ± 0.03 mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).

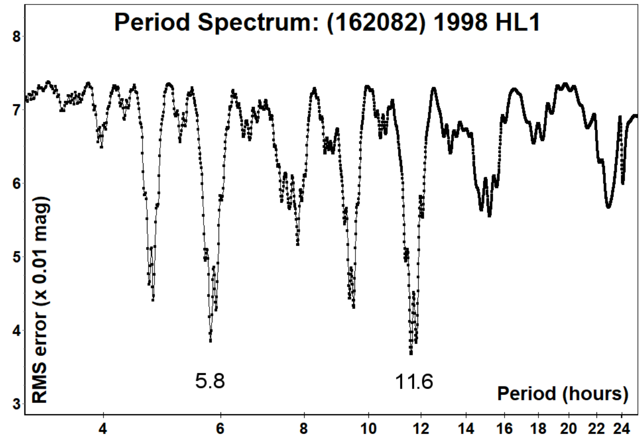


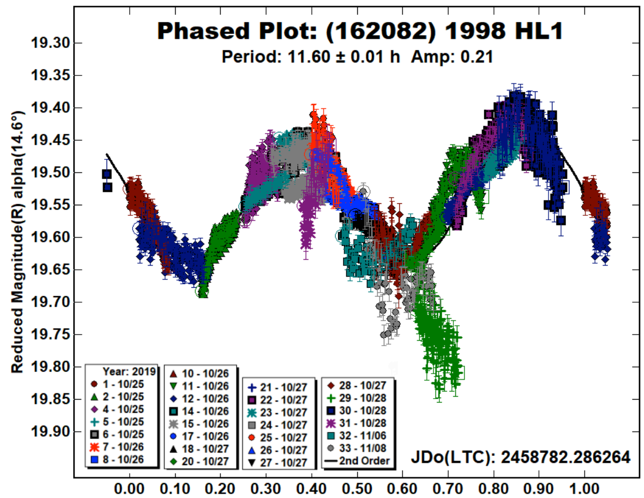
3533 Toyota is an Xk-type (Bus & Binzel, 2002) member of the Flora family. It was discovered on 1986 October 30 by K. Suzuki and T. Urata at Toyota. Collaborative observations were made over four nights. We found a synodic period of P = 2.9816 ± 0.0004 h and amplitude A = 0.15 ± 0.03 mag. The period is close to the previously published results in the asteroid lightcurve database (LCDB; Warner et al., 2009).



(162082) 1998 HL1 is an Amor near-Earth asteroid, classified as PHA that was discovered on 1998 April 18 by LINEAR at Socorro. Collaborative observations were made over six nights, starting with close approach to the Earth on 2019 October 25. The period spectrum shows several solutions between 4 and 12 hours with almost the same strength. The prominent solutions are monomodal, near 5.8 hours, and bimodal, near 11.6 hours.

We prefer that longer period solution, P = 11.60 ± 0.01 h and amplitude A = 0.21 ± 0.07 mag. This is significantly different from the solution published by Carreño et al. (2020; 3.024 ± 0.003 h) and it is close to the solution found by Warner & Stephens (2020; 11.778 ± 0.007 h). The lightcurve shows amplitude variations due to the large variations in the viewing geometry during the asteroid's close approach to Earth.





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LIGHTCURVES OF SEVEN MAIN-BELT ASTEROIDS

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CCD photometric observations of seven main-belt asteroids were made from 2019 October-December. We report on the results of lightcurve analysis for 2634 James Bradley, 3171 Wangshoguang, 3662 Dezhnev, 3819 Robinson, 4686 Maisica, (7397) 1986 QS, and (51149) 2000 HF52.

During the period ranging from 2019 October-December. Bigmuskie Observatory and Osservatorio Astronomico BSA, worked together to study the rotational periods of seven main-belt asteroids chosen from the CALL website (*http://minorplanet.info /call.html*). The first two months proved to be very difficult because of an unusually prolonged period of bad weather that interrupted observations almost completely until the end of November. This was particularly true for (7397) 1986 QS and 3662 Dezhnev, whose observations cover a large time spam and some observing sessions separated by many days.

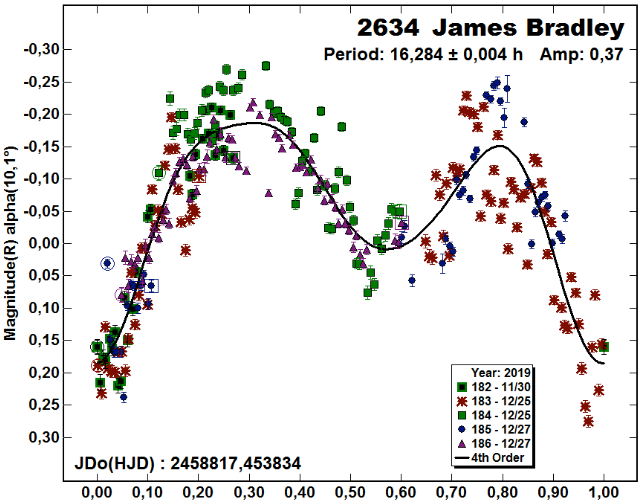
Observations at Bigmuskie Observatory were made with a Marcon 0.30-m *f*/8 Ritchey-Chretién coupled with a Moravian G3 01000 CCD camera that used a KAF-1001E chip (1024x1024, 24-microns) with a resulting field-of-view of 36x36 arcmin and pixel scale of 2 arcsec/pixel. At Osservatorio Astronomico BSA, observations were made with a Marcon 0.30-m *f*/5 Newtonian telescope with an Atik 314L+ CCD camera using a Sony ICX285AL sensor (1360x1024, 6.5-microns). Both observatories used *MaximDL* (*http://diffractionlimited.com/product/maxim-dl/*) for camera control, *The Sky 6 Pro* (*http://www.bisque,com*) for mount control, and *Voyager* (*http://software.starkeeper.it*) to automate the entire observatory.

All photometric reductions were done with *MPO Canopus* v10.7.12.9 (*http://bdwpublishing.com*). Precise night-to-night zero-point calibration was obtained using the Comparison Star Selector utility in *MPO Canopus*. Whenever possible, both observatories used five solar-colored comparison stars from the MPOSC3 catalog supplied with *MPO Canopus*.

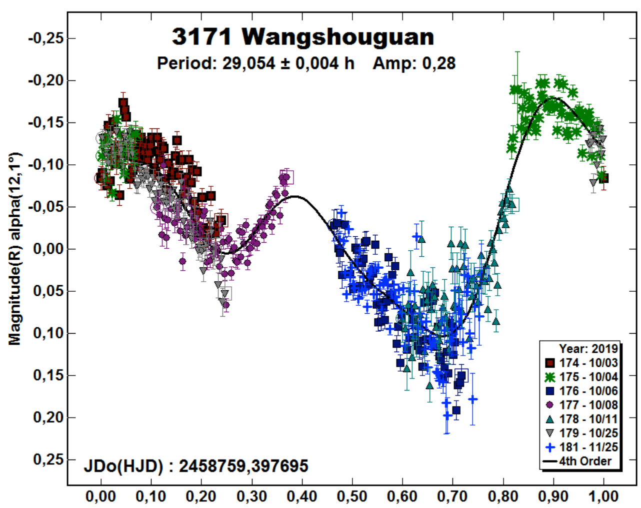
Number	Name	2019 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2634	James Bradley	19/11/30-12/27	10.1,1.9	165	3	16.284	0.004	0.37	0.05	MB-O
3171	Wangshoguang	19/10/03-11/25	17.0,19.3	130	11	29.054	0.004	0.28	0.10	MB
3662	Dezhnev	19/10/07-12/14	7.6,21.1	25	11	9.074	0.001	0.10	0.10	MB
3819	Robinson	19/12/22-12/23	13.5,13.1	119	13	3.70	0.002	0.32	0.05	MB
4686	Maisica	19/10/02-10/25	3.4,13.6	8	5	9.789	0.004	0.09	0.05	MB
7397	1986 QS	19/11/06-12/23	5.3,20.8	41	10	2.864	0.001	0.29	0.05	MB
51149	2000 HF52	19/12/24-12/27	11,4,12.8	76	10	3.446	0.001	0.33	0.05	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. LPAB and BPAB 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).

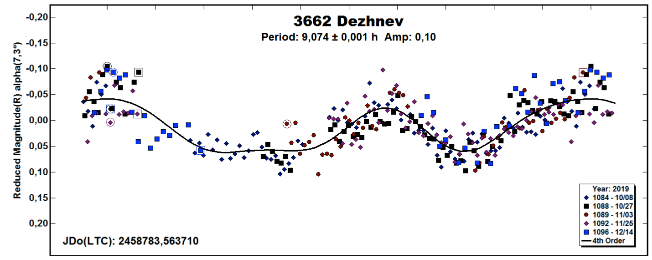
2634 James Bradley. This target was worked at BSA Osservatorio. Exposures were 360 s using an R filter. The five sessions spanned about a month due to poor weather conditions. After making the observations, it was realized that Durech and Hanus (2018), using mostly Gaia DR2 data, created a shape and spin axis model. They found a sidereal rotation period of 16.514 ± 0.002 h but reported no amplitude. Our result was 16.284 ± 0.004 h with a lightcurve amplitude *A* = 0.37 mags.



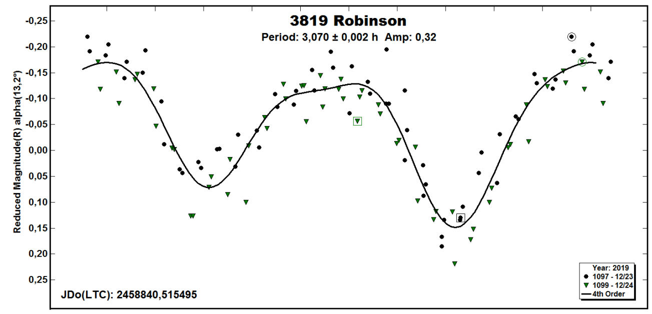
3171 Wangshouguan was named in honor of Wang Shouguan, a member of the Chinese Accademy of Sciences. Wang contributed to the development of modern Chinese Astronomy and served as chief editor of *Acta Astrophysica Sinica* since its inception. The asteroid was observed at Osservatorio BSA. Exposures were 300 s using an R filter. Seven nights totaling 52 hours of observations led to *P* = 29.054 ± 0.004 h, *A* = 0.28 mag.



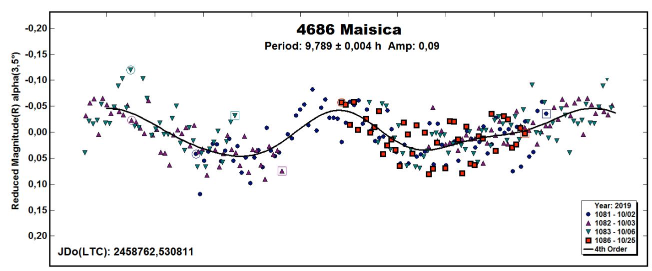
3662 Dezhnev. This target was worked with the 0.30-m R-C telescope with 300 sec unguided exposures and an R Toptec filter. As said before, the observations cover a long time span due to a prolonged period of bad weather period that made it difficult to cover the entire lightcurve. Our analysis found *P* = 9.074 ± 0.001 h and amplitude of *A* = 0.10 mag.



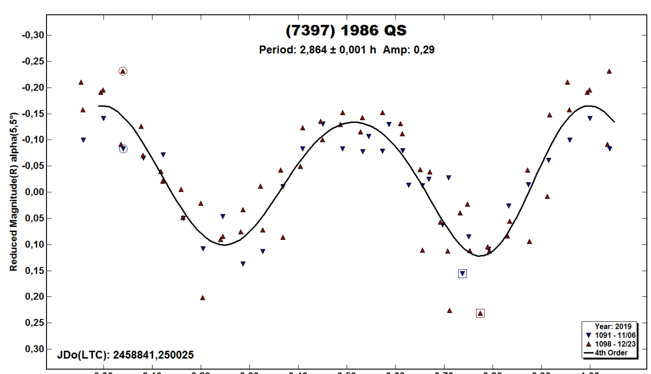
3819 Robinson was observed at Bigmuskie Observatory using the same equipment as for 3662 Dezhnev. This target proved to be a very easy one, with a short period and large amplitude. After only two sessions, we found a period of 3.070 ± 0.002 h, *A* = 0.32 mag.



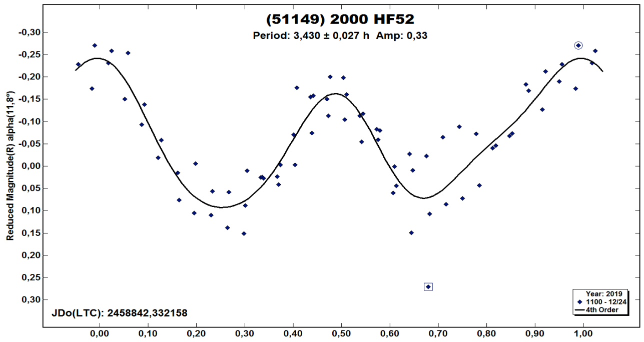
4686 Maisica. This is the third target worked at the Bigmuskie Observatory. The very low amplitude of the lightcurve made it difficult to find a secure solution. During the first stage, *MPO Canopus* jumped between periods of about 8 and 11 hours. Only in the end did we find the final period of *P* = 9.789 ± 0.004 h and *A* = 0.09 mag. Pravec et al. (2019) reported a period of 9.779 h.



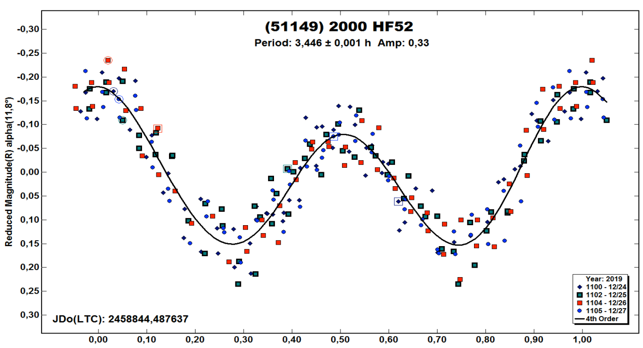
(7397) 1986 QS was observed at Bigmuskie Observatory. Exposures were 300 s using an R filter. This target took two nights that were almost six weeks apart due to bad weather. The period was found on the first night, but we preferred to add a second session to refine the solution.



(51149) 2000 HF52. The exposures for the observations at Bigmuskie Observatory increased to 420 s for this asteroid because of its faintness, more important, because the first session showed deviations that might have been caused by a satellite. The outlying data points in the single session plot (1100, Dec 24) are clearly seen around the minimum of phase 0.70. These outlying data points were removed when plotting the full data set.



Additional sessions showed no more deviations and, after a more accurate analysis, it seemed that the deviations in the first session were due to a very faint field star. This should make an interesting target when it's in less crowded fields. The period is $P = 3.446 \pm 0.001$ h, $A = 0.33$ mags.



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THE ROTATION RATES OF THREE NEAR-EARTH ASTEROIDS AND A MARS-CROSSING ASTEROID

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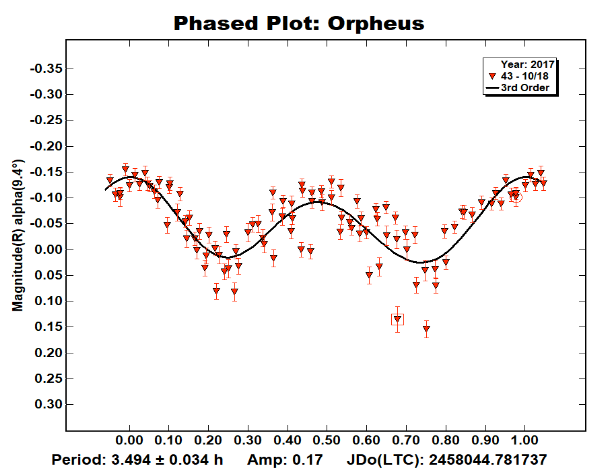
Photometric observations of three near-Earth asteroids (NEAs) and a Mars-crossing asteroid (MCA) were performed during 2017 October 18 to October 22. Fourier analysis of the four targets yielded rotation periods of: 3.494 ± 0.034 h for 3361 Orpheus, 6.653 ± 0.008 h for 1990 UQ, 5.491 ± 0.003 h for 1999 RT198 and 5.319 ± 0.002 h for 1998 ST4.

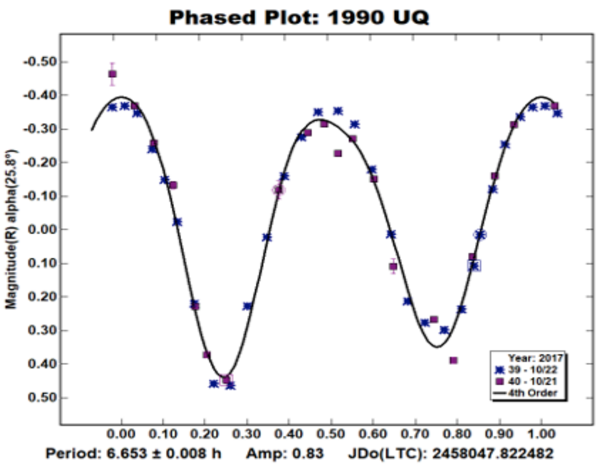
We report asteroid lightcurve measurements taken using NASAcam, a 2K × 2K thermoelectrically cooled CCD camera, mounted on the 31-inch National Undergraduate Research Observatory (NURO) telescope at the Lowell Observatory in Flagstaff, Arizona. Four asteroids were observed during 2017 October using an R-band filter. The data reduction and analysis were conducted using the Image Reduction and Analysis Facility (IRAF) and the Minor Planet Observer (MPO) Canopus program.

3361 Orpheus is an Apollo class NEA discovered at Cerro El Roble on 1982 April 24 by C. Torres with a diameter of 0.3 km (Chapman et al., 1994). Photometric observations were performed on two nights, 2017 October 18 and October 20. A total of 9.5 hours of observations produced 96 data points for analysis. The rotation period was found to be 3.494 ± 0.034 h with an amplitude of 0.17 ± 0.02 mag. Three lightcurves have been reported (LCDB, Warner et al., 2009): Skiff (2013; P = 3.53 h, A = 0.22 mag), Polishook (2012; P = 3.51 h, A = 0.20 mag), Wisniewski (1991; P = 3.58 h, A = 0.32 mag). Our results agree with those reported by Skiff (2013) and Polishook (2012).

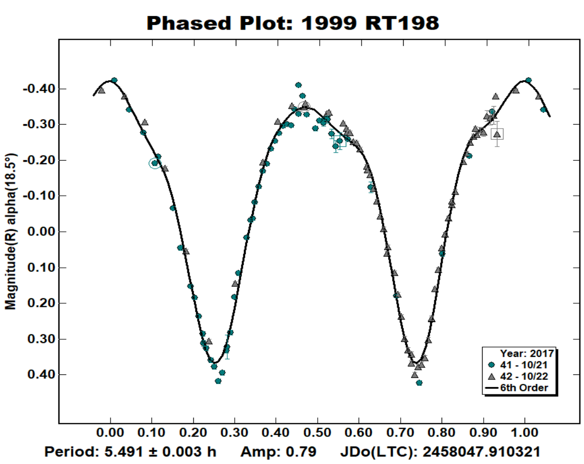


(5189) 1990 UQ is an Apollo class NEA discovered at Siding Spring on 1990 October 20 by R. McNaught. Photometric observations were performed on two consecutive nights, 2017 October 21 and October 22. A total of 12 hours of observations produced 46 data points for analysis. The rotation period was found to be 6.653 ± 0.008 h for an amplitude of 0.83 ± 0.03 mag. A lightcurve has been reported to the LCDB: Warner (2018b;

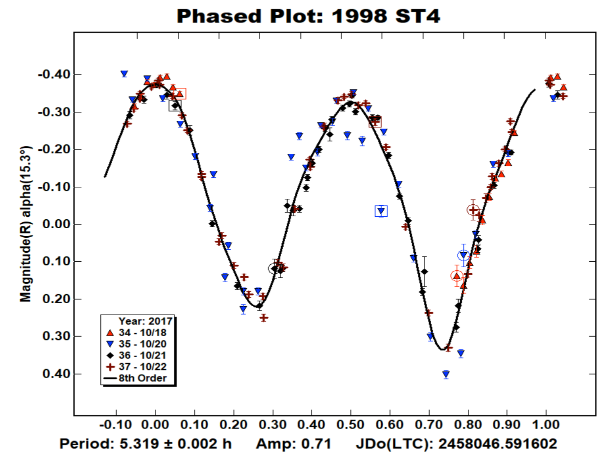
P = 6.676 h, A = 1.02 mag) with double our data points. Yet the rotational periods are in close agreement.



(24029) 1999 RT198 is an MCA discovered at Socorro on 1999 September 10 by LINEAR. Photometric observations were performed on two nights between 2017 October 21 and October 22. A total of 16 hours of observations produced 118 data points for analysis. The rotation period was found to be 5.491 ± 0.003 h with an amplitude of 0.79 ± 0.01 mag. A search of the asteroid lightcurve database (LCDB, Warner et al., 2009) indicated a posting on the Collaborative Asteroid Lightcurve Link (CALL) website. Previous results reported by Skiff (2011); P = 5.492 h, A = 0.65 mag are in agreement with our measurements.



(333888) 1998 ST4 is an Amor class NEA discovered at Socorro on 1998 September 19 by LINEAR. Photometric observations were performed on four nights, 2017 October 18 and from October 20 to October 22. A total of 33 hours of observations produced 140 data points for analysis. The rotation period was found to be 5.319 ± 0.002 h with an amplitude of 0.71 ± 0.01 mag. A search of the asteroid lightcurve database (LCDB, Warner et al., 2009) indicated one previously reported lightcurve: Warner (2018a; P = 5.316 h, A = 0.64 mag). The period found is in full agreement with Warner (2018).



Acknowledgements

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Number	Name	2017 mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
3361	Orpheus	10/18	96	9.4	30	-3	3.494	0.034	0.17	0.02	NEA
5189	1990 UQ	10/21-10/22	46	25.8	13	-11	6.653	0.008	0.83	0.03	NEA
24029	1999 RT198	10/21-10/22	118	18.5	49	-12	5.491	0.003	0.79	0.01	MCA
333888	1998 ST4	10/18-10/22	140	15.3	16	11	5.319	0.002	0.71	0.01	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. 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).

PHOTOMETRY OF 2729 URUMQI AT THE XINGMING OBSERVATORY IN URUMQI CITY

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Lightcurve photometry observations of the main-belt asteroid 2729 Urumqi were made at Xingming Observatory in 2019 December. We find that the asteroid has a synodic rotation period of 3.127 ± 0.001 h and amplitude of 0.22 ± 0.01 mag. Multi-band photometric sessions shows the mean color indices of g-r = 0.67 ± 0.02, and r-i = 0.20 ± 0.02 mag. According to these color indices, 2729 Urumqi can be classified as a type S asteroid.

We used the Ningbo bureau of Education and Xinjiang Observatory Telescope (NEXT: 60-cm *f*/8.0 Ritchey-Chretien + FLI PL230-42 CCD) at Xingming Observatory (IAU Code C42), which located in Urumqi city, to obtain lightcurves of the main-belt asteroid 2729 Urumqi on 2019 Dec 26 and 27. The image scale was 0.64 arcsec/pixel. Exposures with a Sloan r-filter were 120 s.

All images were calibrated using standard procedures, including flat-correction and dark and bias frames using *Maxim DL*. *MPO Canopus* was used to analyze the lightcurve data, and *Source Extractor* was used to get the multi-band photometric data.

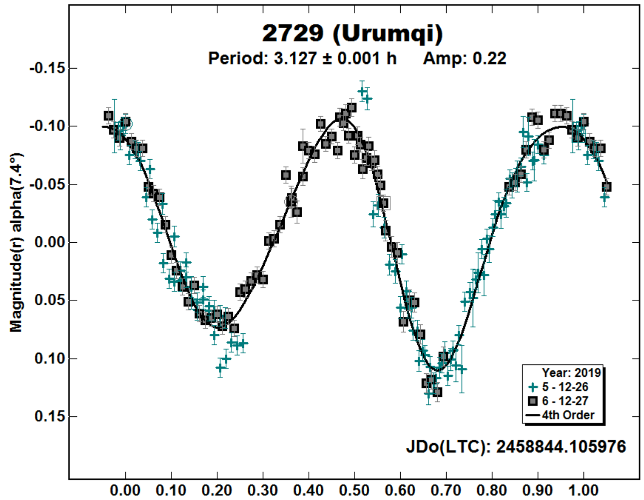
2729 Urumqi was discovered on 1979 Oct 18 at Purple Mountain Observatory. Our data analysis shows a bimodal lightcurve with a synodic rotation period of P = 3.127 ± 0.01 h and amplitude of A = 0.22 ± 0.01 mag, which confirms the previous observations (Slivan et al., 2008; Liu 2016).

Multi-band images in g, r and i filters were obtained on 2018 Dec 26 and 27 in the following order: rgri-rgri. We used the AAVSO Photometric All-Sky Survey (APASS) catalog (Henden et al., 2009) as the photometric reference stars catalog to reduce data to g, r and i band directly. Aperture and differential photometry of five field stars and asteroid were used to find the asteroid's magnitude.

g-r: 0.67 ± 0.02	r-i: 0.20 ± 0.02

Table I. Summary of the mean color indices of 2729 Urumqi.

According to our g-r and r-i color result, 2729 Urumqi is similar to the more common S-type asteroid (Ivezić et al., 2002; Bolin, et al., 2019). This is in agreement Vereš et al. (2015).



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Number	Name	2019/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2729	Urumqi	12/26-12/27	1.9,2.3	90	2	3.127	0.001	0.22	0.01	KOR

Table II. 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 family/orbital group from Warner et al. (2009). KOR: Koronis

THE ROTATION PERIODS OF THE ASTEROIDS 587 HYPSIPYLE, 1152 PAWONA, AND 2937 GIBBS

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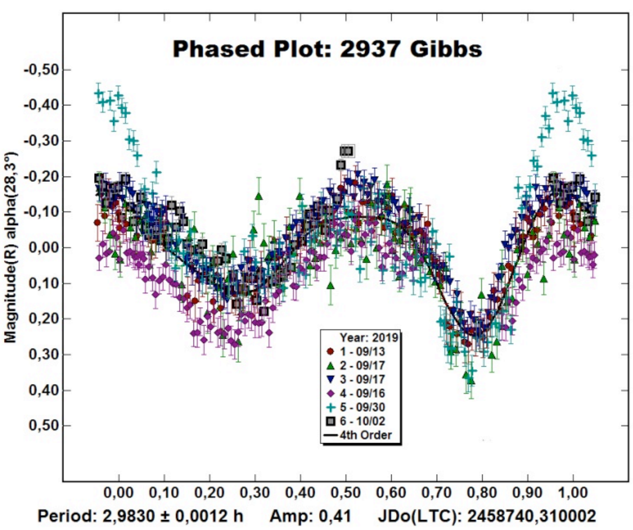
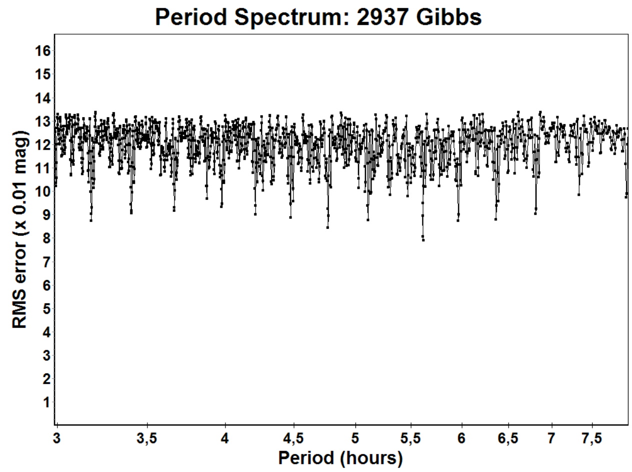
We present photometric synodic rotation periods for the asteroids 2937 Gibbs (P=2.983 ± 0.001 h and a possible P2=5.626 ± 0.001 h), 1152 Pawona (P=3.4151 ± 0.0003 h), and 587 Hypsipyle (P=2.8881 ± 0.0005 h).

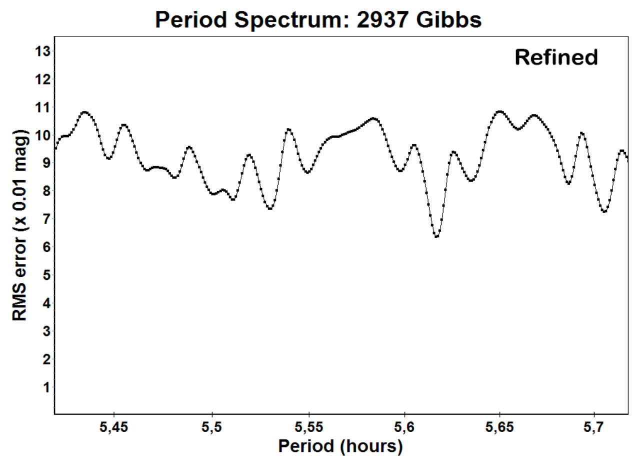
The reported observations were made with a 0.20-m f/4.5 Newtonian reflector equipped with an Atik 314L+ b/w CCD and a 0.23-m f/10 Schmidt-Cassegrain reflector coupled with an Atik 414 EX b/w CCD. Exposures ranged from 70 to 100 s, binned 2x2, with no filter used ("clear"). The result plate scales were 2.95 arcsec/pix for the Newtonian and 1.60 arcsec/pix for the SC. Lightcurves and rotation periods on processed images were obtained with MPO Canopus v 10.7.8.1 (Warner, 2016). Our first search for previous results always started with the asteroid lightcurve database (LCDB; Warner et al., 2019) and MPB issues as well.

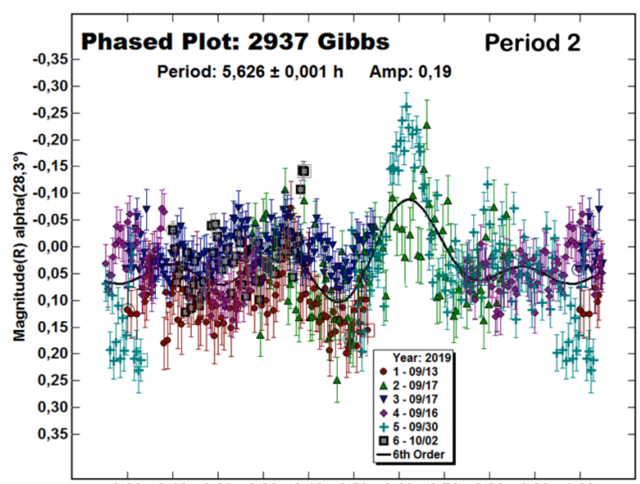
2937 Gibbs is a Mars crosser Phocaea asteroid discovered in 1980 June 14 by E. Bowell at Anderson Mesa Station, Arizona (Schmadel, 2007). Behrend (2005) and Stephens (2017) found periods in the 3.06-3.18 h range, but Warner and Stephens (2019) and Benishek (2019) independently confirmed a better 2.984 h solution. Warner and Stephens (2019) found two secondary periods of 5.62 and 7.49 ± 0.01 h, suspecting potential tumbling states. From September 13 up to October 2 2019, six sets of photometric observations were made for a total of 650 data points over 17 hours. Our results are P = 2.983 ± 0.001 h and A = 0.41 ± 0.05 mag.



Encouraged by Warner's 2019 results we used Canopus MPO dual period utility to search for a secondary period after the removal of the primary period. We present the best solution on the following period spectra and phased plot.

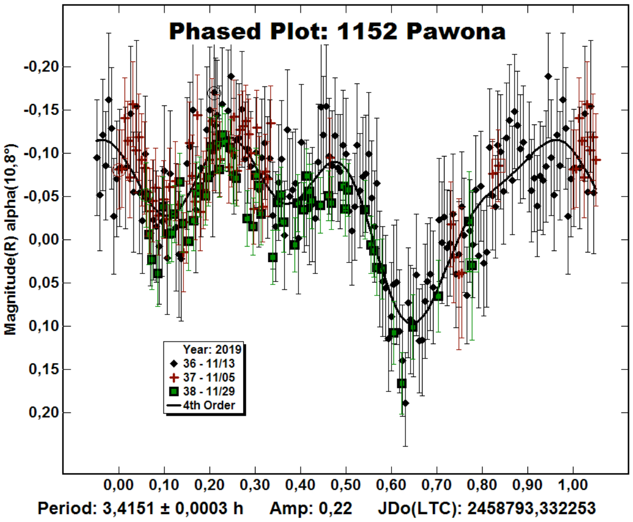




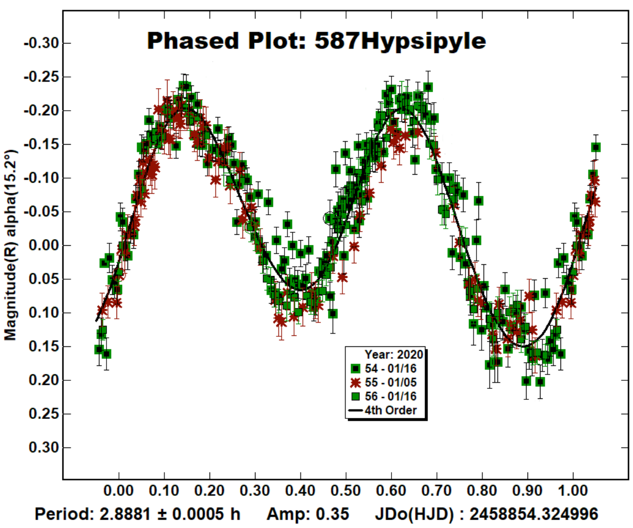


Although the S/N i slow, our possible P2 is 5.626 h ± 0.001 h with amplitude 0.19 ± 0.05 mag; no evidence of a 7.49 h solution was found.

1152 Pawona is a 17 km vestoid in the inner MB region discovered on Jan 1930 by K. Reinmuth. On November 5-29, 2019 we made three observation sets over 10 hours, with 285 data points. Our observations derived P = 3.4151 ± 0.0003 h and A = 0.22 ± 0.05 mag, confirming the results of Schmidt (2017) and Klinglesmith III et al. (2017).



587 Hypsipyle is a 12 km wide Phocaea family asteroid in the inner MB region, discovered on 1906 Feb 22 by M. F. Wolf at Heidelberg Observatory. From 2020 Jan 05-16 we made three observation sets over 11 hours, with 352 data points, confirming the 2019 LCDB data (P=2.8881 ± 0.0005 h, A = 0.35 ± 0.05 mag).



Acknowledgements

The authors would like to express his gratitude to Brian D. Warner for his MPO Canopus software, along with the book "A Practical Guide to Lightcurve Photometry and Analysis".

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Number	Name	20xx/mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2937	Gibbs	19/09/13-10/02	650	28.3,27.4	355	35	2.983	0.001	0.41	0.05	MC
	P2						5.626	0.001	0.19	0.05	
1152	Pawona	19/11/05-11/29	285	7.4,16.4	28	06	3.4151	0.0003	0.22	0.05	MB
587	Hypsipyle	20/01/05-01/16	352	14.4,15.2	103	23	2.8881	0.0005	0.35	0.05	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).

ROTATIONAL PERIODS AND LIGHTCURVES OF 2051 CHANG, 3171 WANGSHOUGUAN, 8141 NIKOLAEV, AND 10426 CHARLIEROUSE

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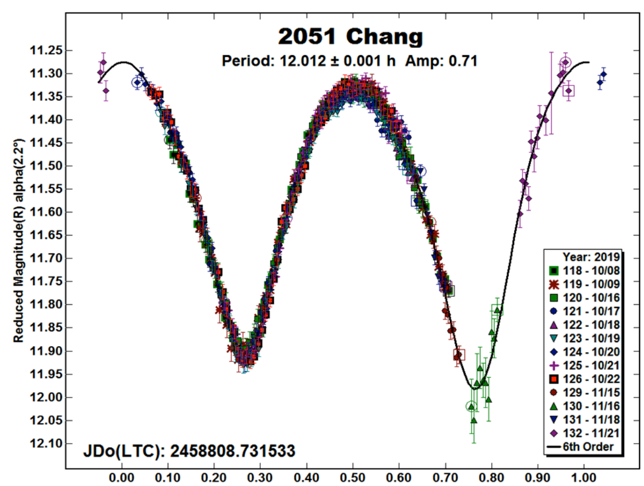
A summary of the lightcurves and rotation period determinations for 2051 Chang, 3171 Wangshouguan, 8141 Nikolaev and 10426 Charlierouse from 2019 October to 2020 January is presented in this paper.

The aim of this research was to find the rotational periods of main-belt asteroids 2051 Chang, 3171 Wangshouguan, 8141 Nikolaev and 10426 Charlierouse. No entries in the LCDB for these asteroids existed at the time of the observations.

CCD photometric observations were mainly carried out by means of Elianto observatory located in the south of Italy (Pontecagnano) using a 0.3-m Newton telescope operating at f/4 equipped with a Moravian KAF1603 ME CCD camera (1536×1024 array of 9-micron pixels) with a clear filter. The observations were also performed using a 0.25-m Ritchey-Chretien telescope operating at f/8 located in the south of Italy (Pontecagnano) equipped with a SBIG STT Kodak KAF-8300 CCD camera (3326×2504 array of 5.4-micron pixels) with a clear filter. Some photometric observations were also acquired by New Mexico Skies Observatory remote telescopes (iTelescope-T21 (2019), iTelescope-T11 (2019)). iTelescope-T21 is a 0.43-m (f/4.5) Dall-Kirkham astrograph equipped with a FLI-PL6303E CCD camera (used with a clear filter) while iTelescope-T11 is a 0.51-m (f/4.5) Dall-Kirkham astrograph equipped with a FLI-PL11002M CCD camera (used with a clear filter).

All images were astrometrically aligned, dark and flat-field corrected using Maxim DL software. *MPO Canopus* (Warner, 2017) was used to measure the magnitudes, perform Fourier analysis, and produce the final lightcurves. In particular, data were reduced in *MPO Canopus* using differential photometry. Night-to-night zero point calibration was accomplished by selecting up to five comparison stars with near-solar colors using the "comp star selector" feature. To analyze the data points of 3171 Wangshouguan and 10426 Charlierouse, CMC15 star catalog (Warner, 2007) was used for determining the comparison star magnitudes. APASS catalogue was used for reducing data related to 2051 Chang and 8141 Nikolaev. This catalogue provides native Johnson V band with internal consistency within 0.03 magnitudes. Using VizieR web site (*VizieR, 2016*), Sloan r' band was converted in standard Cousin R by R = r' - 0.065 × (g' – i') - 0.174 (North Equator, Munari, 2012). The "StarBGone" routine within MPO Canopus was used to subtract stars that occasionally merged with the asteroid during the observations. MPO Canopus was also used for rotation period analysis. The software employs a FALC Fourier analysis algorithm developed by Harris (Harris, 1989). Table I gives the observing circumstances and results of all asteroids.

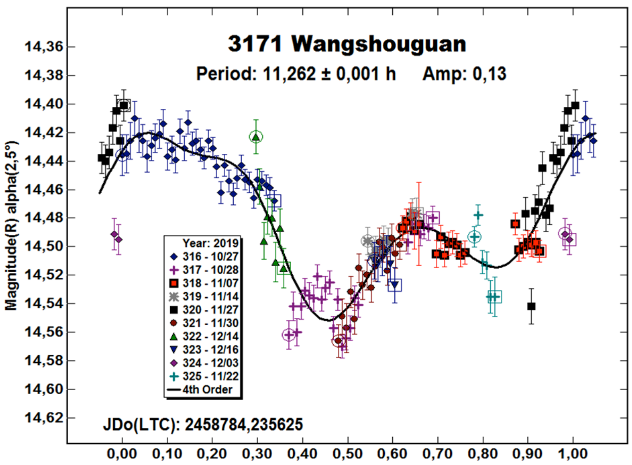
2051 Chang (1976 UC) was discovered on 1976 October 23 at Agassiz Station by Harvard College (now Oak Ridge Observatory). It is a main-belt asteroid with a semi-major axis of 2.841 AU, orbital period of 4.79 years, eccentricity of 0.756 and inclination of 1.356 deg. This fourteen-kilometer-asteroid has an absolute magnitude of 11.5 and a geometric albedo of 0.248 (JPL, 2019). CCD photometric observations were performed between 2019 October 8 and 2019 November 21. Nine observation sessions were produced for lightcurve analysis using 0.3-m Newton to collect the data points and adopting an exposure time of 360 s. A preliminary analysis of the data suggested a rotational period for this object very close to 12 hours. Therefore, we acquired additional data (four sessions) by remote telescopes described above (iTelescope-T21 (2019), iTelescope-T11 (2019)) to cover the supposed period using an exposure time ranging from 240 s to 300 s. By putting together all the available data points (564), the best solution coming from the period spectrum was 12.012 ± 0.001 h with an amplitude of 0.71 mag. The results are in good agreement with those recently found (Marchini, 2020).



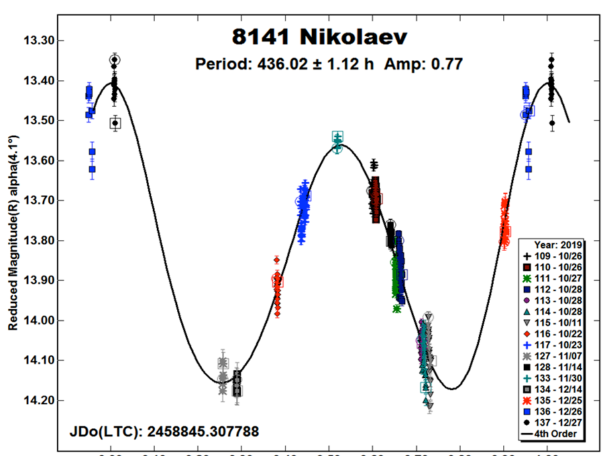
Number	Name	20yy mm/dd	Pts	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2051	Chang	19/10/08-19/11/21	564	2.16-15.34	17.1	1.3	12.012	0.001	0.71	0.01	MB
3171	Wangshouguan	19/10/27-19/12/16	143	2.45-16.41	39.4	3.0	11.262	0.001	0.13	0.01	MB
8141	Nikolaev	19/10/26-19/12/27	402	4.13-32.45	33.9	5.9	436.02	1.12	0.77	0.01	MB
10426	Charlierouse	19/12/01-20/01/06	491	8.84-19.54	65.0	-13.6	36.935	0.009	0.53	0.01	MB

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 (Harris *et al.*, 1984). Grp is the asteroid family/group (Warner et al., 2009).

3171 Wangshouguan (1979 WO) was discovered on 1979 November 19 by Purple Mountain Observatory at Nanking. 3171 Wangshouguan is a main-belt asteroid with a semi-major axis of 3.180 AU, orbital period of 5.76 years, eccentricity of 0.145 and inclination of 11.422 deg. Its diameter is 38.8 km, absolute magnitude of 11.1 and a geometric albedo of 0.048 (JPL, 2019). A total of 143 lightcurve data points were collected from 2019 October 27 to 2019 December 16 in 9 observing sessions, using exposure time of 360 s. An additional session on 2019 November 27 acquired by a remote telescope (iTelescope-T21 (2019)) was taken using an exposure time of 300 s. We derived a period of 11.262 ± 0.001 h as strongly suggested by the period spectrum analysis. The data gave a lightcurve with an asymmetrical shape and amplitude of 0.13 mag.



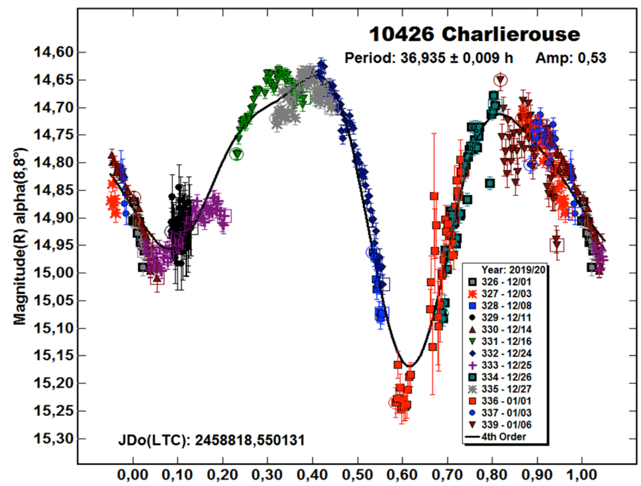
8141 Nikolaev (1982 SO4) was discovered on 1982 September 20 by N. S. Chernykh at the Crimean Astrophysical Observatory. 8141 Nikolaev is a main-belt asteroid with a semi-major axis of 2.390 AU, orbital period of 3.70 years, eccentricity of 0.291 and inclination of 7.522 deg. Its diameter is 4.3 km, absolute magnitude of 13.6 and a geometric albedo of 0.243 (JPL, 2019). A total of 402 lightcurve data points were collected from 2019 October 26 to 2019 December 27 in 16 observing sessions by using exposure time ranging from 200 s to 360 s. For this asteroid twelve sessions were performed by 0.25-m RC reflector telescope and four sessions were carried out by 0.3-m Newton telescope both of them described above.



It was very hard to obtain a solution using a short (from few hours to tens of hours) period. The period analysis gave the best solution for 436.02 ± 1.12 h and an amplitude of 0.77 mag. The rotational period is associated with a lightcurve showing a weak asymmetric bimodal behavior. However, tumbling also might be considered as responsible of the observed phenomenology. From the collected data, it is clear that the lightcurve is only partially sampled. New observations and additional data of 8141 Nikolaev at next oppositions will be required in order to improve the current analysis and eventually confirming its very long rotation period.

10426 Charlierouse (1999 BB27) was discovered on 1999 January 16 by Spacewatch at Kitt Peak. It is a main-belt asteroid with a semi-major axis of 2.634 AU, orbital period of 4.27 years, eccentricity of 0.158 and inclination of 13.644 deg. Its diameter is 9.3 km, absolute magnitude is 12.1 and a geometric albedo is 0.294 (JPL, 2019).

A total of 491 lightcurve data points were collected from 2019 December 1 to 2020 January 6 in 13 observing sessions by using 0.3-m Newton telescope described above with an exposure time ranging from 120 s to 360 s. We found a period of 36.935 ± 0.009 h with an amplitude of 0.53 mag. as suggested by the period spectrum analysis.



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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2020 APRIL-JUNE

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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 come from using radar data alone.

We present several lists of asteroids that are prime targets for photometry during the period 2020 April-June.

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 ≤ 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 3.7 million observations for 14920 objects (2020 Feb 20), this makes the site one of the larger publicly available sources for 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, d*o not overlook asteroids with* U = 2/2+ *on the assumption that the period is sufficiently established.* Regardless, do not let the existing period influence your analysis since even 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).

		Brightest			LCDB Data		
Number	Name	Date	Mag	Dec	Period	Amp	U
1813	Imhotep	04 02.0	15.0	+0	17.994	0.42-0.80	2+
6259	Maillol	04 08.2	15.3	-3			
4626	Plisetskaya	04 10.0	15.1	-8			
5630	Billschaefer	04 14.5	15.2	-7	69.	0.9	2-
5247	Krylov	04 16.8	14.6	-21	81.5	1.5	2
6808	Plantin	04 26.3	15.1	-17	5.82	0.32	1
1451	Grano	04 26.8	14.8	-7	138.	0.06-0.65	2+
3417	Tamblyn	04 29.1	15.2	-2	5.467	0.12	2
52768	***1998 OR2***	***05 01.6***	***10.8***	***-36***	***4.112***	***0.16-0.29***	***2+***
539940	***2017 HW1***	***05 03.1***	***15.4***	***+2***			
2283	Bunke	05 03.2	14.5	-10	3.96	0.04-0.06	2
16446	1989 MH	05 05.8	15.3	-3	4.977	0.65	2
85184	***1991 JG1***	***05 06.4***	***15.1***	***-17***			
6414	Mizunuma	05 08.2	15.4	-19			
388945	***2008 TZ3***	***05 08.8***	***13.8***	***-32***	***44.2***	***0.56***	***2***
438908	***2009 XO***	***05 09.5***	***14.3***	***-10***			
18029	1999 KA16	05 12.3	15.1	-16			
37152	2000 VV56	05 12.8	14.3	-27			
2115	Irakli	05 17.2	14.7	-21	29.765	0.34-0.36	2
17953	1999 JB20	05 17.7	15.0	-18	37.279	0.08	1
3151	Talbot	05 18.5	14.7	-5	19.49	0.40	2+
6496	Kazuko	05 18.6	15.3	-30			
7910	Aleksola	05 19.3	15.2	-10			
3615	Safronov	05 21.5	15.0	-17	>16.	0.2	2-
1594	Danjon	05 21.6	13.3	-17	>12.	0.03	1
1592	Mathieu	05 26.6	14.4	-2	28.46	0.50	2+
136795	***1997 BQ***	***05 26.9***	***14.6***	***-70***			
10646	Machielalberts	05 27.2	15.5	-28	3.058	0.29	2
36188	1999 TD37	05 29.6	15.5	-25			
32459	2000 SK87	05 31.0	15.5	-27			
3683	Baumann	06 04.1	14.8	-10	15.758	0.21	2
13374	1998 VT10	06 05.5	14.9	-26	3.23	0.41	2
1850	Kohoutek	06 06.5	14.3	-24	3.68	0.31	2
19711	1999 TG219	06 06.7	15.5	-46			
7594	Shotaro	06 07.7	15.4	-18	9.643	0.26	2
12528	1998 KL31	06 08.7	15.4	-21			
8352	1989 GE	06 10.5	14.9	-31			
5569	Colby	06 11.4	15.4	-33			
4326	McNally	06 14.5	15.4	-20			
6064	Holasovice	06 14.7	15.2	-12			
169675	***2002 JM97***	***06 16.8***	***15.3***	***-44***			
22135	2000 UA100	06 19.9	15.5	-19	393.	0.25	2-
10902	1997 WB22	06 20.1	15.3	-21			
3874	Stuart	06 21.4	15.5	-25			
1233	Kobresia	06 22.1	14.3	-27	27.83	0.32-0.34	2
1611	Beyer	06 22.1	15.4	-20	13.29	0.12-0.35	2+
3637	O'Meara	06 23.7	14.5	+0	7.71	0.13-0.25	2+
4109	Anokhin	06 24.4	15.0	-20			
6520	Sugawa	06 25.6	15.2	-17			
3796	Lene	06 27.9	14.5	-22			
19204	Joshuatree	06 30.7	15.3	+1	480.	0.1-0.95	2+
10547	Yosakoi	06 30.9	14.9	-30			

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-G_{12}, introduced by Muinonen *et al.* (2010; *Icarus* **209**, 542-555). It will be some years before H-G_{12} 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 α > 7°, 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
1269	Rollandia	04 08.8	0.96	13.8	-04	19.98	0.02-0.13	2
954	Li	04 21.4	0.41	14.2	-11	7.207	0.11-0.25	3
276	Adelheid	04 22.6	0.30	12.8	-12	6.315	0.07-0.17	3
24	Themis	04 26.2	0.10	11.0	-14	8.374	0.09-0.14	3
384	Burdigala	05 01.5	0.35	13.5	-14	21.1	0.03	2-
813	Baumeia	05 04.7	0.68	13.9	-15	10.544	0.18-0.18	3-
910	Anneliese	05 06.3	0.44	13.5	-16	11.286	0.13-0.16	3
1247	Memoria	05 07.0	0.86	14.4	-14			
175	Andromache	05 11.0	0.70	12.8	-20	8.324	0.28-0.30	3
673	Edda	05 11.8	0.16	13.8	-18	22.340	0.12-0.21	3
270	Anahita	05 16.6	0.65	11.0	-21	15.06	0.25-0.32	3
1822	Waterman	05 17.2	0.33	14.0	-19	7.581	0.51	3
1499	Pori	05 19.4	0.22	14.2	-20	3.356	0.12-0.34	3
712	Boliviana	05 20.2	0.97	12.5	-17	11.743	0.10-0.12	3
4844	Matsuyama	05 21.4	0.84	14.1	-22	2.723	0.35	3
211	Isolda	05 22.4	0.60	12.7	-22	18.365	0.09-0.14	3
208	Lacrimosa	05 23.3	0.79	12.8	-23	14.085	0.15-0.33	3
435	Ella	05 24.5	0.78	13.3	-23	4.623	0.30-0.38	3
2379	Heiskanen	05 30.6	0.29	14.4	-21	3.76	0.17-0.23	3
468	Lina	05 30.9	0.16	14.1	-22	16.33	0.13-0.18	3
1850	Kohoutek	06 06.5	0.56	14.4	-24	3.68	0.31	2
976	Benjamina	06 08.0	0.94	13.2	-20	9.700	0.17-0.18	3-
488	Kreusa	06 08.3	0.62	12.1	-21	32.666	0.08-0.2	2+
322	Phaeo	06 13.1	0.80	12.6	-21	17.584	0.13-0.20	3
229	Adelinda	06 13.4	0.77	13.6	-26	6.60	0.04-0.30	3
1304	Arosa	06 13.8	0.71	12.9	-21	7.748	0.13-0.38	3
449	Hamburga	06 14.8	0.12	13.0	-23	18.263	0.08-0.17	2+
974	Lioba	06 21.7	0.25	13.5	-24	38.7	0.37	3
64	Angelina	06 22.0	0.43	11.5	-25	8.752	0.04-0.42	3
1082	Pirola	06 22.8	0.88	14.0	-21	15.852	0.53-0.62	3
1848	Delvaux	06 24.2	0.73	14.5	-25	3.637	0.57-0.69	3
700	Auravictrix	06 26.0	0.24	13.1	-23	6.075	0.18-0.43	3
521	Brixia	06 27.7	0.61	12.5	-25	28.479	0.05-0.12	3
3796	Lene	06 27.9	0.63	14.4	-22			
2094	Magnitka	06 29.1	0.32	14.3	-24	6.112	0.80-0.86	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 ≥ 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 Date	Mag	Dec	LCDB Data Period	Amp	U
479	Caprera	04 05.5	14.4	+4	9.43	0.10-0.25	3
972	Cohnia	04 06.6	14.9	-17	18.472	0.19-0.21	3
1107	Lictoria	04 07.5	14.0	+2	8.562	0.16-0.30	3
1100	Arnica	04 08.0	14.9	-9	14.535	0.09-0.28	3
524	Fidelio	04 09.1	13.9	-17	14.198	0.18-0.22	3
5080	Oja	04 11.1	15.5	-14	7.222	0.31-0.39	3
1309	Hyperborea	04 13.0	14.8	-10	13.88	0.34-0.54	3
1028	Lydina	04 13.5	14.5	-2	11.68	0.22- 0.7	3
418	Alemannia	04 15.5	13.7	-16	4.671	0.14-0.33	3
219	Thusnelda	04 21.4	12.7	-9	59.74	0.19-0.24	3
954	Li	04 21.5	14.2	-11	7.207	0.11-0.25	3
58	Concordia	04 22.0	12.2	-6	9.895	0.09-0.15	3
658	Asteria	04 22.6	14.6	-14	21.034	0.22-0.28	3
895	Helio	04 24.8	13.6	-40	9.347	0.10-0.23	3
781	Kartvelia	04 28.1	14.2	+12	19.04	0.16-0.28	3-
790	Pretoria	04 29.7	12.7	-30	10.37	0.05-0.18	3
1523	Pieksamaki	04 29.9	14.6	-24	5.320	0.28- 0.5	3
663	**Gerlinde**	**04 30.7**	**12.7**	**-21**	**10.251**	**0.19-0.35**	**3**
2897	**Ole Romer**	**04 30.8**	**15.4**	**-14**	**2.601**	**0.07-0.15**	**3**
2004	Lexell	05 01.5	15.4	-18	5.443	0.42-0.51	3
2241	Alcathous	05 02.5	15.3	-30	7.689	0.20-0.25	3
1443	Ruppina	05 02.9	15.0	-14	5.88	0.27-0.42	3
3317	Paris	05 04.6	15.3	+18	7.091	0.08-0.11	3
750	Oskar	05 04.8	14.8	-13	6.258	0.07-0.20	3
323	Brucia	05 05.7	13.5	+5	9.463	0.19-0.36	3
1830	Pogson	05 06.0	14.9	-10	2.57	0.10-0.18	3
1694	Kaiser	05 08.2	15.4	+22	13.02	0.14-0.32	3
1426	Riviera	05 08.4	13.4	-32	4.404	0.30-0.31	3
261	Prymno	05 09.3	11.9	-13	8.002	0.13-0.20	3
696	Leonora	05 10.2	15.1	-33	26.896	0.04-0.31	3
558	Carmen	05 10.4	13.4	-6	11.387	0.2-0.31	3
175	Andromache	05 11.2	12.8	-20	8.324	0.28-0.30	3
224	Oceana	05 11.8	11.9	-26	9.401	0.09-0.14	3
1123	Shapleya	05 12.0	14.8	-13	52.92	0.25-0.38	3-
1172	Aneas	05 12.0	15.0	-24	8.705	0.06-0.62	3
388	Charybdis	05 12.9	12.8	-26	9.516	0.14-0.25	3
359	Georgia	05 14.5	12.7	-26	5.537	0.16-0.54	3
840	Zenobia	05 16.1	14.0	-28	5.565	0.08-0.28	3
3447	Burckhalter	05 16.6	14.8	-54	59.8	0.10-0.39	3
913	Otila	05 17.0	13.5	-11	4.872	0.09-0.45	3
1867	Deiphobus	05 18.0	15.2	-44	58.66	0.10-0.27	3-
712	Boliviana	05 20.2	12.5	-17	11.743	0.10-0.12	3
2144	Marietta	05 20.7	15.5	-16	5.488	0.40-0.44	3
3800	Karayusuf	05 22.8	15.3	+7	2.232	0.15-0.19	3
1660	Wood	05 24.9	15.2	-2	6.809	0.14-0.26	3
3913	Chemin	05 25.9	15.5	+22	3.408	0.17-0.53	3
654	Zelinda	05 27.0	11.7	-38	31.735	0.08- 0.3	3
267494	2002 JB9	05 27.6	14.4	-42	2.426	0.12-0.21	3
3451	Mentor	05 27.7	15.4	+7	7.702	0.13-0.63	3
4709	**Ennomos**	**05 29.0**	**15.3**	**-25**	**12.275**	**0.40-0.47**	**3**
1096	Reunerta	05 29.5	13.6	-18	13.036	0.20-0.39	3
1741	Giclas	05 29.5	15.4	-23	2.943	0.10-0.15	3
468	Lina	05 31.0	14.1	-22	16.33	0.13-0.18	3
1113	Katja	05 31.3	14.5	-40	18.465	0.08-0.17	3
779	Nina	06 03.6	11.1	-35	11.186	0.06-0.32	3
653	Berenike	06 04.1	13.5	-8	12.489	0.03-0.11	3
30856	**1991 XE**	**06 04.4**	**15.4**	**-15**	**5.353**	**0.70-1.23**	**3**
868	Lova	06 09.2	14.3	-18	41.118	0.10-0.40	3
100	Hekate	06 09.6	11.3	-15	27.066	0.11-0.23	3
2653	Principia	06 09.6	15.2	-16	5.523	0.45-0.52	3
59	Elpis	06 10.1	12.0	-10	13.671	0.07-0.42	3
3868	Mendoza	06 10.5	15.5	-9	2.771	0.07-0.20	3
295	Theresia	06 12.8	14.6	-24	10.702	0.11-0.22	3
1304	**Arosa**	**06 13.8**	**12.8**	**-21**	**7.748**	**0.13-0.38**	**3**
1321	Majuba	06 15.0	13.6	-36	5.207	0.22-0.43	3
1116	Catriona	06 16.0	15.2	-46	8.832	0.09-0.20	3
1046	Edwin	06 16.1	15.1	-35	5.291	0.14-0.27	3
604	Tekmessa	06 16.2	14.4	-29	5.560	0.43-0.60	3
240	Vanadis	06 19.5	13.3	+23	10.64	0.08-0.34	3
191	Kolga	06 19.7	13.4	-7	17.604	0.21- 0.5	3
1717	Arlon	06 23.2	15.4	-33	5.148	0.07-0.12	3
1848	**Delvaux**	**06 24.2**	**14.5**	**-25**	**3.637**	**0.57-0.69**	**3**
453	Tea	06 24.9	12.3	-35	6.812	0.03-0.37	3
7750	**McEwen**	**06 28.8**	**14.6**	**-7**	**27.818**	**0.43-0.65**	**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 an asteroid that already has a well-known period 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 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 many observations. 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.

The "A" is for Arecibo; "G" is for Goldstone.

Asteroid	Period	Amp	App	Last	R SNR
(363599)2004 FG11 NEA BIN	7.021	0.30	2	2016	A: 90 G: 30
2010 JJ41 **NEA**	**-**	**-**	**-**	**-**	**A: 350** **G: 110**
(52768) 1998 OR2 **NEA**	**4.112**	**0.16** **0.29**	**1**	**2009**	**A: 2150** **G: 700**
2016 HP6 **NEA**	**-**	**-**	**-**	**-**	**A: 205** **G: 80**
(388945) 2008 TZ3 **NEA**	**44.2**	**0.56**	**2**	**2018**	**A: 205** **G: 70**
(438908) 2009 XO **NEA**	**-**	**-**	**-**	**-**	**A: 1800** **G: 560**
2000 KA **NEA**	**-**	**-**	**-**	**-**	**A: 510** **G: 150**
(136795) 1997 BQ **NEA**	**-**	**-**	**-**	**-**	**A: 425** **G: 145**
(144411) 2004 EW9 NEA	49.94	0.9 1.9	1	2004	A: 610 G: 205
(163348) 2002 NN4 NEA	14.5	0.74	1	2016	A: 1280 G: 430
2016 JT38 **NEA**	**-**	**-**	**-**	**-**	**A: 160** **G: 50**
(441987) 2010 NY65 **NEA**	**4.973**	**0.21** **0.24**	**4**	**2019**	**A: 310** **G: 100**

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.

(363599) 2004 FG11 (H = 21.0)
Taylor et al. (2012) used radar to discover that this asteroid is binary. They reported a primary period of $P < 4$ h. On the other hand, Dumitru et al. (2018) reported a period of 7.021 h. If nothing else, the goal should be to find a definitive solution for the rotation period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	14 41.5	+06 37	0.16	1.14	18.5	27.5	148	117	+0.46	+57
04/03	14 50.4	+09 48	0.13	1.11	18.2	29.9	146	92	+0.67	+57
04/05	15 03.7	+14 29	0.11	1.09	17.8	34.1	142	68	+0.86	+57
04/07	15 25.9	+21 52	0.08	1.06	17.4	41.9	135	50	+0.98	+55
04/09	16 10.2	+34 00	0.06	1.03	17.1	56.3	121	51	-0.99	+47
04/11	18 00.8	+50 52	0.05	1.01	17.4	81.6	96	74	-0.88	+29
04/13	21 37.0	+55 18	0.05	0.98	18.9	112.9	64	91	-0.70	+2

2010 JJ41 (H = 21.8)
There is no entry in the LCDB for a rotation period. The estimated size is 130 m, so it's possible that the asteroid has a rotation period $P < 2.2$ h. Keep exposures as short as possible until you have a good idea of the period.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/16	19 54.5	+27 13	0.03	1.00	17.7	96.6	82	50	-0.39	+0
04/17	18 09.8	+27 04	0.03	1.01	16.6	73.5	105	68	-0.30	+21
04/18	16 31.0	+22 23	0.03	1.02	16.2	51.1	127	94	-0.22	+40
04/19	15 23.0	+16 35	0.04	1.03	16.2	35.0	144	119	-0.15	+53
04/20	14 40.4	+11 59	0.05	1.05	16.4	25.2	154	139	-0.09	+60
04/21	14 13.0	+08 41	0.06	1.06	16.7	19.9	159	155	-0.04	+63
04/22	13 54.4	+06 20	0.07	1.07	17.0	17.4	161	167	-0.01	+64
04/23	13 41.1	+04 37	0.08	1.08	17.3	16.7	162	166	+0.00	+65
04/24	13 31.3	+03 18	0.09	1.09	17.7	16.9	162	155	+0.01	+64
04/25	13 23.7	+02 16	0.10	1.10	18.0	17.6	161	142	+0.04	+64

(52768) 1998 OR2 (H = 15.8)
Skiff et al. (2019) reported a period of 4.1120 h for this 2.1 km NEA. Based on galactic latitude and moon phase, early April is probably the best time for northern observers to catch this asteroid.

Despite the very low galactic latitudes in May and June, it may still be possible to get useful data since the exposures can be kept short (>20 s to keep scintillation noise to a minimum) and so reduce contamination by very faint field stars.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	07 52.8	+38 17	0.14	1.04	14.1	71.4	101	23	+0.46	+28
04/11	08 15.2	+31 56	0.10	1.02	13.5	77.0	97	122	-0.88	+31
04/21	09 04.9	+15 12	0.06	1.02	12.3	73.6	103	126	-0.04	+36
05/01	11 13.3	-31 06	0.04	1.04	10.8	46.5	132	60	+0.52	+27
05/11	14 41.4	-55 36	0.07	1.07	11.7	35.7	142	53	-0.84	+4
05/21	16 22.3	-54 39	0.12	1.11	12.8	31.4	145	132	-0.03	-3
05/31	16 57.7	-51 31	0.17	1.17	13.5	25.7	150	91	+0.60	-5
06/10	17 12.3	-48 30	0.23	1.23	14.1	20.8	155	54	-0.80	-5
06/20	17 19.8	-45 43	0.30	1.30	14.7	18.1	157	155	-0.02	-5
06/30	17 25.8	-43 09	0.38	1.37	15.3	18.1	155	57	+0.69	-4

2016 HP6 (H = 25.3)

The estimated size for this NEA is 140 m, which makes it another candidate for a super-fast rotator (*P* < 2 h). The window of opportunity is short, only 9 nights or so. Unfortunately, the moon may be a problem.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/02	13 39.4	+23 11	0.02	1.02	18.7	40.2	139	51	+0.63	+78
05/03	13 58.7	+21 33	0.02	1.02	18.3	37.9	141	44	+0.74	+74
05/04	14 23.6	+19 10	0.02	1.02	17.9	34.9	145	39	+0.83	+67
05/05	14 55.8	+15 38	0.01	1.02	17.5	31.4	148	35	+0.91	+59
05/06	15 37.2	+10 28	0.01	1.02	17.1	28.7	151	33	+0.97	+48
05/07	16 28.2	+03 22	0.01	1.02	16.9	29.9	150	31	+1.00	+33
05/08	17 26.2	-05 00	0.01	1.02	17.1	37.1	142	29	-0.99	+17
05/09	18 24.6	-12 56	0.01	1.02	17.5	47.7	132	27	-0.97	+0
05/10	19 16.6	-19 00	0.01	1.02	18.0	57.8	122	24	-0.91	-14

(388945) 2008 TZ3 (H = 20.4)

This 250-m NEA is almost certainly a “tumbler” (non-principal axis rotation). Warner (2016) found periods of 44.2 h and 52.4 h. It was not possible to tell which period, if either, was that of rotation or precession.

Pravec et al. (2019), found a better solution of 39.15 h and 34.11 h. However, those are also just two of several possible solutions. Confirmation will require a coordinated campaign of observers at well-separated longitudes and, most important, data that is well-calibrated (<0.03 mag) to a common zero point.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/10	13 41.8	+17 51	0.16	1.15	17.9	22.9	153	37	-0.94	+75
04/15	13 38.6	+17 35	0.14	1.13	17.4	24.2	153	100	-0.49	+76
04/20	13 33.6	+16 40	0.11	1.10	17.0	25.8	151	154	-0.09	+76
04/25	13 25.9	+14 33	0.08	1.08	16.4	27.7	150	135	+0.04	+75
04/30	13 12.7	+09 51	0.06	1.06	15.6	29.5	149	74	+0.41	+72
05/05	12 44.1	-02 24	0.03	1.04	14.5	32.6	146	3	+0.91	+60
05/10	10 48.6	-42 30	0.02	1.02	13.9	58.8	120	83	-0.91	+15
05/15	04 22.3	-55 47	0.03	1.00	16.5	102.8	76	78	-0.46	-43
05/20	02 54.4	-43 28	0.05	0.99	18.2	112.7	65	52	-0.07	-60

(438908) 2009 XO (H = 20.5)

No rotation period is given in the LCDB. The estimated diameter is 240 m, so it’s *probable* that the period is *P* > 2.2 h. The sky motion is going to be large, requiring shorter exposures than might otherwise be used, but the asteroid is bright enough that good data should still be possible.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/06	08 37.5	+14 20	0.03	1.01	16.0	96.1	82	78	+0.97	+30
05/09	11 53.2	-04 40	0.03	1.03	14.3	47.3	132	70	-0.97	+55
05/12	13 47.4	-14 58	0.04	1.05	14.6	20.7	159	81	-0.75	+46
05/15	14 36.3	-18 13	0.06	1.07	15.2	11.6	168	107	-0.46	+38
05/18	15 01.1	-19 32	0.08	1.09	15.8	8.4	171	136	-0.19	+34
05/21	15 15.8	-20 11	0.10	1.11	16.4	7.7	172	168	-0.03	+31
05/24	15 25.4	-20 34	0.13	1.14	16.9	8.0	171	156	+0.02	+29
05/27	15 32.3	-20 49	0.15	1.16	17.3	8.9	170	120	+0.18	+28
05/30	15 37.6	-20 59	0.18	1.19	17.7	10.1	168	80	+0.49	+27

2000 KA (H = 21.7)

Coming in with a diameter of about 140 m, 2000 KA may be a super-fast rotator and so short exposures are advised for at least the initial observations. The rule of thumb is that exposures should be no more than 0.187*period if *rotational smearing* is to be avoided (see Pravec et al., 2000; *Icarus* **147**, 477-486). For example, if the rotation period is 0.1 h (6 minutes), exposures should be no longer than about 67 seconds.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/11	19 56.7	+76 56	0.03	1.00	17.5	101.7	77	102	-0.84	+23
05/13	16 28.1	+46 03	0.02	1.02	15.9	65.0	114	87	-0.65	+44
05/15	15 51.8	+16 13	0.03	1.04	15.6	34.6	144	99	-0.46	+47
05/17	15 37.9	+00 11	0.04	1.05	15.9	18.7	160	121	-0.27	+42
05/19	15 30.6	-08 23	0.06	1.07	16.3	11.2	168	145	-0.13	+38
05/21	15 26.2	-13 29	0.07	1.08	16.7	8.5	171	168	-0.03	+35
05/23	15 23.3	-16 48	0.09	1.10	17.2	8.7	171	167	+0.00	+33
05/25	15 21.3	-19 07	0.10	1.11	17.6	10.1	169	142	+0.05	+31
05/27	15 20.0	-20 49	0.12	1.13	18.0	11.7	167	117	+0.18	+30
05/29	15 19.1	-22 07	0.13	1.14	18.4	13.3	165	90	+0.38	+29

(136795) 1997 BQ (H = 18.0)

This is a case where the asteroid reaches brightest well after it’s favorably positioned for radar observations. Arecibo is scheduled to observe about May 18. While relatively bright, this is another asteroid keeping near the galactic plane and so getting good data may be challenging.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/30	09 12.3	-81 41	0.07	1.04	14.6	67.6	109	96	+0.49	-22
06/04	15 45.9	-81 49	0.10	1.07	15.1	55.2	120	68	+0.96	-21
06/09	17 00.3	-75 48	0.13	1.10	15.5	47.5	127	58	-0.88	-20
06/14	17 20.2	-71 26	0.16	1.13	15.9	42.1	132	90	-0.43	-19
06/19	17 29.0	-68 05	0.19	1.16	16.3	38.0	135	128	-0.05	-18
06/24	17 34.1	-65 19	0.23	1.20	16.6	34.9	138	127	+0.09	-17
06/29	17 38.0	-62 53	0.27	1.23	16.9	32.6	139	78	+0.58	-16
07/04	17 41.7	-60 41	0.30	1.26	17.2	31.0	140	37	+0.98	-15
07/09	17 45.4	-58 40	0.34	1.30	17.5	29.9	140	67	-0.85	-15
07/14	17 49.3	-56 46	0.39	1.34	17.8	29.3	140	116	-0.40	-15

(144411) 2004 EW9 (H = 16.6)

Pravec et al. (2004) found a rotation period of 49.94 h, making this NEA another good candidate for a coordinated observing campaign, the period being nearly commensurate with an Earth day. The estimated diameter is 1.42 km.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
04/01	13 44.8	-37 31	0.53	1.46	17.2	23.6	144	119	+0.46	+24
04/06	13 40.9	-39 21	0.48	1.43	16.9	23.2	146	59	+0.93	+23
04/11	13 35.2	-41 14	0.43	1.39	16.6	23.3	147	39	-0.88	+21
04/16	13 27.6	-43 10	0.39	1.35	16.3	24.0	147	89	-0.39	+19
04/21	13 17.5	-45 09	0.35	1.31	16.1	25.6	146	133	-0.04	+17
04/26	13 04.7	-47 09	0.31	1.27	15.8	28.3	143	131	+0.08	+16
05/01	12 48.5	-49 09	0.28	1.23	15.6	31.9	140	85	+0.52	+14
05/06	12 28.2	-51 09	0.24	1.19	15.4	36.7	135	48	+0.97	+12
05/11	12 02.3	-53 07	0.21	1.16	15.2	42.7	129	76	-0.84	+9
05/16	11 28.4	-54 56	0.18	1.12	15.0	49.9	122	113	-0.36	+6
05/21	10 42.7	-56 18	0.16	1.08	14.9	58.7	114	116	-0.03	+2
05/26	09 40.5	-56 30	0.13	1.05	14.8	69.7	103	88	+0.11	-3
05/31	08 20.1	-53 50	0.11	1.02	14.8	83.6	90	74	+0.60	-10

(163348) 2992 NN4 (H = 20.1)

Warner (2017) reported a period of 14.50 h for this 750-m NEA. Middle to late June appears to be the best time for observations.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/05	22 22.9	-19 28	0.03	1.02	15.5	74.1	104	87	+0.99	-55
06/08	20 08.0	-22 25	0.04	1.04	14.6	40.6	138	13	-0.94	-26
06/11	18 28.1	-20 07	0.05	1.06	14.4	15.9	163	49	-0.71	-4
06/14	17 32.2	-17 14	0.06	1.08	14.7	5.7	174	99	-0.43	+9
06/17	17 00.4	-15 08	0.08	1.09	15.5	12.0	167	142	-0.17	+16
06/20	16 40.9	-13 43	0.10	1.11	16.2	18.3	160	172	-0.02	+21
06/23	16 28.3	-12 46	0.12	1.12	16.8	23.2	154	133	+0.03	+24
06/26	16 19.8	-12 07	0.14	1.14	17.3	27.1	149	90	+0.25	+26
06/29	16 14.1	-11 42	0.16	1.15	17.7	30.3	145	47	+0.58	+27
07/02	16 10.3	-11 26	0.18	1.16	18.1	33.0	141	8	+0.88	+28

2016 JT38 (H = 20.2)

The estimated size is 270 m, so it's more likely than not that this NEA has a rotation period *P* > 2.2 h. If you can manage it, this is an excellent chance to get data over a wide range of phase angles and so establish a good set of H-G parameters.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
05/20	16 01.4	-20 21	0.26	1.27	18.1	2.5	177	146	-0.07	+24
05/23	15 58.7	-20 00	0.23	1.24	17.6	0.5	179	176	+0.00	+25
05/26	15 55.3	-19 33	0.20	1.21	17.5	3.5	176	137	+0.11	+25
05/29	15 50.9	-18 56	0.17	1.18	17.3	7.0	172	96	+0.38	+27
06/01	15 45.0	-18 05	0.14	1.15	17.0	11.1	167	52	+0.71	+28
06/04	15 36.7	-16 50	0.12	1.13	16.6	16.0	162	6	+0.96	+31
06/07	15 23.9	-14 50	0.09	1.10	16.2	22.4	156	40	-0.98	+34
06/10	15 01.7	-11 05	0.06	1.07	15.7	31.7	146	87	-0.80	+40
06/13	14 12.8	-02 10	0.04	1.04	15.1	49.5	129	138	-0.52	+55

(441987) 2010 NY65 (H = 21.4)

The rotation period of this 160-m NEA is either 4.98 h or 5.55 h, give or take. The difference is one-half rotation over 24 hours. If the curve is highly symmetrical, it will be easy to run into *rotational aliasing*, which is caused by not knowing the true number of rotation over the span of a data set. Put another way, the wrong solution matches data from a given night to the wrong half of the lightcurve.

Because of the short summer evenings for northern observers, getting a complete rotation every time may not be possible. Here again, a well-coordinated campaign involving well-separated observers would be a big help.

DATE	RA	Dec	ED	SD	V	α	SE	ME	MP	GB
06/26	13 36.0	+38 49	0.03	1.02	16.8	89.2	89	47	+0.25	+75
06/27	14 30.2	+34 03	0.03	1.02	16.7	78.0	100	49	+0.35	+68
06/28	15 06.7	+29 33	0.04	1.03	16.8	69.6	108	48	+0.46	+60
06/29	15 31.9	+25 49	0.04	1.04	16.9	63.5	114	44	+0.58	+54
06/30	15 49.9	+22 48	0.05	1.04	17.1	58.9	119	40	+0.69	+49
07/01	16 03.3	+20 23	0.06	1.05	17.2	55.4	122	37	+0.79	+46
07/02	16 13.6	+18 25	0.06	1.05	17.4	52.7	125	36	+0.88	+43
07/03	16 21.8	+16 48	0.07	1.06	17.6	50.6	126	38	+0.94	+40
07/04	16 28.4	+15 27	0.08	1.07	17.8	48.9	128	43	+0.98	+38
07/05	16 33.9	+14 18	0.08	1.07	17.9	47.6	129	50	+1.00	+37

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IN THIS ISSUE

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

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The deadline for the next issue (47-3) is April 15, 2020. The deadline for issue 47-4 is July 15, 2020.