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COMPOSITE LIGHTCURVES OF THREE MAIN-BELT ASTEROIDS

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We present composite lightcurves of Koronis family asteroids (2092) Sumiana and (2953) Vysheslavia, and serendipitous observations of main-belt asteroid (2705) Wu. The lightcurve of Sumiana was assembled from seven nights of observations and its period and amplitude are 30.523 ± 0.014 h and 0.38 ± 0.04 mag respectively. Our observations of Vysheslavia and Wu are consistent with previously reported periods.

Our research team at the Union College Observatory (UCO) continues its mission to define Koronis family asteroid spin periods (Wilkin et al., 2023; Zora et al., 2024). We work to increase the sample size of objects to enable larger statistical studies (Slivan et al., 2003; Slivan et al., 2023), with a broader goal of studying the impact of solar radiation on spin via the YORP mechanism (Rubincam, 2000).

Observations were planned with the aid of *Koronisfamily.com* (Slivan, 2003). Four telescopes were used through iTelescope.net (T19, T21, T72) and Telescope.Live (CHI-1). Telescope, camera, and filter information are given in Table I. Observation dates and telescopes are given in the legends in the lightcurve figures. We used *AstroImageJ* (Collins et al., 2017) to perform photometry on all images. Corrections for light travel time were applied using ephemerides from the JPL Horizons web app (JPL, 2024).

(2092) Sumiana. No published periods or lightcurves for Sumiana were found in the LCDB (Warner et al., 2009) or in the astrophysical literature. We observed on seven nights with four telescopes over two months in spring of 2024. Exposure times were 240 s except for Apr 14, when they were 300 s, and binning was 2×2. Values for April 14 were averaged in boxes of 4 due to their larger scatter. Despite its lower quality, we retained the photometry from this night because it results in a greater total time span which should increase the precision in the period determination.

Because no single night's lightcurve records a full rotation, we explain in detail how we arrived at our fitted period. For Feb 29, the CHI-1 and T21 observations overlap in time, and the same comparison star was used for photometry. Although the filters used (Sloan *r′* and Cousins *R*) are distinct, their bandpasses mostly overlap, so any systematic effect introduced by not allowing a relative shift in magnitudes between the two observing sessions is assumed to be small. By capturing an adjacent minimum and maximum, we derive an approximate amplitude of 0.34 mag. In context of the discussion by Harris et al. (2014), this amplitude is not quite large enough for a quadruply-periodic lightcurve to be a formal geometric impossibility, but for a realistic asteroid shape a doubly-periodic lightcurve is most likely for Sumiana.

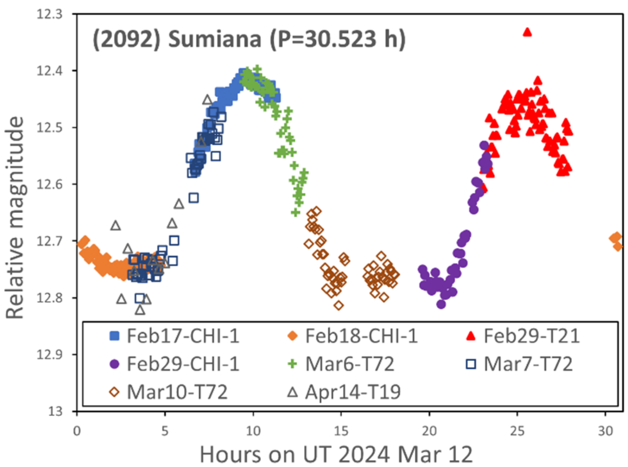
Name	Site	Telescope	Camera	Array	Filter	FOV (′)	Scale (″/pix)
T19	Beryl Junction, UT	0.43-m CDK f/6.8	FLI-16803	4096×4096×9μm	*Red*	43.2×43.2	0.63
T21	Beryl Junction, UT	0.42-m CDK f/4.5	FLI-PL6303E	3072×2048×9μm	*R*	32.8×29.2	0.96
T72	Rio Hurtado, Chile	0.51-m CDK f/6.8	FLI-ML16200	4500×3600×6μm	*R*	26.9×21.5	0.36
CHI-1	Rio Hurtado, Chile	0.61-m RC f/6.8	QHY 600M Pro	9576×6382×3.8μm	*r′*	31.0×20.7	0.39

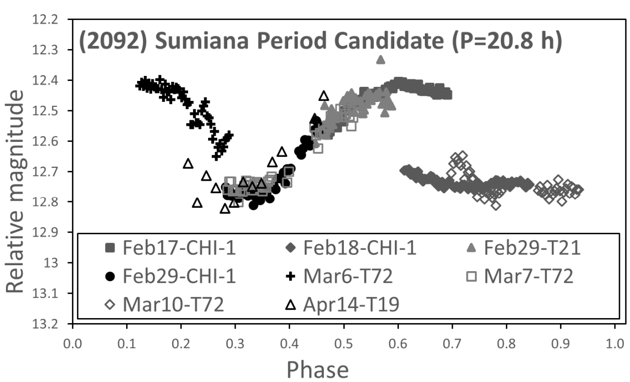
Table I. Telescopes and Cameras. RC=Ritchey-Chretien; CDK=Corrected Dall Kirkham. Filters: *R*: Cousins *R*; *r′*: Sloan *r′*.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
2092	Sumiana	2024 02/17-04/14	1.8,18.5	145	4	30.523	0.014	0.38	0.04	Kor
2705	Wu	2024 03/06-03/10	20.5,19.7	41	3	-	-	-	-	MB
2953	Vysheslavia	2024 02/12-02/13	1.6,2.0	139	-2	6.29	0.02	0.14	0.03	Kor

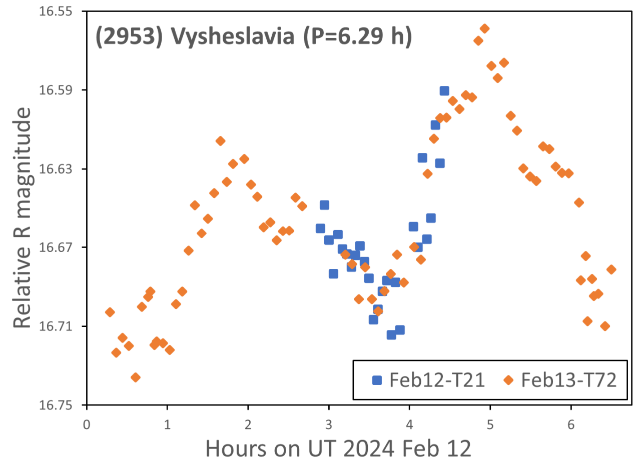
Table II. Observing circumstances and results. The phase angle is given for the first and last dates. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

A lower bound of 18 h was estimated as the period of a relatively symmetric doubly-periodic lightcurve by assuming that the elapsed time between the two extrema observed on Feb 29 corresponds to about one quarter of a rotation. To allow for possible significant asymmetry in the lightcurve, adopting a generous factor of 2 gives an estimated upper bound of 36 h for the period. Starting with these constraints, we use the three maxima from Feb 17, Feb 29 and Mar 6 as reference points to create a list of candidate periods with an integer number of half periods between each pair of maxima. The photometry was folded at each of the resulting period candidates, with relative magnitudes of individual nights shifted to attempt to derive a self-consistent composite. Only one period value resulted in a self-consistent composite, yielding period 30.523 ± 0.014 h, and amplitude 0.38 ± 0.04 mag. We also show an example lightcurve from the derived list folded at candidate period 20.8 h, which came closest to, but still did not achieve, self-consistency.

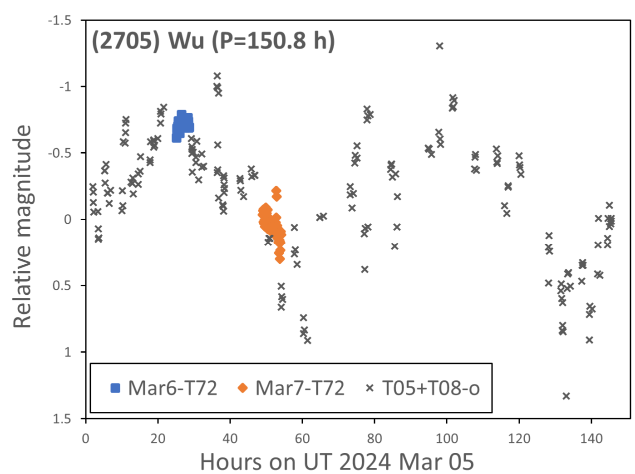




<u>(2953) Vysheslavia</u>. A published period 6.2945 h is given by Vokrouhlický et al. (2006), who provided two spin-axis solutions. Shape models have been published by Vokrouhlický et al. (2006) and Ďurech et al. (2020). We observed Vysheslavia with two telescopes on two consecutive nights in 2024 Feb. Exposure times were 180 s for Feb 12 and 240 s for Feb 13. Both nights used 2×2 binning. The relative magnitude values for the first night were shifted to produce a self-consistent composite, resulting in amplitude 0.14 ± 0.03 mag and period 6.29 ± 0.02 h. The period value is consistent with previous findings.



<u>(2705) Wu</u>. Oey (2010) proposed that this object is a candidate tumbler, and Athanasopoulos (2020) proposed that it is a member of a primordial family, while Athanasopoulos et al., (2022) concluded that it is an interloper. Previously published period values include 150.5 ± 0.5 h (Oey, 2010), 150.8 ± 0.01 h (Ďurech et al., 2020), and 150.78 ± 0.02 h (Athanasopoulos, 2022). Shape models and spin axes based upon sparse-in-time data have been presented (Ďurech et al., 2020; Athanasopoulos, 2022). Our observations were serendipitous in two of our Sumiana fields and used the same telescope and reference star on consecutive nights, for which systematic effects on the relative brightnesses are small enough to neglect for the present discussion. We also accessed sparse-in-time photometry in the *o* filter (orange, 560-820 nm) from telescopes T05 and T08 of the ATLAS project (Tonry et al., 2018). We applied corrections for light time, solar phase angle (G=0.15), and unit distance (JPL, 2024) and plotted the result as a reference to obtain a partial composite lightcurve. The ATLAS data were taken from the same apparition as our observations and limited to span from 2023 Oct to 2024 Apr. Our observations are consistent with the published period values of ~150.8 h.



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LIGHTCURVE ANALYSIS AND ROTATION PERIOD FOR NEA 2006 WB

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Analysis of lightcurve observations of NEA 2006 WB during its closest approach to Earth in 2024 yields a synodic rotation period solution of 8.53 ± 0.29 h. Even though this period is compatible with the value found by the Arecibo telescope in 2006, the data set allowed for many other periods with similar RMS values in the Fourier analysis. Thus the 8.53 h period solution must be considered ambiguous and inconclusive.

2006 WB is a very small near-Earth asteroid. NASA JPL analysis determined that it presents no imminent threat and so is not listed as a potentially hazardous asteroid (PHA). It orbits the sun every 286 days (0.78 years), reaching a minimum perihelion distance of about 0.70 au and aphelion distance of 1.0 au (JPL, 2024). Based on its absolute magnitude of H = 22.8 and depending on the assumed albedo, the diameter of 2006 WB is probably between 0.048 to 0.214 km.

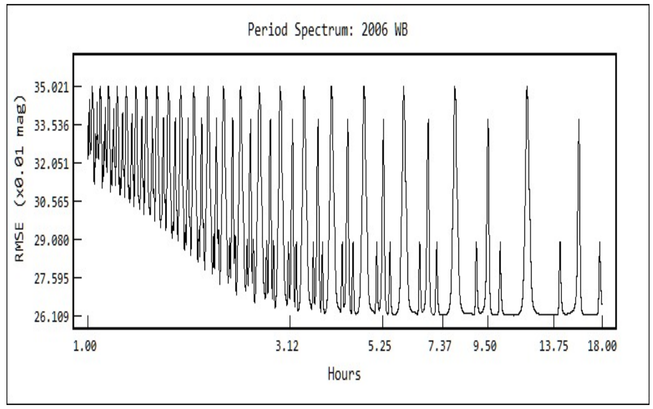
2006 WB was discovered by the Catalina Sky Survey in 2006 November, when it passed about 0.018 au (2.7 million km) from Earth. Radar observations at Arecibo a month later suggested a rotation period of approximately 8 h.

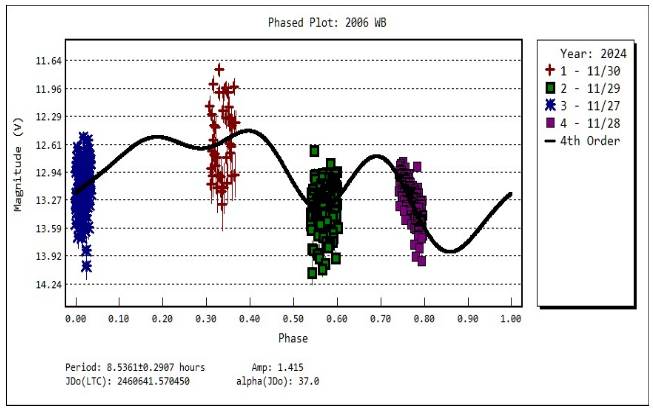
The NEA was observed during its last approach in 2024 November at the OARU Observatory (X33) in Manaus, Brazil. Observations were carried out with a 0.2 m *f*/5 reflecting telescope equipped with an ASI 294 MC Pro camera. No photometric filters were used and exposure times varied from 10 to 30 seconds. On the last night of observations, the asteroid was V > 16 and so the photometric data became more dispersed.

Tycho Tracker Pro (Parrott, 2024) was used to measure the images and do a period search using Fourier analysis. The resulting lightcurve suggests a rotation period of 8.53 ± 0.29 hours with a peak-to-peak amplitude of about 1.41 mag; this would imply a significantly elongated shape or albedo variations on the asteroid's surface. The former is the more likely cause.

While the period found here is close to that found by the Arecibo, it cannot be considered conclusive. In fact, it is highly ambiguous. A look at the period spectrum generated by the Fourier analysis shows numerous other solutions with essentially the same RMS fit, which are likely *rotational aliases*, i.e., periods that are the result of one or more integral half-rotations of the one attributed to the dominant period.

More studies will be necessary to complement and accurately determine the rotation period of this asteroid, whose next closest approach to Earth will not occur until 2039 November.





Acknowledgments

I thank my wife, Andrea Nobre, for accepting my absence during the nights I dedicated to observing this asteroid.

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2006 WB	2024 11/27-11/30	*37.0,80.5	38	7	8.53	0.29	1.41	0.26	NEA

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).

LIGHTCURVE ANALYSIS AND ROTATION PERIOD FOR PHA 2020 XR

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Lightcurve observations of the potentially hazardous asteroid (PHA) 2020 XR during its closest approach to Earth in 2024 yielded a synodic rotation period of 10.70 ± 0.04 h. This result should not be considered secure given a large number of other periods of similar RMS fit found by the Fourier analysis.

2020 XR is a small asteroid whose orbit crosses the orbit of Earth. It has been classified as a potentially hazardous asteroid (PHA) due to its predicted future close passes with Earth. It orbits the sun every 1,440 days (3.94 years), coming as close as 0.97 au and reaching as far as 4.03 au from the Sun (JPL, 2024). Based on its absolute magnitude (H = 19.9) and depending on the albedo, the estimated diameter is between 0.28 and 0.62 km.

Observations were made at the OARU Observatory (X33) in Manaus, Brazil, from 2024 Dec 2-11, which was during the asteroid's most recent close approach. A 0.2-m *f*/5 reflecting telescope equipped with an ASI 294 MC Pro camera was used for the unfiltered observations. Exposure times varied from 10-30 s. All the observations were made with 2×2 binning, which gave a plate scale of 1.91 arcsec/pixel.

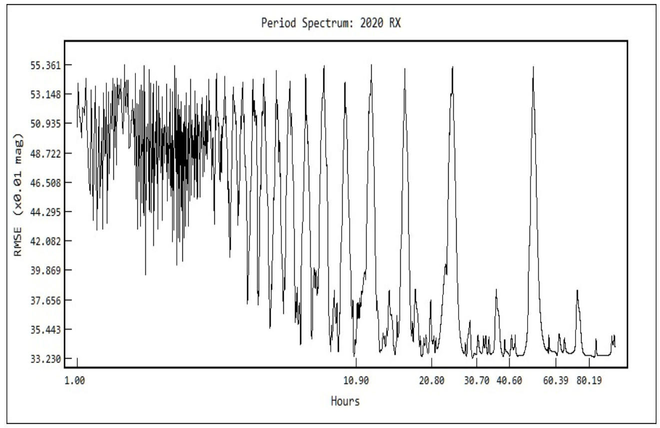
Data reduction and period analysis were performed with *Tycho Tracker Pro* v11.7.8 (Parrott, 2024). The asteroid and seven comparison stars were measured for differential photometry. The comparison stars were selected with color indices within the range of 0.5 < B-V < 0.95, aligning with the typical color range of asteroids.

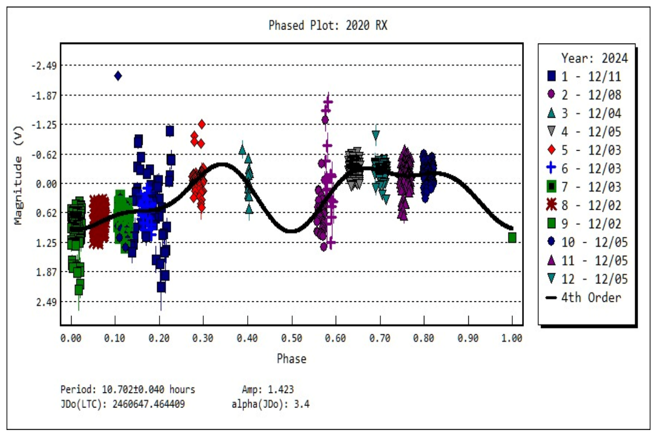
The lightcurve suggests a rotation period of 10.70 ± 0.04 h. The amplitude is about 1.42 mag, which is most likely the result of a significantly elongated shape. This is a relatively short period, but it is compatible with the vast majority of asteroids in the asteroid's size range (Warner et al., 2009).

A look at the period spectrum generated by the Fourier analysis shows that the period 10.70 h is far from secure. Numerous other solutions with nearly the same RMS fit are also present. These represent *rotational aliases*, i.e., periods that correspond to integral half-rotations of the one associated with the adopted period.

The asteroid lightcurve database (LCDB; Warner et al., 2009) listed no previously reported periods. In addition, no other lightcurve data for this object was found in the Asteroid Lightcurve Data Exchange Format (ALCDEF) database (*https://alcdef.org*) or in the *Minor Planet Bulletin*.

More studies will be necessary to complement and accurately determine the rotation period of this asteroid, whose next closest approach to Earth will occur in 2028 November.





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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2020 XR	2024 12/02-12/11	*3.4,9.2	257	-1	10.70	0.04	1.42	0.33	PHA

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).

LIGHTCURVE AND ROTATION PERIOD OF 2266 TCHAIKOVSKY

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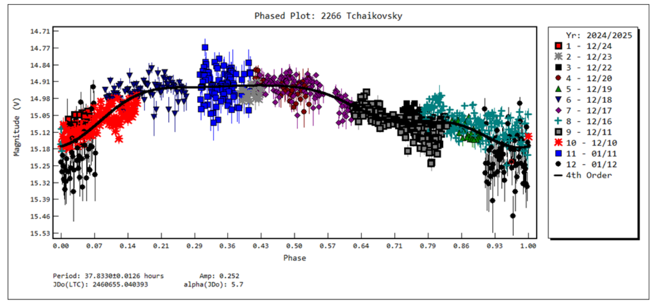
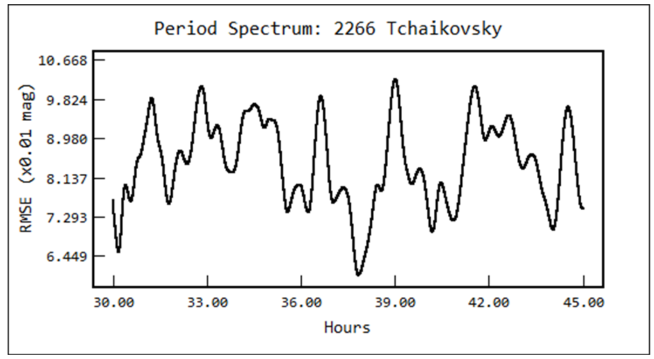
Twelve sets of photometric observations of the main-belt asteroid 2266 Tchaikovsky were obtained from 2024 December 10th to 2025 January 12th. Using *Tycho Tracker* software, we plotted the lightcurve of 2266 Tchaikovsky and measured its rotation period to be 37.8330 ± 0.0126 h with a lightcurve amplitude of 0.252 mag., in agreement with its tabulated value.

All observations of 2266 Tchaikovsky reported here were performed at the Luyi Wang Observatory, Sichuan, China, using a 0.28m reflector operating at *f*/2.2 and equipped with QHY268C CCD. No filters used for better signal-to-noise. 974 observations were taken in 12 nights and exposure times for these observations contain 120, 180, and 300 seconds. The camera was binned at 2×2 pixels. The image scale after 2×2 binning was 2.50 arcsec/pixel and the field of view 130.1' × 86.9'.

Tycho Tracker was used for the data analysis and measurement. Calibration frames were applied and the images aligned prior to measuring. The V magnitudes from APASS DR-9 catalog were used for the comparison stars.

2266 Tchaikovsky is a main-belt asteroid, discovered at Nauchnyj on 1974-11-12 by L.I. Chernykh. According to the asteroid lightcurve database (LCDB; Warner et al., 2009), the mean absolute magnitude is H = 10.89 and with phase slope parameter G = 0.12. We used these values in our analysis. A fourth-order Fourier lightcurve was fit to P = 37.8330 ± 0.0126 h with an amplitude A = 0.252 ± 0.058 mag for a light-time corrected zero-point of JD = 2460655.04. These results agree with the value reported by Warner (2011); however, we consider there remains a possibility of P = 75.9h, which needs more observations to confirm.





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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.
2266	Tchaikovsky	2024 12/10-2025 01/12	5.7,16.3	67	5	37.8330	0.0126	0.2519	0.0580

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).

LIGHTCURVE AND ROTATION PERIOD OF THE SLOW ROTATOR 6176 HORRIGAN

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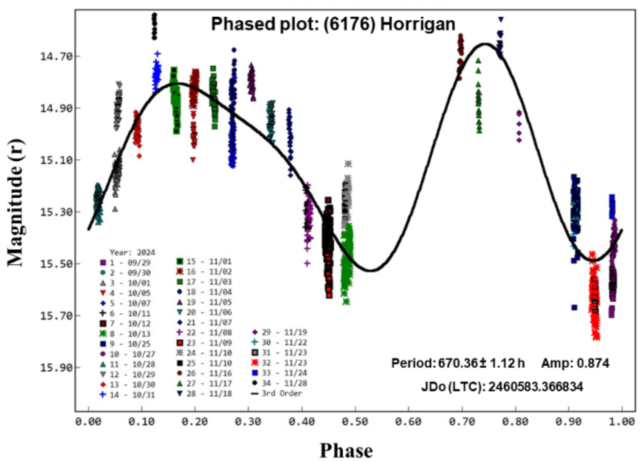
Based on preliminary lightcurve measurements of 6176 Horrigan in September 2024, a long period seemed evident. Consequently, an additional two months of observations were devoted to this object. Analysis of the additional collected data has produced a lightcurve with a period of 670.36 ± 1.12 hours and an amplitude of 0.874 magnitudes.

6176 Horrigan is a main-belt asteroid discovered 1985 January 16 by Z. Vavrova at Klet. It has a semi-major axis of 2.252 AU, orbital period of 3.381 years, eccentricity of 0.154 and inclination of 5.663 deg. (JPL, 2024). This 5.62 km asteroid has an absolute magnitude of 13.49 and a geometric albedo of 0.321. No previous rotation period and lightcurve were reported for this object at the best of our knowledge. Observations were conducted by using a 0.30-m Newtonian telescope at f/4, equipped with a Moravian KAF 1603 ME CCD camera (1536×1024 array of 9.0-micron pixels) unfiltered (Elianto II Observatory) and a 0.50-m Ritchey-Chretien telescope operating at f/8, using a FLI-PL4240 CCD camera (2048×2048 array of 13.5-micron pixels) unfiltered (OASDG, Agerola, Naples, L07). A total of 1368 lightcurve data points were collected in 34 observing sessions from 2024 September 29 to 2024 November 28 with exposing times ranging from 180 s through 360 s. Photometry and period determination were carried out with *TychoTracker Pro* Version 11.8 (Parrott, 2024). Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into Tycho. A measuring aperture equal to 4× FWHM of the target was used for asteroids and comp stars. Interference from field stars resulted in the exclusion of affected observations.

From the collected data we show that this asteroid belongs to the category of objects with a slow rotation. A period of 670.36 ± 1.12h was computed with an amplitude of 0.874 ± 0.120 mag.



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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period (h)	P.E.	Amp	A.E.	Grp
6176	Horrigan	2024 09/29-11/28	6.1,25.6	16	-7	670.36	1.12	0.87	0.12	MB

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

THE AMBIGUOUS ROTATION PERIOD OF 1269 ROLLANDIA IS SOLVED BY A GLOBAL COLLABORATION OF OBSERVERS

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A global collaboration of photometric observers has found for 1269 rotational parameters: synodic period 59.70 ± 0.01 hours with an unsymmetric bimodal lightcurve and amplitude 0.09 ± 0.01 hours.

Many authors have published rotation periods for the Hilda-type asteroid 1269 Rollandia, all of them different results. These include Behrend (2019web), 72 hours; Colazo et al. (2021), 39.81 hours; Fauvaud and Fauvaud, 15.32 hours; Polakis (2019), 28.272 hours; Polakis (2020), 60.45 hours; Slyusarev et al. (2012), 30.98 hours revised in Slyusarev et al. (2013) to >36 hours. Warner et al. (2017), 19.98 hours. Warner et al. (2019) published eight lightcurves with ambiguous periods between 13 and 32 hours that provided fits to their observations in 2016 and 2019. Romanishin (2021) obtained 8-hour sessions on consecutive nights in 2013 May, using the 0.9m SMARTS telescope at Cerro Tololo Observatory in Chile. His observations provide a fit to a suggested 65-hour period lightcurve but with only 30% phase coverage. They also show that his two sessions rule out many of the published smaller periods.

The three authors of this paper, from their respective observatories in North America, Europe, and Australia obtained 31 sessions between 2024 Sept. 5 and Nov. 19 that provide full phase coverage to an unsymmetrical bimodal lightcurve with period 59.70 ± 0.01 hours and amplitude 0.09 ± 0.01 magnitudes. This lightcurve has a period fairly close to that found by Polakis (2020) and improves upon it with a far greater density of points, a much longer interval of observation, and observations from widely spaced longitudes. All of the other previously published rotation periods are now ruled out.

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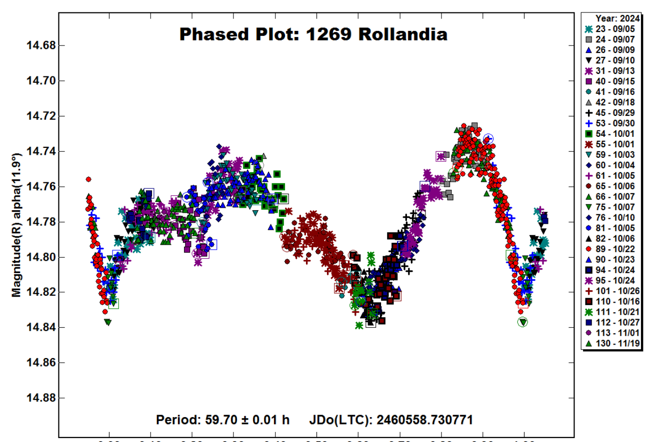

Number	Name	yyyy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
1269	Rollandia	2024/09/05-11/19	*11.9, 6.4	35	-3	59.70	0.01	0.09	0.01

Table I. Observing circumstances and results. The phase angle is given for the first and last date, where the * indicates a minimum was reached between these dates. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).

LIGHTCURVE AND ROTATION PERIOD OF 1237 GENEVIEVE

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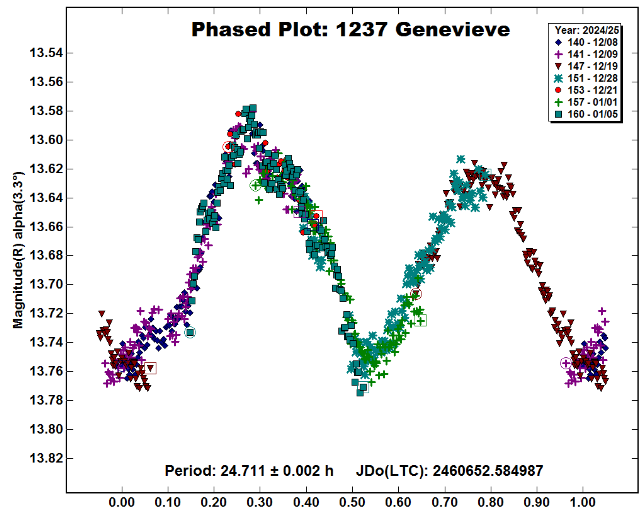
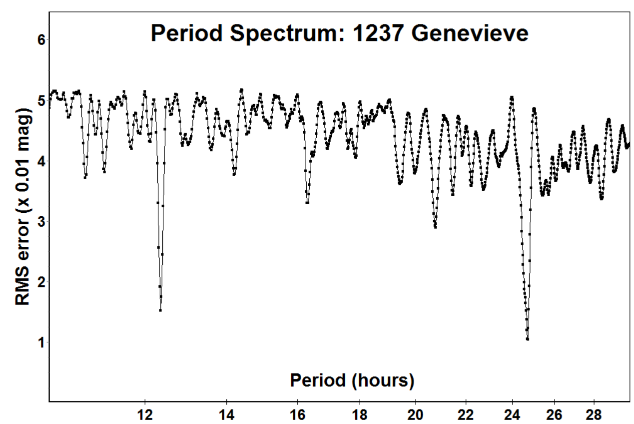
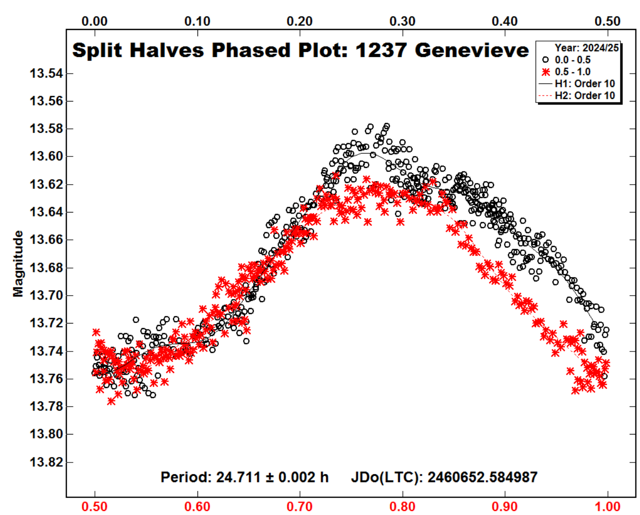
A collaboration of observers from Europe and North America have found for 1237 Genevieve a synodic rotation period of 24.711 ± 0.002 hours and amplitude 0.14 ± 0.01 magnitudes.

The new observations by Pilcher 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, 60 second exposures. Observations by Marchini and Papini were made at the Astronomical Observatory of the University of Siena (Italy) with a 30 cm f/5.6 MCT, SBIG STL-6303E CCD, 300 second exposures. Image measurement and lightcurve construction were with *MPO Canopus* software with calibration star magnitudes for solar colored stars from the CMC15 catalog reduced to the Cousins R band. Zero-point adjustments of a few × 0.01 magnitude were made for best fit. To reduce the number of data points on the lightcurve and make it easier to read, data points have been binned in sets of 3 with maximum time difference 5 minutes.

1237 Genevieve. Previously published rotation periods for 1237 show conflicting values. These include Binzel (1987), 16.37 hours; Behrend (2005web), 24.82 hours; Polakis (2018), 16.48 hours; Polakis (2022), 16.31 hours; Dose (2023), 12.346 hours; Colazo et al. (2024), 24.71 hours; amplitudes from 0.11 to 0.26 magnitudes. These periods are approximately 1/2, 2/3, and 1/1 of 24.7 hours, respectively. New observations were continued for seven nights 2024 Dec. 8 to 2025 Jan. 5 to enable corresponding maxima near phase 0.3, as observed on December 8, 9 and on January 5, respectively, to be aligned. These data provide a good fit to a period of 24.711 ± 0.002 hours, amplitude 0.14 ± 0.01 magnitudes, with a slightly asymmetric bimodal lightcurve. A split halves plot of the 24.711-hour period shows that the two halves are distinct and rules out a period near 12.34 hours. A period spectrum between 10 hours and 30 hours shows that a period near 16.4 hours can also be ruled out. Therefore, we claim that our 24.711-hour synodic period is both reliable and accurate. This result is consistent with Behrend (2005web) and Colazo et al. (2024). All other reported periods are now rejected.







Number	Name	yyyy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
1237	Genevieve	2024/12/08-2025/01/05	* 3.3 - 10.8	81	5	24.711	0.002	0.14	0.01

Table I. Observing circumstances and results. 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).

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LIGHTCURVES AND ROTATION PERIODS OF 691 LEHIGH, 795 FINI, AND 1302 WERRA

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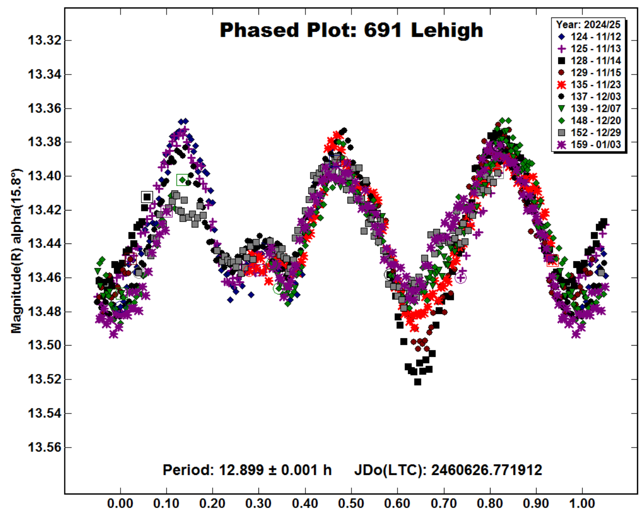
Synodic rotation periods and amplitudes are found for 691 Lehigh 12.899 ± 0.001 hours, 0.13 ± 0.02 magnitudes with an irregular trimodal lightcurve; 795 Fini 51.71 ± 0.01 hours, 0.06 ± 0.01 magnitudes.; and 1302 Werra 13.957 ± 0.002 hours, 0.15 ± 0.02 magnitudes with an irregular trimodal lightcurve.

The new 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, 60 second exposures, unguided, clear filter. Image measurement and lightcurve construction were with *MPO Canopus* software with calibration star magnitudes for solar colored stars from the CMC15 catalog reduced to the Cousins R band. Zero-point adjustments of a few × 0.01 magnitude were made for best fit. 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.

691 Lehigh. Previously reported periods are by Stephens (2000), 5.08 hours; Behrend (2005web), 12.88 hours; Menke (2005), 10.482 hours; Behrend (2009web), 12.86 hours; Warner (2009), 12.891 hours; Behrend (2011web), 12.88 hours; and Pál et al. (2020), 12.9023 hours; with amplitudes ranging from 0.09 to 0.16 magnitudes. New observations on ten nights 2024 Nov. 12 - 2025 Jan. 3 provide a good fit to a lightcurve with period 12.899 ± 0.001 hours, amplitude 0.13 ± 0.02 magnitudes with three unsymmetrical maxima and minima per rotational cycle. The amplitudes of the several extrema, but not their phases in the lightcurve, varied considerably through the range of phase angles from 15.8° to a minimum of 1.8° and then back to 4.4° encountered in these sessions. The 12.899-hour period found in this study is very close to five of the seven previously reported periods. Periods near 5.08 and 10.482 hours are now ruled out.

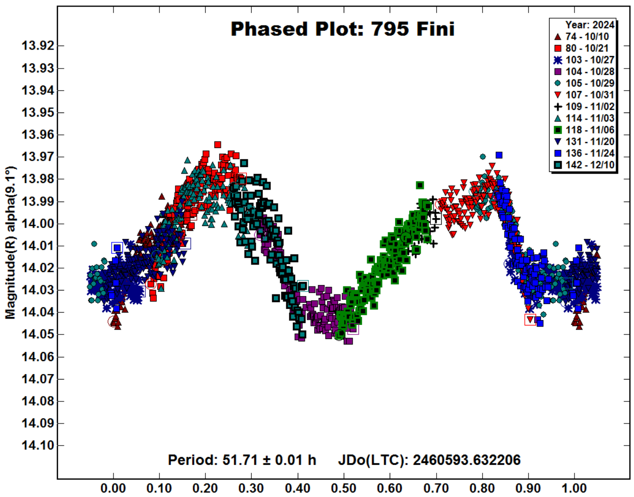


795 Fini. Seven previously published lightcurves of this asteroid all have different periods and low amplitudes from 0.02 to 0.11 magnitudes. The earliest results were by Warner (2003), 8.641 hours from observations in 2003 January - March, revised in Warner (2011) to 9.292 hours when remeasured with improved calibrations. A period of 7.59 hours based on additional observations made in 2010 October - November was also reported by Warner (2011). Other periods were published by Pravec et al. (2012web), 4.65 hours; Waszczak et al. (2015), 26.971 hours; Polakis (2022), 51.4 hours; and Colazo et al. (2023), 30.526 hours.

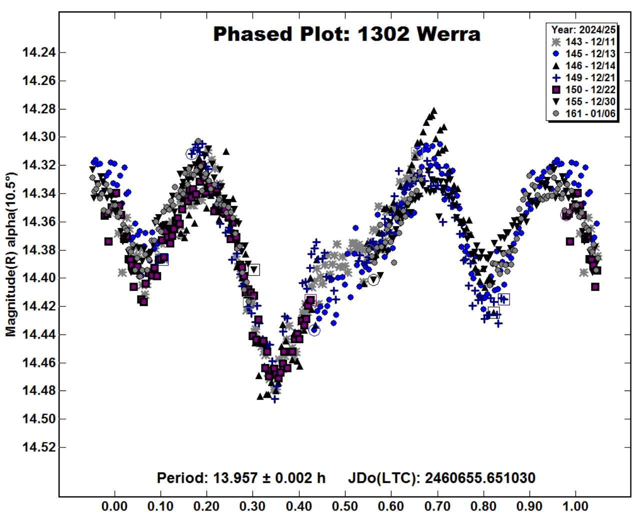
New observations on 12 nights 2024 Oct. 10 - Dec. 10 obtained a data set far more dense than any previously published. A good fit is provided to a lightcurve with period 51.71 ± 0.01 hours, amplitude 0.06 ± 0.01 magnitudes with two unsymmetrical maxima and minima per rotational cycle. This new result is consistent with and improves upon Polakis (2022) and rules out all other previously published values.

Number	Name	yyyy/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E	Amp	A.E.
691	Lehigh	2024/11/12-2025/01/03	*15.8 - 4.4	92	1	12.899	0.001	0.13	0.02
795	Fini	2024/10/10-2024/12/10	*5.6 - 13.9	40	7	51.71	0.01	0.06	0.01
1302	Werra	2024/12/11-2025/01/06	10.5 - 1.2	103	1	13.957	0.002	0.15	0.02

Table I. Observing circumstances and results. 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).



1302 Werra. Previously reported periods are by Behrend (2009web), 8.19 hours; Polakis and Skiff (2019), 14.013 hours; Behrend (2020web), 8.185 hours; and Polakis (2020), 13.94 hours. New observations on seven nights 2024 Dec. 11 - Jan. 6 provide a good fit to an irregular trimodal lightcurve with period 13.957 ± 0.002 hours, amplitude 0.15 ± 0.02 magnitudes. This result is compatible with Polakis and Skiff (2019) and Polakis (2020). Periods near 8.19 hours are now definitively ruled out.



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PHOTOMETRIC OBSERVATIONS AND ANALYSIS OF SIX MAIN-BELT ASTEROIDS

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We report the results of our photometric observations and lightcurve analysis of six main-belt asteroids: 3423 Slouka, 4367 Meech, (7878) 1992 DZ, 9628 Sendaiotsuna, (14127) 1998 QA91, and 17851 Kaler. The asteroids were observed by a network of four observatories located in Malta and Slovakia.

We conducted photometric observations of six main-belt asteroids from observatories located in Malta (3) and Slovakia (1). Through these observatories listed in Table I, we have observed 3423 Slouka, 4367 Meech, (7878) 1992 DZ, 9628 Sendaiotsuna, (14127) 1998 QA91, and 17851 Kaler. We employed a clear filter (unfiltered observations) with SR (Sloan r) zero point for all other images and calibrated all of our images using dark and flat-field subtraction frames.

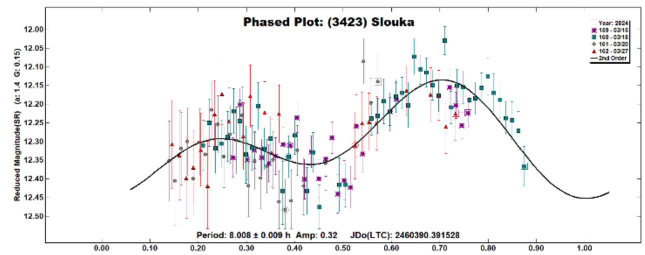
Observatory/ Country	Scope	Camera	Observed
Flarestar Obs. (MPC: 171) MALTA	0.25-m SCT	Moravian G2-1600	14127 (5) 7878 (3)
Luckystar Obs. (MPC: M55) SLOVAKIA	0.25-m SCT	Atik 460EX	4367 (6) 9628 (6)
Manikata Obs. MALTA	0.20-m SCT	SBIG ST-10	17851 (4)
Znith Astronomy Obs. MALTA	0.20-m SCT	Moravian G2-1600	3423 (4)

Table I. Instrumentation and observation runs. SCT: Schmidt-Cassegrain Telescope. The number in parentheses is the number of nights observed.

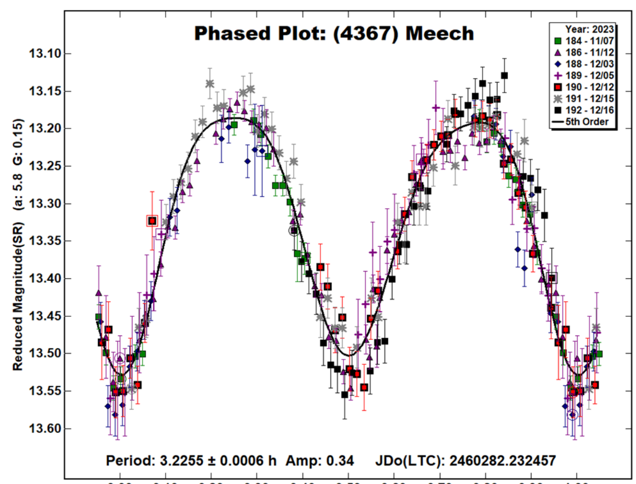
We remotely-controlled all of our equipment over the Internet or from a nearby location for each telescope. We used *Sequence Generator Pro* software (Binary Star Software) for image acquisition at the Maltese observatories. Luckystar Observatory, situated in Slovakia, used the *NINA* image acquisition software (Berg, 2023). We used *MPO Canopus* software version 10 (Warner, 2017) for our image analysis, to obtain differential aperture photometry, and to construct lightcurves. Table I gives the details of the instrumentation and number of observation nights for each target. We selected near-solar color comparison stars using the Comparison Star Selector (CSS) feature of *MPO Canopus*. We based all brightness measurements on the Asteroid Terrestrial-impact Last Alert System (ATLAS) catalogue (Tonry et al., 2018).

3423 Slouka is a main-belt asteroid that was discovered on 1981 February 9 by Czech astronomer L. Brozek at Klet observatory. This body has estimated diameter of 16.58 km based on an absolute magnitude of H = 12.63. The orbital semi-major axis is 3.051 au, the eccentricity is 0.11, and period is 5.33 yr (JPL, 2024).

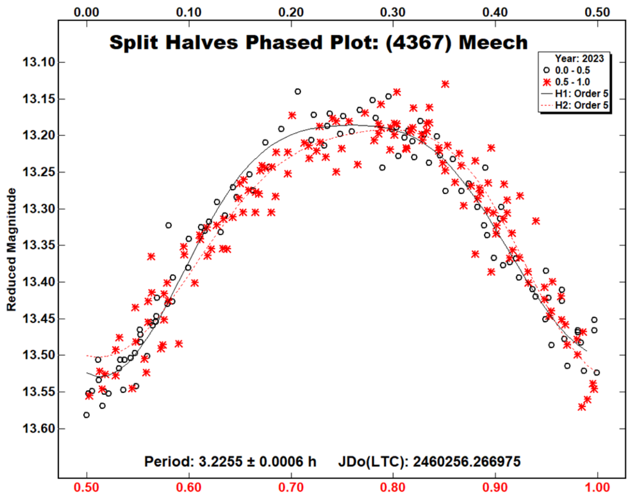
The asteroid was observed from Znith observatory on four nights between 2024 March 16-27. Based on these observations, the synodic period was determined to be 8.008 ± 0.009 h., with an amplitude of 0.32 ± 0.09 mag. It is worth noting that the LCDB database (Warner et al., 2009) does not currently show any published period for this target.

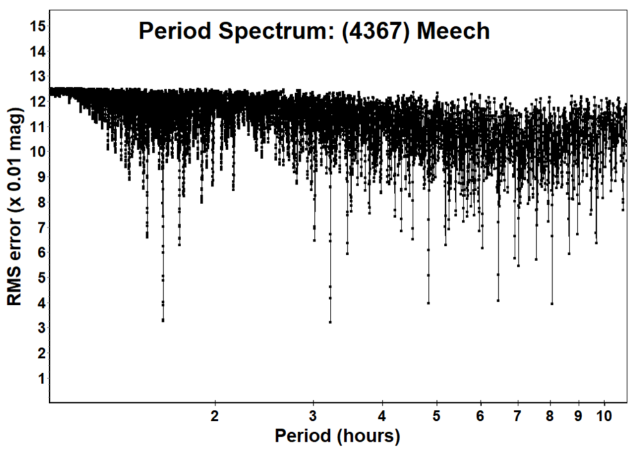


4367 Meech is a main-belt asteroid discovered at Siding Spring observatory by J.S. Bus on 1981 March 2; it is named in honor of Dr. Karen J. Meech, astrobiologist and astronomer, who is a specialist in planetary astronomy. The absolute magnitude is H = 12.85 mag, which gives D ~ 14.98 km. It orbits the sun with a semi-major axis of 2.879 au and an eccentricity is 0.23 (JPL, 2024).

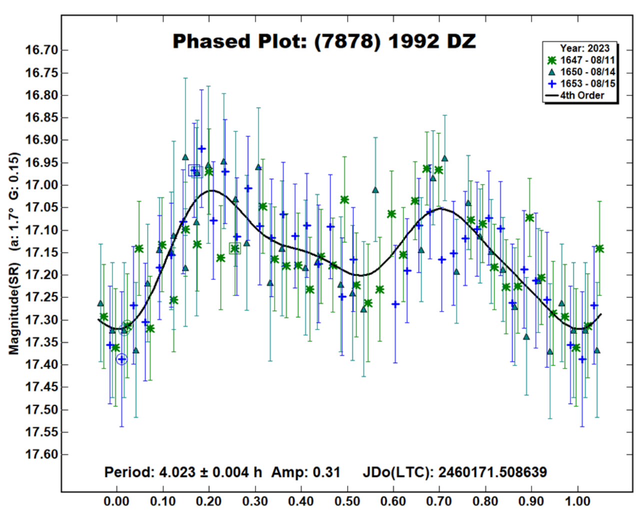


The asteroid was observed on six nights by Luckystar Observatory from 2023 November 7 to December 16. Analysis of the data shows P = 3.2255 ± 0.0006 h, with an amplitude of 0.34 ± 0.04 mag. The LCDB database does not currently show any published period for Meech. Our analysis of the lightcurve shows standard bimodal solution as the most probable (based on the lowest RMS value), but this solution shows very similar shape of both halves. The half-period of 1.613 h was considered, based on the split-halves diagram and very similar RMS values (RMS = 3.2061 for bimodal and RMS = 3.2740 for monomodal solution). Considering minor differences in the shape of both halves and the fact that the monomodal solution led to result of C-type asteroid of 15 km diameter rotating beyond the spin barrier, the bimodal solution appears more plausible.





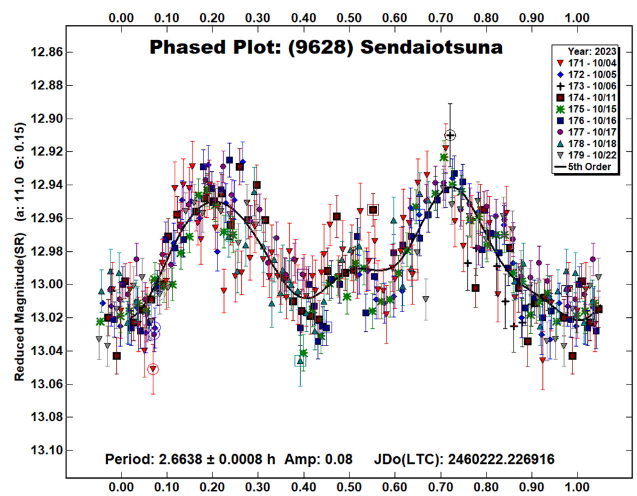
(7878) 1992 DZ is a main-belt asteroid discovered by N. Kawasato at Uenohara on 1992 February 27. The estimated diameter is 5.853 ± 0.230 km (H = 13.42 mag). The orbit has semi-major axis of 2.621 au, eccentricity of 0.098, and period of 4.24 yr.



Flarestar Observatory observed this target on three nights from 2023 August 11-15. Our results show a synodic period of 4.023 ± 0.004 h with an amplitude of 0.31 ± 0.2 mag. It´s worth noting that the significantly higher RMS of observations were caused by the low brightness of the target (V ~ 17.1-17.3), which was at the limit of the equipment capabilities. Due to the fact that the LCDB database does not show any published period, we consider our results as a good starting point for further analysis of this target.

9628 Sendaiotsuna is a main-belt asteroid discovered by E.F. Helin at Palomar on 1993 July 16. It has an estimated diameter of 8.884 ± 0.152 km based on an absolute magnitude of H = 12.40 mag. It orbits the sun with a semi-major axis of 2.609 au, eccentricity of 0.203, and period of 4.21 yr. The asteroid is named after the Sendai Otsunahiki, which is a 400-year-old tug-of-war festival held in Satsumasendai City in the evening of the day before the autumnal equinox.

Luckystar Observatory observed the asteroid on six nights from 2023 October 4-22. Our results show a synodic period of 2.6638 ± 0.0008 h with an amplitude of 0.08 ± 0.01 mag. These are consistent with the previously published period by Dose (2024; 2.664 ± 0.001 h), Marcini and Papini (2024; 2.664 ± 0.001 h), and (Farfan et al., 2024; 2.674 ± 0.009 h).

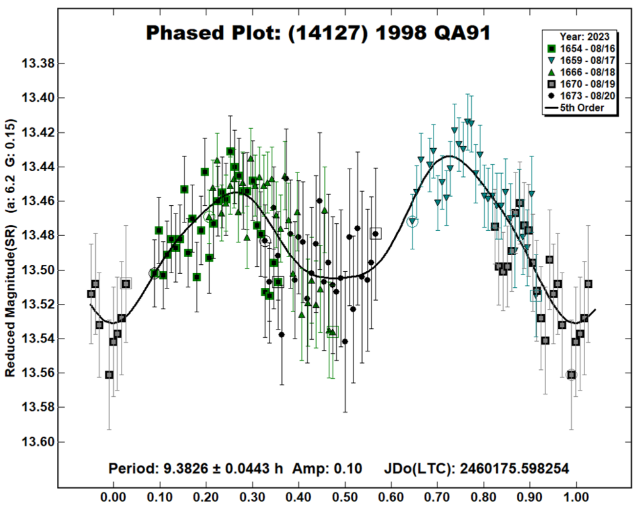


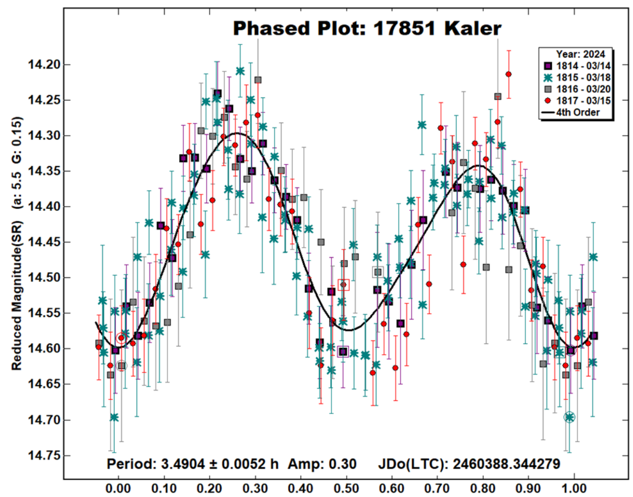
(14127) 1998 QA91 is a main-belt asteroid discovered by LINEAR at Socorro on 1998 August 28. It has estimated diameter of 6.076 ± 0.127 km based on H = 13.09 mag and orbits the sun with a semi-major axis of 2.604 au, eccentricity of 0.200, and period of 4.20 yr (JPL, 2024).

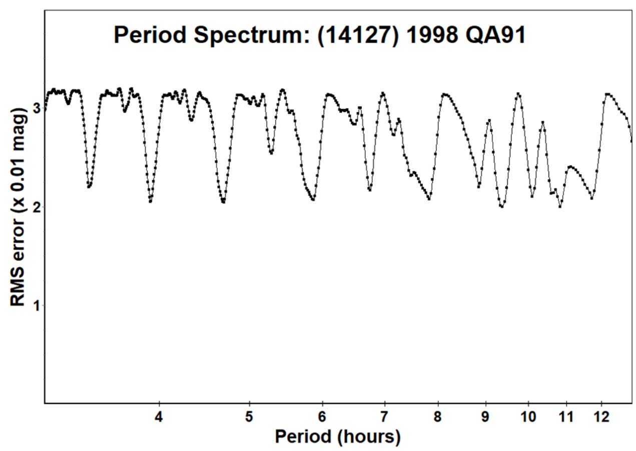
1998 QA91 was observed on five nights from Flarestar Observatory from 2023 August 16-20. Our data produced a rotation period of 9.3826 ± 0.0443 h with an amplitude of 0.08 ± 0.02 mag. The limited amount of data for this target resulted into several potential solutions with nearly the same RMS value. The adopted binodal solution is likely correct, but further observations will be needed to confirm this result since the LCDB database does not show any previously published period.

Number	Name	yyyy mm/dd	Phase	LPAB	BPAB	Period(h)	P.E.	Amp	A.E.	Grp
3423	Slouka	2024 03/15-03/27	0.9,6.1	172	0	8.008	0.009	0.32	0.09	MB
4367	Meech	2023 11/07-12/16	5.5,20.2	41	10	3.2255	0.0006	0.34	0.04	MB
7878	1992 DZ	2023 08/11-08/15	1.4,2.9	315	2	4.023	0.004	0.31	0.20	Eunomia
9628	Sendaiotsuna	2023 10/04-10/22	11.1,12.1	161	7	2.6638	0.0008	0.08	0.01	Eunomia
14127	1998 QA91	2023 08/16-08/20	6.6,4.8	331	6	9.3826	0.0443	0.08	0.02	Eunomia
17851	Kaler	2024 03/14-03/20	6.0,3.3	182	4	3.4904	0.0009	0.30	0.06	Hertha

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







(17851) Kaler is a main-belt asteroid discovered by the Near-Earth Asteroid Tracking program (NEAT) at Haleakala on 1998 May 1. It has an estimated diameter of 4.911 ± 0.198 km (H = 13.88). It orbits the sun with semi-major axis of 2.398 au, an eccentricity of 0.146, and period of 3.71 yr (JPL, 2024). This asteroid is named after James B. Kaler, a professor at the University of Illinois from 1976 to 2003, who is known for his spectroscopic research on planetary nebulae.

Manikata Observatory observed the asteroid on four nights from 2024 March 14-20. Our analysis yielded a synodic period of 3.4904 ± 0.0009 h with an amplitude of 0.30 ± 0.06 mag. These results are consistent with previously published period of P = 3.492 ± 0.002 h by Benishek (2024).

Acknowledgements

We would like to thank Brian Warner for his work in the development of *MPO Canopus* and for his efforts in maintaining the CALL website (Warner, 2016; 2021). This research has made use of the JPL's Small-Body Database (JPL, 2024).

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PHOTOMETRIC OBSERVATIONS AND LIGHTCURVE ANALYSIS OF (25450) 1999 XQ7

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(Received: 2025 January 14)

In this paper we report the results of our photometric observation campaign and lightcurve analysis of an asteroid (25450) 1999 XQ7 during its favorable opposition in 2024.

(25450) 1999 XQ7 is an inner main-belt asteroid with no record of a synodic period in LCDB database (Warner et al., 2009). The CALL webpage (Warner, 2016) listed this asteroid as a potential target for photometric observation due to the favorable opposition on 2024 November 7 and relatively high brightness of V ~ 15.6.

Photometric observations were carried out from three observatories located in Slovakia, Malta and Canada. A total of 23 sessions were obtained from 2024 November 1 to December 14, totaling 688 individual observations. Table I provides the complete equipment list and the observer's total runs. Initial sessions were all-night observations (approximately 9 hours) and then they were adapted to batch observations plan of approximately one hour duration. Exposure times varied from 180 s (Luckystar Observatory) to 240/300 s (Flarestar and A la belle étoile Observatory).

All images were taken through a clear filter (unfiltered) with an SR (SLOAN r´) bandpass zero point and were calibrated using dark and flat-field master frames subtraction. All brightness measurements were based on the Asteroid Terrestrial-impact Last Alert System (ATLAS) catalogue (Tonry et al., 2018).

We remotely-controlled all our equipment over the Internet or from a nearby location for each telescope. *NINA* software (Berg, 2023) was used for image acquisition by A la belle étoile and Luckystar Observatories. Flarestar Observatory used *Sequence Generator Pro* software (Binary Star Software). We used *MPO Canopus* software versions 10 and 12 (Warner, 2017) for our image analysis, to obtain differential aperture photometry, and to create the final lightcurve. We selected near-solar color comparison stars ($0.5 \leq B\text{-}V \leq 0.9$) using the Comparison Star Selector (CSS) feature of *MPO Canopus*.

We estimate the synodic rotation period of (25450) 1999 XQ7 to be 299.68 ± 0.37 h, with an amplitude of 0.92 ± 0.05 mag. The suggested, and most probable solution, has the lowest RMS value. Another solution, proposed by Fourier algorithm, has a very similar RMS value close to a double-period length (719 h). Based on the fact that asteroids with amplitudes greater than 0.2 magnitudes typically exhibit a bimodal solution, we preferred the solution with nearly 300-hour period.

Number	Name	Family	H	Dkm	a (au)	e	i (deg)	P(yrs)	Discovered by	yyyy/mm
25450	1999 XQ7	9104	14.39	3.94	2.35	0.228	5.87	3.61	C.W. Juels	1999/12

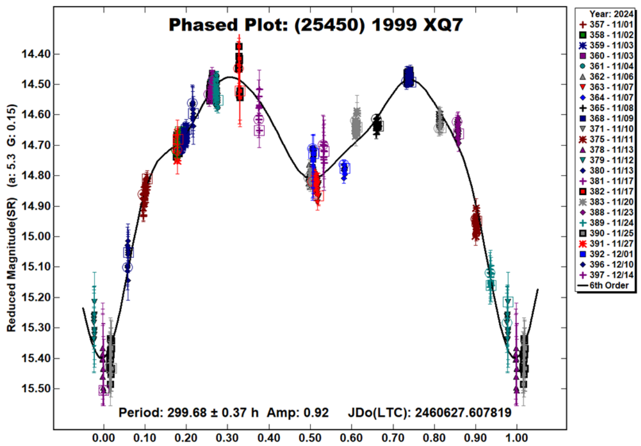
Table II. Orbital and discovery information. Fam is the group or family using the LCDB values. An asterisk indicates a generic group, otherwise, the numbers are from Nesvorny et al. (2015). Web Sources: JPL: *https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/* MPInfo: *https://minorplanet.info/php/oneasteroidinfo.php*

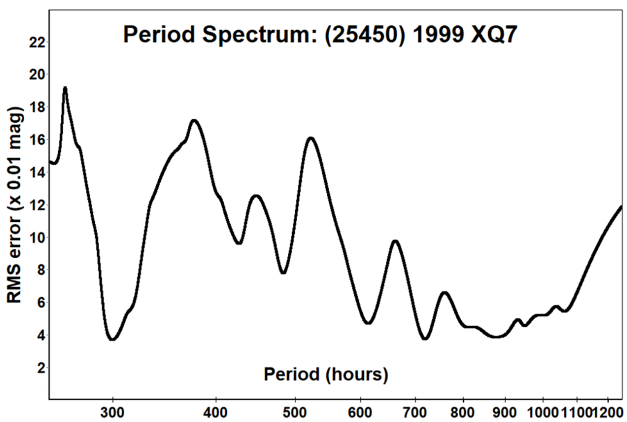
Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
25450	1999 XQ7	2024 11/01-12/14	5.3,21.2	47	6	299.68	0.37	0.92	0.05	MBI

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

Observatory/ Country	Scope	Camera	Obs. Runs
A la belle étoile Obs. CANADA	0.2-m MK	Moravian G2-1600	2
Flarestar Obs. (MPC: 171) MALTA	0.25-m SCT	Moravian G2-1600	8
Luckystar Obs. (MPC: M55)/ SLOVAKIA	0.25-m SCT	Atik 460EX	13

Table I. Instrumentation and Observation Runs. SCT: Schmidt-Cassegrain Telescope, MK: Maksutov-Cassegrain.





Acknowledgements

We would like to thank Brian Warner for his work in the development of *MPO Canopus* and for his efforts in maintaining the CALL website (Warner, 2016; 2021). This research made use of the JPL's Small-Body Database (JPL, 2024).

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PHOTOMETRIC OBSERVATIONS OF ASTEROIDS 1626 SADEYA, 5552 STUDNICKA AND 5565 UKYOUNODAIBU

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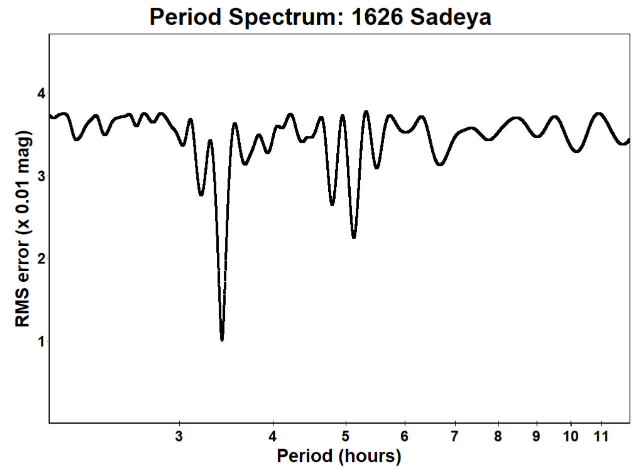
Photometric observations of three main-belt asteroids were conducted to determine their synodic rotation periods. We found: for 1626 Sadeya, $P = 3.421 \pm 0.002$ h with $A = 0.11 \pm 0.01$ mag; for 5552 Studnicka, $P = 5.912 \pm 0.001$ h with $A = 0.12 \pm 0.02$ mag; for 5565 Ukyounodaibu, $P = 5.752 \pm 0.001$ h with $A = 0.20 \pm 0.03$ mag.

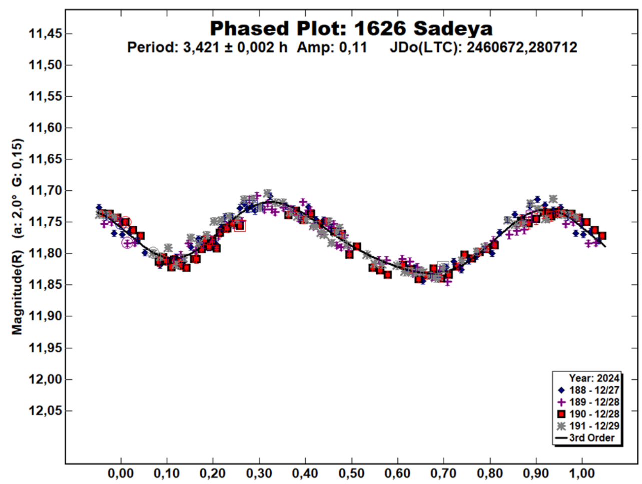
CCD photometric observations of three main-belt asteroids were carried out in November-December 2024 at the Astronomical Observatory of the University of Siena (K54). We used a 0.30-m *f*/5.6 Maksutov-Cassegrain telescope, SBIG STL-6303E NABG CCD camera; the pixel scale was 2.30 arcsec when binned at 2×2 pixels. For 1626 Sadeya we used a Rc filter and 180 seconds of exposure time, for the other asteroids we used a Clear filter and 300 seconds of exposure time.

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

A search through the asteroid lightcurve database (LCDB; Warner et al., 2009) indicates that our result may be the first reported lightcurve observations and results for 5552 Studnicka.

<u>1626 Sadeya (1927 AA)</u> was discovered by J. Comas Sola at Barcelona on 1927 January 10 and named in honor of the Sociedad Astronómica de España y América. It is an inner main-belt asteroid with a semi-major axis of 2.364 AU, eccentricity 0.274, inclination 25.319°, and an orbital period of 3.63 years. Its absolute magnitude is H = 11.10 (JPL, 2025). The NEOWISE satellite infrared radiometry survey (Mainzer et al., 2016) found a diameter $D = 15.140 \pm 0.490$ km using an absolute magnitude H = 10.50. In 2020 the binary nature of this asteroid was discovered by the authors among the BinAst (Photometric Survey for Asynchronous Binary Asteroids) collaboration (Pravec, 2024web) and announced through a CBET (Benishek, 2020). Observations were conducted over two nights and collected 229 data points. The period analysis confirms a rotational period of $P = 3.421 \pm 0.002$ h with an amplitude $A = 0.11 \pm 0.01$ mag, in perfect agreement with previously reported results by multiple researchers as listed in the LCDB. We did not record any events introduced by the satellite during our observations.

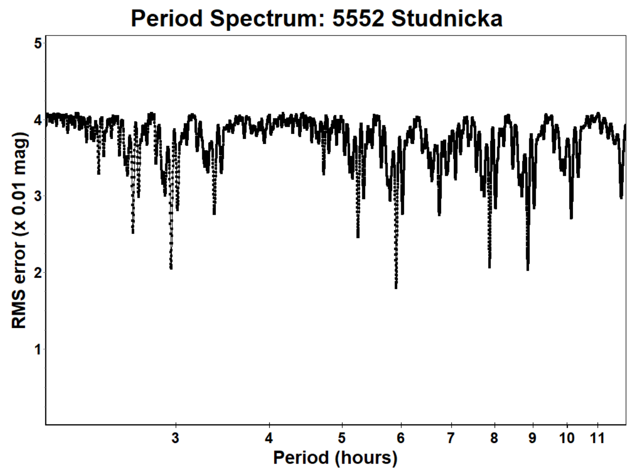


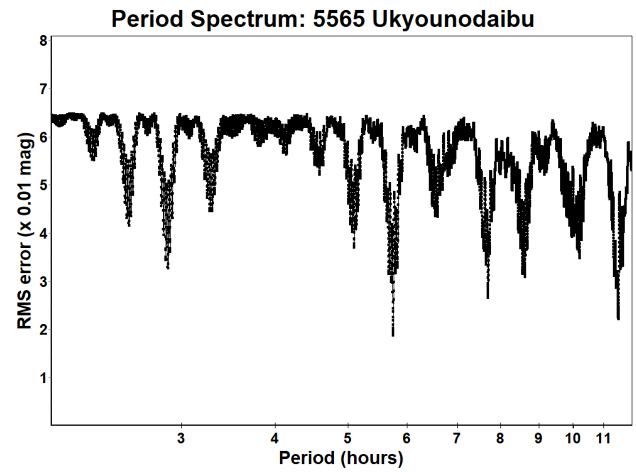


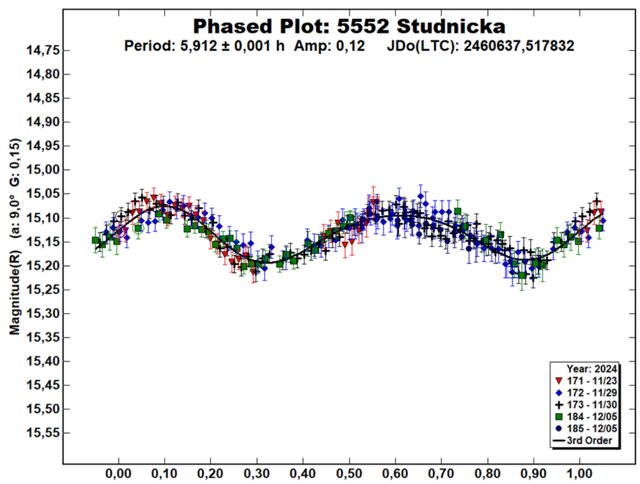
<u>5552 Studnicka (1982 SJ1)</u> was discovered on 1982 September 16 by A. Mrkos at Klet and named in memory of František Josef Studnička (1836-1903), professor of mathematics at Charles University in Prague, also active in astronomy and meteorology. It is an outer main-belt asteroid with a semi-major axis of 2.776 AU, eccentricity 0.248, inclination 8.218°, and an orbital period of 4.62 years. Its absolute magnitude is H = 12.97 (JPL, 2025). The NEOWISE satellite infrared radiometry survey (Mainzer et al., 2016) found a diameter $D = 7.331 \pm 0.106$ km using an absolute magnitude H = 12.70. Observations were conducted over four nights and collected 233 data points. The period analysis shows a rotational period of $P = 5.912 \pm 0.001$ h with an amplitude $A = 0.12 \pm 0.02$ mag.

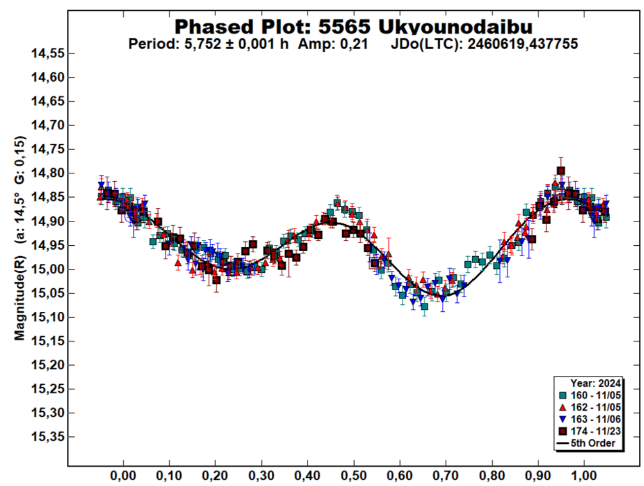
Number	Name	2024/mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1626	Sadeya	12/27-12/29	*2.0,2.0	96	2	3.421	0.002	0.11	0.01	MB-I
5552	Studnicka	11/22-12/05	*9.0,7.2	71	-11	5.912	0.001	0.12	0.02	MB-O
5565	Ukyounodaibu	11/04-11/23	14.6,8.3	67	-14	5.752	0.001	0.20	0.03	MB-O

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 extremum 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).









5565 Ukyounodaibu (1991 VN2) was discovered on 1991 November 10 by Natori and Urata at Yakiimo and named for the Japanese poetess, Kenreimon-in Ukyounodaibu (1157-?). It is an outer main-belt asteroid with a semi-major axis of 2.810 AU, eccentricity 0.217, inclination 10.306°, and an orbital period of 4.71 years. Its absolute magnitude is H = 12.24 (JPL, 2025). The NEOWISE satellite infrared radiometry survey (Mainzer et al., 2016) found a diameter D = 12.286 ± 0.279 km using an absolute magnitude H = 11.90.

Observations were conducted over four nights and collected 212 data points. The period analysis shows a rotational period of P = 5.752 ± 0.001 h with an amplitude A = 0.20 ± 0.03 mag, in agreement with the one published in the LCDB (Behrend, 2024web).

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LIGHTCURVES OF 40 ASTEROIDS

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(Received: 2025 January 11)

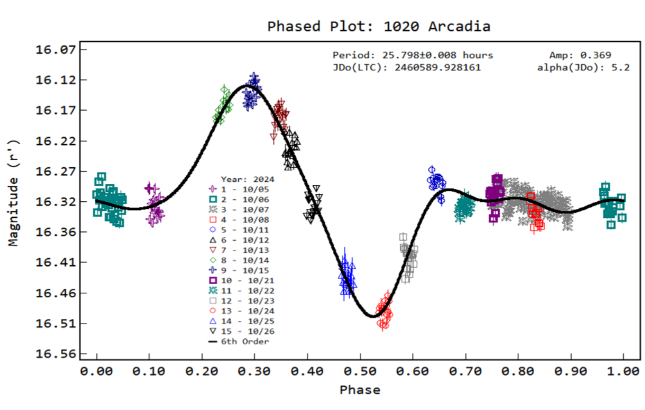
We present lightcurves and synodic rotation periods for 40 asteroids based on observations obtained at the Dimension Point Observatory (V42) from September 2024 through January 2025.

We report results from photometric observations of 40 minor planets conducted from September 2024 through January 2025 at Dimension Point Observatory (V42). Images were acquired using a 0.61-m *f*/6.5 Corrected Dall-Kirkham telescope with Finger Lakes Instrumentation Kepler KL400 back-illuminated CMOS camera and a 0.51-m *f*/8 Ritchey-Chrétien telescope with an SBIG AC4040 CMOS camera. The equipment was operated remotely using *ACP Expert* (Denny, 2024) and *MaximDL* (George, 2024). Time was synchronized using a local stratum 1 time source and Meinberg NTP client software. Exposures were typically 120 seconds unfiltered or through a yellow blue-blocking long-pass filter with cutoff at 500 nm.

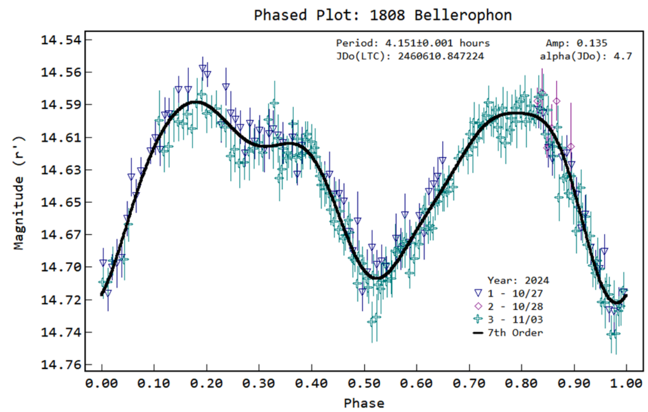
Target selection and observation planning were performed using the authors own Python scripts. Orbital elements, ephemeris and other information were obtained from the Minor Planet Center (MPC) website (*http://www.minorplanet.net*), the JPL Solar System Dynamics website (*http://ssd.jpl.nasa.gov*) (Giorgini, 1996), the Lowell Observatory Minor Planet Services website (*http://asteroid.lowell.edu*) (Moskovitz, 2022) and the LCDB database (Warner et al., 2009).

Image calibration, plate solving, measurement and period analysis were performed using *Tycho-Tracker* V12.1 (Parrott, 2024). Calibration masters were prepared using *AstroImageJ* (Collins, 2017). Comparison stars of near solar color were chosen from the ATLAS refcat2 star catalog using Sloan r´ magnitudes (Tonry et al., 2018). Additional period analysis was carried out using *MPO Canopus* V10.8.4.1 (Warner, 2020).

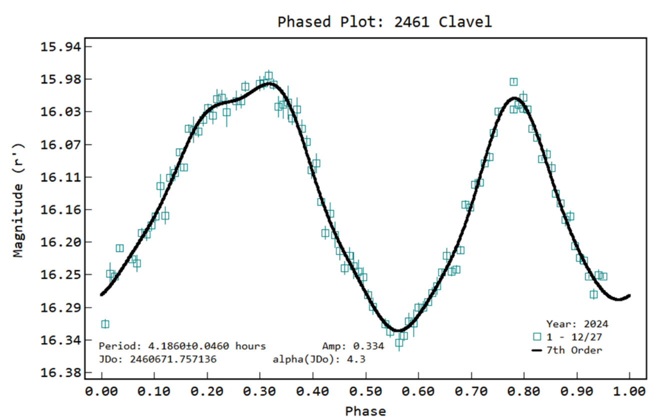
1020 Arcadia is a middle main-belt asteroid, which is a member of the Agnia dynamical family, discovered in 1924 by Reinmuth at Heidelberg. It is named for the Greek region of Arcadia in central Peloponnese. We observed Arcadia on fifteen nights in 2024 October. Gartrelle (2012) reported a period of 17.02 ± 0.02 h. We found a best fit period of 25.798 ± 0.008 h with an amplitude of 0.37 ± 0.02 mag.



1808 Bellerophon. is a middle main-belt asteroid discovered in 1960 by van Houten and van Houten-Groeneveld at Palomar. It is named after the mythological Greek hero who vanquished the Chimera. We observed it on three nights in 2024 October and November. We found prior reports from Harris (1983, no reference available) of 4.0 h, Waszczak et al. (2015) of 3.820 h and Dose (2025) of 4.147 ± 0.002 h. Analysis of our data resulted in a best fit period of 4.151 ± 0.001 h with an amplitude of 0.14 ± 0.01 mag, in close agreement with Dose and differing with the other reports.



2461 Clavel. This member of the Themis family was discovered in 1981 by Debehogne at La Silla. We observed it on one night in 2024 December. We found survey reports from Waszczak et al. (2015) 5.238 h, Ďurech et al. (2020) 4.72078 h, Erasmus et al. (2020) 4.721 h, and Behrend (2020web) 3.5 ± 0.5 h. The LCDB quality score U was 2. We found a period of 4.186 ± 0.0460 h with an amplitude of 0.33 ± 0.02 mag, differing with the survey results.

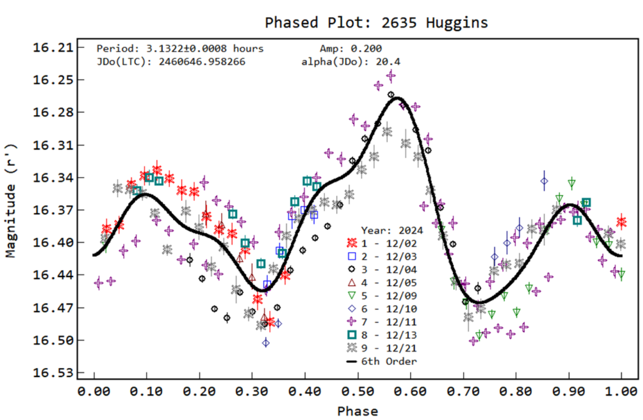


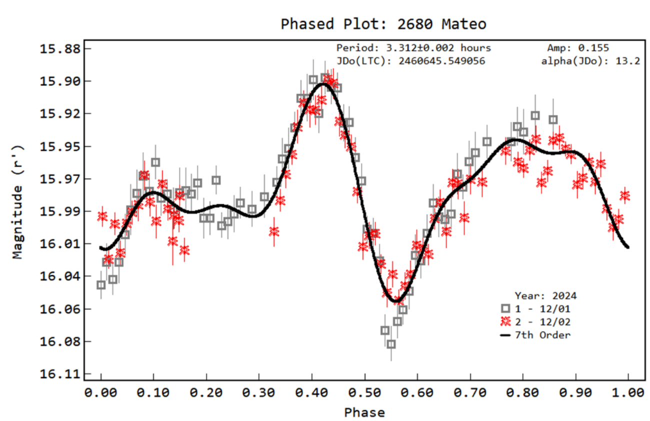
2635 Huggins. We observed this member of the Flora family on nine nights in 2024 December. Discovered by Ted Bowell at Anderson Mesa in 1982, it is named for William Huggins, a pioneer in astronomical spectroscopy. Huggins was the first to study the spectrum of a nova and measured the radial velocity of Sirius.

We found several prior rotation period reports: Erasmus et al. (2020) 48.295 h, Mazzone (2012web - unable to find a reference) 9.4 h, Chang et al. (2016) 3.33 h, Waszczak et al. (2015) 3.129 h and Benishek (2022) 3.131 h. We found a period of 3.1322 ± 0.0008 h with an amplitude of 0.20 ± 0.03 mag, in agreement with Benishek and close to Waszczak et al.

Number	Name	2024 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1020	Arcadia	10/05-10/26	*5.5,3.19	26	-1	25.798	0.008	0.37	0.02	Agnia
1808	Bellerophon	10/27-11/03	4.7,1.2	43	1	4.151	0.001	0.14	0.01	MB-O
2461	Clavel	12/27-12/27	4.3,4.4	84	-1	4.186	0.046	0.33	0.01	Themis
2635	Huggins	12/02-12/21	20.4,13.2	113	0	3.1322	0.001	0.20	0.03	Flora
2680	Mateo	12/01-12/02	13.2,13.7	46	3	3.312	0.002	0.16	0.01	Hertha
3213	Smolensk	11/03-11/10	7.7,4.9	60	0	3.565	0.001	0.26	0.02	Themis
3434	Hurless	10/17-10/29	13.2,12.2	59	-2	6.794	0.001	0.23	0.02	Misa
3987	Wujek	10/22-10/24	4.8,3.7	39	0	8.049	0.004	0.36	0.02	MB-O
4118	Sveta	11/03-11/30	9.6,17.2	22	11	8.738	0.001	0.15	0.02	Eos
4513	Louvre	11/27-11/27	11.9,12.0	36	-2	2.966	0.009	0.32	0.01	Eos
4615	Zinner	12/09-12/24	10.0,14.0	66	18	2.946	0.001	0.05	0.02	MB-I
4618	Shakhovskoj	10/25-10/29	9.7,10.2	32	14	6.777	0.001	0.51	0.04	Mitidika
5128	Wakabayashi	11/09-11/21	11.4,7.0	74	4	5.310	0.001	0.14	0.03	MB-O
5491	Kaulbach	12/03-12/-4	14.8,15.5	50	7	2.781	0.001	0.19	0.02	Flora
6094	Hisako	09/25-11/20	5.3,19.8	1	9	75.42	0.010	0.79	0.03	Eunomia
6119	Hjorth	12/22-12/22	12.7,12.8	66	4	4.404	0.007	0.60	0.03	Eunomia
6137	Johnfletcher	12/22-12/26	8.0, 7.1	107	15	6.936	0.004	0.27	0.02	MB-O
7397	1986 QS	11/29-12/01	13.7,12.9	94	11	2.813	0.001	0.30	0.02	Gefion
8162	1990 SK11	10/02-11/19	*2.9,22.4	13	3	8.220	0.002	0.11	0.02	MB-I
8163	Ishizaki	10/31-11/05	8.3,5.9	54	-3	3.243	0.002	0.33	0.03	MB-I
9171	Carolyndiane	12/30-01/02	10.2,11.2	77	14	14.089	0.014	0.44	0.04	Maria
10221	Kubrick	11/22-12/09	12.7,5.4	86	6	11.069	0.002	0.17	0.02	MB-I
10269	Tusi	11/22-12/21	*2.37,9.4	66	0	11.793	0.002	0.11	0.02	Themis
12119	Memamis	11/11-12/25	*11.7,15,45	67	9	12.178	0.003	0.30	0.03	MB-I
12209	Jennalynn	12/31-01/07	8.7,7.5	112	18	20.774	0.023	0.16	0.02	MB-I
12426	Racquetball	10/12-10/22	13.8,8.9	44	4	2.883	0.001	0.18	0.03	MB-I
12489	1997 GR36	12/22-01/02	*5.0,2.9	99	3	19.257	0.009	0.14	0.02	Astraea
15817	Lucianotesi	09/14-09/15	8.8,8.7	355	-6	15.76	0.01	0.873	0.06	NEA/Amor
16693	Moseley	09/08-11/09	*12.3,20.9	3	16	71.82	0.03	>1.00		Eunomia
19419	Pinkham	10/25-10/26	6.4,5.9	39	2	2.496	0.002	0.12	0.02	MB-I
20963	Pisarenko	10/21-10/24	8.3,7.5	41	14	3.139	0.001	0.21	0.03	Eunomia
21269	Bechini	11/10-11/19	12.3,17.5	30	6	2.592	0.001	0.14	0.03	MB-I
22074	2000 AB113	10/13-10/14	8.8,8.5	37	-13	3.808	0.004	0.37	0.03	Eos
26121	1992 BX	10/16-10/16	14.5,14.4	45	13	3.593	0.01	0.31	0.03	Chaldaea
33834	Hannahkaplan	10/24-10/24	5.3,5.3	28	9	3.532	0.008	0.54	0.03	MB-M
43028	1999 VE23	10/25-11/09	*7.2,4.6	42	-5	3.937	0.002	0.30	0.02	MB-I
49584	1999 CE133	11/01-11/19	5.1,12.6	29	1	4.874	0.001	0.22	0.03	Themis
50349	2000 CC70	10/27-10/27	13.3,13.2	15	7	3.224	0.014	0.30	0.03	MB-I
66076	1998 RD53	09/09-10/13	8.0,4,9	8	2	8.936	0.004	0.75	0.05	Eos
154589	2003 MX2	10/11-11/06	*21.7,5.9	35	-8	42.510	0.013	0.56	0.01	NEA/Amor

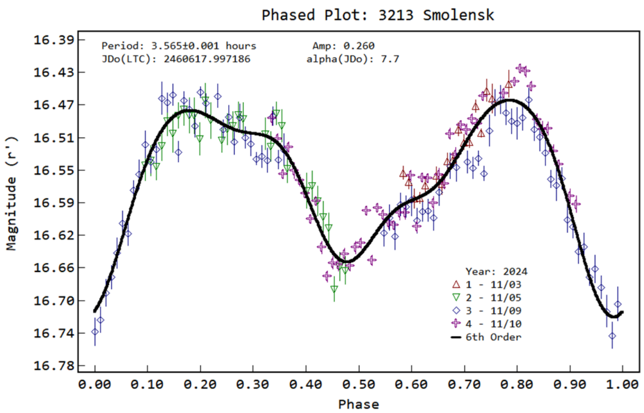
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).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



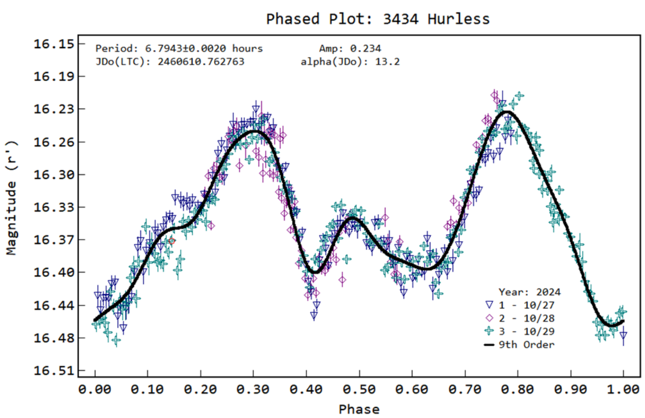


2680 Mateo. We observed this member of the Hertha family on two nights in 2024 December and found a period of 3.3125 ± 0.0015 h with an amplitude of 0.16 ± 0.01 mag. Recently, Benishek (2024) reported 3.3130 ± 0.0005 h. Our result is in agreement.

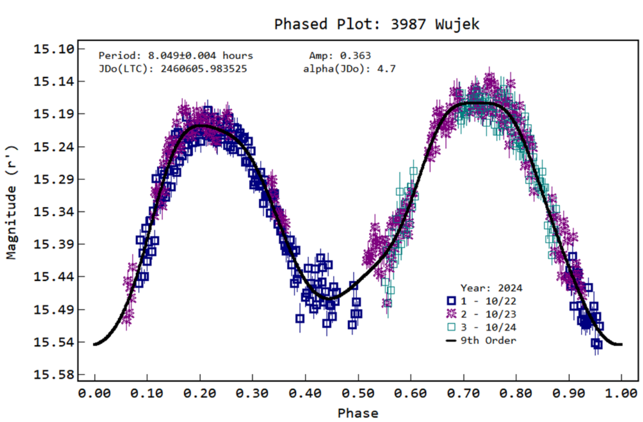
3213 Smolensk. This member of the Themis family was discovered in 1977 by Chernykh at Nauchnyj. We observed it on four nights in 2024 November. We found survey results from Waszczak et al. (2015) of 3.564 ± 0.0054 h and 3.563 ± 0.0026 h. The LCDB quality score U was 2. We found a best fit period of 3.565 ± 0.001 h with an amplitude of 0.26 ± 0.02 mag, agreeing with Waszczak.



3434 Hurless. Brian Skiff discovered this member of the Misa family in 1981 at the Anderson Mesa Station of the Lowell Observatory. It is named for Carolyn J. Hurless, an AAVSO merit award winner, who was the most active and prolific female observer in the history of the AAVSO. The AAVSO online education program, the *Carolyn Hurless Online Institute for Continuing Education* (CHOICE), is named in her honor. We observed 3434 Hurless on three nights in 2024 October and found a best fit period of 6.7843 ± 0.002 h with an amplitude of 0.23 ± 0.02 mag. We found no prior rotation period reports.

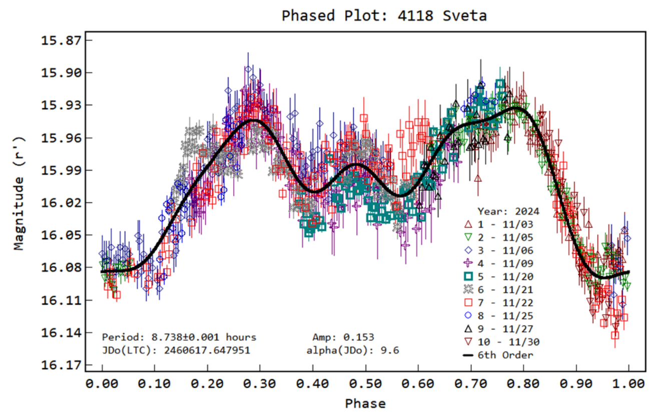


3987 Wujek is an outer main-belt asteroid discovered in 1986 by Ted Bowell at Lowell Observatory. We observed Wujek on three nights in 2024 October.

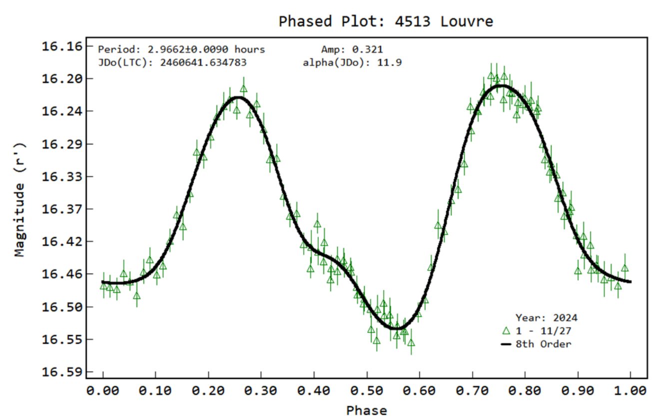


We found prior reports from Schmidt (2016) of 8.037 ± 0.014 h and Ďurech et al. (2020) of 8.05505 ± 0.00002 h. We found a period of 8.049 ± 0.004 h with an amplitude of 0.36 ± 0.02 mag, in agreement with Schmidt, and slightly shorter than the result from Ďurech et al.

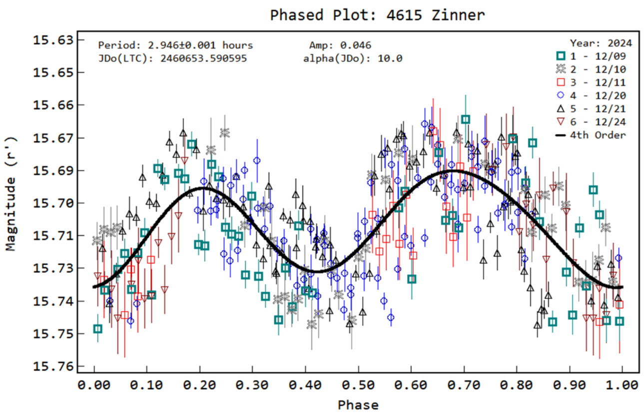
4118 Sveta. This member of the Eos family was discovered in 1982 by Zhuravleva at Nauchnyj. It is named for Russian aviator and cosmonaut Svetlana Savitskaya, the second woman to fly in space and the first woman to walk in space. Savitskaya was a champion of the 1970 FAI World Aerobatic Championships and set several FAI worlds records. We observed Sveta on ten nights in 2024 November and found a period of 8.738 ± 0.001 h with an amplitude of 0.15 ± 0.02 mag. We found no prior rotation period reports.



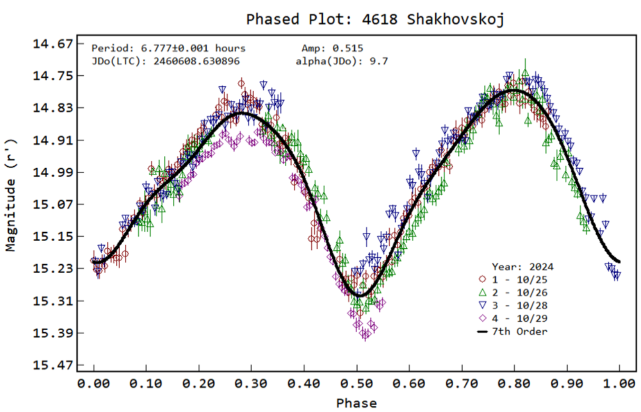
4513 Louvre is an outer main-belt asteroid that is a member of the Eos family. We observed it on one night in 2024 November. We found prior reports from Waszczak et al. (2015) of 2.937 ± 0.001 h and Ďurech et al. (2020) of 2.937329 ± 0.000005 h. Our best fit period of 2.966 ± 0.009 h, slightly longer than prior reports. The peak-to-peak lightcurve amplitude is 0.32 ± 0.02 mag.



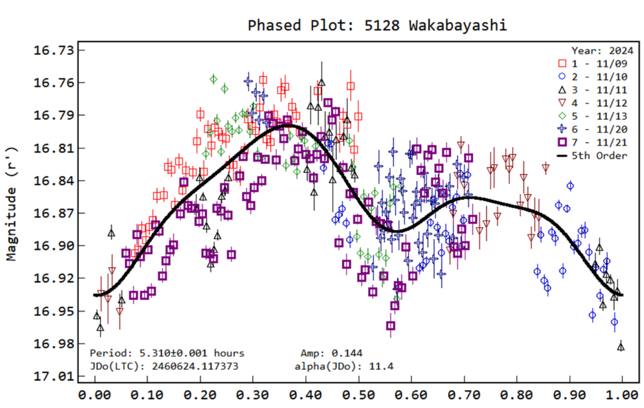
4615 Zinner. This middle main-belt asteroid was discovered in 1923 by Karl Reinmuth at Heidelberg. Named for German astronomer Ernst Zinner, we observed it on six nights in 2024 December and found a rotation period of 2.946 ± 0.001 h with an amplitude of 0.05 ± 0.02 mag. We found no prior rotation period reports.



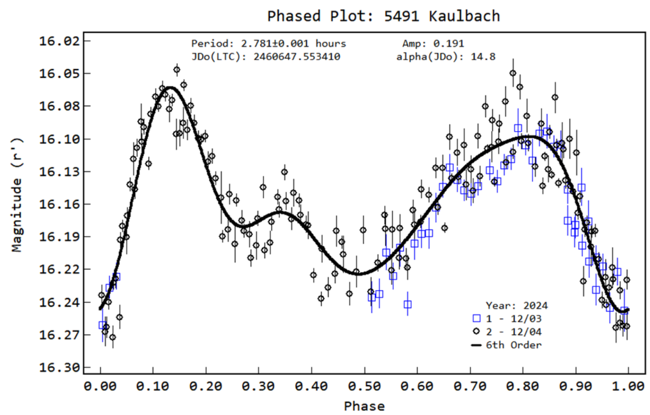
4618 Shakhovskoj. A member of the middle main-belt Mitidika dynamical family, this asteroid was discovered in 1977 by Chernykh at Nauchnyj. We observed it on four nights in 2024 October, finding a period of 6.777 ± 0.001 h with an amplitude of 0.51 ± 0.04 mag. We found no prior rotation period reports.



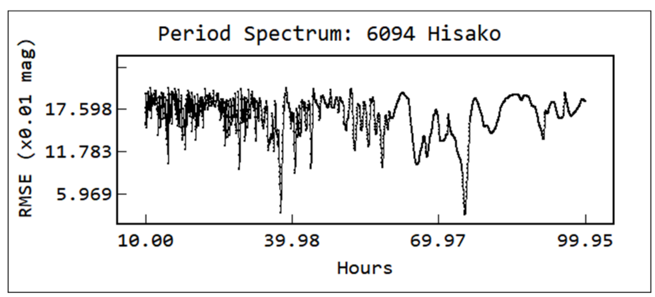
5128 Wakabayashi is an outer main-belt asteroid discovered in 1989 by Koishikawa at Ayashi. We observed it on seven nights in 2024 November. There are prior reports from Klinglesmith et al. (2013) of 5.86 ± 0.02 h and Waszczak et al. (2015) of 5.311 ± 0.0054 h. We found a period of 5.310 ± 0.001 h with an amplitude of 0.14 ± 0.03 mag, making the period in agreement with Waszczak et al.

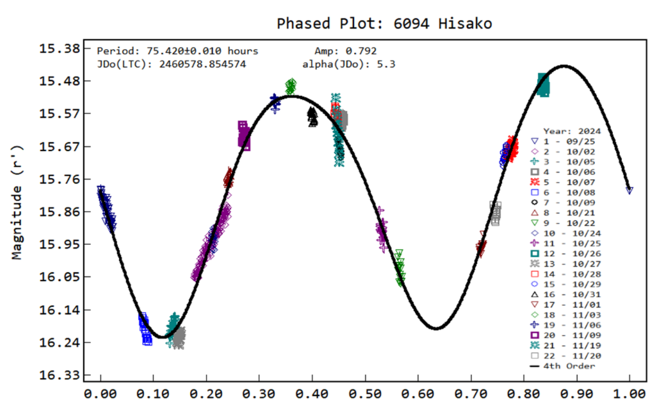


5491 Kaulbach is an inner main-belt asteroid discovered in 1971 by van Houten and Gehrels at Palomar. A member of the Flora family, it is named for German painter Wilhelm von Kaulbach. We observed it on two nights in 2024 December. We found a period of 2.781 ± 0.001 h with an amplitude of 0.19 ± 0.02 mag. We were unable to find any prior rotation period reports.

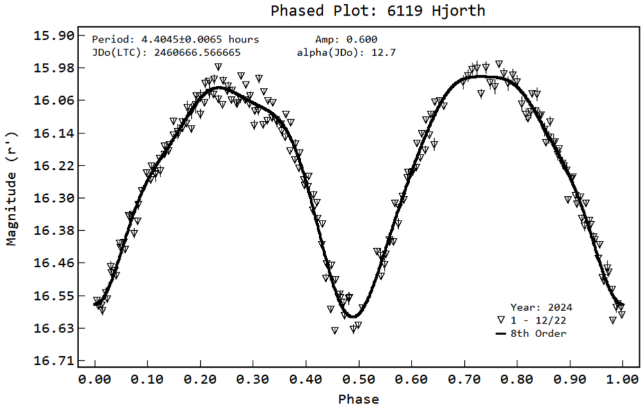


6094 Hisako is a middle main-belt asteroid that is a member of the Eunomia family. It was discovered in 1990 by Hioki and Hayakawa at Okutama. It is named after Hisako Hioki, the mother of the discoverer. We observed it on 21 nights in 2024 September through November. We found prior reports from Behrend (2015web) of 16.4 h, Klinglesmith et al. (2016) of 4.050 h, and a recent report from Wiles (2024) of 75.13 ± 0.03 h. We found a best fit period of 75.42 ± 0.01 h, with an amplitude of 0.79 ± 0.03 mag, close to the report from Wiles and disagreeing with the others.

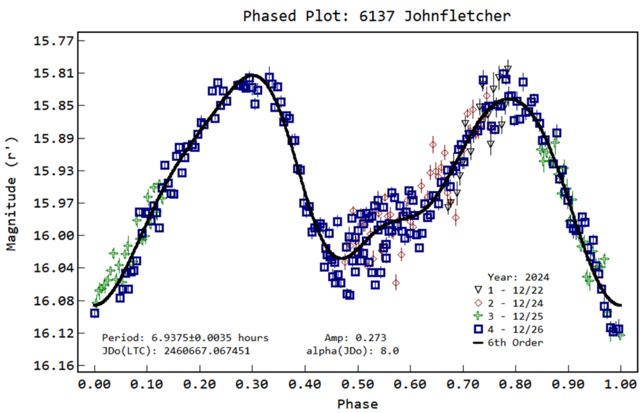




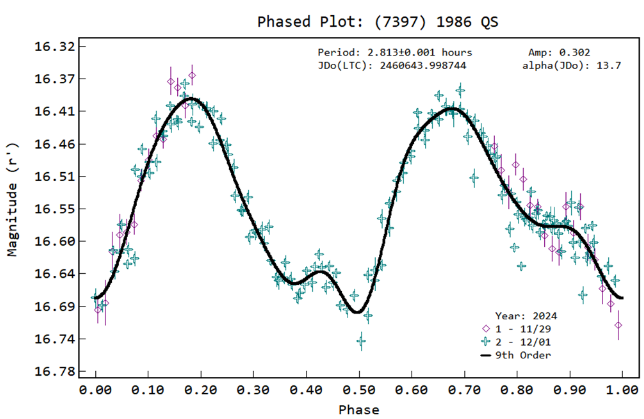
6119 Hjorth. We found a period of 4.405 ± 0.007 h with an amplitude of 0.60 ± 0.03 mag for this member of the Eunomia family. Named for Jens Hjorth, a professor of astrophysics at the University of Copenhagen, it was discovered in 1986 by Jensen at Brorfelde. We found no prior rotation period reports.



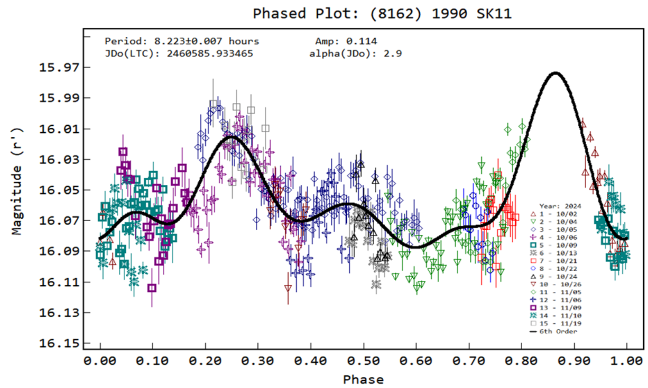
6137 Johnfletcher. Discovered in 1991 by Natori and Urata at Yakiimo, this outer main-belt asteroid is named for British amateur astronomer John Fletcher. We observed it on four nights in 2024 December, finding a rotation period of 6.9375 ± 0.0035 h with an amplitude of 0.27 ± 0.02 mag. We found no prior rotation period reports.



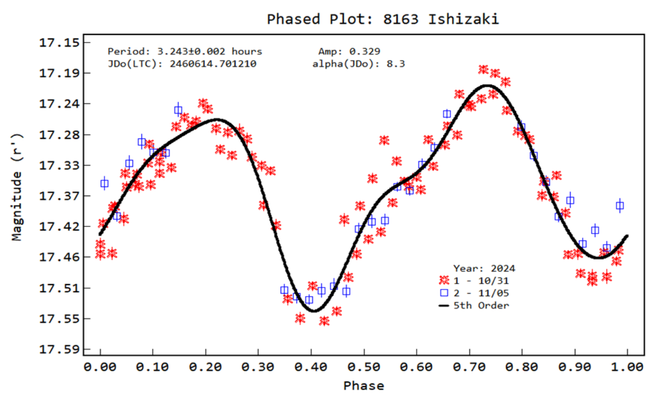
(7397) 1986 QS. This outer main-belt asteroid is a member of the Gefion family. We observed it on two nights in 2024 November and December. We found one prior report from Ferrero and Bonamico (2020) of 2.864 ± 0.001 h. The LCDB quality score U was 2+. We found a period of 2.813 ± 0.001 h with an amplitude of 0.30 ± 0.02 mag, shorter than that from Ferrero.



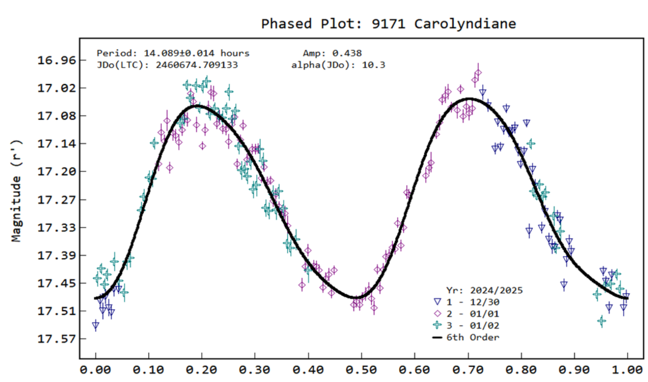
(8162) 1990 SK11. We observed this inner main-belt asteroid on fifteen nights in 2024 October and November. We found reports from Waszczak et al. (2015) of 2.224 ± 0.0016 h and Benishek (2024) of 4.550 ± 0.006 h. Our analysis resulted in a best fit of 8.220 ± 0.002 h with an amplitude of 0.11 ± 0.02 mag, disagreeing with prior reports. Given the small coverage gap and noisy data, this result could be wrong.



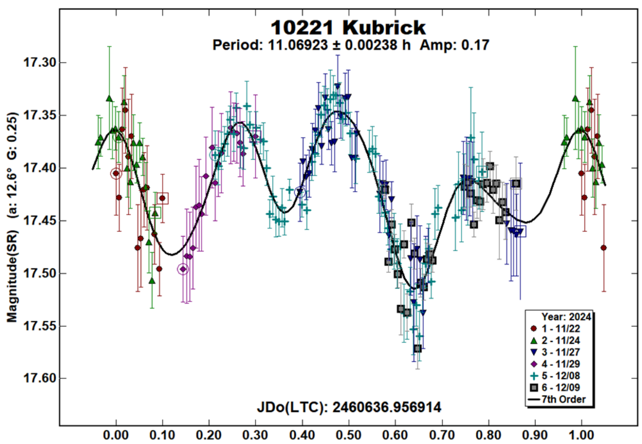
8163 Ishizaki. This inner main-belt asteroid was discovered in 1990 by Seki at Geisei. We observed it on two nights in 2024 October and November. There was one survey result (Waszczak et al., 2015) of 3.243 ± 0.0012 h. The LCDB quality score was 2. We found a best fit of 3.243 ± 0.002 h with an amplitude of 0.33 ± 0.03 mag, agreeing with the Waszczak et al. survey.



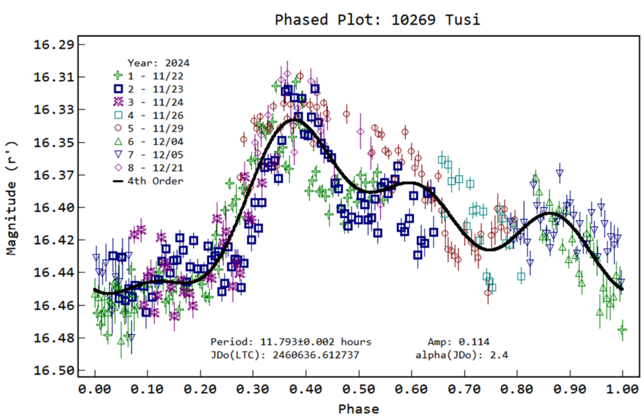
9171 Carolyndiane. We observed this member of the Maria family, named for Carolyn Diane Young, wife of New Zealand amateur astronomer Albert Jones, on three nights in 2024 December and 2025 January. We found a period of 14.089 ± 0.014 h with an amplitude of 0.44 ± 0.04 mag. We were unable to find any prior rotation period reports.



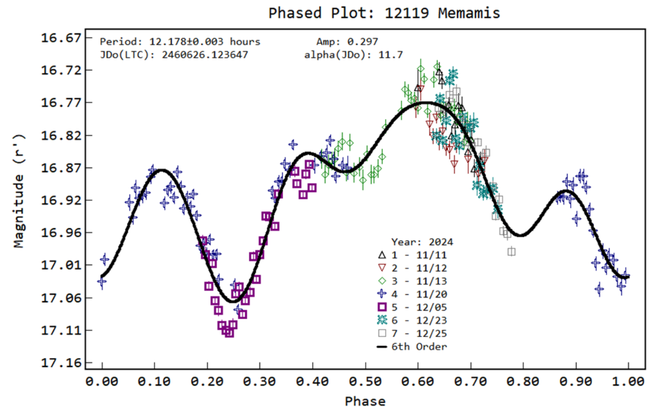
10221 Kubrick is an inner main-belt asteroid discovered by Pravec at Ondrejov. We observed it on six nights in 2024 November and December. Chang et. al. (2019) reported 11.01 ± 0.25 h and Dose (2021) reported 11.070 ± 0.002 h. The LCDB quality score U was 2. Analysis of our data resulted in a best fit period of 11.069 ± 0.002 h with an amplitude of 0.17 ± 0.02 mag, in agreement with Dose. As mentioned by Dose, we found that increasing the value of the phase slope parameter, *G,* resulted in a better fit.



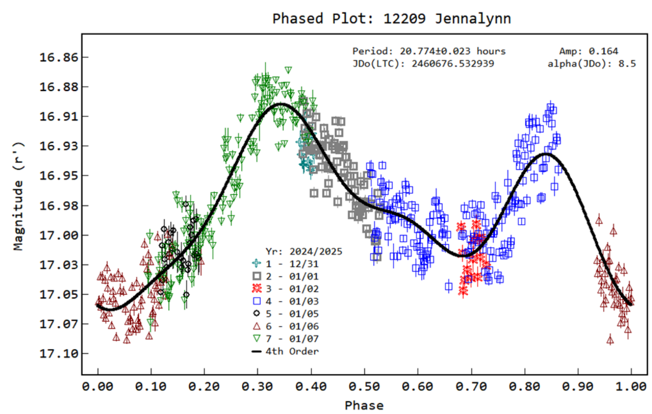
10269 Tusi is an outer main-belt asteroid that is a member of the Themis family. Discovered in 1979 by Chernykh at the Crimean Astrophysical Observatory It is named for Azerbaijanian astronomer Nasi as-Din at-Tusi Abu Djafar Mukhammed ibn Mukhammed. We observed it on eight nights in 2024 November and December. We found one prior report from Szabó et al. (2016) of 10.81 ± 0.33 h. The LCDB quality score U was 1. Analysis of our data resulted in a best fit period of 11.793 ± 0.002 h, slightly longer than the Szabo et al. report.



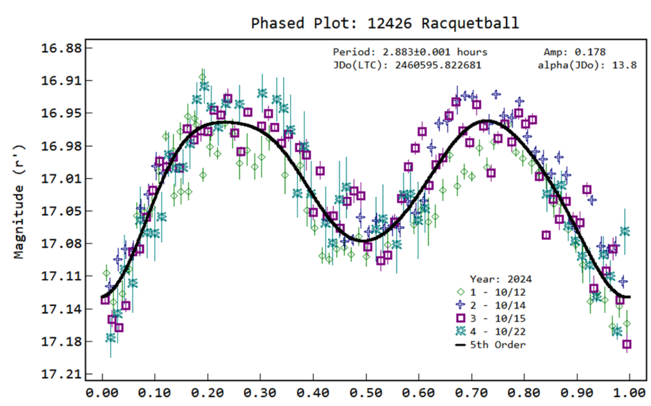
12119 Memamis. This inner main-belt asteroid was discovered in 1999 by LINEAR at Socorro. Named for Megan Marie Miskowski, we observed it on seven nights in 2024 November and December, finding a best fit period of 12.178 ± 0.003 h with an amplitude of 0.30 ± 0.03 mag. We found no prior rotation period reports. There are some small gaps in coverage, so this result could be wrong.



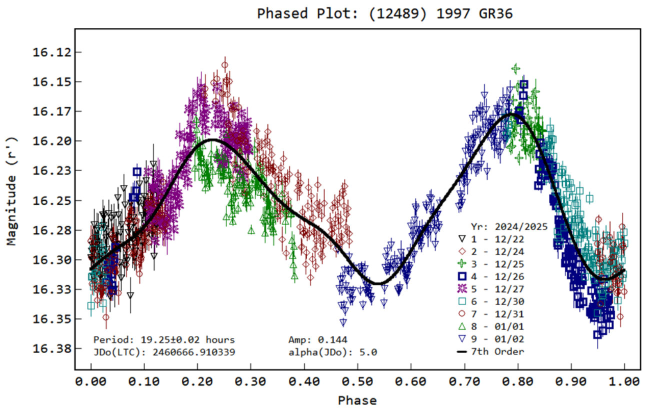
12209 Jennalynn. Discovered in 1981 by Bus at Siding Spring, this inner main-belt asteroid is named after Dr. Jenna Lynn Jones whose PhD dissertation concerned the shape modeling and analysis of thermal observations of the NEA 1627 Ivar. We observed it on seven nights, finding a period of 20.0774 ± 0.023 h with an amplitude of 0.16 ± 0.02 mag. We found no prior rotation period reports.



12426 Racquetball is an inner main-belt asteroid discovered by the AMOS team at Haleakala in 1995. We observed it on four nights in 2024 October. We found one survey report from Waszczak et al. (2015) of 2.882 ± 0.0009 h. The LCDB quality score U was 2. Analysis of our data found a best fit of 2.883 ± 0.001 h with an amplitude of 0.18 ± 0.03 mag, agreeing with Waszczak et al.

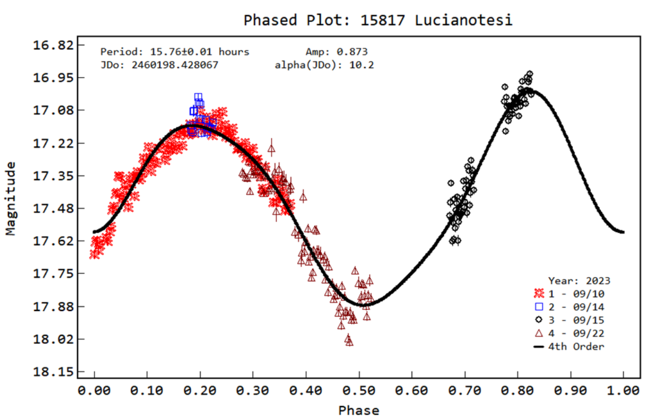


(12489) 1997 GR36. We observed this member of the Astraea family on nine nights in 2024 December and 2025 January, finding a best fit period of 12.257 ± 0.009 h with an amplitude of 0.14 ± 0.02 mag. We found no prior period reports.



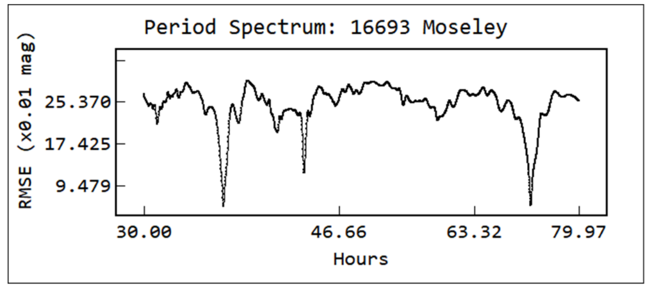
15817 Lucianotesi is a NEA that is a member of the Amor family. Fornas et al. (2024) reported 12.687 ± 0.005 h with an amplitude of 0.57 ± 0.02 mag.

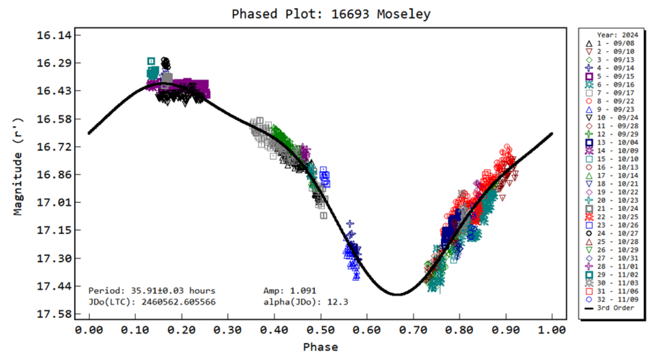
While our two nights of observations were insufficient to make any period determination, Fornas published their observations to the ALCDEF web site (*https://alcdef.org*). As it happens, our observations occurred between the two nights of the Fornas et al. observations. Combining their observations with ours resulted in a best fit of 15.76 ± 0.01 h with an amplitude of 0.87 ± 0.06 mag. There are still significant gaps in the lightcurve, so this result could be wrong. However, it seems clear that the period is longer than the prior report.

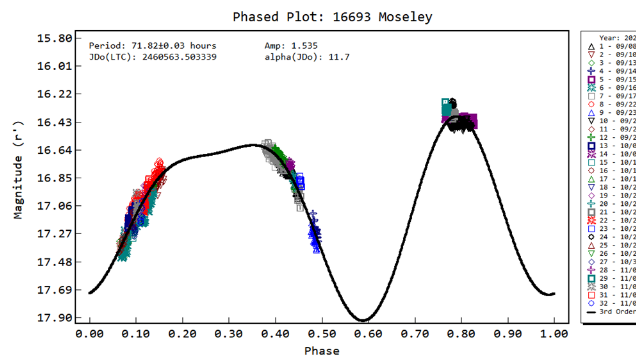


16693 Moseley is a middle main-belt asteroid that is a member of the Eunomia family and was discovered in 1994 by D.J. Asher at Siding Spring. We observed it on 32 nights in 2024 September through November. We found no prior rotation period reports.

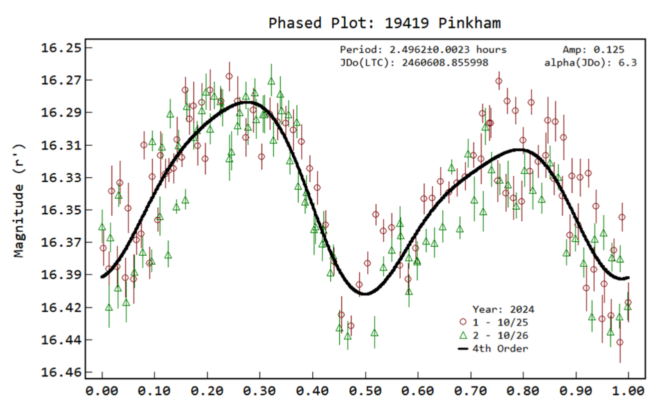
We found two possible periods, 35.91 ± 0.03 h with an amplitude of 1.09 ± 0.06 mag and 71.82 ± 0.03 h. We adopted the longer period since it results in a typical bimodal lightcurve. While this is likely close to the correct period, the shorter period cannot be ruled out. With the relatively long period and sparse coverage, this result could be completely wrong.



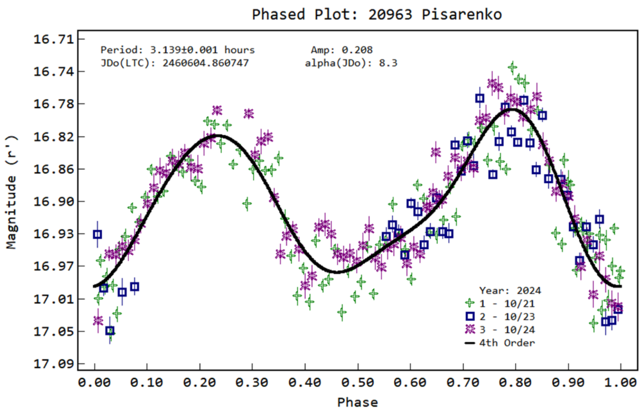




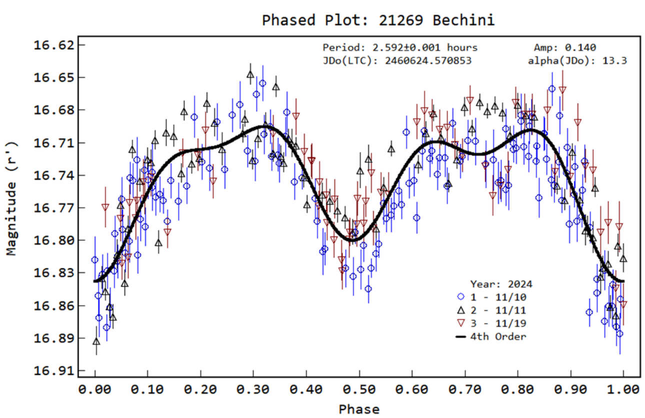
19419 Pinkham is a middle main-belt asteroid discovered in 1998 by the Lincoln Laboratory Near-Earth Asteroid Research Team and Socorro. We observed it on two nights in 2024 October. Waszczak et al. (2015) reported a period of 2.496 h. The LCDB quality score U was 2. Analysis of our data resulted in a best fit period of 2.496 ± 0.002 h and amplitude of 0.13 ± 0.02 mag, agreeing with Waszczak et al.



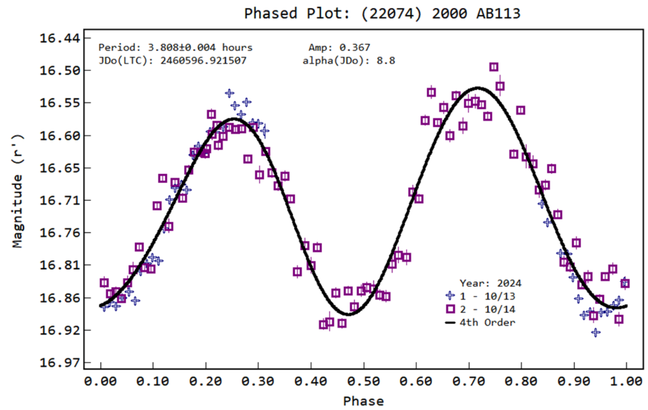
20963 Pisarenko is a middle main-belt asteroid discovered in 1977 by Chernykh at the Crimean Astrophysical Observatory. It is a member of the Eunomia dynamical family. We observed it on three nights in 2024 October. Pál et al. (2020) reported 3.13968 ± 0.00005 h. Analysis of our data resulted in a best fit period of 3.139 ± 0.001 h with an amplitude of 0.21 ± 0.03 mag, in agreement with Pál et al.



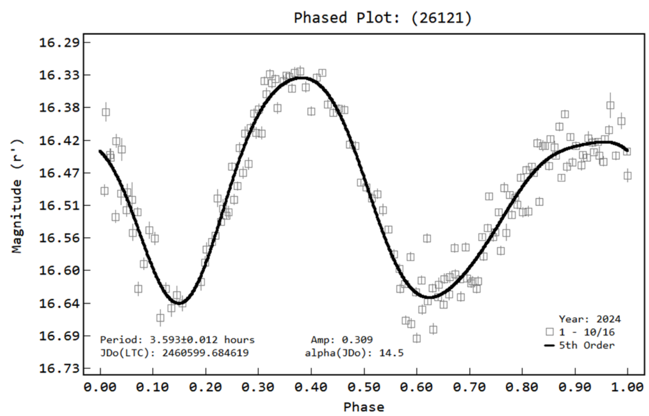
21269 Bechini is an inner main-belt asteroid discovered in 1996 by Tesi and Boattini at San Marcello Pistoiese. It is named for Roberto Bechini, an amateur astronomer and member of the Sam Marcello amateur astronomy group. We observed it on three nights in 2024 November. Analysis of our data gave a best fit period of 2.592 ± 0.001 h with an amplitude of 0.14 ± 0.03 mag. We found no prior rotation period reports.



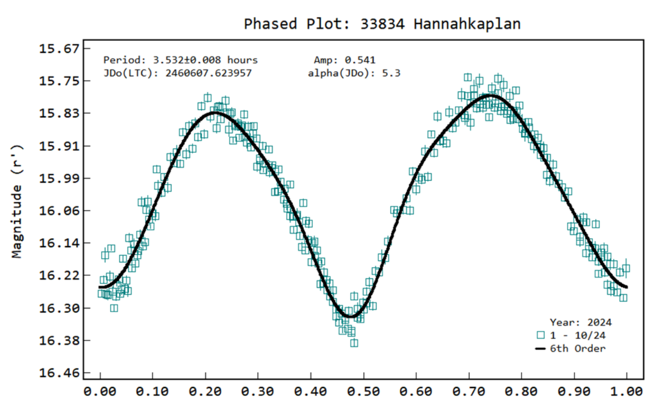
(22074) 2000 AB113 is an outer main-belt asteroid that is a member of the Eos family. Discovered by LINEAR at Socorro, we observed it on two nights in 2024 October. There is a survey report from Ďurech et al. (2020) of 3.801357 ± 0.000005 h with an LCDB quality score U of 2. We found a period of 3.808 ± 0.004 h with an amplitude of 0.37 ± 0.03 mag, close to the report from Ďurech et al.



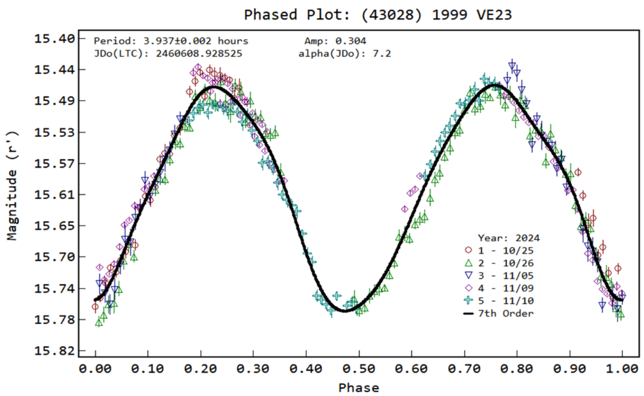
(26121) 1992 BX. This member of the Chaldea family was discovered in 1992 by Ueada and Kaneda at Kushiro. We found a survey report from Waszczak et al. (2015) of 3.554 ± 0.0035 h with an LCDB quality score U of 2. Analysis of our data resulted in a period of 3.593 ± 0.012 h with an amplitude of 0.31 ± 0.03 mag, slightly longer than the survey report.



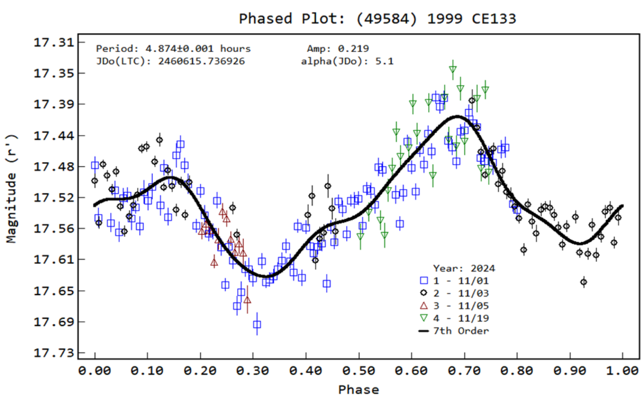
33834 Hannahkaplan is a middle main-belt asteroid discovered in 2000 by LONEOS at Anderson Mesa. It is named for Hanna H. Kaplan, who was a postdoctoral researcher at Southwest Research Institute working on the OSIRIS-Rex mission and is currently a research scientist at the NASA Goddard Space Flight Center. We found one survey report from Ďurech et al. (2020) of 3.542 ± 0.000007 h. The LCDB quality score U was 2. We found a period of 3.532 ± 0.008 h, or slightly shorter but close to the survey report.



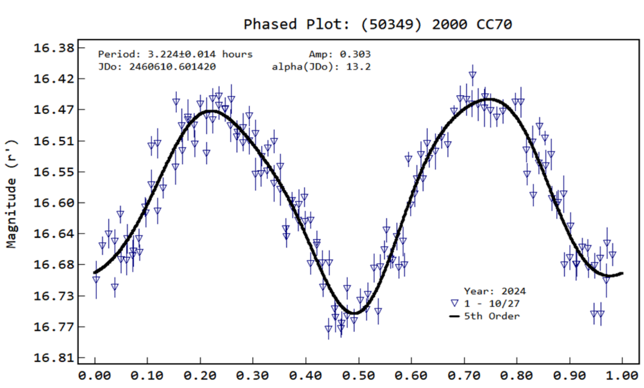
(43028) 1999 VE23 is an inner main-belt asteroid discovered by Sposetti at Gnosca. We observed it on four nights in 2024 October and November. Ferrero (2021) reported 3.940 ± 0.002 h with an amplitude of 0.36 ± 0.05 mag. The LCDB quality score U was 2. We found a best fit period of 3.937 ± 0.002 h with an amplitude of 0.30 ± 0.02 mag, in agreement with Ferrero.



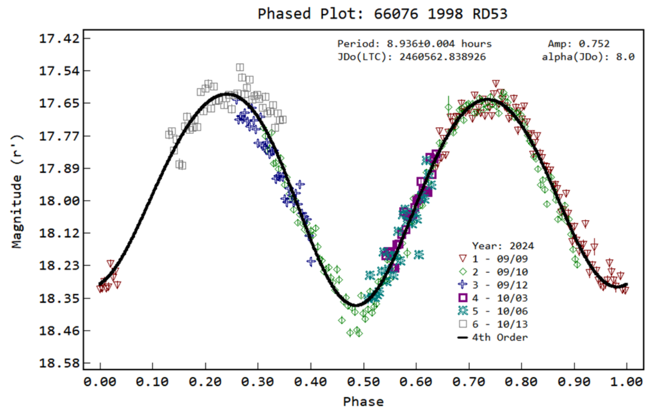
(49584) 1999 CE133 is an outer main-belt asteroid that is a member of the Themis family discovered by Spacewatch at Kitt Peak. We observed it on four nights in 2024 November. Chang et al. (2016) reported 4.82 ± 0.10 h. The LCDB quality score U was 1. Analysis of our data resulted in a best fit of 4.874 ± 0.001 h, slightly longer than the prior report.



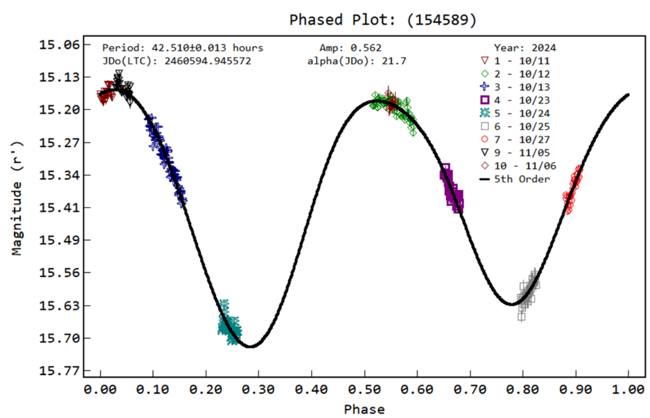
(50349) 2000 CC70 is an inner main-belt asteroid discovered in 2000 by LINEAR at Socorro. We observed it on one night in 2024 October. Waszczak et al. (2015) reported a period of 3.224 ± 0.0011 h. The LCDB quality score was 2. Analysis of our data resulted in a best fit period of 3.224 ± 0.014 h with an amplitude of 0.30 ± 0.03 mag, in agreement with Waszczak et al.



(66076) 1998 RD53 is an outer main-belt asteroid that is a member of the Eos family. It was discovered in 1998 by LINEAR at Socorro. We observed it on six nights in 2024 September and October. Ďurech et al. (2016) reported 8.93855 h and Pál et al. (2020) reported 8.95075 h. The LCDB quality score U was 2. Analysis of our data resulted in a best fit of 8.936 ± 0.004 h with an amplitude of 0.75 ± 0.05 mag, agreeing with Ďurech et al.



(154589) 2003 MX2 is a near-earth asteroid that is a member of the Amor family discovered by LINEAR at Socorro. We observed it on ten nights in 2024 October and November. Warner (2018) reported a period of 1.661 ± 0.002 h. The LCDB quality score U was 1+. Analysis of our data resulted in a best fit period of 42.510 ± 0.013 h with an amplitude of 0.56 ± 0.01 mag, disagreeing with Warner.



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LIGHTCURVES OF EIGHTEEN ASTEROIDS

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We present lightcurves and synodic rotation periods for eighteen asteroids including the family parent asteroid (2732) Witt.

We present asteroid lightcurves obtained via the workflow process described by Dose (2020) and later improved (Dose, 2021). This workflow applies to each image an ensemble of typically 25-80 nearby comparison ("comp") stars selected from the ATLAS refcat2 catalog (Tonry et al., 2018). This abundance of comp stars and our custom diagnostic plots allow for rapid identification and removal of outlier, variable, and poorly measured comp stars.

The product of this custom workflow is one night's time series of absolute Sloan r' (SR) magnitudes for one target asteroid. These absolute magnitudes are corrected for instrument transforms, sky extinction, and image-to-image ("cirrus") fluctuations, and thus they represent absolute magnitudes at the top of earth's atmosphere. These magnitudes are imported directly into *MPO Canopus* software (Warner, 2021) where they are adjusted for distance and phase-angle dependence, matched with their corresponding time, fit by Fourier analysis including identifying any aliases, and plotted.

Phase-angle corrections are made by applying a *H-G* model and finding the *G* value that minimizes best-fit RMS error across all nights' data for that apparition. Whenever we cannot estimate *G*, usually due to a narrow range of phase angles, we apply the Minor Planet Center's default value of 0.15. No nightly zero-point adjustments (Delta Comps in *MPO Canopus*) were made to any data presented here, other than by estimating *G*.

Lightcurve Results

Eighteen asteroids were observed from New Mexico Skies observatory at 2210 meters elevation in southern New Mexico (before November 7) or from Howling Coyote Remote Observatories at 2295 meters elevation in western New Mexico (after November 7). Images were acquired with: a 0.50-m PlaneWave OTA on a PlaneWave L-500 mount and equatorial wedge, and a SBIG AC4040M CMOS camera fitted with a Schott GG495 light yellow filter and cooled to -15°C (before November 7) or -20°C (after November 7).

This equipment was operated remotely via *ACP* software (DC-3 Dreams), running one-night plan files generated by python scripts (Dose, 2020). Exposure times targeted 2-5 millimagnitudes uncertainty in asteroid instrumental magnitude, subject to a minimum exposure of 120 seconds to ensure suitable comp-star photometry, and to a maximum of 480 seconds.

FITS images were calibrated using temperature-matched, exposure-matched, median-averaged dark images and recent flat images of a flux-adjustable light panel. Calibrated images were plate-solved by *TheSkyX* (Software Bisque), and target asteroids were identified in *Astrometrica* (Herbert Raab). All photometric images were visually inspected; the author excluded images with inadequate tracking or seeing quality, digital artifacts caused by changing CMOS read mode, excessive interference by cloud or moon, or having stars, satellite tracks, cosmic ray artifacts, residual image artifacts, or other apparent light sources within 12 arcseconds of the target asteroid's signal centroid. Images passing these screens were submitted to the workflow.

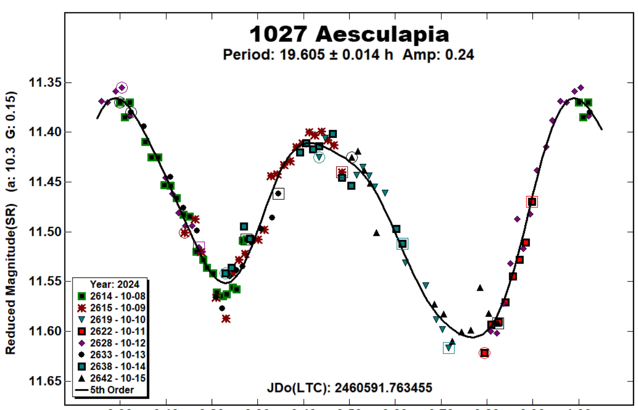
Transforms required by the GG495 light-yellow filter used here are modest in size and essentially linear (first-order), and they yield magnitudes in the standard Sloan r' (SR) passband. In our hands, using this filter (rather than a clear filter or no filter) improves transform linearity and night-to-night magnitude reproducibility to a degree outweighing the minor loss of signal-to-noise ratio caused by ~15% loss of measured flux.

Our workflow employs as comp stars all ATLAS refcat2 entries having: distance of at least 15 arcseconds from image boundaries and from other catalogued flux sources, no catalog VARIABLE flag, SR magnitude within [-2, +1] of the target asteroid's SR magnitude on that night (except that very faint asteroids used comp stars having magnitudes in the range 14 to 16), Sloan r'-i' color value within [0.10, 0.34], and absence of variability as seen in session plots of each comp star's instrumental magnitude vs time.

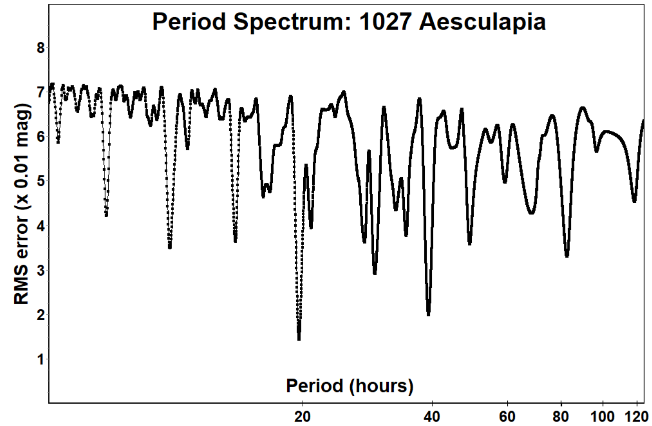
In this report, "period" denotes an asteroid's synodic rotation period, and "mmag" denotes millimagnitudes (0.001 magnitude). In the lightcurves below, *MPO Canopus* v10 shows "SR" for both Pan-STARRS and Sloan r' values.

<u>1027 Aesculapia</u>. This Themis-family asteroid was found to have a synodic rotation period of 19.605 ± 0.014 h, in reasonable agreement with one survey result (19.506 h, Waszczak et al., 2015) and one other result with lightcurve (19.90 h, Polakis, 2020), as well as being consistent with one constraint result (> 15 h, Behrend, 2024web), but in disagreement with other published results (6.83 h, Maleszewski and Clark, 2004; 14.4 h, Behrend, 2004web; 9.791 h, Ehlert and Kingery, 2015; 13.529 h, Hess et al., 2017).

Our observations over 8 consecutive nights yield a bimodal lightcurve with Fourier fit RMS error of 14 mmag. The narrow range of our phase angles does not allow for estimating optimum *G* value (*H-G* model), so we apply the MPC default value of 0.15.

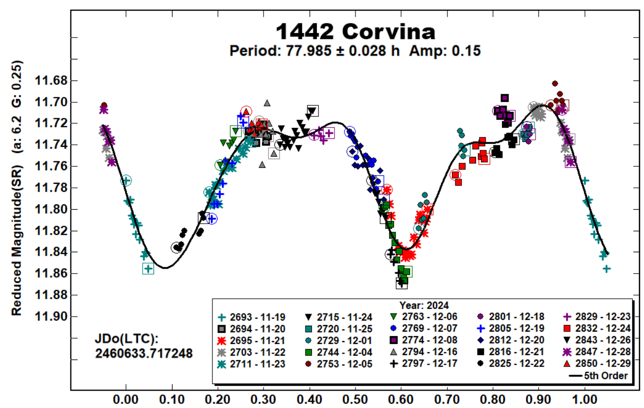


Our period spectrum's dominant signals appear at our period estimate and at twice that duration. Minor signals appear near the reported period estimates of Maleszewski and Clark, Ehlert and Kingery, and Hess et al.

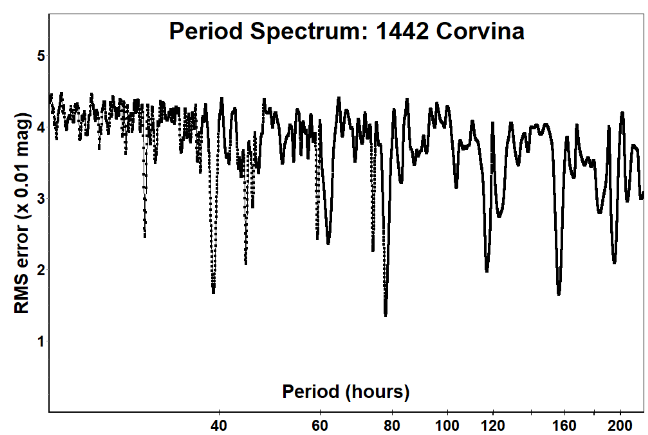


<u>1442 Corvina</u>. Observations during 25 nights have yielded our period estimate of 77.985 ± 0.028 h for this Koronis-family asteroid, agreeing with one published result (77.92 h, Slivan, 2021) but differing from another (31.36 h, Polakis, 2021). Our RMS error is 14 mmag, with our optimum *G* value being near 0.25.

The lightcurve is bimodal and shapes of the 2 brightness maxima are complex; in our hands, Fourier fits were often unreasonably poor when applying a lower fit order or when adopting the MPC default *G* value of 0.15.

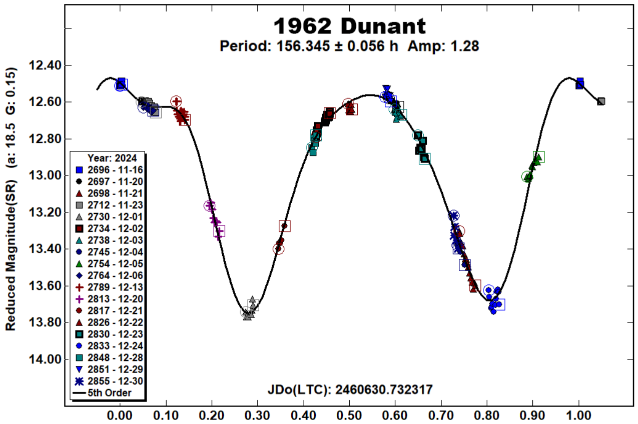


In our period spectrum, dominant signals appear at 0.5, 1.0, and 2.0 times our period estimate. Little or no signal appears near 31.36 h.

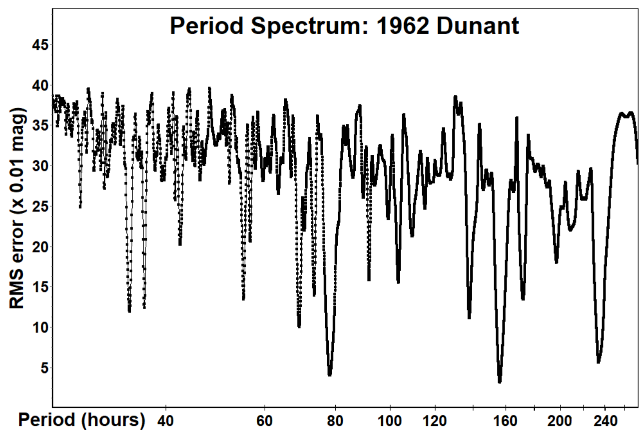


<u>1962 Dunant</u>. By observing this outer main-belt asteroid for 19 nights during 2024's unusually favorable opposition, we find a rotation period of 156.345 ± 0.056 h. We know of no previously

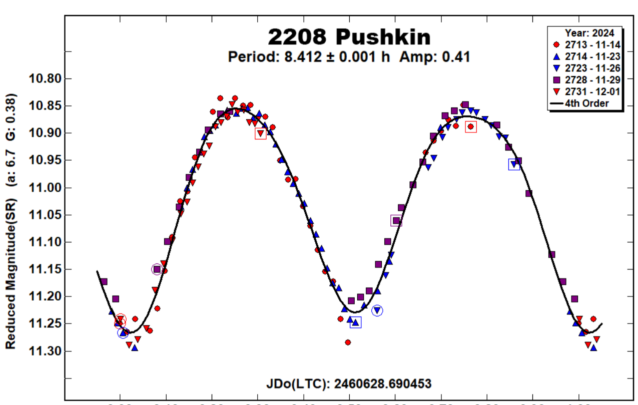
published period or lightcurve. A bimodal interpretation is supported by the lightcurve's large amplitude and by the differing shapes of alternating brightness maxima. RMS error is 32 mmag, and optimum *G* value is near 0.15.



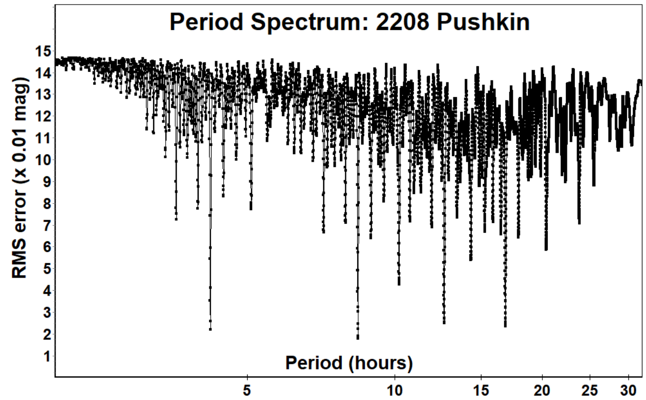
Our period spectrum is dominated by signals at 1, 2, and 3 times our proposed rotation period. Relative weakness of the signal near 0.5 times our proposed period further supports a bimodal shape.



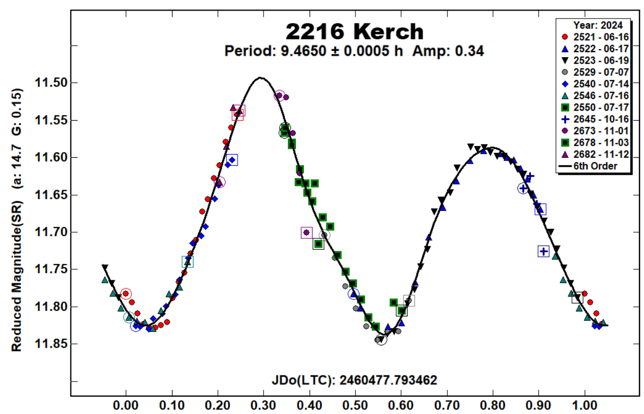
2208 Pushkin. For this outer main-belt asteroid, we report a rotation period of 8.412 ± 0.001 h, in agreement with one published survey estimate (8.405 h, Waszczak et al., 2015). The amplitude of 0.41 mag persuades us to adopt a bimodal lightcurve interpretation, though the folded lightcurve's two halves are similar. Our Fourier fit RMS error is 18 mmag, and our best *G* estimate was the MPC default of 0.15.



The period spectrum's major signals appear at 0.5, 1, 1.5, and 2 times our period estimate, consistent with a bimodal lightcurve whose halves are very similar in shape. The secondary signal near 10.2 h is an alias of our estimate by 1/2 rotation per day.

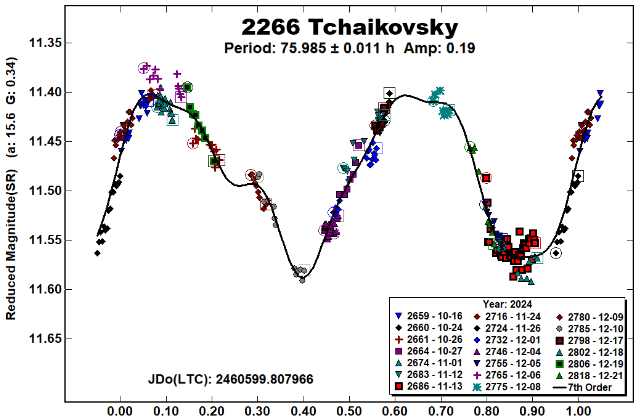


2216 Kerch. Our new period estimate of 9.4650 ± 0.0005 h for this Eos-family asteroid matches all three previously published estimates (9.462 h, Krotz et al., 2010; 9.47 h, Yeh et al., 2020; 9.46607 h, Ďurech et al., 2020). The lightcurve is clearly bimodal in shape, and it remained remarkably consistent though our 16 weeks of observations and through a very wide range of phase angles. Our RMS error is 14 mmag and was optimized with a *G* value of 0.15.

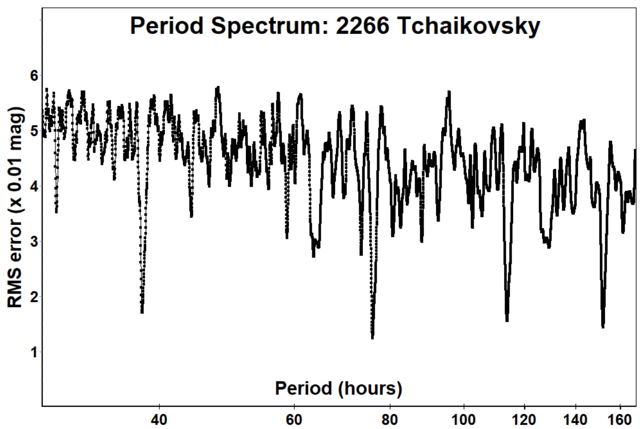


2266 Tchaikovsky. We observed this outer main-belt asteroid for 20 nights during its favorable 2024 opposition, and we propose a rotation period of 75.985 ± 0.011 h, in agreement with one survey estimate (76.1605 h, Pál et al., 2020) but differing from two other published estimates (4.883 h, Warner, 2006; 37.7 h, Warner, 2011), this last having been presented on a monomodal basis and being in fact close to half our new estimate.

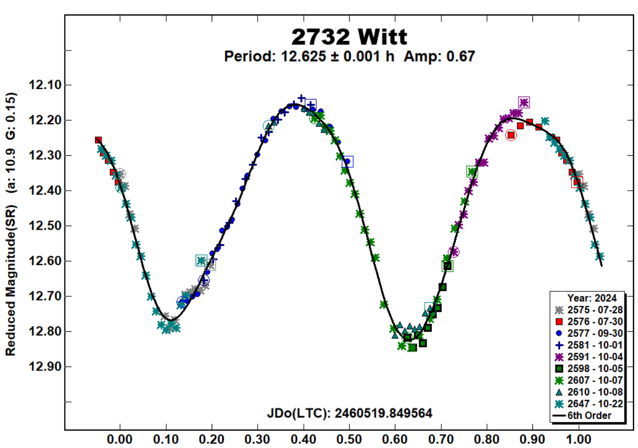
Despite our lightcurve's modest amplitude, we favor a bimodal interpretation because of differing shapes of the dimming phase segments as well as differing shapes of the brightness minima. Our Fourier fit RMS error is 12 mmag, and applying a *G* value of 0.34 resulted in RMS error about 40% of the error obtained when the MPC default of 0.15 was applied.



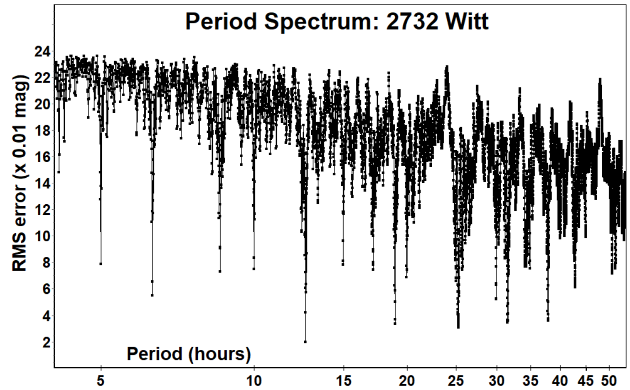
Our period spectrum has major signals only at 0.5, 1, 1.5, and 2 times our period estimate.



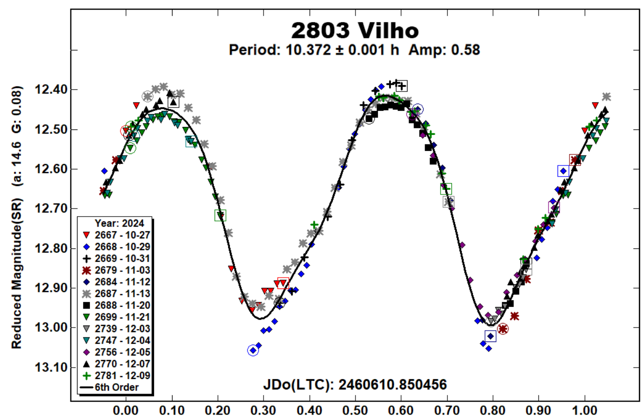
2732 Witt. For this parent asteroid of the Witt family, we confirm previous period constraints and estimates (> 0.88 h, Erasmus et al., 2018 and Erasmus et al., 2019; 12.662 h, Behrend, 2018web; 12.6244 h, Pilcher, 2025) with our new estimate of 12.625 ± 0.001 h. The lightcurve's amplitude is large, and its shape is clearly bimodal. Our RMS error is 20 mmag, and optimum *G* value is the MPC default of 0.15, which we applied.



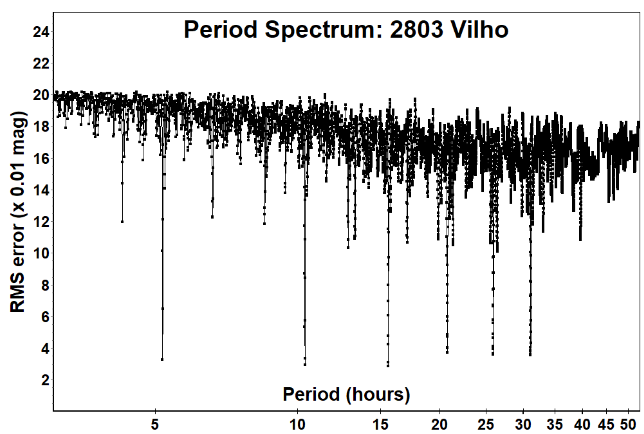
In the period spectrum, major signals appear only at multiples of ½ our period estimate, as common for bimodal lightcurves whose halves are similar.



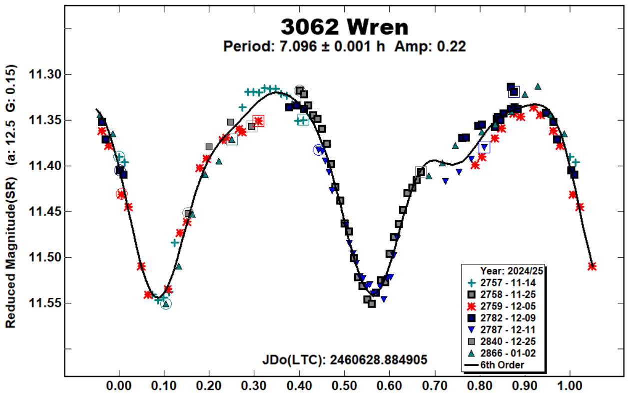
2803 Vilho. Our period estimate of 10.372 ± 0.001 h for this Themis-family asteroid agrees with one published survey estimate (10.37278 h, Ďurech et al., 2019) but differs from another report (12.5 h, Behrend, 2015web). Our Fourier fit RMS error is 27 mmag, as minimized by our G estimate of 0.08.



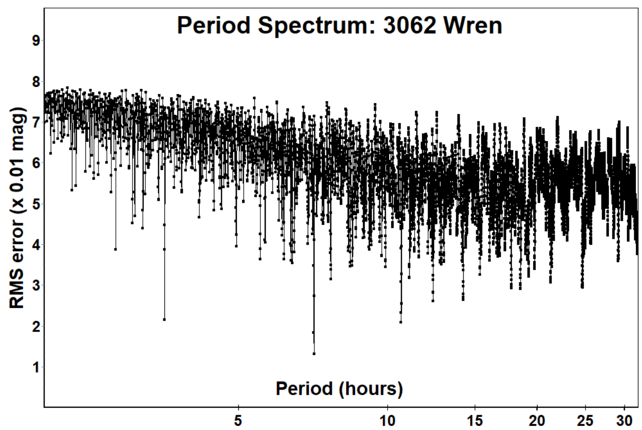
The period spectrum appears as expected for a bimodal lightcurve of high signal-to-noise ratio and similar halves.



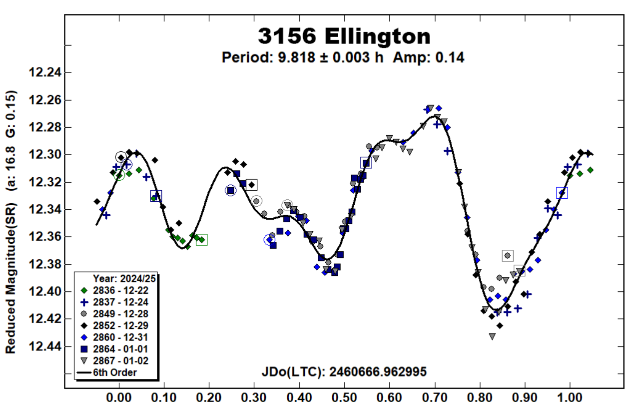
3062 Wren. We estimate the rotation period for this Eos-family asteroid to be 7.096 ± 0.001 h, agreeing with most (6.967 h, Behrend, 2006web; 7.097 h, Carbo et al., 2009; 7.097 h, Vinson et al., 2014) but not all (5.50 h, Behrend, 2020web) published reports. The lightcurve appears to be bimodal in shape, though our data do not strictly rule out a monomodal solution. Our RMS error is 12 mmag, and the MPC default *G* value of 0.15 was close to optimum.



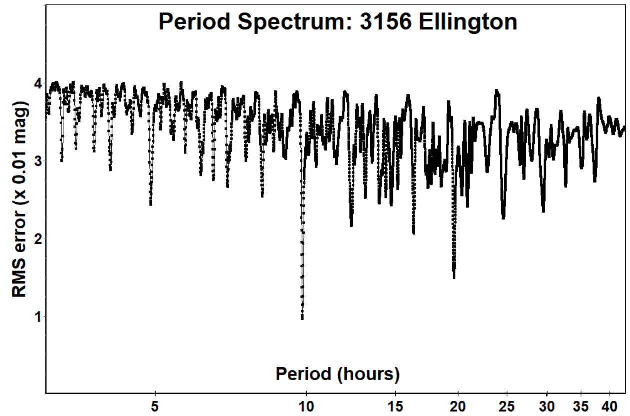
One signal at our period estimate dominates the period spectrum, with secondary signals appearing at 0.5 times (monomodal solution) and at 1.5 times our estimate.



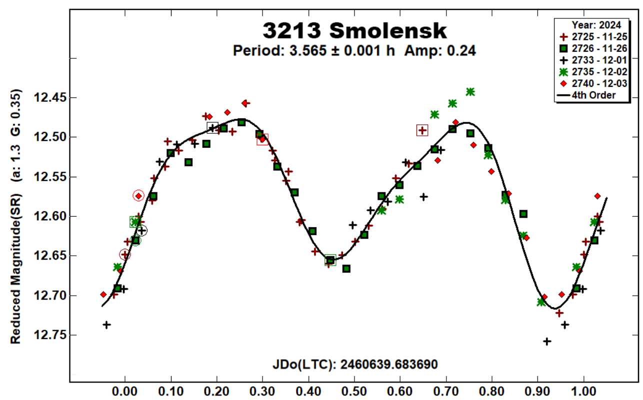
3156 Ellington. For this outer main-belt asteroid, we report a period of 9.818 ± 0.003 h, agreeing with one survey report (9.82234 h, Pál et al., 2020) but differing from all other known reports (3.53 h, Warner, 2011web; 12.48 h, Behrend, 2006web; 8.33 h, Menke, 2008). Our lightcurve shape is atypical, and its modality is ambiguous. RMS error is 10 mmag, and because it was insensitive to the G value applied, we adopted the MPC estimate of 0.15.



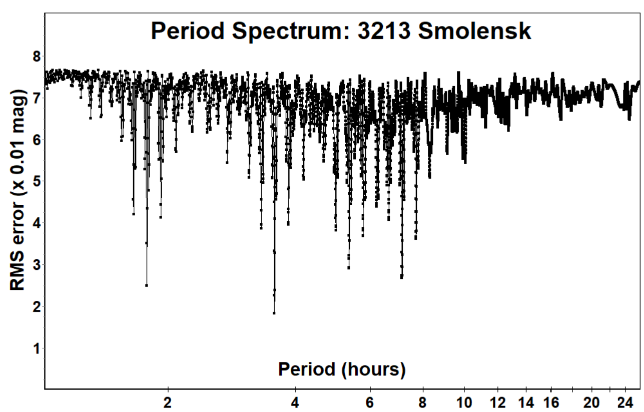
The period spectrum is dominated by one signal at our period estimate. The previously reported estmate of 12.48 h is an alias of our solution by ½ period per day.



3213 Smolensk. We find a rotation period of 3.565 ± 0.001 h for this Themis-family asteroid, agreeing with previously reported survey results (3.564 h and 3.563 h, Waszczak et al., 2015). Our Fourier fit RMS error is 18 mmag, and applying a *G* value (*H-G*) of 0.35 markedly decreased the error relative to that using MPC's default value of 0.15.



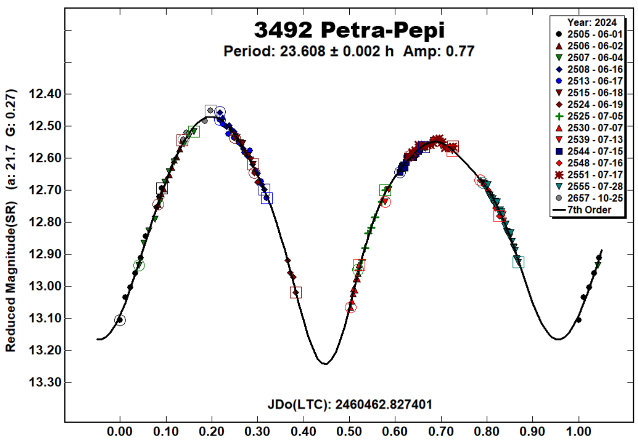
Despite the secondary aliasing typical of fast rotators, the period spectrum is dominated by one signal at our period estimate.



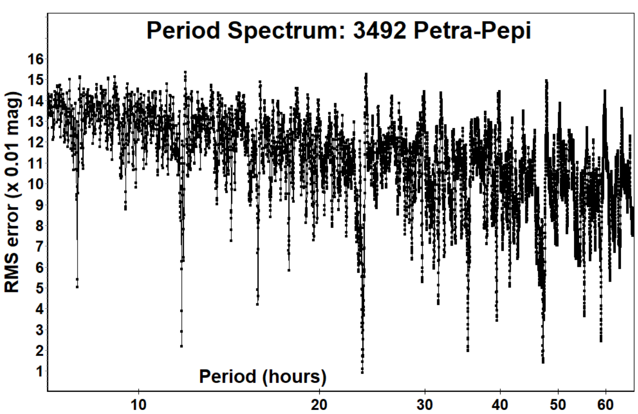
3492 Petra-Pepi. From 15 nights of observations of this Eunomia-family asteroid, we obtain a high-amplitude, clearly bimodal lightcurve and a period estimate of 23.608 h ± 0.002 h, agreeing with one previous report (23.58 h, Behrend, 2019web) but disagreeing with two others (47.05 h, Stephens, 2011; 46.570 h, Hanuš et al., 2013). Our RMS error is 9 mmag, and applying a *G* value of 0.27 modestly decreased the error relative to applying MPC's default value of 0.15.

Our lightcurve is missing data at both brightness minima, and this is due to two unfortunate (for observers) properties of this period: (1) the nearness to 24 h means that one's observations advance in phase very little from night to night, so that full phase coverage requires a campaign of at least 60 days; and more subtly, (2) the period's exact difference from 24 h causes loss of observing nights near full moons to repeat in phase every two lunar cycles. This latter means that, for any single opposition of this asteroid, two spans of phases, separated by about 0.5, will always be missing from a phased lightcurve, no matter how many weeks long the observing campaign or how many hours long the nightly observing sessions.

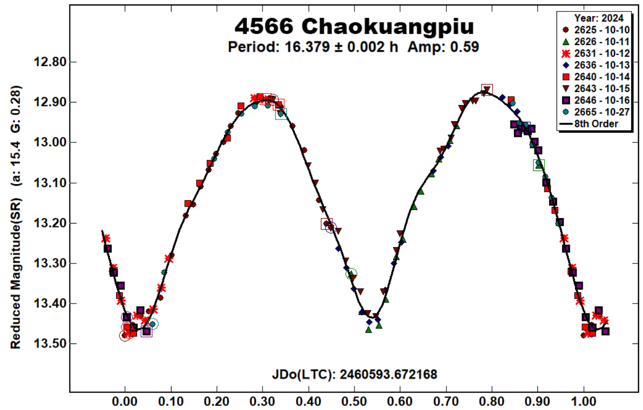
As this effect is lunar rather than sidereal, resulting phase coverage gaps cannot be remedied by cooperative observing from multiple longitudes. That is: single-opposition lightcurves of (3492) Petra-Pepi built from terrestrial observations will probably always contain phase-coverage gaps very much like those we display below. These gaps would be minimized by observing closer to the moon near full moons; the lightcurve's high amplitude might help make that possible.

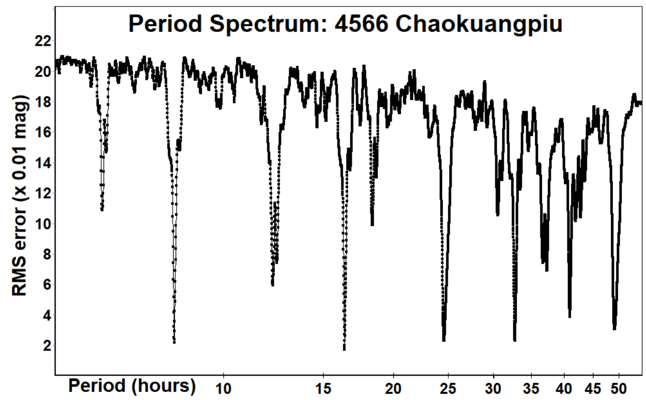


Despite gaps in phase coverage, our period spectrum is essentially unambiguous. The previously reported estimates near 47 h appear as a strong secondary signal; but corresponding lightcurves are tetramodal in shape.

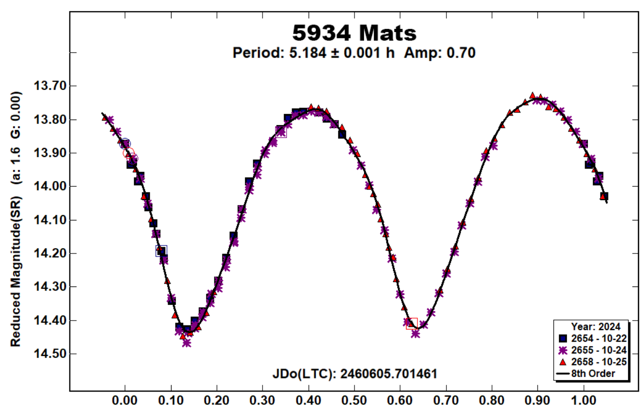


4566 Chaokuangpiu. We find a rotation period of 16.379 ± 0.002 h for this Itha-family asteroid, in agreement with one survey result (16.3825 h, Ďurech et al., 2020). The lightcurve amplitude is large enough to favor bimodal interpretation, resulting in our estimate. Applying *G* value of 0.28 gave the best fit, yielding an RMS error of 17 mmag.

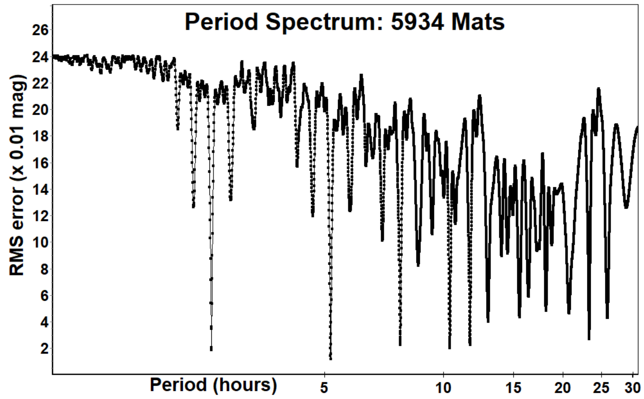




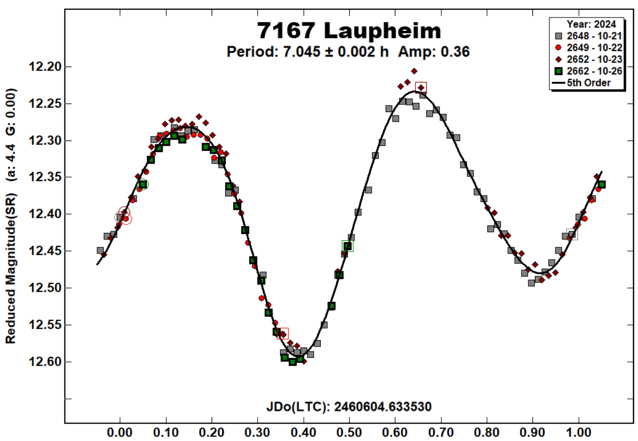
5934 Mats. For this asteroid, commonly assigned to the Nysa or Hertha family, three nights of observations sufficed to estimate its rotation period as 5.184 ± 0.001 h, in agreement with one known published report (5.184 h, Erasmus et al., 2020). The period spectrum and the lightcurve's large amplitude together support our bimodal interpretation. A G value of 0.0 modestly improved the fit relative to the MPC default G of 0.15, yielding our RMS error of 12 mmag.



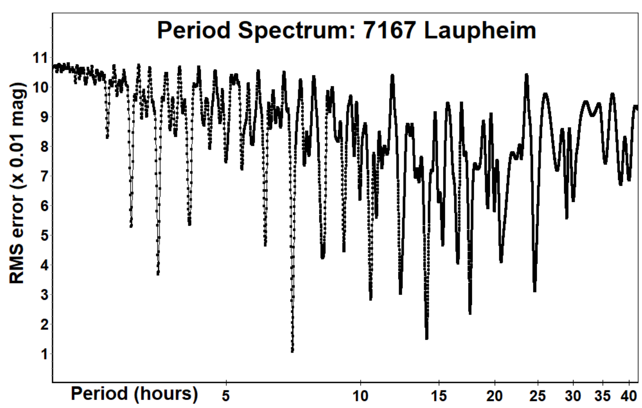
The period spectrum is dominated by signals at multiples of ½ our period estimate, as expected from the lightcurve shape.



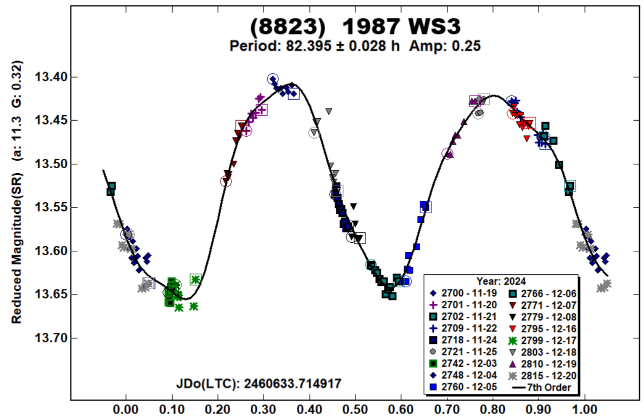
7167 Laupheim. Four nights of observations sufficed to determine the period of this outer main-belt asteroid as 7.045 ± 0.002 h, in agreement with one survey report (7.040 h, Waszczak et al., 2015). Applying G value of 0.0 modestly improved the Fourier fit relative to the MPC default G of 0.15, yielding our RMS error of 11 mmag.

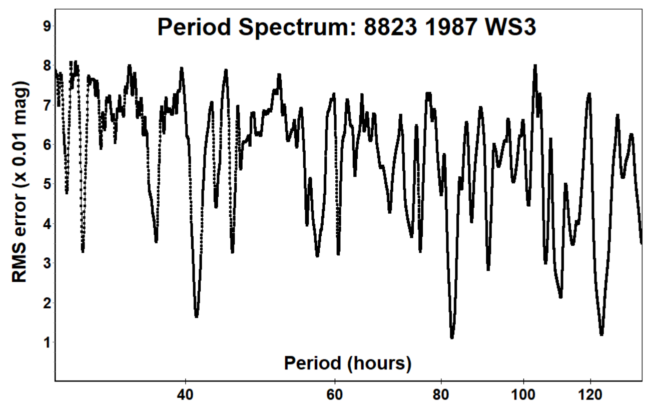


The period spectrum is dominated by a signal at our period estimate, with a strong secondary signal at twice our estimate.

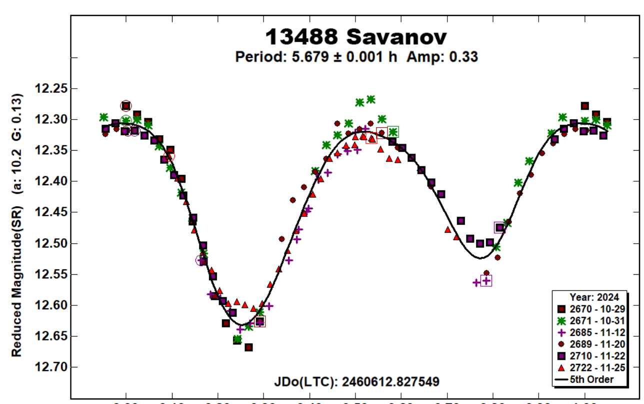


(8823) 1987 WS3. Three estimates have recently been published for the rotation period of this Mitidika-family asteroid, and all three differ (110.88 h, Behrend, 2020web; 86 h, Marchini et al., 2021; 80.811 h, Noschese et al., 2021). From 17 nights of observation spanning 32 calendar nights (9 period durations), we find a period of 82.395 ± 0.028 h, remarkably disagreeing with all three previous reports. Our phase coverage is quite nearly complete, yielding a lightcurve that is clearly bimodal in shape. Adopting a *G* value of 0.32 strongly reduced the fit RMS error relative to the MPC default of 0.15, resulting in an RMS error of 11 mmag.



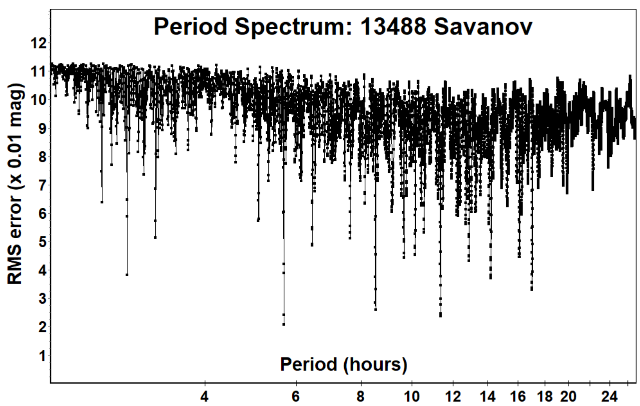


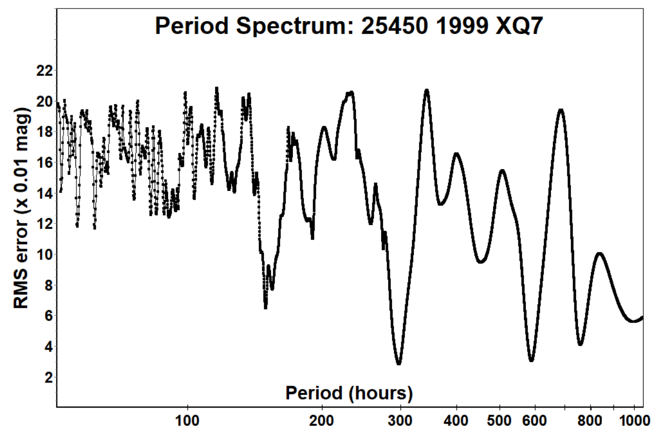
13488 Savanov. For this relatively faint Eos-family asteroid, we estimate the period to be 5.679 ± 0.001 h, agreeing with both published survey results (5.678 h, Waszczak et al., 2015; 5.67941 h, Ďurech et al., 2018). Our lightcurve is clearly bimodal in shape. The optimum G value is 0.13, yielding a RMS error of 19 mmag.



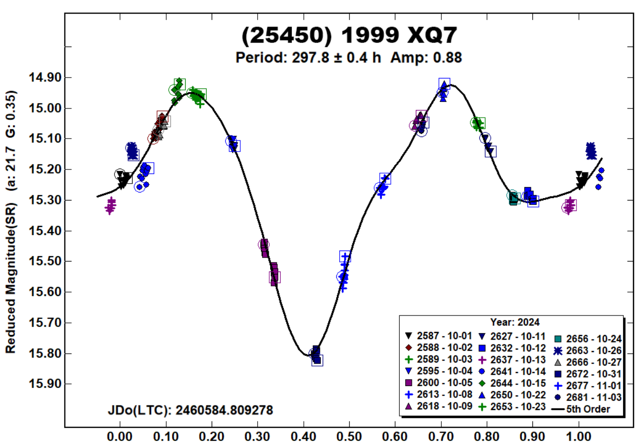
Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1027	Aesculapia	2024 10/08-10/15	10.4,8.4	46	0	19.605	0.014	0.24	0.04	THM
1442	Corvina	2024 11/19-12/29	6.1,18.1	44	0	77.985	0.028	0.15	0.03	KOR
1962	Dunant	2024 11/16-12/30	18.4,24.0	17	0	156.345	0.056	1.28	0.08	MB-O
2208	Pushkin	2024 11/14-12/01	6.8,1.1	72	-1	8.412	0.001	0.41	0.04	MB-O
2216	Kerch	2024 06/16-11/12	*14.8,20.6	304	5	9.465	0.001	0.34	0.05	EOS
2266	Tchaikovsky	2024 10/16-12/21	*15.7,9.6	66	-4	75.985	0.011	0.19	0.05	MB-O
2732	Witt	2024 07/28-10/22	*11.1,18.9	332	-1	12.625	0.001	0.67	0.04	WIT
2803	Vilho	2024 10/27-12/09	*14.7,3.6	69	1	10.372	0.001	0.58	0.08	THM
3062	Wren	2024-5 11/14-01/02	*12.7,7.8	83	-7	7.096	0.001	0.22	0.04	EOS
3156	Ellington	2024-5 12/22-01/02	16.9,13.8	120	20	9.818	0.003	0.14	0.03	MB-O
3213	Smolensk	2024 11/15-12/03	*3.1,4.4	60	0	3.565	0.001	0.24	0.06	THM
3492	Petra-Pepi	2024 06/01-10/25	*21.8,22.9	303	4	23.608	0.002	0.77	0.10	EUN
4566	Chaokuangpiu	2024 10/10-10/27	15.5,8.1	46	8	16.379	0.002	0.59	0.06	ITH
5934	Mats	2024 10/22-10/25	1.6,2.7	29	-2	5.184	0.001	0.70	0.04	NYS
7167	Laupheim	2024 10/21-10/26	4.4,5.5	24	8	7.045	0.002	0.36	0.05	MB-O
8823	1987 WS3	2024 11/19-12/20	11.1,23.9	43	4	82.395	0.028	0.25	0.04	MIT
13488	Savanov	2024 10/29-11/25	*10.3,1.2	60	1	5.679	0.001	0.33	0.08	EOS
25450	1999 XQ7	2024 10/01-11/03	21.9,4.8	43	4	297.800	0.400	0.88	0.12	MB-I

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





(25450) 1999 XQ7. From 20 nights' observations of this inner main-belt asteroid, we estimate a rotation period of 297.8 h ± 0.4 h. We know of no previous reports of period or lightcurve for this asteroid. The lightcurve shape is unusual, with similar brightness maxima but with minima differing by half a magnitude. We detect no effect of precession ("tumbling") on the lightcurve. *G* value of 0.35 optimized the RMS error, which is 28 mmag.



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LIGHTCURVE AND ROTATION PERIOD ANALYSIS FOR TWENTY-FIVE MINOR PLANETS

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Photometric measurements of CCD observations on twenty-five minor planets were made from 2024 April through 2025 January. Phased lightcurves were created for each one. All data has been submitted to the ALCDEF database.

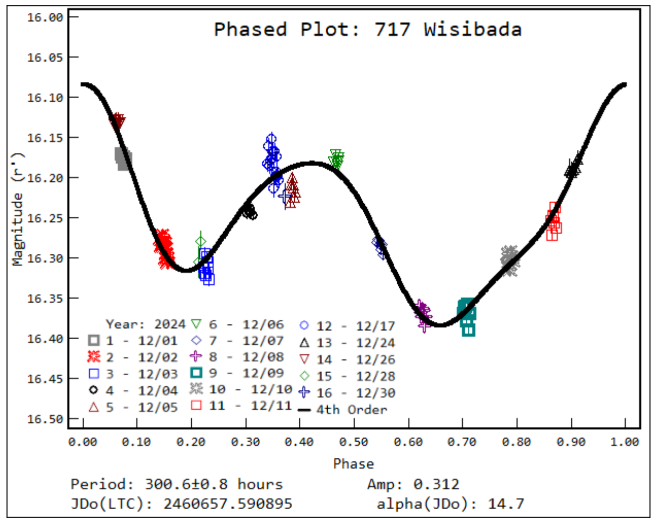
Photometric CCD observations of twenty-five main-belt asteroids were performed at Chiricahua Skies Observatory (MPC V43) near Sunizona, Arizona. Images from 2024 April through 2024 November were taken using a 0.35m f/4.69 Corrected Dall-Kirkham telescope and Teledyne CCD47-10 sensor yielding an image scale of 1.61”/pixel. In 2024 December the 0.35m Corrected Dall-Kirkham was reconfigured to operate at its native f/7.3 focal ratio and a QHY-268 CMOS camera was installed yielding an image scale of 0.3”/pixel. Table I shows observing circumstances and results. All images for these observations were obtained between 2024 December and 2025 January.

Data reduction and period analysis were done using *Tycho* (Parrott, 2024). The asteroid and five or more 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.

Comparison star magnitudes were obtained from the ATLAS catalog (Tonry et al., 2018), which is incorporated directly into *Tycho*. A measuring aperture equal to 4× FWHM of the target was used for asteroids and comp stars. Interference from field stars resulted in the exclusion of affected observations. Period determination was done using *Tycho*.

Asteroids were selected from the CALL website (Warner, 2011), either for having uncertain periods or no reported period at all. The Asteroid Lightcurve Database (LCDB) Warner et al. (2009) was consulted to locate previously published results. All new data for these asteroids has been submitted to the ALCDEF database.

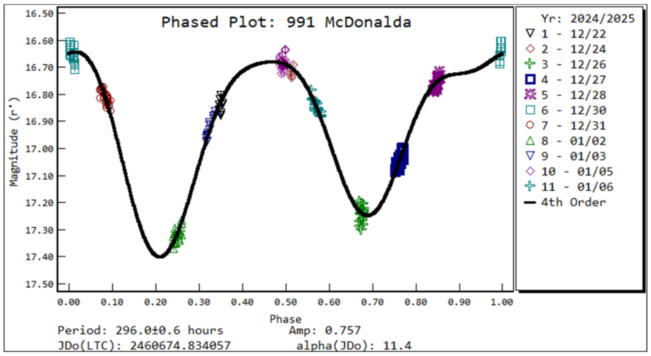
717 Wisibada is an outer main-belt asteroid with an estimated diameter of 27.66 km. A search of the LCDB revealed three separate period solutions reported during the 2023 apparition. Dose (2023) reported a period of 609.06 ± 0.49 h; Polakis (2024) reported a period of 480.8 ± 2.2 h and Colazo et al. (2023) reported a period of 1250 ± 35 h. In 2024 December observations were obtained during sixteen nights of a thirty-night period and used to calculate a period solution of 300.6 ± 0.8 h, disagreeing with all previously published solutions. The amplitude of the lightcurve is 0.312 ± 0.018 magnitude.



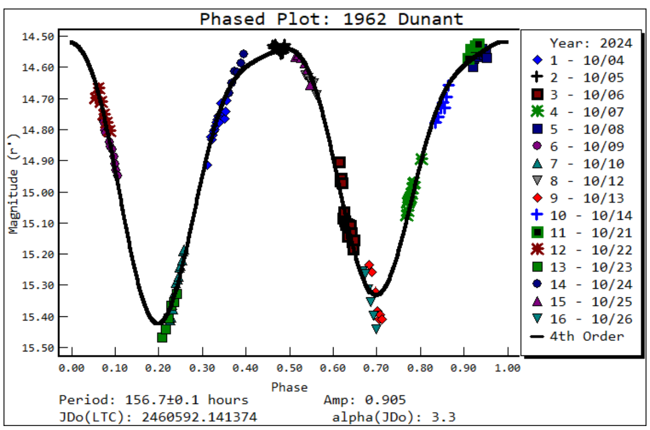
Number	Name	yy/mm/dd-mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
717	Wisibada	24/12/01-12/30	10.2,16.3	129	1	300.6	0.8	0.312	0.018	MB-O
991	McDonalda	24/12/22-25/01/06	12.9,9.8	140	2	296.0	0.6	0.757	0.022	Themis
1962	Dunant	24/10/04-10/26	1.2,11.3	9	0	156.7	0.1	0.905	0.019	MB-O
2493	Elmer	24/10/23-10/26	7.7,9.2	15	1	4.754	0.001	0.549	0.019	MB-O
2779	Mary	24/04/11-04/17	5.7,8.9	194	5	7.178	0.005	0.043	0.011	MB-I
3418	Izvekov	24/10/30-11/01	1.1,2.0	41	-1	9.627	0.003	0.372	0.013	Themis
3469	Bulgakov	24/12/01-12/11	3.3,6.8	61	-4	176.1	1.0	0.085	0.011	Eos
3583	Burdett	24/10/06-10/14	9.5,13.6	36	0	2.719	0.001	0.136	0.014	Hertha
3654	AAS	24/10/05-10/14	2.9,8.8	9	0	3.547	0.003	0.101	0.027	MB-I
4510	Shawna	24/10/23-10/29	9.7,12.8	14	3	19.21	0.06	0.099	0.009	Vesta
5050	Doctorwatson	24/10/25-10/28	9.2,10.9	17	1	3.321	0.001	0.103	0.019	MB-I
5510	1988 RF7	24/10/22-10/29	21.0,24.0	69	-5	53.32	0.10	0.610	0.026	Mars
5552	Studnicka	24/10/23-10/28	18.9,20.7	67	-9	5.915	0.003	0.119	0.018	MB-O
5914	Kathywhaler	24/12/01-12/11	*0.1,2.7	71	0	196.2	0.7	0.215	0.014	Sylvia
6516	Gruss	24/12/04-25/01/07	0.7,16.9	73	1	185.0	0.8	0.126	0.023	MB-I
6666	Fro	24/11/09-11/13	0.3,2.2	48	0	4.912	0.001	0.243	0.023	MB-I
6985	1994 UF2	24/11/02-11/19	0.9,8.2	42	0	20.00	0.01	0.166	0.025	Vesta
7556	Perinaldo	24/10/04-10/26	1.1,10.7	9	0	158.5	0.1	0.563	0.027	MB-O
7654	1991 VV3	24/10/06-10/22	5.1,14.4	35	-1	63.41	0.05	0.226	0.020	Hertha
7926	1986 RD5	24/10/11-10/24	3.4,8.7	11	2	19.71	0.01	0.282	0.039	MB-O
8805	Petrpetrov	23/10/30-11/08	*1.3,3.7	41	-1	5.571	0.001	0.120	0.019	MB-I
9133	d’Arrest	24/10/31-11/08	*1.0,3.4	41	-1					Eunomia
9914	Obukhova	24/11/05-11/12	2.0,4.2	44	-2	4.914	0.009	0.063	0.018	Misa
31902	Raymondwang	24/10/11-10/21	4.5,10.0	11	2	6.207	0.001	0.954	0.133	MB-I

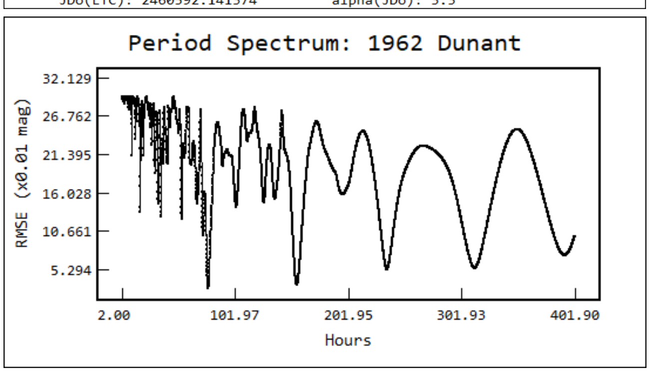
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984).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

991 McDonalda has a single period published in the LCDB by Pilcher (2024) of > 16 hours. He notes that only a single night of data was obtained and that a large amount of telescope time would be required to determine an accurate period solution. From 2024 December to 2025 January, the author committed telescope time to make 218 observations on eleven different nights. This data was used to determine that 991 McDonalda is a slow rotator with a large amplitude. The calculated period is 296.0 ± 0.6 hours and the amplitude is 0.757 ± 0.022 magnitude.

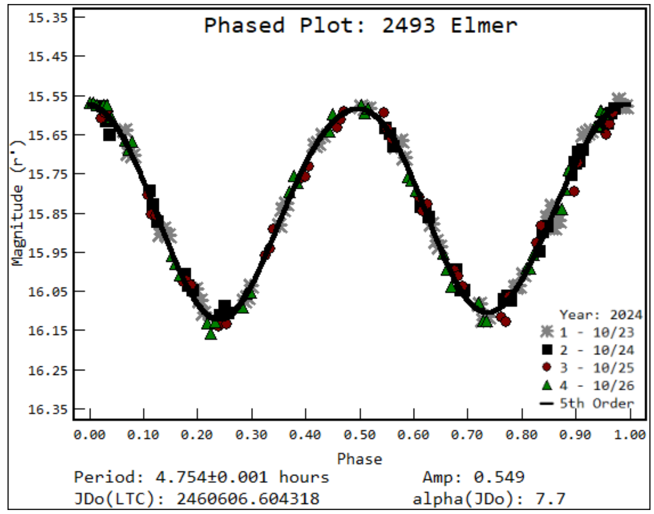


1962 Dunant is an outer main-belt asteroid with no published periods in the LCDB. Observations were conducted over a three-week period in 2024 October and 429 images were captured in sixteen observing sessions. A monomodal period of 78.4 h produces a slightly better fit, but the bimodal period solution is preferred and reported here. That period is 156.7 ± 0.1 h with an amplitude of 0.905 ± 0.019 mag.

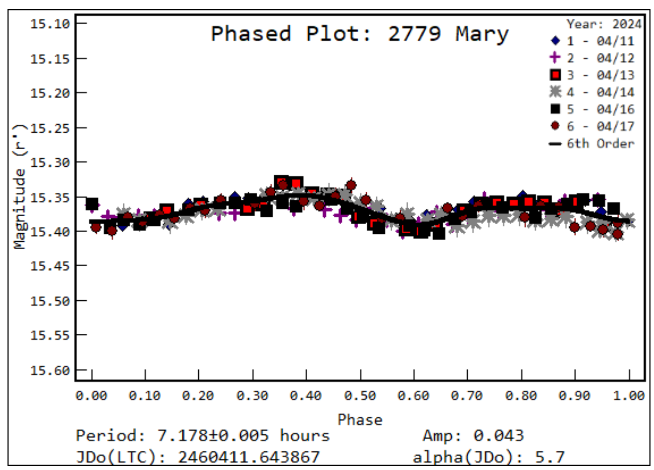


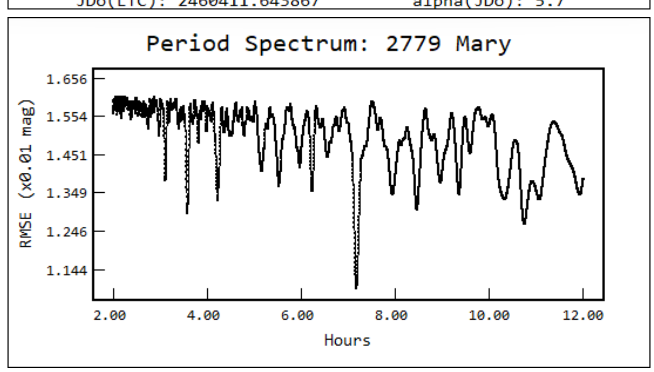


2493 Elmer was imaged on four consecutive nights in 2024 October resulting in 169 observations for period analysis. Durech et al. (2019) reported a period of 4.75449 ± 0.000002 h for this asteroid. The author calculated a period solution of 4.754 ± 0.001 h in agreement with Durech's previous result. The amplitude of the lightcurve is 0.549 ± 0.019 magnitude.

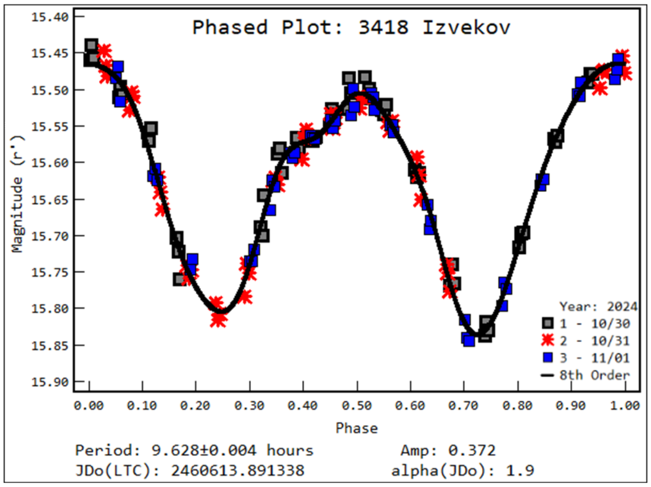


2779 Mary was observed on six consecutive nights in 2024 April. Behrend (2006web) reported a provisional period of 3.36 ± 0.05 h based on a single night of data in 2006, and Pilcher (2021) reported a period of 3.583 ± 0.001 h. 366 observations were made by the author and a period solution of 7.178 ± 0.005 h was calculated. The period spectrum shows a strong minimum at 7.178 hours. The period shown here is twice the period reported by Pilcher – disagreeing with previous observations of this asteroid. The amplitude of the lightcurve is 0.043 ± 0.011 magnitude.

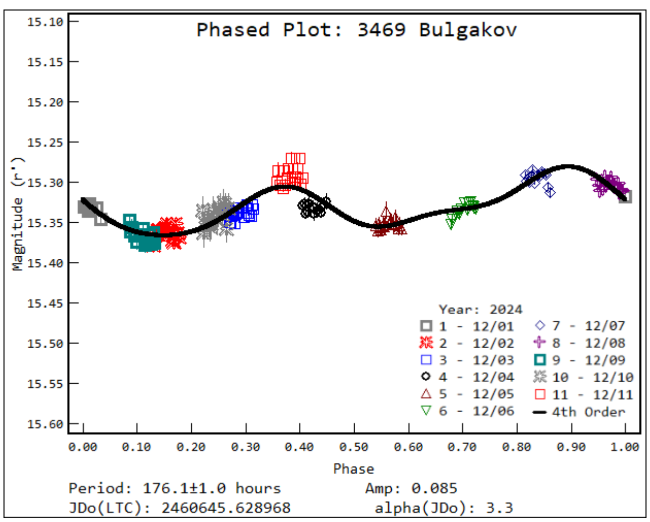




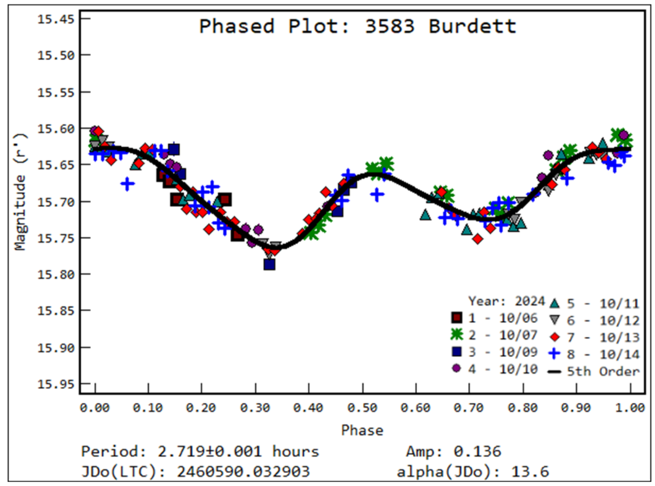
3418 Izvekov is a member of the Themis family of asteroids. A search of the LCDB revealed no reported solutions. During three consecutive nights, 149 images were gathered, producing a period solution of 9.627 ± 0.003 h. The amplitude of the lightcurve is 0.372 ± 0.013 magnitude.



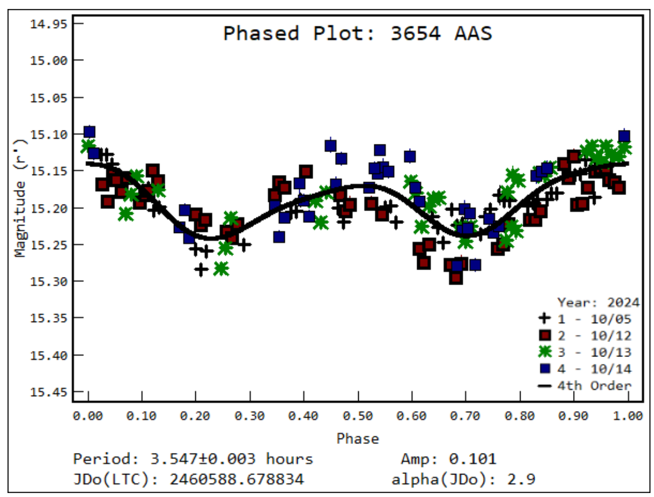
3469 Bulgakov is an Eos family asteroid with an estimated diameter of 18.86 km. Two period solutions were found in the LCDB. The earliest reported period by Behrend (2011web) is 6.48 ± 0.05 h; Durech et al. (2020) reported a period of 180.76 ± 0.01 h. A lightcurve was constructed from 511 data points obtained during an observing run of eleven consecutive nights in 2024 December. The calculated period of 176.1 ± 1.0 h is in agreement with the period published by Durech. The amplitude of the lightcurve is 0.085 ± 0.011 mag.



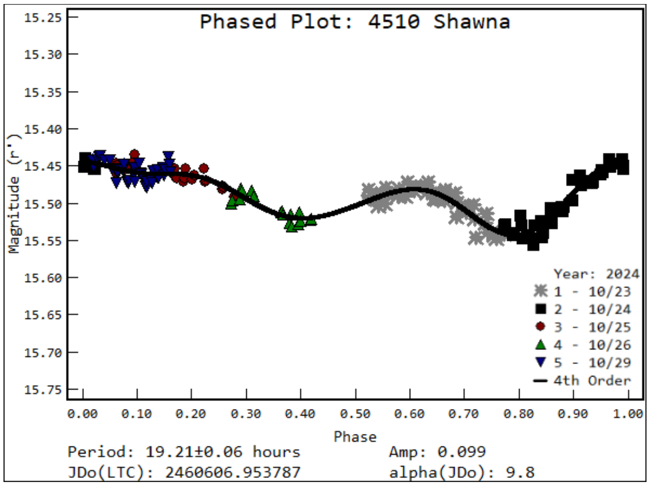
3583 Burdett is a Hertha family asteroid with no published period solutions in the LCDB. Observations were taken over eight nights in 2024 October. These resulted in a calculated period solution of 2.719 ± 0.001 h with an amplitude of the lightcurve is 0.136 ± 0.014 magnitude.



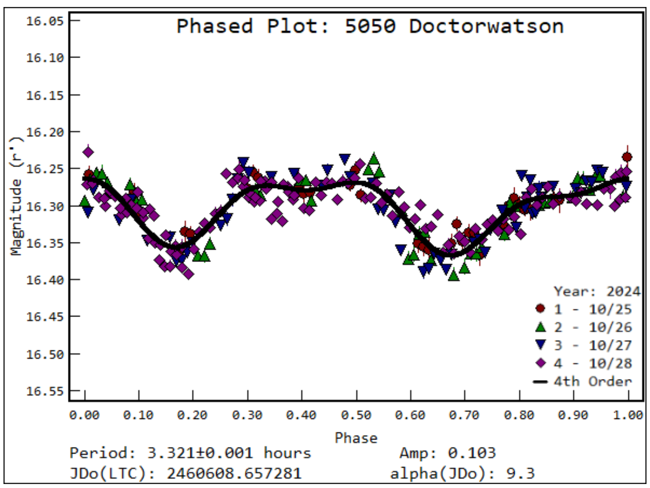
3654 AAS was observed over 4 nights in 2024 October. This inner main-belt asteroid has no published period solutions noted in the LCDB. 165 observations were made and used to determine a period solution of 3.547 ± 0.003 h. The amplitude of the lightcurve is 0.101 ± 0.027 magnitude.



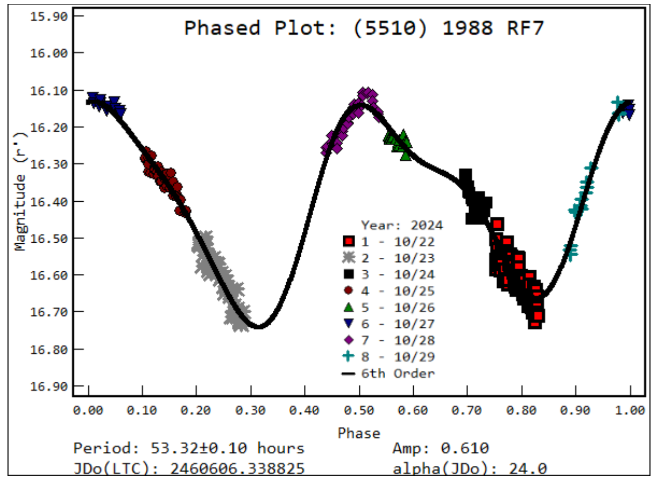
4510 Shawna is a Vesta family asteroid with no published periods in the LCDB. The author observed the asteroid on five nights in 2024 October and determined a period of 19.21 ± 0.06 h. The amplitude of the lightcurve is 0.099 ± 0.009 magnitude. Additional observations could refine the shape and period of the asteroid since the author was unable to obtain full coverage of its rotational period.



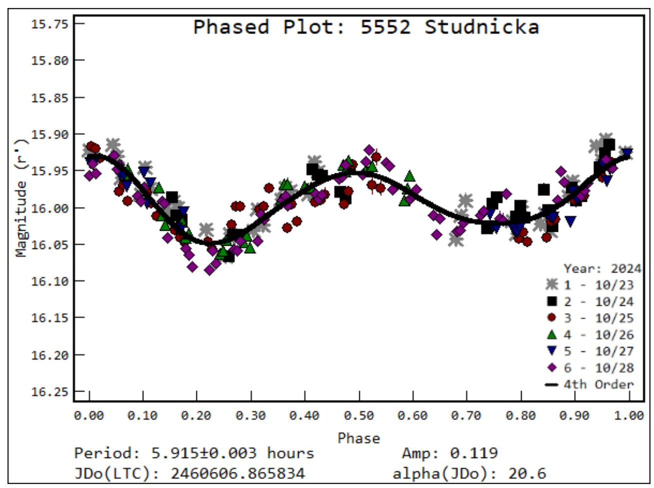
5050 Doctorwatson, a main-belt asteroid, was observed over four consecutive nights in 2024 October. In that time, 285 observations were made to derive a period solution of 3.321 ± 0.001 h and an amplitude of 0.103 ± 0.019 magnitude. No period solutions for this asteroid were found in the LCDB.



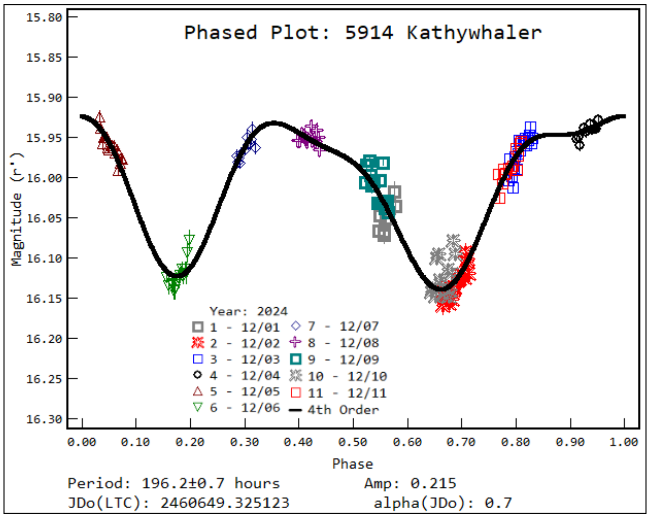
5510 1988 RF7 is an asteroid with a Mars-crossing orbit that lists a single period in the LCDB. Oey (2016) observed the asteroid on a single night when it shared the field with a different target. His comments note that the period of 3.2 ± 0.4 h is not conclusive and is based on sparse data. The author observed this target for eight consecutive nights and a period determination was made from the 273 images collected in that period. The author calculates a period of 53.32 ± 0.10 h with an amplitude of 0.610 ± 0.026 magnitude based on the more extensive data available for analysis.



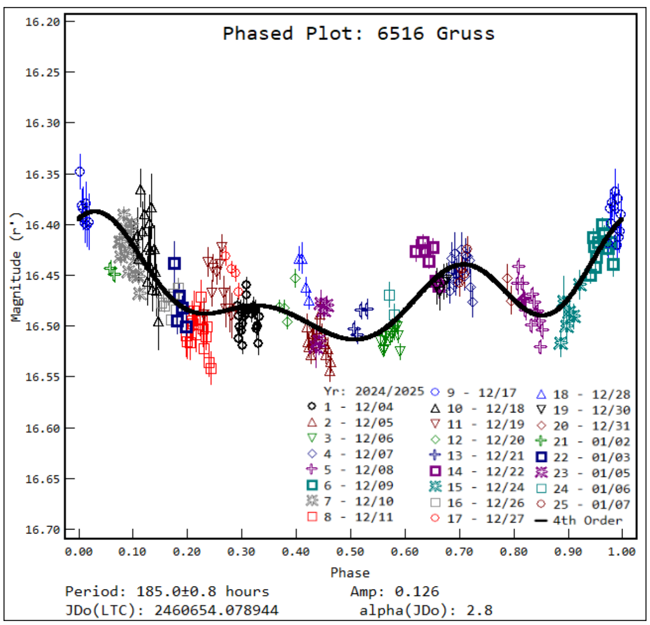
5552 Studnicka was observed on six consecutive nights in 2024 October. This outer main-belt asteroid has no published period solutions noted in the LCDB. During the 2024 apparition 230 observations were made and used to determine a period solution of 5.915 ± 0.003 h. The amplitude of the lightcurve is 0.119 ± 0.018 magnitude.



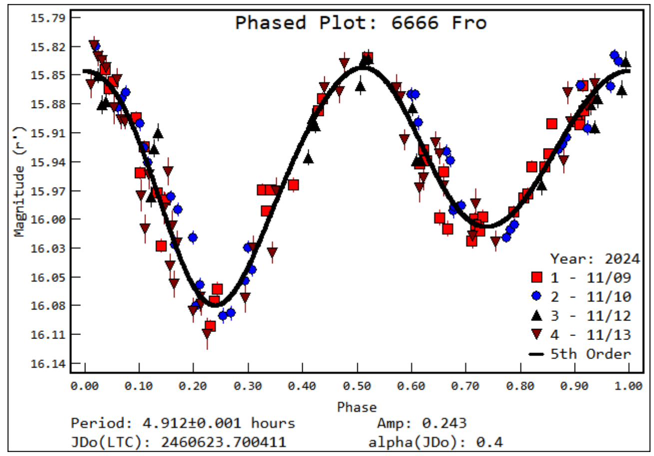
5914 Kathywhaler is a Sylvia family asteroid observed on eleven consecutive nights in 2024 December. Waszczak et al. (2015) reported a period of 38.73 ± 0.0725 h. A total of 457 data points obtained during the 2024 apparition and used to calculate a period solution of 196.2 ± 0.7 h, providing a different result from Waszczak. The period solution was only determined after iterating on multiple values for G. Using a value of G=0.60 provided the solution reported here. The amplitude of the lightcurve is 0.215 ± 0.014 magnitude.



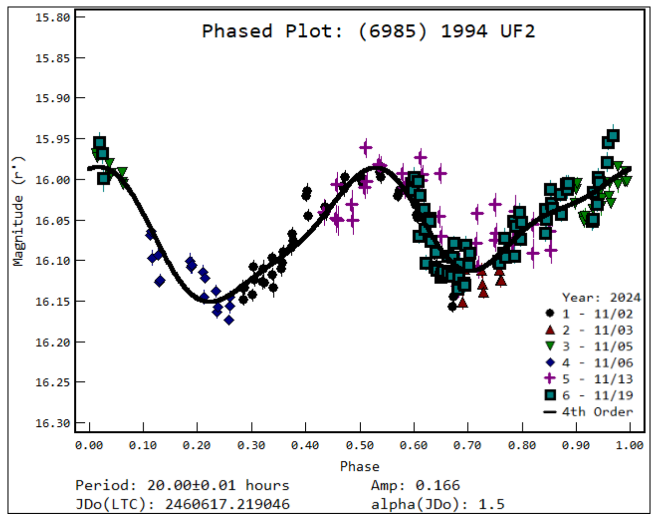
6516 Gruss is an inner main-belt asteroid with a single previously reported period listed in the LCDB. Clark (2014) reported a period of 13.003 ± 0.008 h. Data was obtained by the author over twenty-five nights between 2024 December and 2025 January to calculate a period solution of 185.0 ± 0.8 h, differing from the previous result. The amplitude of the lightcurve is 0.126 ± 0.023 magnitude.



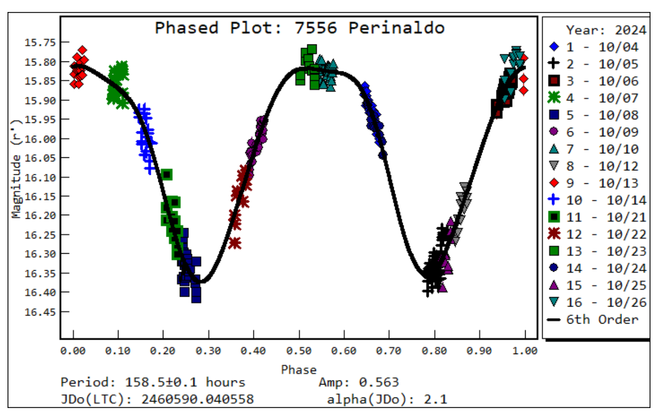
6666 Fro is an inner main-belt asteroid with an estimated diameter of 4 km. No period solutions exist in the LCDB. In 2024 November a total of 169 data points were obtained during four nights and used to calculate a period solution of 4.912 ± 0.001 h. The amplitude of the lightcurve is 0.243 ± 0.023 magnitude.



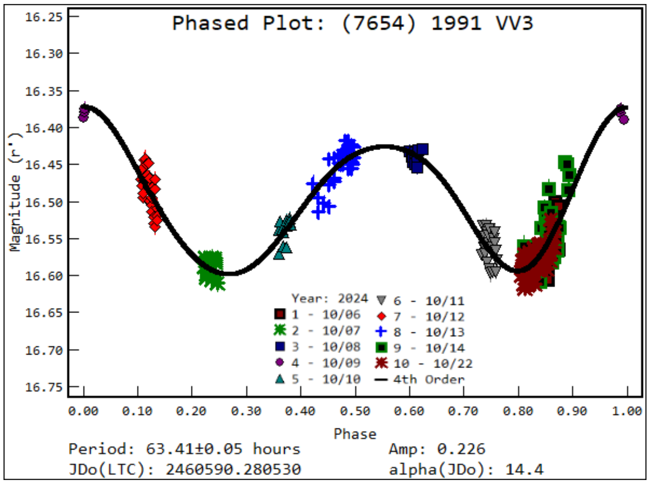
6985 1994 UF2, a Vesta family asteroid, was observed on six nights in 2024 November. A search of the LCDB revealed no published periods. The author calculated a period of 20.00 ± 0.01 h with an amplitude of 0.166 ± 0.025 magnitude.



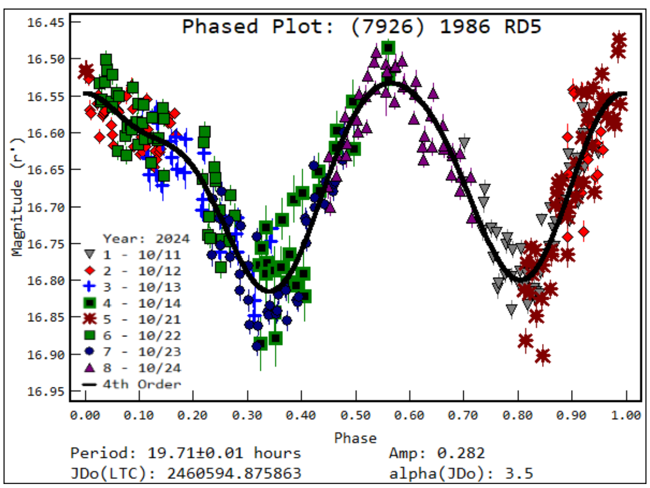
7556 Perinaldo was imaged on sixteen nights in 2024 October for the purpose of determining its rotation period. One previously reported period was found in the LCDB. Durech et al. (2019) reported a period of 159.102 ± 0.002 h for this asteroid. The author calculated a period of 158.5 ± 0. 1 h for this slow rotator in agreement with Durech's result. The amplitude of the lightcurve is 0.563 ± 0.027 magnitude.



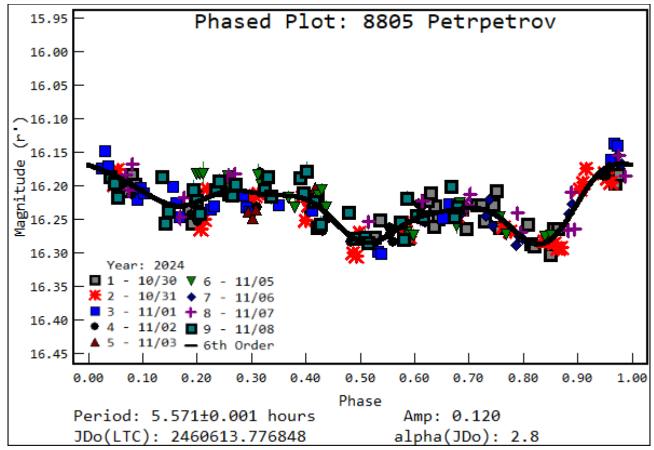
7654 1991 VV3, a Hertha family asteroid, was observed over ten nights in 2024 October. In that time, 234 observations were made to derive a period solution of 63.41 ± 0.05 h and an amplitude of 0.226 ± 0.020 magnitude. No period solutions for this asteroid were found in the LCDB.



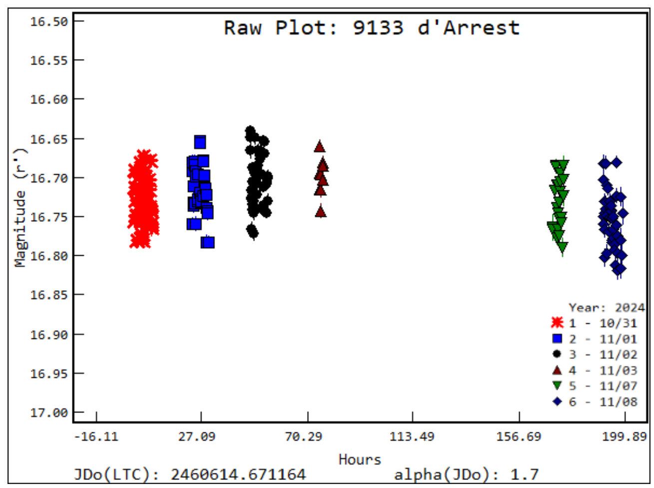
7926 1986 RD5 was observed on 8 nights in 2024 October. This main-belt asteroid has no published period solutions noted in the LCDB. During the 2024 apparition 350 observations were made and used to determine a period solution of 19.71 ± 0.01 h. The amplitude of the lightcurve is 0.282 ± 0.039 magnitude.



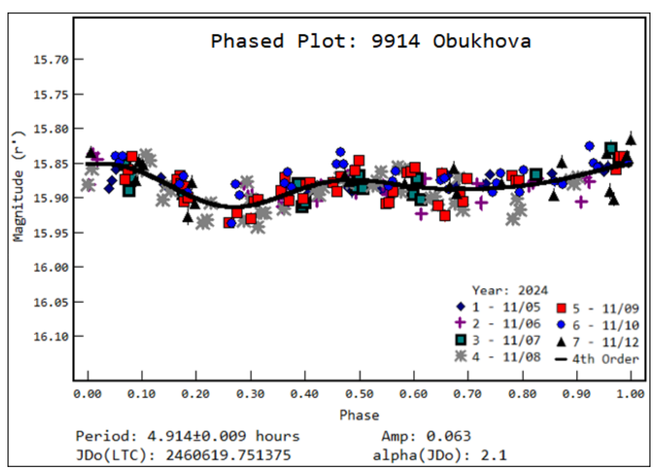
8805 Petrpetrov is an inner main-belt asteroid with no published period solutions in the LCDB. Observations were taken over nine nights in 2024 October and 2024 November. These resulted in a calculated period solution of 5.571 ± 0.001 h. A tri-modal solution was the only reasonable lightcurve calculated by *Tycho* over a wide range of possible solutions. The amplitude of the lightcurve is 0.120 ± 0.019 magnitude.



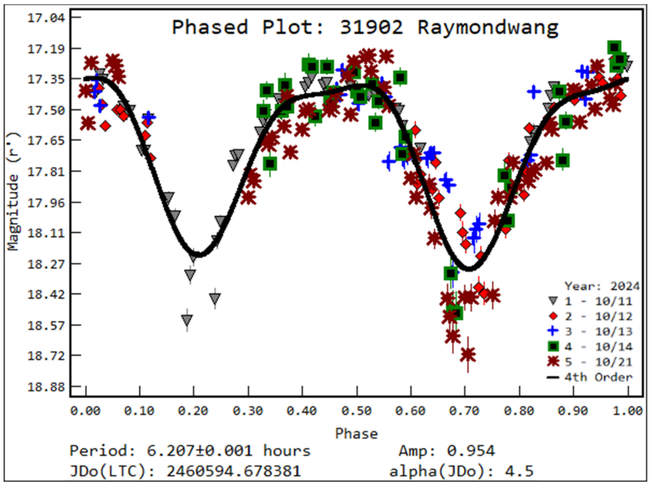
9133 d'Arrest was observed over six nights in 2024 November. Due to a large amount of scatter in the data the author was unable to confidently identify a period solution. The raw plot is published here to provide a baseline for future observations. It indicates that this asteroid is likely a slow rotator. There are no published periods for this target in the LCDB.



9914 Obukhova, a Misa family asteroid was observed on seven nights in 2024 November. A search of the LCDB revealed no published periods. The author calculated a period of 4.914 ± 0.009 h with an amplitude of 0.063 ± 0.018 magnitude.



31902 Raymondwang is an inner main-belt asteroid with an estimated diameter of 2.157 km. No period solutions exist in the LCDB. In 2024 October a total of 219 data points were obtained during five nights and used to calculate a period solution of 6.207 ± 0.001 h. The amplitude of the lightcurve is 0.954 ± 0.133 magnitude.



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A LIGHTCURVE ANALYSIS FOR NINE MAIN-BELT AND ONE MARS-CROSSING ASTEROIDS

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Photometric observations of nine main-belt and one Mars-crossing asteroids were obtained from 2024 February 4 to October 10. We derived synodic rotational periods for 728 Leonisis, 1698 Christophe, 1802 Zhang Heng, 2741 Valdivia, 3583 Burdett, 3895 Earhart, (12543) 1998 QM5, (20490) 1999 OW2, (31545) 1999 DN6, and (32575) 2001 QY78. Sidereal rotation periods were found 728 Leonisis, 1802 Zhang Heng, 2741 Valdivia, and 3895 Earhart.

We report on the photometric analysis result for nine main-belt and one Mars-crossing asteroids. This work was done from Observatorio Polop MPC Z93 (Alicante) operated by members of the Valencian Astronomy Association (AVA). This database (*http://www.astroava.org*) shows lightcurves, each phased to a given period.

We managed to obtain several accurate and complete lightcurves. Five of them had no previously reported period.

We concentrated on asteroids with no reported period and those where the reported period was poorly established and needed confirmation. We also prioritized asteroids for which we had dense data collected by our team in previous years with the aim of finding sidereal periods using *LCInvert* (Bdw Publishing). All of the targets were selected from the Collaborative Asteroid Lightcurve (CALL) website (*http://www.minorplanet.info/call.html*) and Minor Planet Center (*http://www.minorplanet.net*). The Asteroid Lightcurve Database (LCDB; Warner et al., 2009) was consulted to locate previously published results.

The observations were made with a 0.20-m Schmidt-Cassegrain and ASI 2600 MM camera. Images were calibrated in *MaximDL* and measured using *MPO Canopus* (Bdw Publishing) with a differential photometry technique. The comparison stars were restricted to near solar-color to avoid introducing color dependencies, especially at larger air masses. The lightcurves give the synodic rotation period. The amplitude (peak-to-peak) that is shown is that for the Fourier model curve and not necessarily the true amplitude.

If there were sufficient data in the Asteroid Lightcurve Data Exchange Format database (ALCDEF; *https://alcdef.org*) in addition to our own, we tried to find a sidereal rotation period using *LCInvert* (Bdw Publishing). This program uses the inversion method described by Kaasalainen and Torppa (2001) and is based on the C code written by Joseph Ďurech that was derived from the original FORTRAN code written by Kaasalainen. The advantage of this method is that it allows the use of *dense* data such those we obtained in our observations, the previous *dense* data kept in ALCDEF, and *sparse* data such as those available in databases from Catalina, USNO, ATLAS, Palomar, etc.

LCInvert uses an iterative method that, based on an initial estimate of the synodic period given by the lightcurve, finds the local minimum of χ^2 and gives the corresponding solution for the sidereal period. The procedure starts with six initial poles for each trial period and selects the period that gives the lowest χ^2. If there is a clear minimum in χ^2 when plotted as a function of the period, we can assume it as a correct solution. There is not always a clear solution. We report on only those asteroids with an unambiguous result.

When using *LCInvert,* we assigned weighting coefficients to consider different density and quality of the data. For *dense* data a weight value of 1 was used; *sparse* data, a value of 0.3 was assigned.

Error estimates for the inversion method are not obvious. The smallest separation (ΔP) of local minima (Kaasalainen et al., 2001), in the period parameter space is roughly given by

$$\Delta P \approx 0.5 * P^2/\Delta t$$

where Δt is the full epoch range of the data set. This derives from the fact that the maxima and minima of a double sinusoidal lightcurve for periods P and $P \pm \Delta P$ are at the same epochs after Δt time.

As stated by Kaasalainen et al. (2001), *"The period error is mostly governed by the epochs of the lightcurves. If the best local χ^2 minimum of the period spectrum is clearly lower than the others, one can obtain an error estimate of, say, a hundredth part of the smallest minimum width ΔP since the edge of a local minimum ravine always lies much higher than its bottom."*

Ďurech proposes an error estimate using

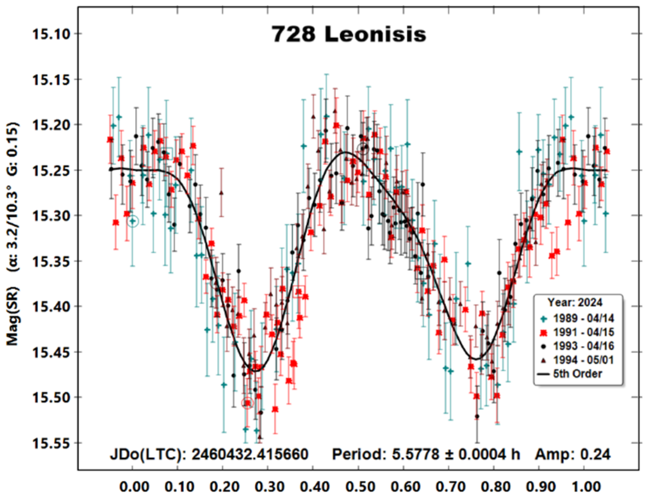
$$\Delta P \approx (1/10 * 0.5) * P^2/\Delta t$$

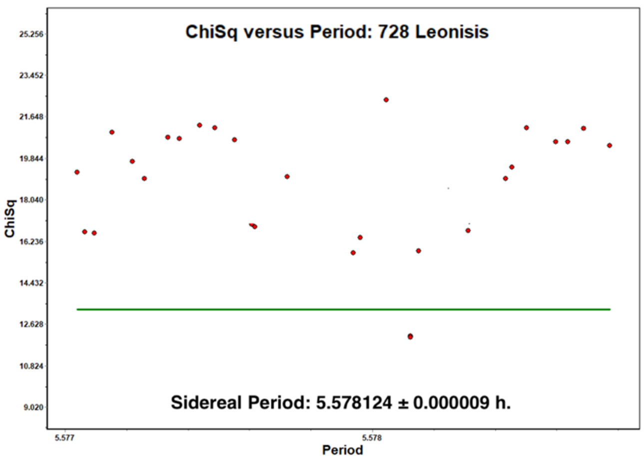
The factor 1/10 means that the period accuracy is 1/10 of the difference between local minima in the periodogram. When using *LCInvert*, we used Durech's formula as error estimate.

728 Leonisis is an asteroid of the Flora family (inner main-belt), that was discovered by Johann Palisa on 1912 February 16 in Vienna. We made observations from 2024 April 14 to May 1. Our analysis derived a synodic rotation period of 5.5778 ± 0.0004 h. Previous results include Behrend (2007web; 5.586 h), Galad (2010; 5.5789 h), Pilcher (2010; 5.5783 h), Waszczak et al. (2015; 5.710 h), and Mas et al. (2018; 5.58 h).

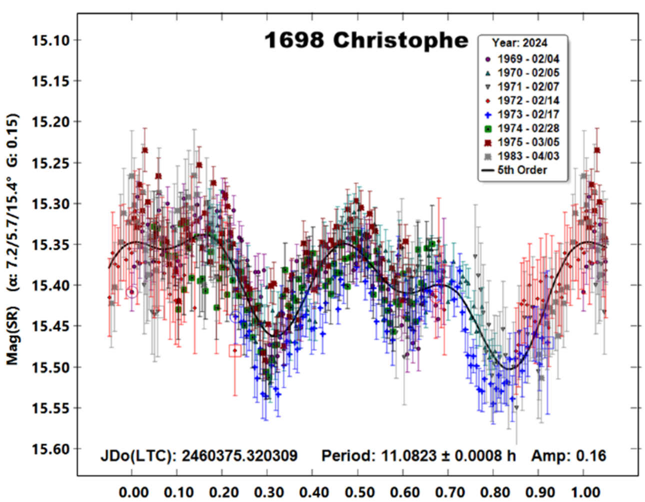
For this asteroid, we had additional dense data from our AVA Team from 2017. On the ALCDEF site, we found data from Pilcher (2010), Waszczak et al. (2015), and Mas et al. (2018). We also used sparse data from Catalina (442 points 2005-2023), Palomar (42 points 2019-2021), USNO (63 points 1998-2004), ATLAS (880 points 2017-2024).

The use of *LCInvert* with both new and old data led to a sidereal rotation period of 5.578124 ± 0.000009 h. That is consistent with Ďurech et al. (2020) who found a sidereal period of 5.57811 h.

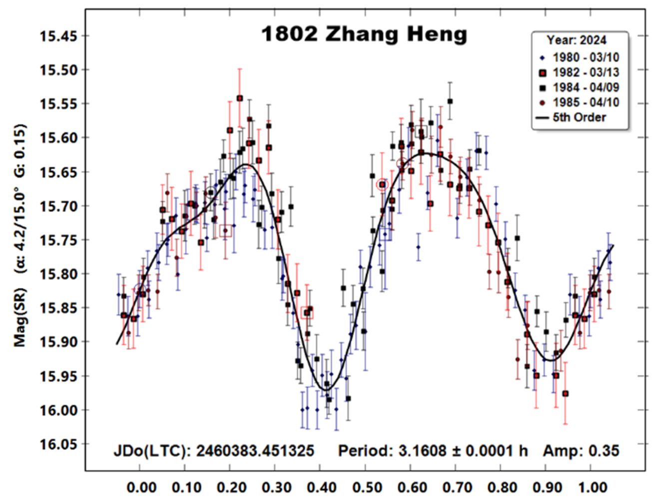




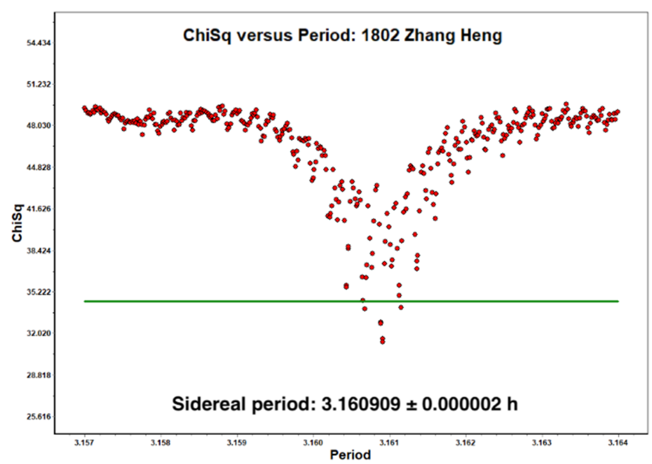
1698 Christophe was discovered by Eugène Joseph Delporte on 1934 February 10 at the Royal Observatory of Belgium, Uccle. We made observations from 2024 February 4 to April 3. We derived a synodic rotation period of 11.0823 ± 0.0008 h. There were no previously reported periods.



1802 Zhang Heng was discovered by the team at the Purple Mountain Observatory in Nanjing, China, on 1964 October 9. It was initially designated as 1964 TW1 and later named in honor of the Chinese astronomer Zhang Heng. We made observations from 2024 March 3 to April 3. We derived a synodic rotation period of 3.1608 ± 0.0001 h. This result is consistent with the previous results from Simpson et al. (2013; 3.162 h), Waszczak et al. (2015; 3.160 h), Mannucci and Montigiani (2019; 3.1554 h), Erasmus et al. (2020; 3.161 h), and Carreño et al. (2020; 3.161 h)

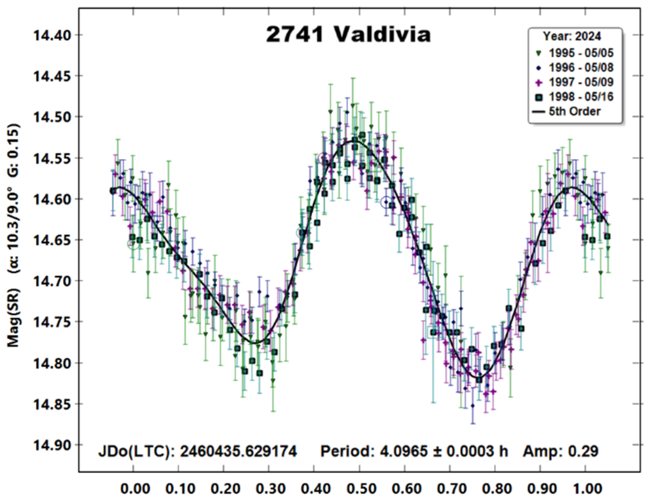


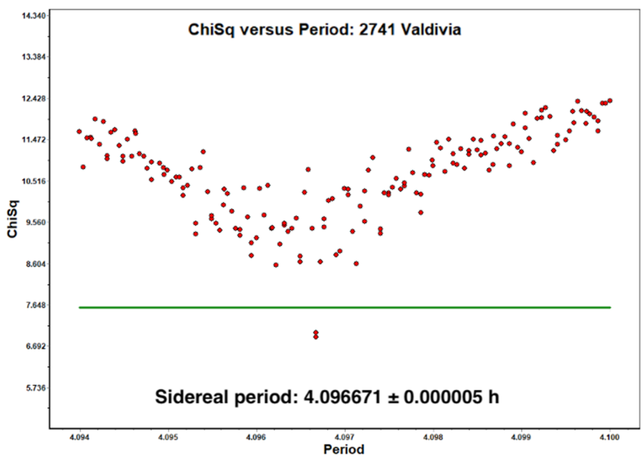
For this asteroid we also had the dense data from our AVA Team and ALCDEF (Carreño et al., 2020). We also used sparse data from Catalina (381 points 2005-2023), Palomar (42 points 2019-2021), LONEOS (34 points 1999-2007), USNO (92 points 1999-2007), and ATLAS (1476 points 2017-2024).



LCInvert led us to a sidereal rotation period of 3.160909 ± 0.000002 h. There was no previously reported sidereal period.

2741 Valdivia has a diameter of approximately 11 km. It was discovered on 1975 December 1 by Chilean astronomers Carlos Torres and Sergio Barros at the Cerro El Roble Station northwest of Santiago de Chile. The asteroid was named after Spanish conquistador Pedro de Valdivia. We made observations from 2024 May 5 to 15. We derived a synodic rotation period of 4.0965 ± 0.0003 h. This result is consistent with earlier results of Behrend (2003web; 8.1922 h and 8.191 h), Pray (2004; 4.096 h), Waszczak et al. (2015; 4.096 h), Brines et al. (2017; 4.098 h), and Pal et al. (2020; 4.09644 h).

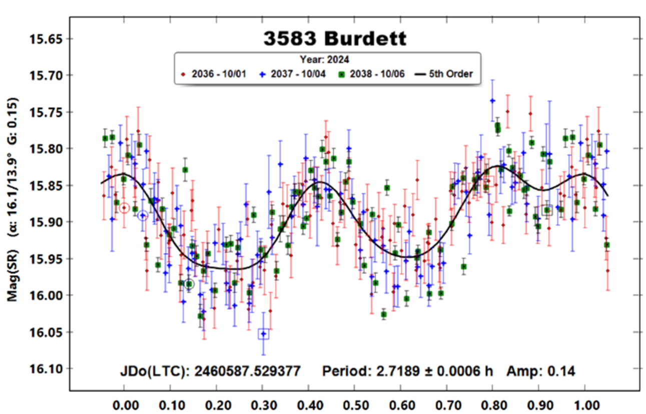




For this asteroid, we also had the dense data from our AVA Team, Brines et al. (2017). On ALCDEF we also found data from Pray (2004) and Hopkins (2024). We also used sparse data from Catalina (419 points 2006-2024), Palomar (127 points 2013-2022) and Atlas (1153 points 2017-2024).

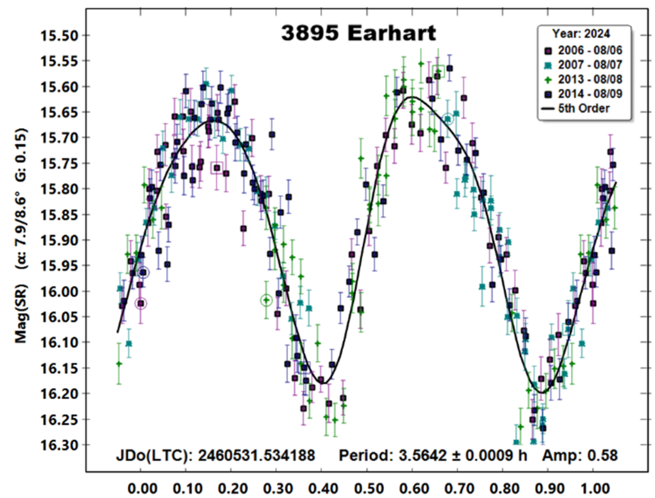
LCInvert led us to a sidereal rotation period of 4.096671 ± 0.000005 h. This is consistent with previous Hanus (2016), who found a sidereal period of 4.09668 h.

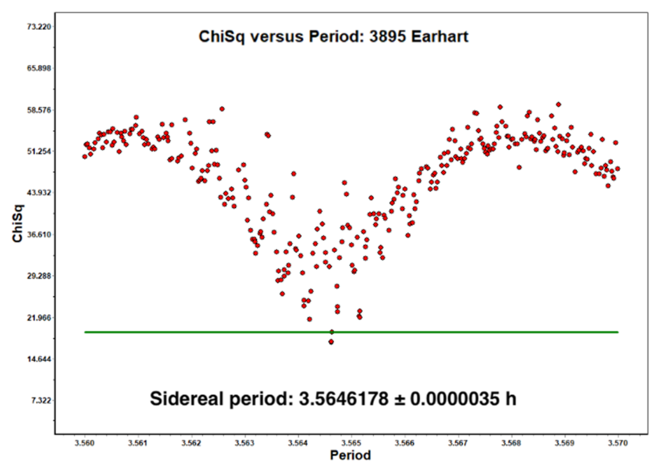
3583 Burdett was discovered on 1929 October 5 by Clyde Tombaugh from the Lowell Observatory in Flagstaff, Arizona. It was named in honor of the American town of Burdett, where the discoverer lived during his youth.



We made observations from 2024 October 1-6 and derived a synodic period of 2.7189 ± 0.0006 h. There was no previously reported period.

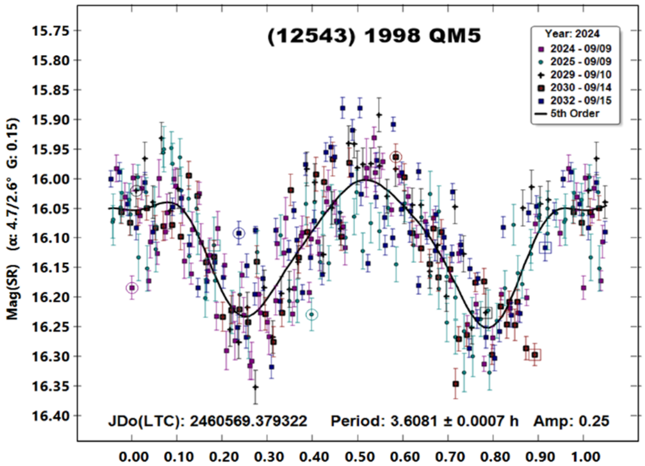
3895 Earhart was discovered on 1987 February 23 by Carolyn Shoemaker from the Palomar Observatory. It was named in honor of the American aviator Amelia Earhart. We made observations from 2024 August 6-9. We found a synodic period of 3.5642 ± 0.0009 h. This value is fully in line with several previously determined periods listed in LCDB: Behrend (2009web; 3.56451 h), Behrend (2016web; 3.5645 h), Behrend (2020web; 3.56501 h), Skiff (2016web; 3.5645 h), Warner (2009; 3.564 h), Aznar et al. (2016; 3.556 h), Stephens and Warner (2021; 3.567 h), and Benishek (2021; 3.57 h and 3.5646 h).



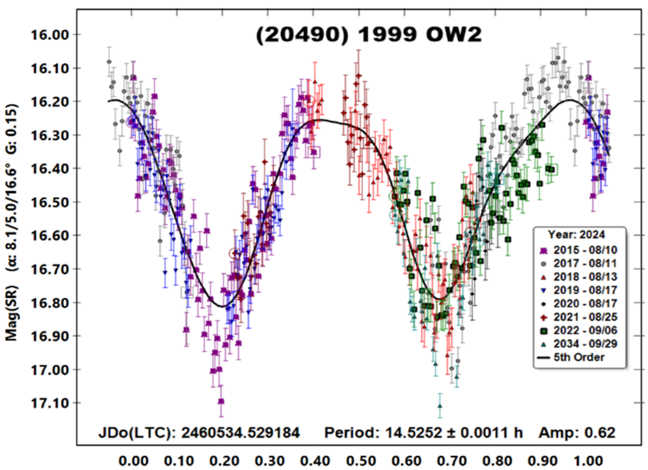


For this asteroid we also had the dense data from our AVA Team, Aznar et al. (2016) and Fornas (2023). On ALCDEF we also found data from Warner (2009) and Stephens and Warner (2021). We also used sparse data from Catalina (485 points 2003-2023), Palomar (68 points 2018-2022), and ATLAS (1323 points 2017-2024). Using these data in *LCInvert* led us to a sidereal rotation period of 3.5646178 ± 0.0000035 h. Ďurech et al. (2020) found a sidereal period of 3.564614 h.

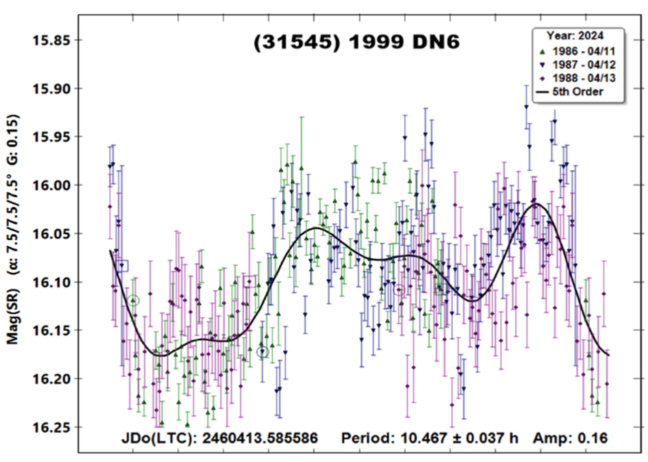
(12543) 1998 QM5 was discovered on 1998 August 23 by Australian amateur Frank B. Zoltowski at Woomera, Australia. We made observations from 2024 September 9-15. Data analysis found a synodic period of 3.6081 ± 0.0003 h. There was no previously reported period for this asteroid.



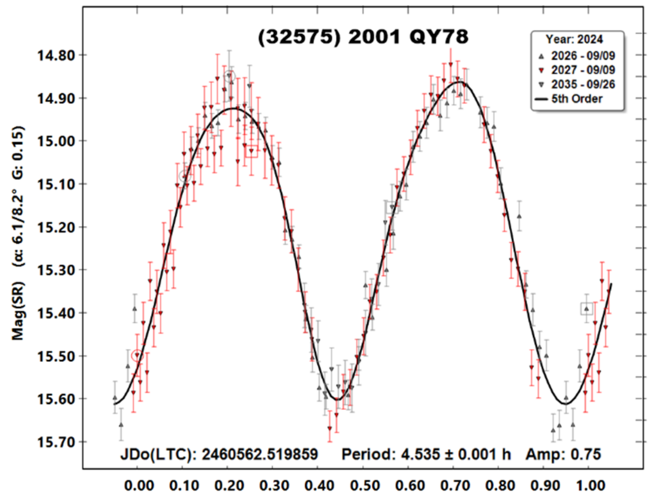
<u>(20490) 1999 OW2</u> has an estimated diameter of 7.779 km. It was discovered on 1990 July 22 at the Magdalena Ridge Observatory by the Lincoln Near-Earth Asteroid Research (LINEAR) project. We observed from 2024 August 10 to September 29, finding a synodic period of 14.5252 ± 0.0011 h. We found no previous period.



<u>(31545) 1999 DN6</u> was discovered in 1999 February 20 at the Magdalena Ridge Observatory by the Lincoln Near-Earth Asteroid Research (LINEAR) project. We made observations from 2024 April 11-13 and found a synodic period of 10.467 ± 0.037 h. We found no previously published period.



<u>(32575) 2001 QY78</u> is a Mars-crossing asteroid discovered on 2001 August 16 at the Magdalena Ridge Observatory by the Lincoln Near-Earth Asteroid Research (LINEAR) project. We found a synodic period of 4.535 ± 0.001 h. This is consistent with previous results from Behrend (2014web), who found a period of 4.5344 h. Ďurech et al. (2016) reported a sidereal period of 4.535495 h.



Acknowledgements

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

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
728	Leonisis	2024 04/14-05/01	3.1,10.2	204	5	5.5778	0.0004	0.24	0.02	MB-I
1698	Christophe	2024 02/04-04/03	7.2,15.5	153	2	11.0823	0.0008	0.16	0.02	MB-O
1802	Zhang Heng	2024 03/03-04/03	0.9,12.4	161	1	3.1608	0.0001	0.35	0.03	MB-M
2741	Valdivia	2024 05/05-05/15	10.2,8.9	234	15	4.0965	0.0003	0.29	0.03	MB-M
3583	Burdett	2024 10/01-10/06	16.1,11.3	36	0	2.7189	0.0006	0.14	0.02	MB-M
3895	Earhart	2024 08/06-08/09	7.7,8.1	304	8	3.5642	0.0009	0.58	0.05	MB-I
12543	1998 QM5	2024 09/09-09/15	4.7,2.6	352	4	3.6081	0.0007	0.25	0.02	MB-I
20490	1999 OW2	2024 08/10-09/29	*8.4,16.3	333	11	14.5252	0.0011	0.62	0.05	MB-M
31545	1999 DN6	2024 04/11-04/13	7.5,7.5	203	12	10.467	0.037	0.16	0.02	MB-M
32575	2001 QY78	2024 09/09-09/26	*6.6,7.8	354	4	4.535	0.001	0.75	0.05	M-C

Table I. **Synodic periods**. 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).

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.
728	Leonisis	2024 04/14-05/01	3.1,10.2	204	5	5.578124	0.000009
1802	Zhang Heng	2024 03/03-04/03	0.9,12.4	161	1	3.160909	0.000002
2741	Valdivia	2024 05/05-05/15	10.2,8.9	234	15	4.096671	0.000005
3895	Earhart	2024 08/06-08/09	7.7,8.1	304	8	3.5646178	0.0000035

Table II. **Sidereal periods.** 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).

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COLLABORATIVE ASTEROID PHOTOMETRY FROM UAI: 2024 OCTOBER-DECEMBER

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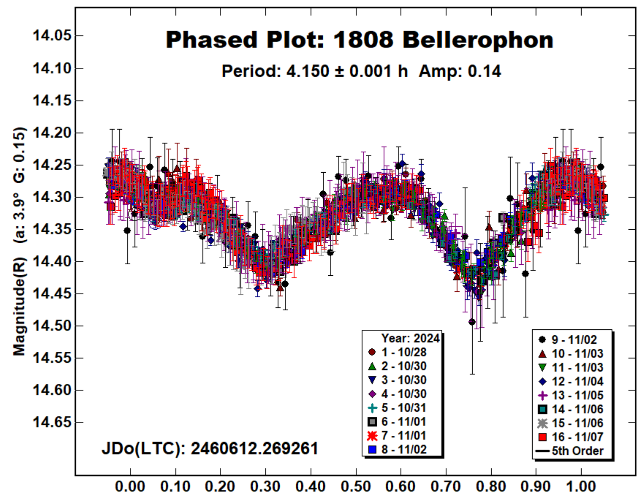
Photometric observations of four asteroids were made in order to acquire lightcurves for shape/spin axis modeling. Lightcurves were acquired for 1808 Bellerophon, 3672 Stevedberg, (36183) 1999 TX16, and (154589) 2003 MX2.

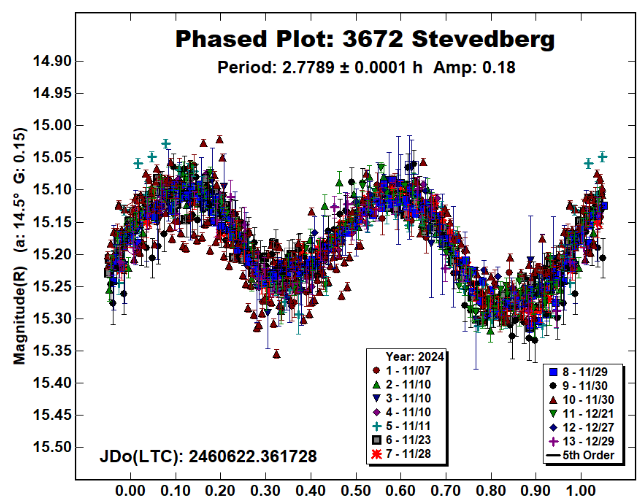
Collaborative asteroid photometry was done inside the Italian Amateur Astronomers Union (UAI; 2024) group. The targets were selected mainly in order to acquire lightcurves for shape/spin axis modeling. Table I shows the observing circumstances and results.

The CCD observations were made in 2024 October-December using the instrumentation described in the Table II. Lightcurve analysis was performed at the Balzaretto Observatory with *MPO Canopus* (Warner, 2023). All the images were calibrated with dark and flat frames and converted to standard magnitudes using solar colored field stars from CMC15 and ATLAS catalogues, distributed with *MPO Canopus*. For brevity, "LCDB" is a reference to the asteroid lightcurve database (Warner et al., 2009).

1808 Bellerophon is a medium albedo middle main-belt asteroid. Collaborative observations were made over ten nights. The period analysis shows a synodic period of P = 4.150 ± 0.001 h with an amplitude A = 0.14 ± 0.03 mag. The period is consistent with Dose (2025; 4.147 ± 0.002 h).



3672 Stevedberg is a medium albedo inner main-belt asteroid. Collaborative observations were made over eleven nights. The period analysis shows a synodic period of P = 2.7789 ± 0.0001 h with an amplitude A = 0.18 ± 0.04 mag. The period is close to the previously published results in the LCDB.



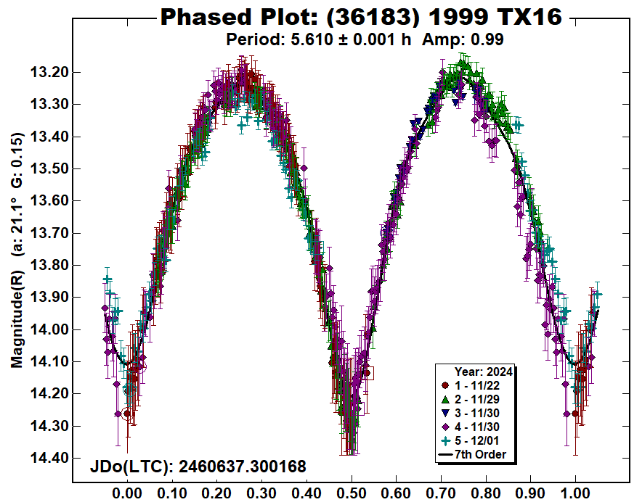
Number	Name	2024 mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
1808	Bellerophon	10/28-11/07	*3.9,1.6	43	1	4.150	0.001	0.14	0.03	MB-M
3672	Stevedberg	11/07-12/29	*14.5,18.2	68	8	2.7789	0.0001	0.18	0.04	MB-I
36183	1999 TX16	11/22-12/01	21.2,36.4	52	17	5.610	0.001	0.99	0.04	NEA
154589	2003 MX2	10/29-11/05	8.1,5.8	40	-5	42.6	0.1	0.59	0.03	NEA

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

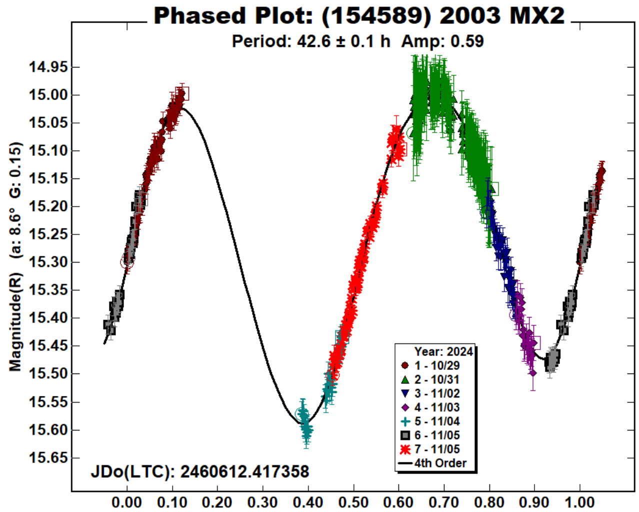
Observatory (MPC code)	Telescope	CCD	Filter	Observed Asteroids (#Sessions)
Iota Scorpii(K78)	0.40-m RCT f/6.1	CMOS QHY 268 (bin 4×4)	R, C	1808(1), 3672(1), 36183(3), 154589(1)
Filzi School Observatory (D12)	0.35-m RCT f/8.0	ASI 2600 MC PRO	C	1808(3), 3672(1), 36183(1)
Astronomical Observatory, University of Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e (bin 2×2)	C	1808(3), 3672(2)
HOB Astronomical Observatory (L63)	0.20-m SCT f/6.0	ATIK 383L+ (bin 2×2)	C	1808(3), 3672(2)
San Marcello Pistoiese Observatory (104)	0.60-m NRT f/4.0	Apogee Alta	C	154589(4)
GiaGa Observatory (203)	0.36-m SCT f/5.8	Moravian G2-3200	C	1808(1), 3672(1), 154589(1)
Osservatorio Astronomico Margherita Hack (A57)	0.35-m SCT f/8.3	SBIG ST10XME (bin 2×2)	Rc	3672(3)
Osservatorio Astronomico Nastro Verde (C82)	0.35-m SCT f/6.3	SBIG ST10XME (bin 2×2)	C	1808(1), 3672(1)
Zen Observatory (M26)	0.30-m RCT f/7.4	ATIK 383L+ (bin 2×2)	C	3672(1), 36183(1)
Osservatorio Serafino Zani (130)	0.40-m RCT f/5.8	Moravian G4 16000 (bin 2×2)	C	3672(1)
M57 (K38)	0.35-m RCT f/5.5	SBIG STT1603ME	Rc	1808(1)
GAV	0-20-m SCT f/6.3	QSI683 (bin 2×2)	Rc	1808(1)

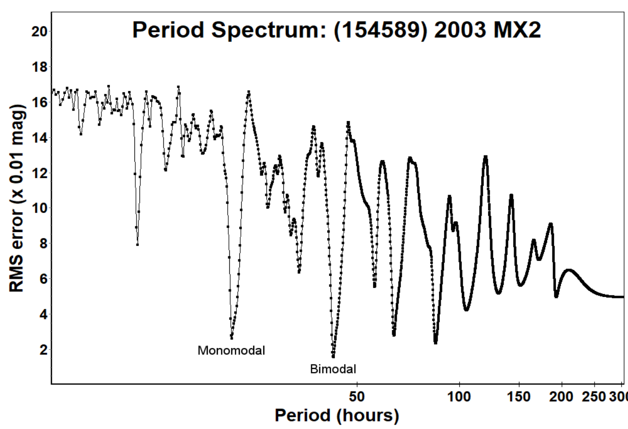
Table II. Observing Instrumentations. MCT: Maksutov-Cassegrain, NRT: Newtonian Reflector, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain.

<ins>(36183) 1999 TX16</ins> is an Amor Near-Earth asteroid of Ld-type (Bus and Binzel, 2002). Collaborative observations were made over seven nights. The period analysis shows a synodic period of P = 5.610 ± 0.001 h with an amplitude A = 0.99 ± 0.04 mag. The period is close to the previously published results in the LCDB.



(154589) 2003 MX2 is an Amor Near-Earth asteroid. Collaborative observations were made over six nights. We found a bimodal solution with a synodic period of $P = 42.6 \pm 0.1$ h and an amplitude $A = 0.59 \pm 0.03$ mag. This solution differs from the one found by Warner (2018; 1.611 ± 0.002 h).





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PHOTOMETRY OF NEAS (187026) 2005 EK70 AND (152787) 1999 TB10

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Near-Earth asteroids (187026) 2005 EK70 and (152787) 1999 TB10 were observed over five nights in February 2024 and four nights in March 2024, respectively, using the Prompt 3 telescope at the Cerro Tololo Inter-American Observatory. The rotational period for (187026) 2005 EK70 is 6.966 ± 0.001 hours and the lightcurve amplitude is 0.20 ± 0.02 magnitude. The rotational period for (152787) 1999 is 2.876 ± 0.001 hours and the amplitude is 0.29 ± 0.05 magnitude. A search of the Asteroid Lightcurve Database provided no previously published results for either NEA.

Observations

LINEAR at Socorro discovered NEA (187026) 2005 EK70 on 2005 March 08, and NEA (152787) 1999 TB10 on 1999 October 07. We obtained CCD photometric observations during the close approach of (187026) 2005 EK70 on 2024 February 25-29, and during close approach of (152787) 1999 TB10 on 2024 March 25-28. Neither of these NEAs have published photometric data in the Asteroid Lightcurve Database (Warner et al., 2009).

Observations were collected from Prompt 3 at the Cerro Tololo Inter-American Observatory (CTIO) (MPC: code 807). Prompt 3 is a 0.6m f/6 Planewave Ritchey-Chrétien on a Planewave HR200 with a FLI 13.5µm 2048×2048 camera. Images were taken using the broadband Clear filter and binned 2×2. The exposure times for (187026) 2005 EK70 were 20-30 seconds, and (152787) 1999 TB10 exposure times were 30-40 seconds. The observing cadence was separated by the read-out time of the CCD. A total of 3,294 science images of (187026) 2005 EK70 were acquired, and we included 2,681 in our analysis. Similarly, for (152787) 1999 TB10, we obtained a total of 1,323 science frames and included 1,010 images in our analysis. A total of 926 images were excluded due to star contamination, wind or meridian flip-induced trails, and intermittent clouds. Flat, bias, and dark frames were obtained each night under similar operating conditions as the science frames. The dark frame exposures were 80 seconds and taken sets of ten using

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
187026	2005 EK70	2024 02/25-02/29	28.4-43.6	143	-17	6.966	0.001	0.20	0.02	NEA
152787	1999 TB10	2024 03/25-03/28	45.3-44.6	158	2	2.876	0.001	0.29	0.05	NEA

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).

the Clear filter with a dark scale correction applied that matched the exposure length. Bias frames were 0.0 second exposures and taken in a set of ten. Dawn flats were acquired in the Clear filter and in a set of ten. The total time imaging (187026) 2005 EK70 and (152787) 1999 TB10 was ~6 and ~3 hours, respectively.

Data Calibration/Analysis

The science frames were bias-, dark-, and flat-field calibrated using the *AstroImageJ* image reduction software according to the standard CCD calibration equation (Howell, 2006). Following data calibration, the images were imported to *MPO Canopus* and a photometric analysis of the data was performed. Each night contains multiple sessions due to the asteroid's velocity with the telescope's field of view rapidly changing along with the asteroid crossing the meridian. The *MPO Canopus Light Curve Wizard* combined each night's segments consisting of 16 sessions across five nights for (187026) 2005 EK70 and 8 sessions spanning four nights for (152787) 1999 TB10.

In general, each image's analysis involved the selection of five stars (non-variable) for magnitude standards. *MPO Canopus* performs a least-squares analysis to determine the relationship between the magnitude and the log of the total counts. For the background correction, a 9×9-pixel circular aperture was utilized to determine counts of the CompStars/Background. For each NEA/Background, a 7×7-pixel circular aperture was deemed the best size for both targets. The data were light-time corrected using the JD at the start of each exposure.

We plotted all segments of usable data as lightcurves, however, the rapid motion of the observed NEAs resulted in the sky and background comp stars changing in each session. This introduced some uncertainty in the magnitudes of the comparison stars. To correct this, we used the deltacomp function to adjust the magnitudes and bring them into agreement with the magnitudes of our first data set for both asteroids.

Results

<u>(187026) 2005 EK70</u>. We produced a composite lightcurve (Fig. 1), and least-squares fit the lightcurve with a Fourier series including five harmonics. A phase angle change of 15.2° resulted in a slight periodic shape change, which can be observed by the misalignment of session 8 with session 16.

We calculated the rotational period at 6.966 ± 0.001 hours with an amplitude of 0.20 ± 0.02 magnitude. There are two maxima and minima present per rotation.

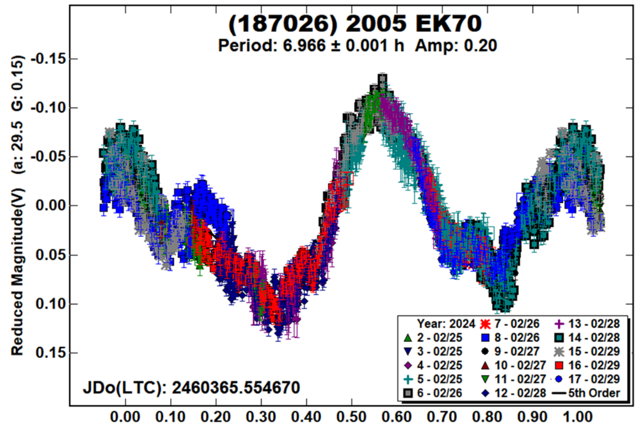

Fig. 1: NEA (187026) 2005 EK70 rotational period of 6.966 ± 0.001 hours with an amplitude of 0.20 ± 0.02 magnitude.

<u>(152787) 1999 TB10</u>. We produced a composite lightcurve (Fig. 2), and least-squares fit the lightcurve with a Fourier series including five harmonics.

The calculated rotational period is 2.876 ± 0.001 hours with an amplitude of 0.29 ± 0.05 magnitude. There are two maxima and minima present per rotation.

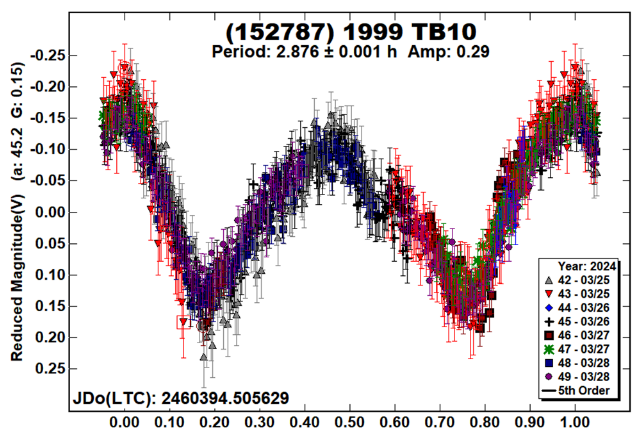

Fig. 2: NEA (152787) 1999 TB10 rotational period of 2.876 ± 0.001 hours with an amplitude of 0.29 ± 0.05 mag.

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LIGHTCURVES OF NEAR-EARTH ASTEROIDS 2024 ON, 2024 MK AND 1998 ST27 AS OBSERVED FROM TRAPPIST

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We report photometric observations of three near-Earth asteroids: 2024 ON, 2024 MK, and 1998 ST27. The observations were performed between June and October 2024 during their close approaches to Earth using the TRAPPIST network. Applying lightcurve analysis, we determined that the rotation period and amplitude of 2024 ON are P = 6.0116 ± 0.0003 h and A = 0.94 ± 0.05 mag. For 2024 MK we found two possible rotation periods. In the first case $P1$ = 0.5028 ± 0.0001 h with $A1$= 0.67 mag ± 0.02, and $P2$ = 0.3663 ± 0.0001 h with $A2$ = 0.45 mag ± 0.02. In the second case $P1$ = 0.7301 ± 0.0011 h with $A1$ = 0.503 mag, and $P2$ = 0.5031 ± 0.0005 h with $A2$ = 0.643 mag. For 1998 ST27 we obtain P = 3.56 ± 0.02 h and A= 0.07 ± 0.01 mag. All measurements have been submitted to the ALCDEF database.

The telescopes used to obtain the lightcurves of 2024 ON, 2024 MK and 1998 ST27, are the TRAPPIST twins, 0.6-m Ritchey-Chrétien telescopes operated under the COMETA team of the University of Liège (Jehin et al., 2011). TRAPPIST-North (TN; MPC code Z53) is located in Morocco - Oukaïmeden, and TRAPPIST-South (TS; MPC code I40) is located in Chile - La Silla. The TN camera is an Andor IKONL BEX2 DD (0.59 arsec/pixel) and the TS camera is a FLI ProLine 3041-BB (0.66 arcsec/pixel).

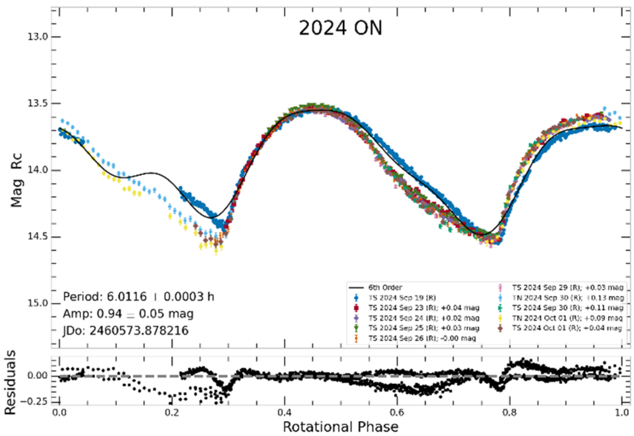
All images recorded were reduced by using standard image calibration with multiple darks, bias and flat frames taken every night onto the twilight sky. For creating calibration frames that are temperature matched, exposure and filter matched, and applying them, we used the internal pipeline of TRAPPIST, *Triton.* All the images that were affected by weather conditions or had any light source interference within 12 pixels with the asteroid due to their movement within the star fields, were excluded.

For the zero-point calibration and lightcurve construction, we used *Photometry Pipeline* (Mommert, 2017). The differential photometry and magnitude calibration was done with the PanSTARSS DR1 catalog with approximately 100 solar reference stars per image.

2024 ON was discovered on 2024 July 27 by the ATLAS network located in Mauna Loa, Hawaii, with a measured absolute magnitude of H = 20.3 (Herman et al., 2024). The asteroid has been categorized as a PHA due to its absolute magnitude that would translate to an approximate size of 350 m, and its MOID of 0.003 au (JPL, 2024a). Two months after its discovery, 2024 ON had a close approach to Earth on September 17 around 10:19 UT with a minimum distance of 0.0066 au or two and a half LD (JPL, 2024a). Observations by the Goldstone Solar System Radar on September 16 revealed that the asteroid is a contact binary (NASA/JPL-Caltech, 2024a).

During this close approach, we successfully observed the asteroid for a total of 10 nights, using both TN and TS. The asteroid was observed with TS using a Rc filter and binning 2×2 for many hours each night between September 19 and October 1. The data consists of 1355 photometric images, for a total of 26.6 hours spread during 8 nights. The exposure time was adjusted each night in order to obtain the best SNR and avoid trails on several pixels. The asteroid was too low on the horizon to be observed with TN during its closest approach but we managed to get data for two nights on September 30 and October 01, when the asteroid was fainter with V = 17.2, also using binning 2×2.

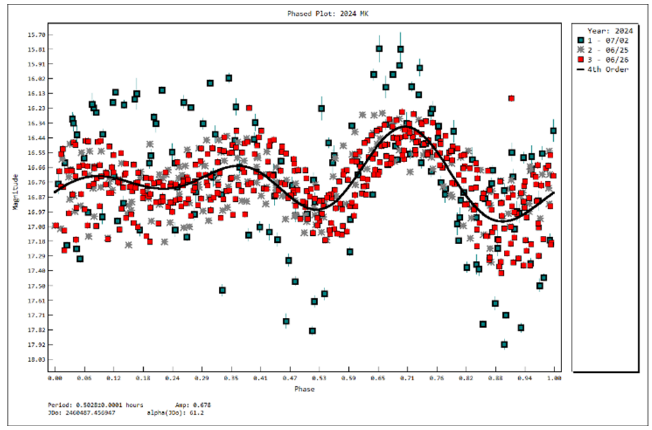
For the lightcurve measurements we used an aperture of 3.5 arcsec/pixel in all cases. The data was best fitted on the period of 6.0116 ± 0.0003 h and an amplitude of 0.94 ± 0.05 mag. We can observe that curve shape changed in time and it is not overlapping completely. At the time of writing, there is no reported value for the rotation period of this asteroid in the Lightcurve Photometry Database (LCDB; Warner et al., 2009).

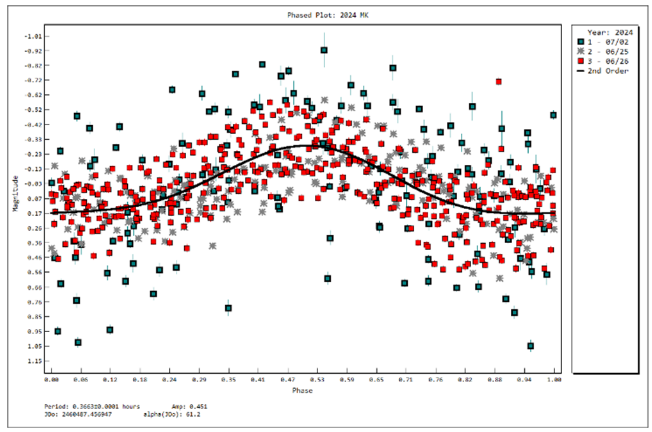


2024 MK was discovered by the ATLAS network, this time from the instrument located in Sutherland Observing Station in South Africa, on 2024 June 16. Its measured absolute magnitude is $H = 21.5$, and it was classified as a PHA as its Earth MOID = 0.0018 au (Hidas et al., 2024). Radar observations have been acquired between June 29 and July 02 (JPL, 2024b) resulting in a diameter of ~150-m (NASA/JPL-Caltech, 2024b).

We have obtained images on June 25 and 26 using TS. On both nights, the data was taken using 60 s exposure time with the Rc filter and binning 2×2. We also successfully observed the asteroid with TN using the Rc filter and binning 2×2 on July 02 with an exposure time of 60 s, and on the night of July 3 with an exposure time of 120 s. Due to the long exposure, the asteroid appears as a small trail on the images. For the photometry analysis from TS, we used an aperture of 3.5 arcsec/pixel. For TN, we measured the images using the *Tycho Tracker* version 11.7.2 software (Parrott, 2024), to be able to use an ellipse aperture. The trail measures an average length of 9 pixels (10.6 arcsec) and we used an aperture radius height and width of 3 and 5 pixels respectively.

Combining the data sets from both telescopes, the period search revealed two distinct periods, suggesting a possible tumbling behaviour. We address two possible cases of rotational periods that have similar RMSE. First case, $P1$ = 0.5028 ± 0.0001 h with $A1$= 0.678 mag, and $P2$ = 0.3663 ± 0.0001 h with $A2$ = 0.451 mag where RMSE = 23.322. In the second case $P1$ = 0.7301 ± 0.0011 h with $A1$ = 0.503 mag, and $P2$ = 0.5031 ± 0.0005 h with $A2$ = 0.643 mag where RMSE = 23.319.





1998 ST27 was discovered on September 24 by the LINEAR (Lincoln Near-Earth Asteroid Search) program. It is classified as a PHA, with an absolute magnitude H = 19.5 and a rotational period in the realm of ~ 3 hours (JPL, 2024a). The last close approach was on October 12 at a minimum distance of 0.023 au or approximate 9 LD (JPL, 2024a).

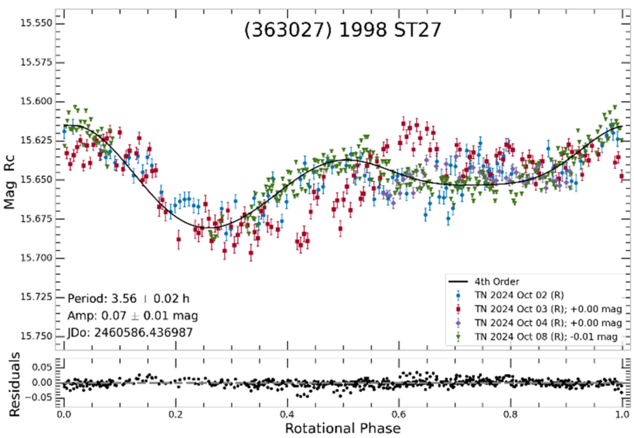
Sets of radar images have been taken for this asteroid since 2001 at Arecibo when it was discovered that it is a binary system (Benner, et al., 2001). Recent radar observations with the Goldstone Solar System Radar taken on October 11 revealed that it is actually a triple system (NASA/JPL-Caltech, 2024c).

Before its closest approach to Earth, we observed the asteroid with TN for four nights, between October 2 and 8, for a total of 1225 images resulting to ~18 hours of observations. The binning used was 2×2 and the aperture for photometry measurements was 3.5 arcsec/pixel. On October 4 and 8, we also observed the asteroid with the Rc, Ic, B, V filters, for color measurements. We produced three color indices, $B\text{-}V$ = 0.71 ± 0.01, $V\text{-}R$ = 0.36 ± 0.01 and $V\text{-}I$ = 0.67 ± 0.01. These values are consistent with a C-type asteroid (Dandy et al., 2023), that matches its low albedo value of 0.059 (*https://ssd.jpl.nasa.gov/)*.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2024 ON	2024 09/19-10/01	*74.8, 73.8	35	-27	6.0116	0.0003	0.94	0.05	NEA
	2024 MK	2024 06/25-07/03	61.1,101.3	324	28	0.5028	0.0001	0.67	0.02	NEA
						0.3663	0.00010.45		0.02	NEA
	2024 MK	2024 06/25-07/03	61.1,101.3	324	28	0.7301	0.0011	0.53	0.02	NEA
						0.5031	0.00050.64		0.02	NEA
363027	1998 ST27	2024 10/02-08	34.5, 18.1	23	14	3.56	0.020.07	0.01NEA		

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).

Based on lightcurve analysis, the rotational period found is 3.56 ± 0.02 h with a maximum amplitude A = 0.07 ± 0.01 mag.



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LIGHTCURVE ANALYSIS FOR SIX NEAR-EARTH ASTEROIDS OBSERVED IN 2009 AND OCTOBER - DECEMBER 2024

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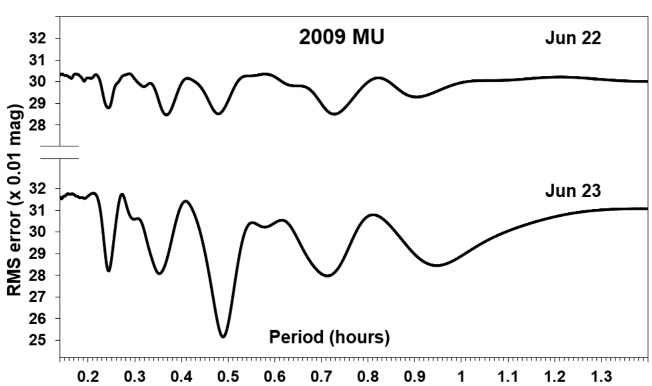
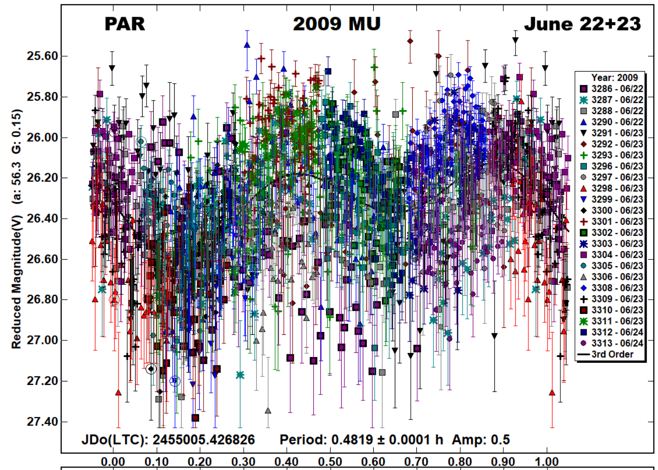
Lightcurves and amplitudes for six near-Earth asteroids observed from Great Shefford Observatory during close approaches in June 2009 and October to December 2024 are reported. All are small objects with rotation periods 1 hour or shorter and four are identified as having tumbling rotation.

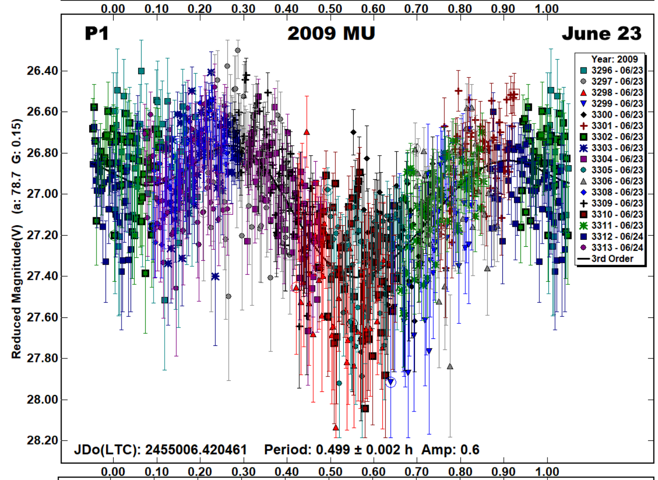
Photometric observations of near-Earth asteroids during close approaches to Earth in June 2009 and October to December 2024 were made at Great Shefford Observatory using a 0.40-m Schmidt-Cassegrain and Apogee Alta U47+ CCD camera. All observations were made unfiltered and with the telescope operating with a focal reducer at f/6. The 1K×1K, 13-micron CCD was binned 2×2 resulting in an image scale of 2.16 arcsec/pix. All the images were calibrated with dark and flat frames and *Astrometrica* (Raab, 2024) was used to measure photometry using APASS Johnson V band data from the UCAC4 catalogue (Zacharias et al., 2013) and G band data from the Gaia DR2 and DR3 catalogues. *MPO Canopus* (Warner, 2023), incorporating the Fourier algorithm developed by Harris (Harris et al., 1989) was used for lightcurve analysis.

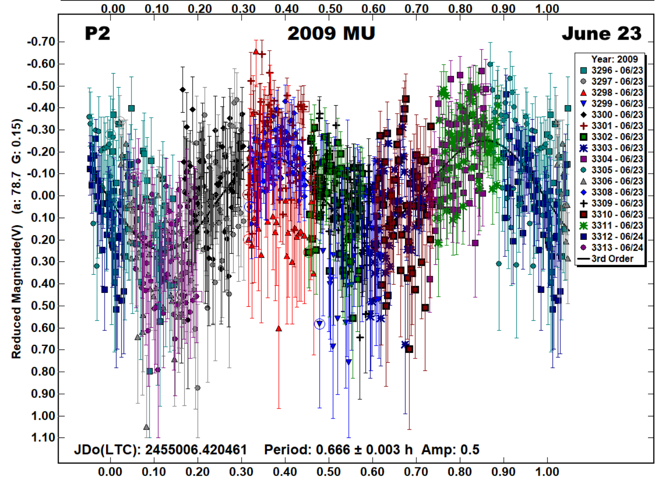
No previously reported results have been found in the Asteroid Lightcurve Database (LCDB) (Warner et al., 2009), from searches via the Astrophysics Data System (ADS, 2025) or from wider searches unless otherwise noted. All size estimates are calculated using H values from the Small-Body Database Lookup (JPL, 2025b), using an assumed albedo for NEAs of 0.2 (LCDB readme.pdf file) and are therefore uncertain and offered for relative comparison only.

2009 MU. The Catalina Sky Survey discovered this Apollo (*H = 24.6, D ~36 m*) on 2009 Jun 19.3 UTC (Gajdos et al., 2009) and it made an approach to 2.3 Lunar Distances (LD) from Earth on 2009 Jun 24.7 UTC. It was observed for 2.8 h starting on 2009 Jun 22.93 UTC and then again for 2.1 h a day later, starting on 2009 Jun 23.92 UTC.



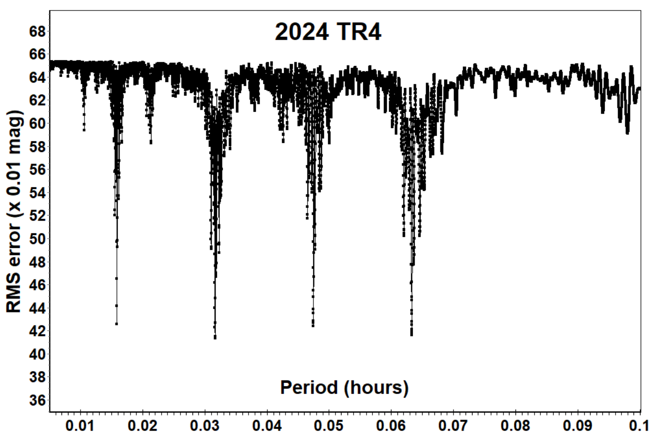






The viewing geometry changed appreciably between the two nights, with the distance decreasing from 5.5 to 3.1 LD, the apparent speed tripling to 100 arcsec/min and phase angle increasing from 56° to 79°. 2009 MU was about half a magnitude brighter on the second date but with shorter exposure times the SNR improved only slightly. Independent period spectrum plots from the 2 nights are given and show very similar minima, with the best fit at ~0.5 h, but with a related minima at ~0.25 h and another pair of minima at ~0.7 h and ~0.35 h. A best-fit phased lightcurve combining measurements from both nights is labelled PAR and gives a bimodal lightcurve with period of 0.4819 ± 0.0001 h, but with a large amount of scatter. The *MPO Canopus* Dual Period Search function was used to investigate possible tumbling, or non-principal axis rotation (NPAR) solutions suggested by the 0.35 h and 0.7 h minima in the period spectrum. Using the better-quality second night, the best-fit NPAR solution gives periods of P1 = 0.499 ± 0.002 h and P2 = 0.666 ± 0.003 h. These lightcurves are labelled P1 and P2 but there are other possible solutions with poorer fits. With the span of observations on each night being < 3h, not enough rotations are covered to determine a reliable solution and it is expected that it may be rated as PAR = -2 on the scale defined in Pravec et al. (2005) where NPA rotation is detected based on deviations from a single period but the second period is not resolved (Petr Pravec, personal communication).

2024 TR4. The ATLAS facility on Mauna Loa discovered this small Aten (*H = 26.9, D ~13 m*) on 2024 Oct 6.5 UTC. It made a very close pass to Earth, to 0.3 Lunar Distances (LD) on 2024 Oct 7.05 UTC (Buzzi et al., 2024). Observations were made for 1 h over a period of 3.4 h starting at 2024 Oct 6.80 UTC with 372 measurements being obtained. Apparent speed increased from 200 to 740 arcsec/min and exposures were reduced from 3.1 to 0.8 s to reduce image trailing. The period spectrum from an initial analysis indicates the best fit solution has a period of 0.031651 ± 0.000003 h (~1.9 min) and large 1.4 mag amplitude, but the resulting lightcurve labelled PAR shows strong indications of tumbling (NPA) rotation.



Using the *MPO Canopus* Dual Period Search function to find an NPAR solution is not entirely satisfactory, but the best-fit periods P1 and P2 are:

P1 = 0.031645 ± 0.000003 h (~1.9 min), amplitude 1.4
P2 = 0.021327 ± 0.000003 h (~1.3 min), amplitude 0.9

Lightcurves for this NPAR solution are labelled P1 and P2. However, other solutions for the secondary period can be resolved, but these all appear to be linear combinations of the frequencies of the best-fit P1 and P2 periods, e.g.:

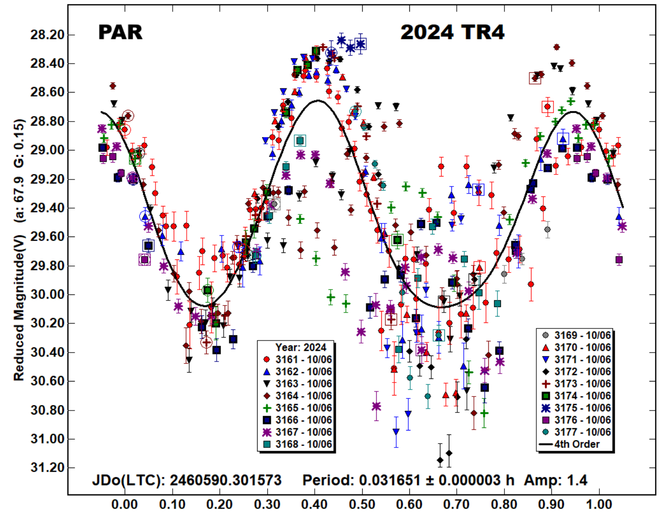
P3 = 0.016099 ± 0.000006 h (~58 sec), amplitude 0.6
P4 = 0.018172 ± 0.000005 h (~1.1 min), amplitude 0.5
P5 = 0.025477 ± 0.000006 h (~1.5 min), amplitude 0.5

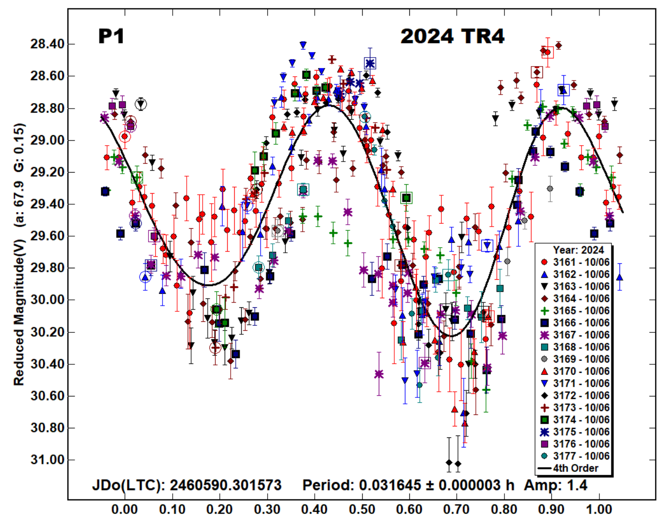
are linear combinations of the frequences of P1 and P2, where:

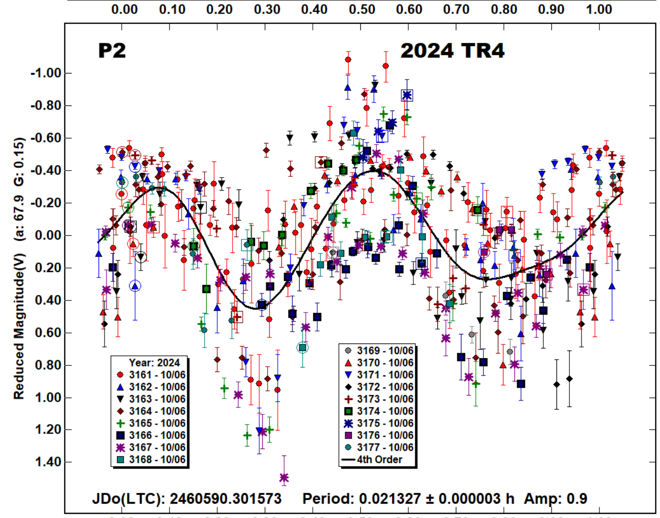
$2/P2 - 1/P1 = 1/P3$
$3/P2 - 1/P1 = 2/P4$
$1/P1 + 1/P2 = 2/P5$

It is expected that 2024 TR4 may be rated as PAR = -3 (NPA rotation reliably detected with the two periods resolved. An ambiguity of the periods solution may be tolerated provided the resulting spectrum of frequencies with significant signal is the same for the different solutions.) (Petr Pravec, personal communication).

The NPAR solution indicates the full amplitude of the tumbling rotation is 2.3 mag. During the 1 h it was actively observed, 2024 TR4 completed 30 rotations of the P1 period and 44 rotations of the P2 period.



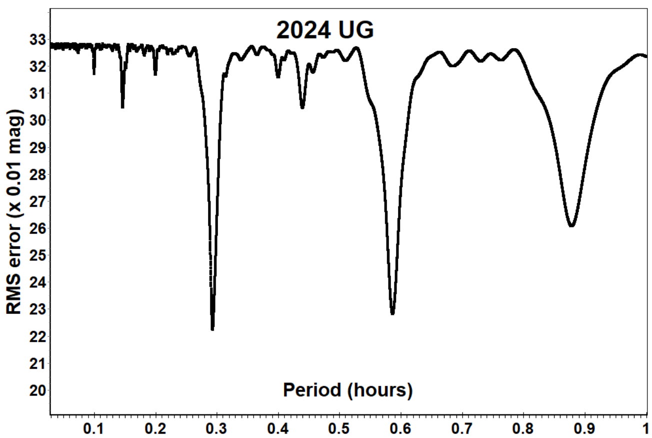


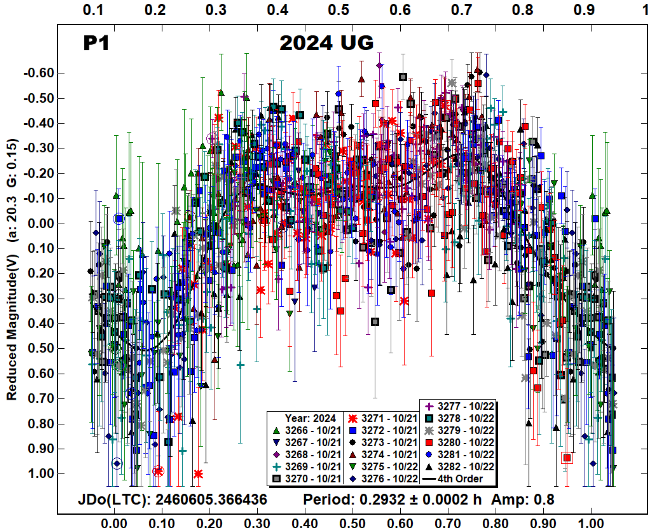


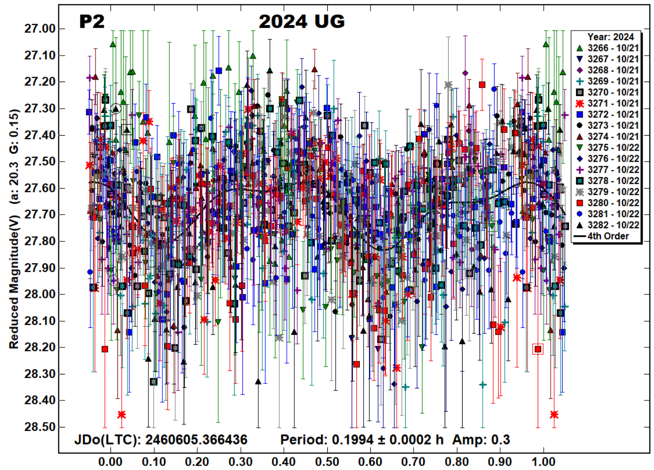
2024 UG. The ZTF collaboration discovered this Apollo (*H = 26.9, D ~12 m*) using the Palomar 1.2-m Schmidt on 2024 Oct 21.1 UTC (Bacci et al., 2024), less than 2 h after it had passed Earth at 2.7 LD. It was actively observed for 3.0 h over a period of 4.8 h starting at 2024 Oct 21.87 UTC. Apparent speed decreased from 80 to 70 arcsec/min and exposures were restricted to no more than 8.2 s to limit image trailing. Initial examination of the period spectrum shows a significant solution at 0.29 h, with related minima at integer multiples of half that value. Also present are a set of weak minima at integer multiples of 0.1 h. Tumbling was again suspected and the best-fit NPAR solution isolated using the *MPO Canopus* Dual Period Search function is:

P1 = 0.2932 ± 0.0002 h, amplitude 0.8
P2 = 0.1994 ± 0.0002 h, amplitude 0.3

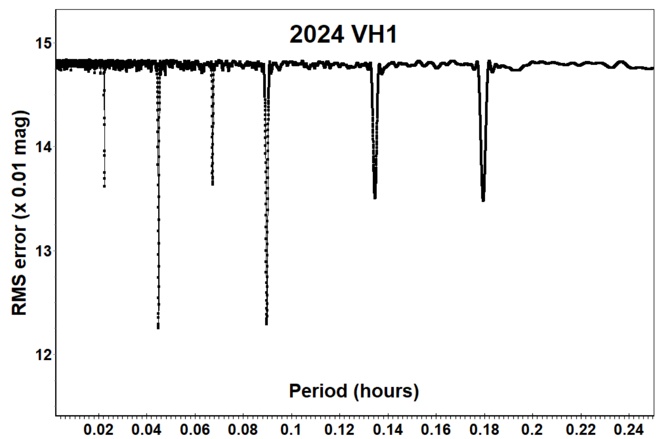
The corresponding lightcurves are labelled P1 and P2. Note that the periods are nearly but not exactly in 3:2 commensurability (0.2932 / 0.1994 = 1.47) and due to the 4.8 h span of observations covering 16 of the P1 rotation periods and 24 of the P2 rotation periods, the NPAR solution is expected to be reasonably secure, with a rating of PAR = -3 (NPA rotation reliably detected with the two periods resolved.) (Petr Pravec, personal communication).

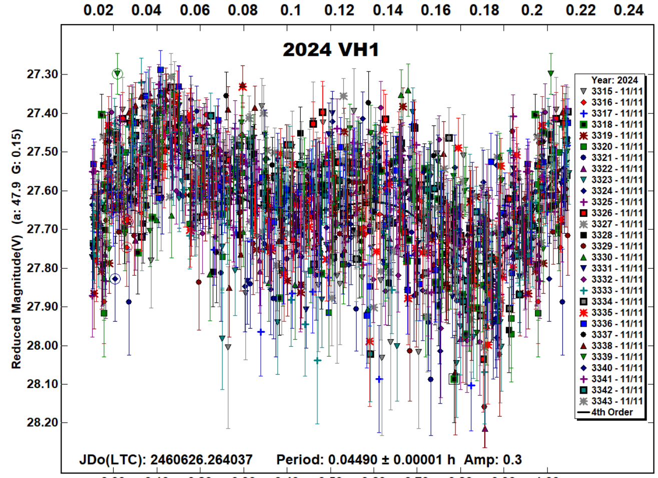




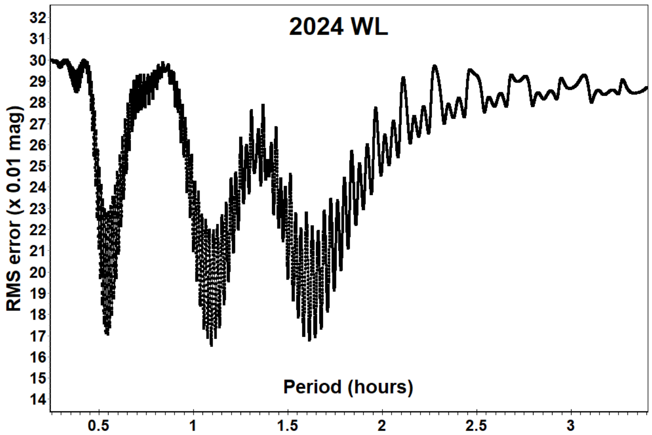


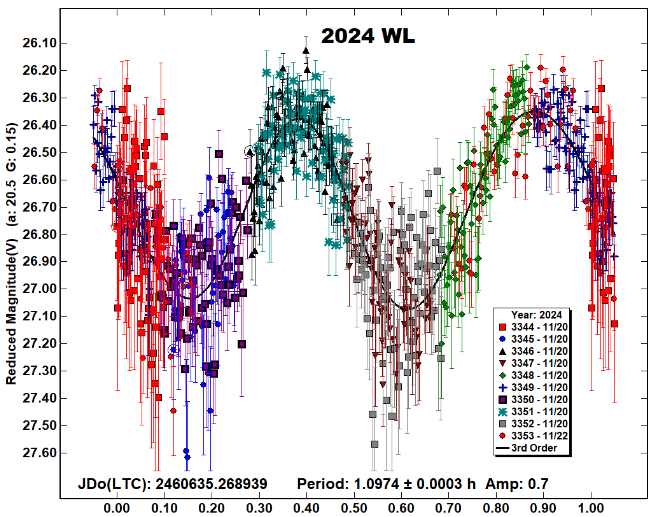
2024 VH1. This Apollo (*H = 26.6, D ~14 m*) was a Pan-STARRS 2 discovery from 2024 Nov 03.3 UTC (Heogner et al., 2024) which made an approach to 1.3 LD nine days later on 2024 Nov 12.34 UTC. It was observed on its final approach for 3.1 h starting at 2024 Nov 11.76 UTC when it was at 1.7 LD from Earth, reaching an apparent speed of 158 arcsec/min and exposures were reduced from 4.4 to 3.2 s during the session. A period spectrum shows a well-defined set of related minima, all being integer multiples of 0.0225 h and a lightcurve of the best-fit period of 0.04490 ± 0.00001 h (~2.7 min) is given. 2024 VH1 completed 69 rotations during the time it was under observation.





2024 WL. The ATLAS telescope at Mauna Loa discovered this Apollo (*H = 25.8, D ~21 m*) on 2024 Nov 20.4 UTC (Galli et al., 2024) some 15 h after it had passed Earth at 3 LD. It was observed for 1.8 h starting on 2024 Nov 20.77 UTC and again for 30 min starting 2024 Nov 21.99 UTC. Combining both sets of measurements indicates a best-fit solution at 1.0974 ± 0.0003 h with an amplitude of 0.7 but, with the limited coverage spanning only 1.7 rotations on the first date and 0.5 rotations on the second, this result is necessarily somewhat uncertain.



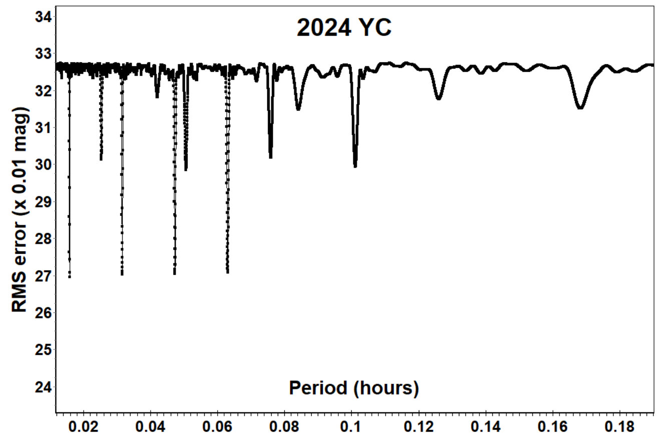


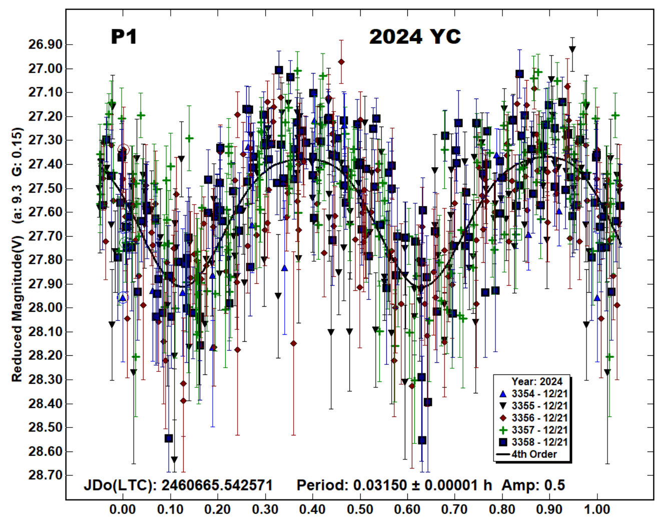
2024 YC. Another discovery of an Apollo (*H = 27.3, D ~10 m*) from the ATLAS Mauna Loa site (Kamel et al., 2024), this is listed as a virtual impactor by Sentry (JPL, 2025a) with a single low probability event in the year 2112. It made an approach to within 1.6 LD of Earth on 2024 Dec 23.0 UTC and was observed for 1.6 h starting 2024 Dec 21.04 UTC. A linearly plotted period spectrum shows several independent sets of equally spaced minima indicating that tumbling rotation is likely. The two strongest sets are at integer multiples of 0.01575 h and 0.02526 h, with a weaker set at multiples of 0.04209 h. The *MPO Canopus* Dual Period Search function located the best-fit pair of NPAR periods to be:

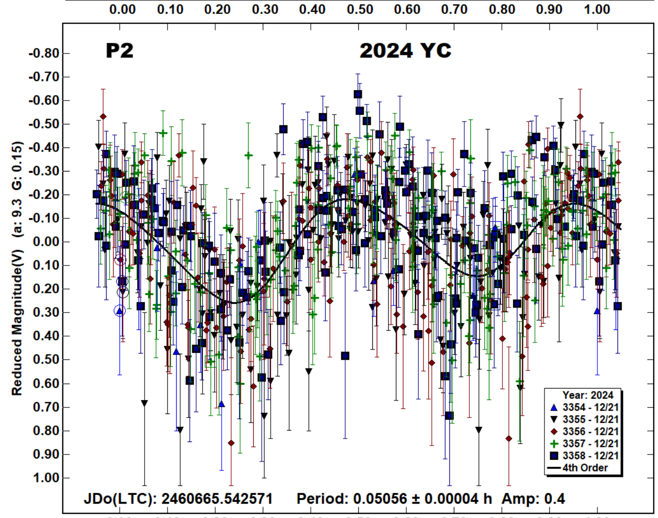
P1 = 0.03150 ± 0.00001 h (~1.9 min), amplitude 0.5
P2 = 0.05056 ± 0.00004 h (~3.0 min), amplitude 0.4

The resulting lightcurves are bimodal and are given here labelled P1 and P2. A weaker NPAR solution has the same dominant P1 period with a second period, P3 = 0.0841 ± 0.0002 h (~5.0 min) and it is noted that the frequency of the P3 period is a linear combination of the frequencies of P1 and P2, where: $1/P1 - 1/P2 \approx 1/P3$. It is not possible to determine whether the main apparent frequencies are the real frequencies of rotation and precession for the tumbler or just linear combinations of them. Nevertheless, it is expected that 2024 YC may be rated as PAR = -3 (NPA rotation reliably detected with the two periods resolved. An ambiguity of the periods solution may be tolerated provided the resulting spectrum of frequencies with significant signal is the same for the different solutions (Petr Pravec, personal communication).

The NPAR solution indicates the full amplitude of the tumbling rotation is 1.0 mag. 2024 YC completed 51 rotations of the P1 period and 31 of the P2 period during the 1.6 h it was under observation.







Number	Name	Integration times	Max intg/Pd	Min a/b	Pts	Flds
	2009 MU	2,6	0.003	1.3*	1643	24
	2024 TR4	0.8-3.1	0.040[1]	2.1*	372	17
	2024 UG	2.5-8.2	0.011[1]	1.9	987	17
	2024 VH1	2-4.4	0.027	1.1*	1366	29
	2024 WL	3.5-20	0.005	1.6	711	10
	2024 YC	4-6	0.053[1]	2.0	582	5

Table I. Ancillary information, listing the integration times used (seconds), the fraction of the period represented by the longest integration time (Pravec et al., 2000), the calculated minimum elongation of the asteroid (Zappala et al., 1990), the number of data points used in the analysis and the number of times the telescope was repositioned to different fields. Note: * = Value uncertain, based on phase angle > 40°, 1 = Calculated using the shorter of the NPAR periods.

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Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E	PAR	H
	2009 MU	2009 06/23-06/24	78.6,82.2	-121	25	0.499	0.002	0.6	0.3	-2	24.6
						0.666	0.003	0.5	0.3		
	2024 TR4	2024 10/06-10/06	67.8,61.8	38	21	0.031645	0.000003	1.4	0.5	-3	26.9
						0.021327	0.000003	0.9	0.5		
	2024 UG	2024 10/21-10/22	20.3,16.0	21	5	0.2932	0.0002	0.8	0.3	-3	26.9
						0.1994	0.0002	0.3	0.3		
	2024 VH1	2024 11/11-11/11	47.6,54.5	47	26	0.04490	0.00001	0.3	0.2		26.6
	2024 WL	2024 11/20-11/22	*20.6,5.6	54	-1	1.0974	0.0003	0.7	0.2		25.8
	2024 YC	2024 12/21-12/21	9.2,10.1	87	4	0.03150	0.00001	0.5	0.3	-3	27.3
						0.05056	0.00004	0.4	0.3		

Table II. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Amplitude error (A.E.) is calculated as √2 × (lightcurve RMS residual). PAR is the expected Principal Axis Rotation quality detection code (Pravec et al., 2005) and H is the absolute magnitude at 1 au from Sun and Earth taken from the Small-Body Database Lookup (JPL, 2025b).

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LIGTHCURVES AND COLORS OF FIVE SMALL NEAR-EARTH ASTEROIDS: 2024 SY6, 2024 TU, 2024 TK1, 2024 TX13, 2024 UF9

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September 2024 and October 2024 observation campaigns resulted in photometric observations of five small near-Earth asteroids. Lightcurves of three asteroids (2024 SY6, 2024 TU, and 2024 TK1) clearly indicated rapid rotation, and those of two others (2024 TX13, and 2024 UF9) remained inconclusive. Color indices of all five asteroids were computed and were used to produce two-color plots to determine the taxonomy class of each of them, and in addition to compute their relative reflectance, which was compared to asteroid spectra (from SMASS and SMASSII) to refine the primary taxonomy classification.

We collected data with the Vatican Advanced Technology Telescope (VATT), the Vatican Observatory's telescope with MPC code 290 located on Mount Graham in southeastern Arizona. VATT is an f/1.0 telescope with a primary mirror of 1.0 m in diameter and a 0.38-m f/0.9 secondary mirror. The instrument used was a CCD camera called VATT4k with the resolution of 4064×4064 pixels and a pixel size of 15×15 µm. Given the normal readout time of 60 seconds, we chose to bin the images two by two to reduce this to 30 seconds, yielding a plate scale of 0.375 arcsec/pixel. VATT4k covers the visible spectrum going from 300 nm to 1000 nm with a maximum quantum efficiency at 450 nm.

For each observing run, after collecting scientific data we corrected the images with master-bias, and master-flat. While the master-bias is generated from two hundred bias images using ccdproc, imred, ccdred, and zerocombine IRAF packages, the master-flat for B, V, R, and I is made from fifteen images on each filter through imred, ccdred, and flatcombine IRAF packages (Tody, 1986; Hergenrother et al., 2009; Kikwaya Eluo et al., 2019, 2022; Kikwaya Eluo and Hergenrother, 2024). We tracked each asteroid following its non-sidereal rate (Hergenrother et al., 2009). Consequently, stars in the field appeared smeared and could not be used for photometry. Instead, for each night we observed a certain number of standard stars in different airmasses (from 1.1 to 2.0) to compute a zero point and an extinction coefficient in each filter to apply to the asteroid according to the following formula: object (in Mag) = (zero point (in Mag) + observed object (in Mag)) - Object airmass * extinction coefficient) (Hergenrother et al., 2009; Kikwaya Eluo et al., 2019, 2022; Kikwaya Eluo and Hergenrother, 2024). We set a circular ring with a 15-pixel radius, and a width of ten pixels for the background to measure the sky. We took twice the FWHM as the aperture to measure the asteroid.

We observed with the filter sequence (V-B-V-R-V-I-V) to ensure the accuracy and the quality of both the shape of the lightcurve and the color of the asteroid (Fedorets et al., 2017; Tricarico, 2017; Schunova-Lilly et al., 2017; Kikwaya Eluo and Hergenrother, 2023; Kikwaya Eluo and Hergenrother, 2024). Note that there are three images in the V filter for every image in the B, R, or I filters.

We used *ALC*, Petr Pravec's Asteroid Lightcurve software, to compute the lightcurve. As we observed the asteroid more than once in V, the lightcurve is mainly given in V. We inserted other filters to ensure the shape of the lightcurve, and also to compute the color of the asteroid. Through this process, we were able to determine color indexes of the asteroid: V-R, B-V, and V-I (Kikwaya Eluo et al., 2022; Kikwaya Eluo and Hergenrother, 2023, 2024), which were utilized to make two-color plots (B-V versus V-R, and V-I versus V-R) (Yoshida et al., 2004; Zellner et al., 1985; Dandy et al., 2002; Dandy et al., 2003). We report the two-color plots of the five small Near-Earth Asteroids in Figures 1 and 2.

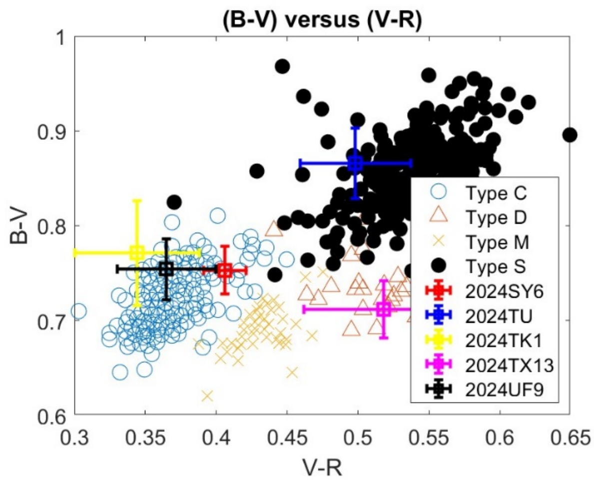

Fig 1. Two-color B-V versus V-R plot for all 5 NEAs.

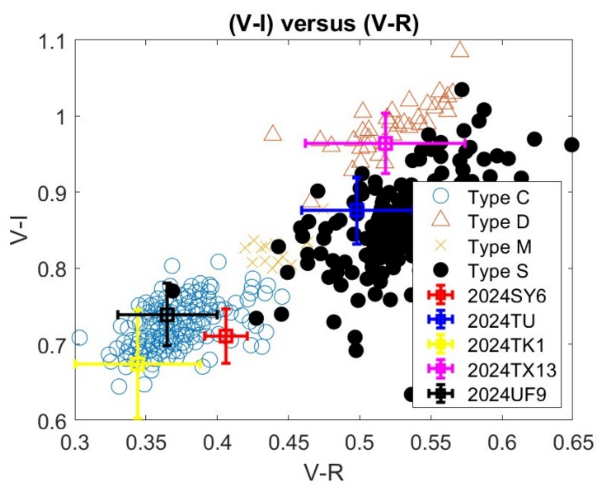

Fig 2. Two-color V-I versus V-R plot for all 5 NEAs.

From the two-color plots we determined the preliminary taxonomy class of each of the five asteroids. From the photometric color indices, we computed the relative reflectance of each asteroid (Holmberg et al., 2006; Kikwaya Eluo et al., 2016) with the value in V-filter set to 1. We used the relative reflectance in the chi-squared comparison with the observed asteroid spectra following Birlan et al. (2016). The comparison is concretely done with the M4AST (Modeling For Asteroids) engine from the Paris Observatory (Popescu et al., 2012, 2016). The asteroid spectra are gathered in the SMASS/SMASSII database presented by Bus and Binzel (2002a, 2002b). We report the relative reflectance of each of the five asteroids in Figure 3. Table I reports the absolute magnitude and orbital information of each asteroid while Table II displays the results of our observations.

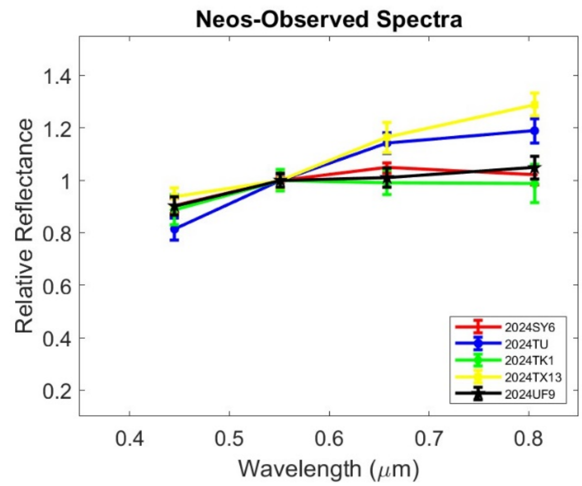

Fig 3. Relative reflectances of five NEAs (2024 SY6, 2024 TU, 2024 TK1, 2024 TX13,2024 UF9).

2024 SY6

2024 SY is an Apollo asteroid with an absolute magnitude of 25.02. We observed it on October 2, 2024, after it was initially reported by Catalina Sky Survey on September 30, 2024. We used 4 filters: B, V, R, and I. For the lightcurve, we mainly used ninety-two images taken with V-filter. The lightcurve shows a rotation period of 0.1886 +/- 0.0001h with an amplitude of 0.076 +/- 0.012 mag (Fig. 4). 20024 SY6 appears to be a rapid rotator. However, some doubt remains on whether the period of 0.1886 h is a correct solution as the uncertainty of observations is close to half of the lightcurve amplitude.

The color indexes of B-V = 0.753 +/- 0.025; V-R = 0.406 +/- 0.015, and V-I = 0.711 +/- 0.036 suggest a C-complex taxonomy for 2024 SY6 (Fig. 1 and Fig. 2). The confirmation comes from the comparison of its relative reflectance and the SMASS and SMASSII asteroid spectra (Bus and Binzel, 2002a, 2002b) which shows three solutions with a chi-squared value of 0.000 (Cg, Cgh, Xk) with two (Cg, and Cgh) falling into C-complex taxonomy (Fig. 5).

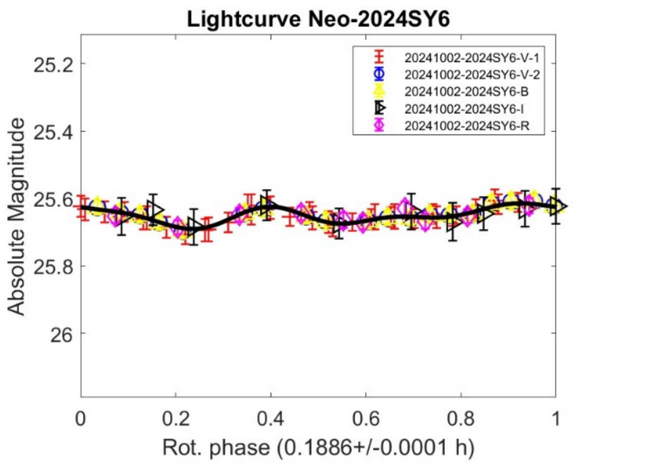

Fig 4. Lightcurve of 2024 SY6 phased to a period of 0.1886 +/- 0.0001h.

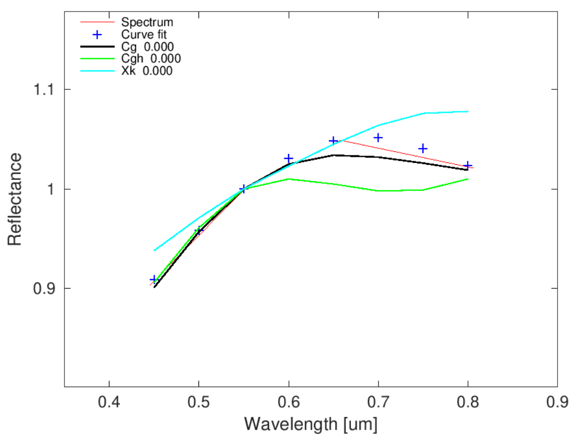

Fig 5. Relative reflectance of 2024 SY6 compared with observed asteroid spectra using the chi-squared method.

2024 TU

2024 TU is an Apollo asteroid with an absolute magnitude of 25.39. Reported initially by Catalina Sky Survey on October 2, 2024, we observed it on October 4, 2024. We observed three separate sequences in the V-filter and obtained successively 29 images, 24 images, and 30 images, giving a total of 83 images used for the lightcurve. These indicated that 2024 TU was a fast rotator with a rotation period of 0.3220 +/- 0.0002 h and an amplitude of 0.397 +/- 0.030 mag (Fig. 6).

We alternated sequentially the observations in V-filter with those in B-filter, R-filter and I-filter for computing color indices. We obtained B-V = 0.866 +/- 0.0001, V-R = 0.498 +/- 0.039, and V-I = 0.876 +/- 0.044, which suggested through two-color plots an S-complex taxonomy for 2024 TU (Fig.1 and Fig. 2). We compared its relative reflectance with the observed spectra in SMASS and SMASSII (Bus and Binzel, 2002a, 2002b), and found three matches: L, S, and Sr, confirming a S-complex for the asteroid (Fig. 7).

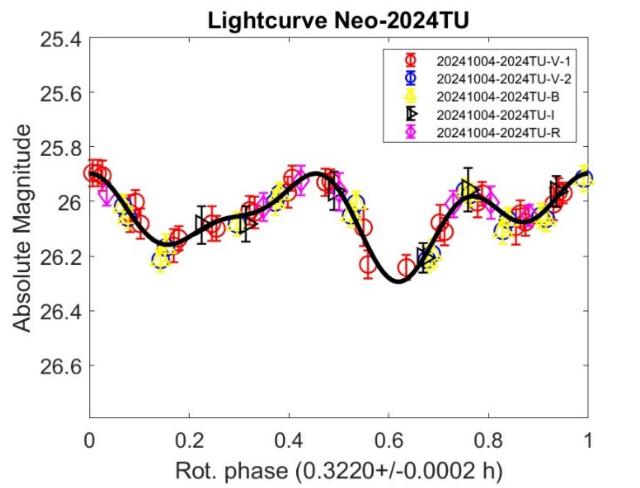

Fig 6. Lightcurve of 2024 TU phased to a period of 0.3220+/-0.0002h.

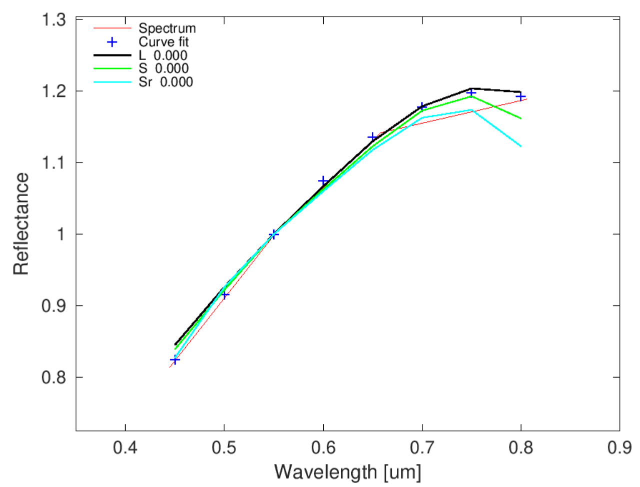

Fig 7. Relative reflectance of 2024 SY6 compared with observed asteroid spectra using the chi-squared method.

Object	yyyy mm/dd	Phase	Delta (AU)	r (AU)	H	a	e	i	B_{PAB}	L_{PAB}	Grp
2024 SY6	2024 10/02	11.9	0.040	1.040	25.02	1.996	0.659	6.778	5.652	5.538	Apollo
2024 TU	2024 10/04	15.1	0.037	1.036	25.39	2.214	0.574	6.475	11.405	8.091	Apollo
2024 TK1	2024 10/05	24.9	0.022	1.020	25.81	1.786	0.466	2.119	8.655	12.553	Apollo
2024 TX13	2024 10/31	22.5	0.017	1.009	24.56	1.079	0.259	3.057	47.926	5.601	Apollo
2024 UF9	2024 11/01	0.90	0.024	1.017	26.16	1.877	0.630	4.081	39.548	-0.869	Apollo

Table I: Observing circumstances. The phase angle, delta (distance to the Earth in AU), r (distance to the Sun in AU), and L_{PAB} and B_{PAB} (approximate phase angle bisector longitude and latitude) are given for the mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).

Object	Period (hours)	Amp(mag)	B-V	V-R	V-I	Tax. Class
2024 SY6	0.1886+/-0.0001	0.076+/-0.012	0.753+/-0.025	0.406+/-0.015	0.711+/-0.036	C-Complex (Cg,Cgh,Xk)
2024 TU	0.3220+/-0.0002	0.397+/-0.030	0.866+/-0.037	0.498+/-0.039	0.876+/-0.044	S-Complex (S,Sr,L)
2024 TK1	0.09928+/-0.00002	0.220+/-0.042	0.771+/-0.055	0.344+/-0.044	0.674+/-0.072	C-Complex (Cgh,Ch,B)
2024 TX13	-----------	------------	0.712+/-0.030	0.518+/-0.056	0.964+/-0.040	X-Complex (Sv,D,T)
2024 UF9	-----------	------------	0.754+/-0.032	0.365+/-0.035	0.739+/-0.041	C-Complex (Cgh,C,Cg)

Table II: Periods of 3 NEAs and colors and Taxonomy classes of all 6 NEAs are reported.

2024 TK1

The observations of 2024 TK1, an Apollo asteroid with an absolute magnitude of 25.80, were initially reported by Mount Lemmon Survey on October 3, 2024. We observed it in 4 different broadband filters: B, V, R, and I on October 5, 2024. We gathered one hundred and twelve images in V-filter for the lightcurve which yielded a rotation period of 0.09928 +/- 0.00002 h with an amplitude of 0.220 +/- 0.042 suggesting that 2024 TK1 is a fast rotator (Fig. 8).

We combined images taken in the B, R and I filters with initial images in the V-filter to compute color indices of 2024 TK1 and its relative reflectance. We found B-V = 0.771 +/- 0.055, V-R = 0.344 +/- 0.044, and V-I = 0.674 +/- 0.072. The two-color plot suggested C-complex taxonomy for 2024 TK1 (Fig. 1, and Fig. 2). The comparison with the observed asteroid spectra from SMASS and SMASSII (Bus and Binzel, 2002a, 2002b) yielded three matches among which two (Cgh, and Ch) confirmed the C-complex taxonomy of 2024 TK1 (Fig. 9).

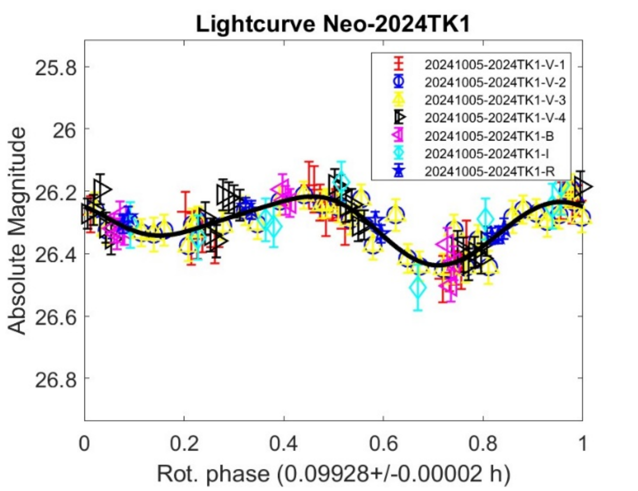

Fig 8. Lightcurve of 2024 TK1 phased to a period of 0.09928 +/- 0.00002 h.

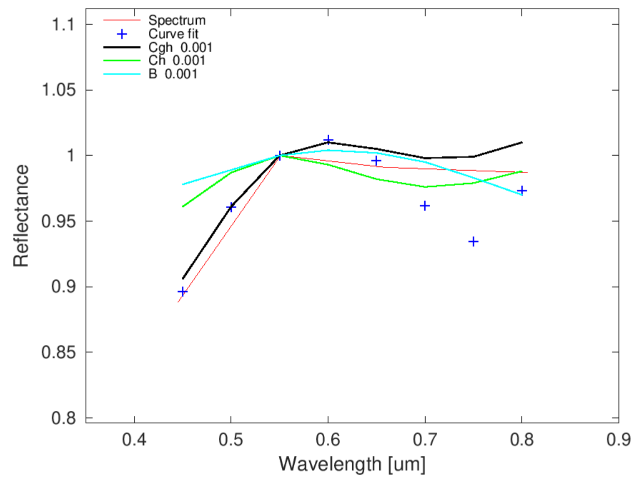

Fig 9. Relative reflectance of 2024 TK1 compared with observed asteroid spectra using the chi-square method.

2024 TX13

2024 TX13 is an Apollo Near Earth Asteroid with an absolute magnitude of 24.56. Reported initially by Mount Lemmon Survey on October 11, 2024, we observed it in broad band B, V, R, and I filters on October 31, 2024. We collected 182 images in the V-filter in six different sequences over a span of eight hours to compute a lightcurve; however, despite the number of images gathered, and its large absolute magnitude value, these data did not yield any clear and conclusive rotation period.

Using these V filter data combined with images observed in the other three broadband filters (B, R, and I), we computed the color indices of 2024 TX13. B-V = 0.712 +/- 0.030, V-R = 0.518 +/- 0.056, 0.964 +/- 0.040. This suggested a X-complex taxonomy of 2024 TX13. In fact, the two-color plot shows that 2024 TX13 falls among M-type asteroids (Fig. 1, and Fig. 2) consistent with an X-complex taxonomy (Bus and Binzel, 2002a, 2002b). We computed the relative reflectance of 2024 TX13 from its color indexes and we compared it with the observed spectra from SMASS and SMASS II (Bus and Binzel, 2002a, 2002b) using the chi-squared method. Three observed spectra matched the relative reflectance of 2024 TX13 (Fig. 10) among which two, D, and T, are consistent with X-complex taxonomy. We classified 2024 TX13 into X-complex.

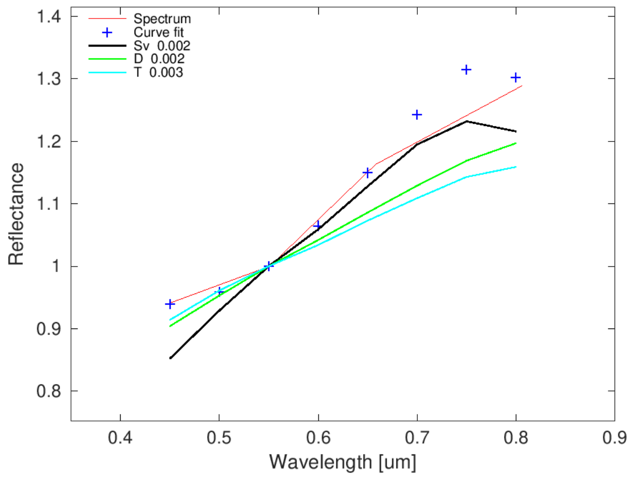

Fig 10. Relative reflectance of 2024 TX13 compared with observed asteroid spectra using the chi-square method.

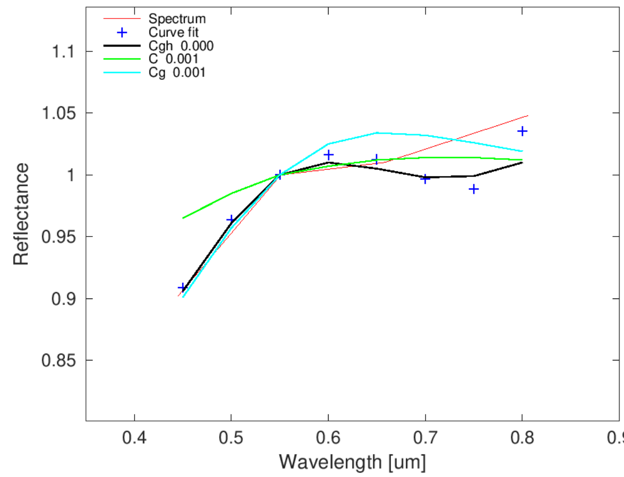

Fig 11. Relative reflectance of 2024 UF9 compared with observed asteroid spectra using the chi-square method.

2024 UF9

2024 UF9 with an absolute magnitude of 26.16 was initially reported by the ATLAS program at Haleakala on the Hawaiian island of Maui on October 10, 2024, and we observed it on November 1, 2024, in four different filters: B, V, R, and I. We collected in five different sequences for a total of 124 images in V-filters over a span of 8 hours, but our attempt to determine a lightcurve did not show any conclusive rotation period. A rotation period was reported by Ondrejov NEO Photometric Program from the same night. The Ondrejov period is 0.039186 +/- 0.000005 h, or 141.0696 +/- 0.0180 s, with an amplitude of 0.09 magnitudes (Pravec et al., 2025web). Our VATT observations had an exposure time of 60 s, or 43% of the Ondrejov rotation period. The optimum exposure time to detect a rotation period is 18.5% of the rotation period Pravec et al., 2000). Our VATT exposure times were too long relative to the rotation period, resulting in a loss of rotation period information and a smoothing out of the lightcurve.

We put together images in V-filter with those in B, R, and I filters to compute the color indexes of 2024 UF9. We found B-V = 0.754 +/- 0.032, V-R = 0.365 +/- 0.035, and V-I = 0.739 +/- 0.040 used in the two-color plot which suggested C-complex taxonomy for 2024 UF9 (Fig. 1, and Fig. 2). We also used the same color indexes to compute the relative reflectance of 2024 UF9 which, compared with the chi-squared method to observed asteroid spectra from SMASS and SMASSII (Bus and Binzel, 2002a, 2002b), yielded three matches (Cgh, C, and Cg) (Fig. 11) all falling into C-complex taxonomy confirming that 2024 UF9 is a C-type Near Earth asteroid.

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A LIGHTCURVE ANALYSIS FOR NINE MAIN-BELT AND ONE MARS-CROSSING ASTEROIDS

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Synodic rotation periods and amplitudes are reported for: 153 Hilda, 975 Perseverantia, 1203 Nanna, 1366 Piccolo, 1397 Umtata, 1763 Williams, 2168 Swope, 3768 Monroe, 6164 Gerhardmuller, 6601 Schmeer, 7000 Curie

The periods and amplitudes of asteroid lightcurves presented in this paper are the product of collaborative work by the GORA (Grupo de Observadores de Rotaciones de Asteroides) group. In all the studies, we have applied relative photometry assigning V magnitudes to the calibration stars.

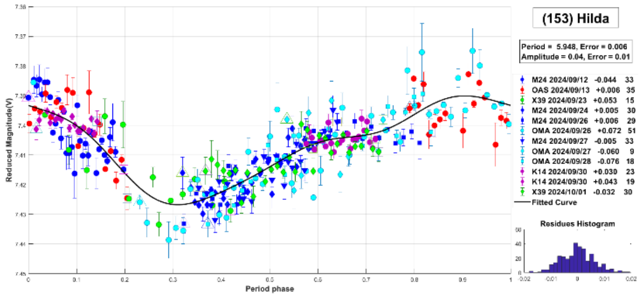
The image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected using dark frames and, in some cases, bias and flat-field corrections were also used. Photometry measurements were performed using *FotoDif* software and for the analysis, we employed *Periodos* software (Mazzone, 2012).

Below, we present the results for each asteroid studied. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - failing that - the GORA internal code, session date, session offset, and several data points.

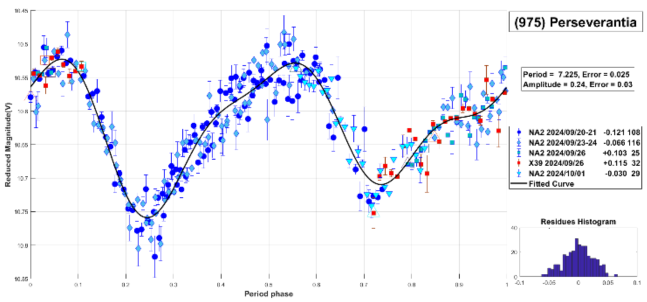
Targets were selected based on the following criteria: 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina or Spain or Italy, i.e. with negative or positive declinations δ, respectively, and 3) objects with few periods reported in the literature and/or with Lightcurve Database (LCDB) (Warner et al., 2009) quality codes (U) of less than 3.

In this work, we present measurements of periods corresponding to asteroids previously analyzed by our team. These lightcurves display improved results and are part of a new long-term project that we are initiating.

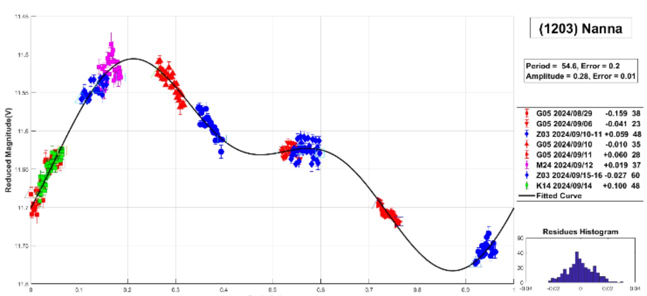
153 Hilda. Hilda is an outer main-belt asteroid, discovered in 1875 by J. Palisa. Classified as a P-type asteroid according to the Tholen taxonomy, it is the parent body of the Hilda family (Nesvorny et al., 2015). The diameter, derived from IRAS observations, is 170.63 km. Shevchenko et al. (2009) measured a rotation period of 5.9587 ± 0.0005 h. Our measurement of the period, P = 5.948 ± 0.006 h, with Δm = 0.04 ± 0.01 mag, agrees well with the value reported by the previous authors.



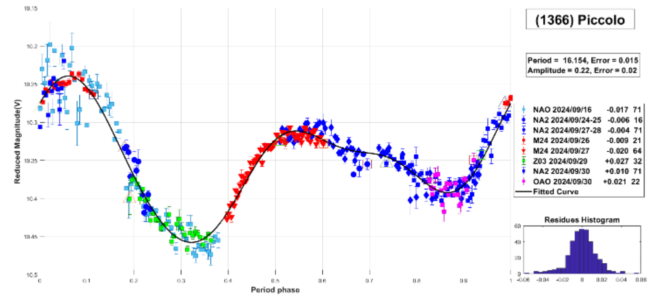
975 Perseverantia. This main-belt asteroid was discovered in 1922 by J. Palisa. Classified as an S-type asteroid according to the Tholen taxonomy, it is a member of the Koronis family (Nesvorny et al., 2015). The diameter is 22.169 km. The reported rotation period for this asteroid is 7.267 h (Behrend, 2003web). Our measurement of the period, P = 7.225 ± 0.025 h, with Δm = 0.24 ± 0.03 mag, agrees well with the value reported by the previous author.



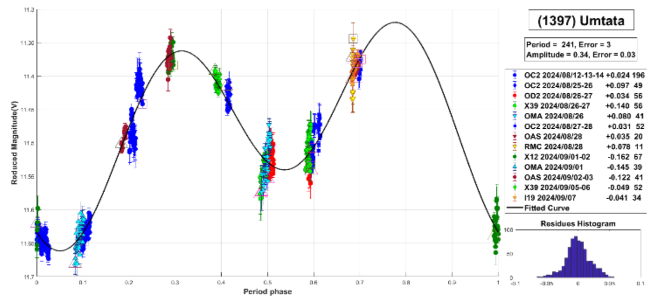
1203 Nanna. This main-belt asteroid was discovered in 1931 by M. Wolf, with a diameter of 35.18 km. The reported rotation period for 1203 Nanna is P = 18.54 ± 0.01 h (Warner, 2011). However, the same author previously measured a longer period: P = 25.80 ± 0.05 h (Warner, 2010). In this work, we propose an even longer period of P = 54.6 ± 0.2 h with Δm = 0.28 ± 0.01 mag.



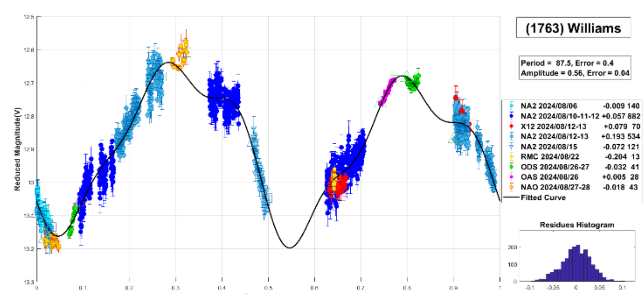
1366 Piccolo. This main-belt asteroid was discovered in 1932 by E. Delporte. It is classified as an X-type asteroid according to the Tholen taxonomy. The diameter is 27.55 km. The reported rotation period for this asteroid is 16.57 h (Binzel, 1987). We measured a period of P = 16.154 ± 0.015 h, with Δm = 0.22 ± 0.02 mag.



1397 Umtata. This main-belt asteroid was discovered in 1936 by C. Jackson, with a diameter of 20.798 km. An intial estimate of rotation period was reported as P = 30 h (Binzel, 1987). In this work, we propose a considerably longer period of P = 241 ± 3 h with Δm = 0.34 ± 0.03 mag.



1763 Williams. Williams is a main-belt asteroid with a diameter of 6.982 km, discovered in 1953 by the Goethe Link Observatory. A previously reported rotation period for this asteroid is P = 88.62 h (Ďurech et al., 2018). Our observations also support the long-period conclusion, yielding a similar value of P = 87.5 ± 0.4 h with Δm = 0.56 ± 0.04 mag.



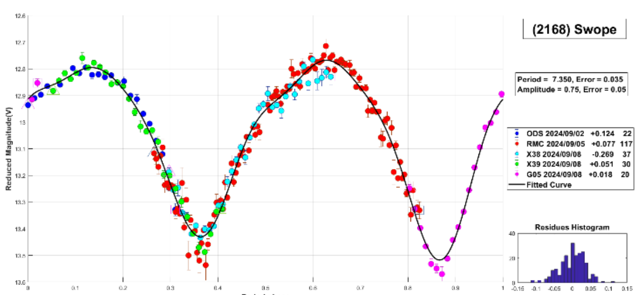
2168 Swope. This main-belt asteroid was discovered in 1955 at the Goethe Link Observatory. It is classified as a V-type asteroid according to the Tholen taxonomy, with a diameter of 8.205 km. Interestingly, we could not find a reported rotation period for this object in the literature. Based on our observations and thorough analysis, we propose a period of P = 7.350 ± 0.035 h and Δm = 0.75 ± 0.05 mag.

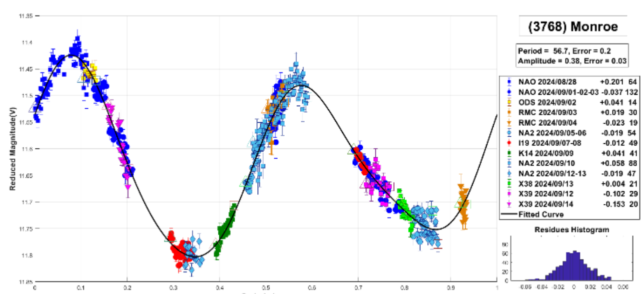
Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
153	Hilda	24/09/12-24/10/02	3.8,8.5	340	8	5.948	0.006	0.04	0.01	HIL
975	Perseverantia	24/09/20-24/10/01	3.5,7.7	349	-2	7.225	0.025	0.24	0.03	KOR
1203	Nanna	24/08/29-24/09/16	11.9,04.5	358	6	54.6	0.2	0.28	0.01	MB-O
1366	Piccolo	24/09/16-24/09/30	6.9,01.7	7	-4	16.154	0.015	0.22	0.02	MB-O
1397	Umtata	24/08/12-24/09/08	*3.6,12.4	324	-5	241	3	0.34	0.03	MB-M
1763	Williams	24/08/06-24/08/29	1.0,15.2	315	2	87.5	0.4	0.56	0.04	MB-I
2168	Swope	24/09/02-24/09/08	4.4,02.4	346	4	7.350	0.035	0.75	0.05	MB-I
3768	Monroe	24/08/28-24/09/14	*4.7,04.9	343	-5	56.7	0.2	0.38	0.03	MB-O
6164	Gerhardmuller	24/07/18-24/09/06	*13.7,17.4	316	-5	361	3	0.36	0.04	FLO
6601	Schmeer	24/08/25-24/08/30	9.0,11.9	320	-3	2.667	0.026	0.14	0.04	MB-I
7000	Curie	24/08/27-24/10/04	*16.9,13.5	355	-14	805	20	0.29	0.03	MB-I

Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extremum 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). MB-I: main-belt inner; MB-M: main-belt middle; MB-O: main-belt outer; FLO: 8 Flora; KOR: 158 Koronis; HIL: 153 Hilda.

Observatory	Telescope	Camera
G05 Obs.Astr.Giordano Bruno	SCT (D=203mm; f=6.3)	CCD Atik 420 m
I19 Obs.Astr.El Gato Gris	SCT (D=355mm; f=10.6)	CCD SBIG STF-8300M
K14 Obs.Astr.de Sencelles	Newtonian (D=250mm; f=4.0)	CCD SBIG ST-7XME
M24 Oss.Astr.La Macchina del Tempo	RCT (D250mm; f=8.0)	CMOS ZWO ASI 1600MM
X12 Obs.Astr.Los Cabezones	Newtonian (D=200mm; f=5.0)	CMOS QHY 174M
X38 Observatorio Pueyrredón	Newtonian (D=300mm; f=4.5)	CCD Apogee U8300
X39 Obs.Astr.Antares	Newtonian (D=250mm; f=4.72)	CCD QHY9 Mono
Z03 Obs.Astr.Río Cofio	SCT (D=254mm; f=6.3)	CCD SBIG ST-8XME
NAO Obs.Astr.Naos	Newtonian (D=250mm; f=4.0)	CMOS QHY 163M
NA2 Obs.Astr.Naos 2	Newtonian (D=200mm; f=5.0)	CMOS ZWO ASI 174
OAO Obs.Astr.Aficionado Omega	Newtonian (D=150mm; f=5.0)	CMOS QHY 174M
OAS Obs.Astr.de Ariel Stechina 1	Newtonian (D=254mm; f=4.7)	CCD SBIG STF-402
OA2 Obs.Astr.de Ariel Stechina 2	Newtonian (D=305mm; f=5.0)	CMOS QHY 174M
ODS Obs.Astr.de Damián Scotta 1	Newtonian (D=300mm; f=4.0)	CMOS QHY 174M
OD2 Obs.Astr.de Damián Scotta 2	Newtonian (D=250mm; f=4.0)	CCD SBIG STF-8300M
OC2 Obs.Astr.de Carlos Ambrosioni	SCT (D=279mm; f=6.7)	CCD SBIG ST8XME
OMA Obs.Astr.Vuelta por el Universo	Newtonian (D=150mm; f=5.0)	CMOS POA Neptune-M
RMC Obs.Astr.de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

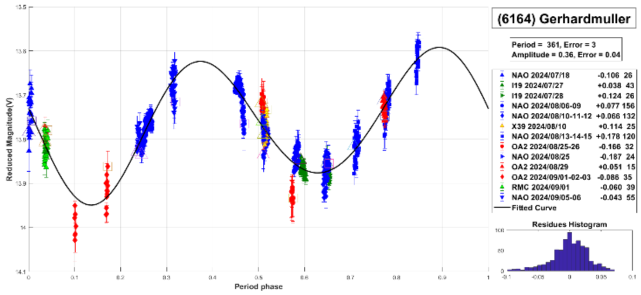
Table II. List of observatories and equipment.



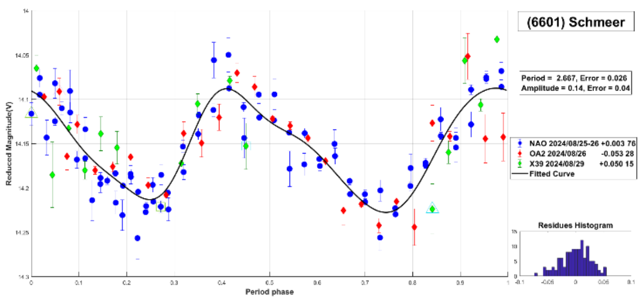


3768 Monroe. This main-belt asteroid was discovered in 1937 by C. Jackson. It is classified as a C-type asteroid according to the Tholen taxonomy, with a diameter of 26.601 km. For this asteroid, we could not find any published rotation periods in the literature. In this work, we propose a period of P = 56.7 ± 0.2 h with Δm = 0.38 ± 0.03 mag.

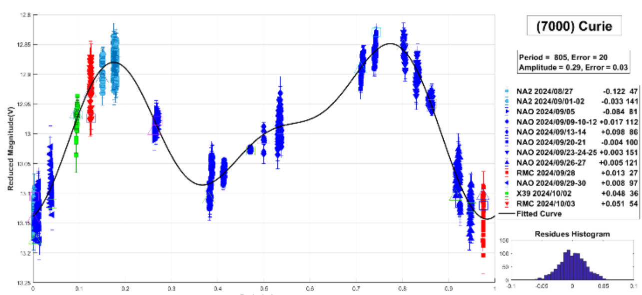
6164 Gerhardmuller. This main-belt asteroid was discovered in 1977 by N.S. Chernykh. It is a member of the Flora family (Nesvorny et al., 2015), with a diameter of 4.912 km. A review of the literature revealed no published rotation periods for this asteroid. In this work, we propose a long period of P = 361 ± 3 h with Δm = 0.36 ± 0.04 mag.



6601 Schmeer. Schmeer is a main-belt asteroid with a diameter of 6.946 km, discovered in 1988 by S. Ueda and H. Kaneda. No published rotation periods for this asteroid were found in the literature. In this work, we propose a short period of P = 2.667 ± 0.026 h with Δm = 0.14 ± 0.04 mag.



7000 Curie. Curie is a main-belt asteroid with a diameter of 6.497 km, discovered in 1939 by F. Rigaux. For this asteroid, we couldn't find published periods in the literature either. In this work, we propose a long period of P = 805 ± 20 h with Δm = 0.29 ± 0.03 mag.



Acknowledgements

We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analyses, Fernando Mazzone for his *Periodos* program, which was used in final analyses, and Matías Martini for his CalculadorMDE_v0.2 used for generating ephemerides used in the planning stage of the observations. This research has made use of the Small Bodies Data Ferret (*https://sbnapps.psi.edu/ferret/*), supported by the NASA Planetary System. This research has made use of data and/or services provided by the International Astronomical Union's Minor Planet Center.

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PHOTOMETRIC ANALYSIS OF PATROCLUS-MENOETIUS MUTUAL EVENTS AND 15 OTHER ASTEROIDS

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Synodic rotation periods and amplitudes are reported for: 617 Patroclus, 903 Nealley, 1205 Ebella, 1962 Dunant, 2032 Ethel, 2046 Leningrad, 2443 Tomeileen, 2801 Huygens, 2821 Slavka, 3583 Burdett, 4225 Hobart, 4916 Brumberg, 5565 Ukyounodaibu, 11441 Anadiego, 13441 Janmerlin, and (47834) 2000 EN114.

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The image acquisition was performed without filters and with exposure times of a few minutes. All images used were corrected using dark frames and, in some cases, bias and flat-field corrections were also used. Photometry measurements were performed using *FotoDif* software and for the analysis, we employed *Periodos* software (Mazzone, 2012).

Below, we present the results for each asteroid studied. The lightcurve figures contain the following information: the estimated period and period error and the estimated amplitude and amplitude error. In the reference boxes, the columns represent, respectively, the marker, observatory MPC code, or - failing that - the GORA internal code, session date, session offset, and several data points.

Targets were selected based on the following criteria: 1) those asteroids with magnitudes accessible to the equipment of all participants, 2) those with favorable observation conditions from Argentina or Spain or Italy, i.e. with negative or positive declinations δ, respectively, and 3) objects with few periods reported in the literature and/or with Lightcurve Database (LCDB) (Warner et al., 2009) quality codes (U) of less than 3.

In this work, we present measurements of periods corresponding to asteroids previously analyzed by our team. These lightcurves display improved results and are part of a new long-term project that we are initiating.

617 Patroclus. In response to the paper "Call for Observations of the Patroclus and Menoetius Mutual Events: Support for the NASA Lucy Mission to the Trojan Asteroids" (Binzel, 2024), we conducted observations of the Patroclus-Menoetius binary system from 2024/08/10 to 2024/10/28. The Patroclus-Menoetius binary is a flyby target for NASA's Lucy mission, scheduled to be reached in March 2033. The binary nature of this system was discovered in 2001 (Merline et al., 2001). We determined an orbital period for its two components of P = 102.9 ± 0.2 h (see Figure 1a). Additionally, we estimated that the two components orbit around their center of mass in 4.28 days (102.786 h; see Figure 1b). These results are in agreement with previous measurements by Marchis et al. (2006) and Mueller et al. (2010).

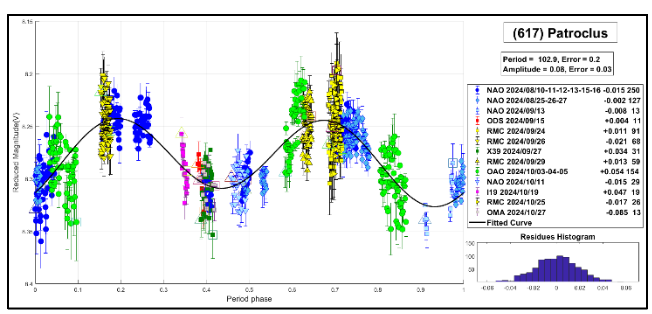


Figure 1a.

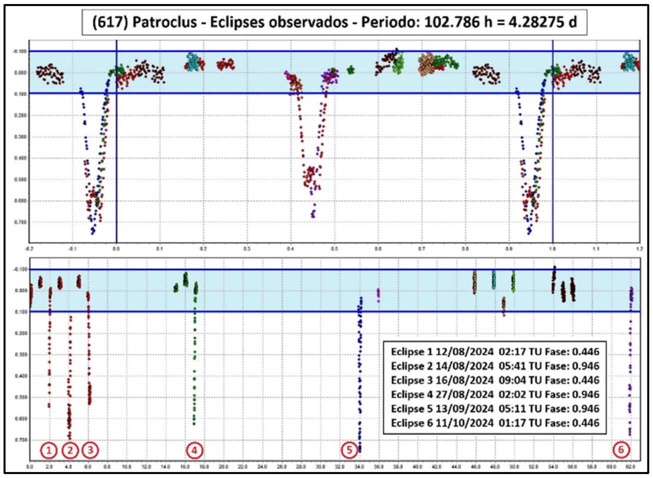
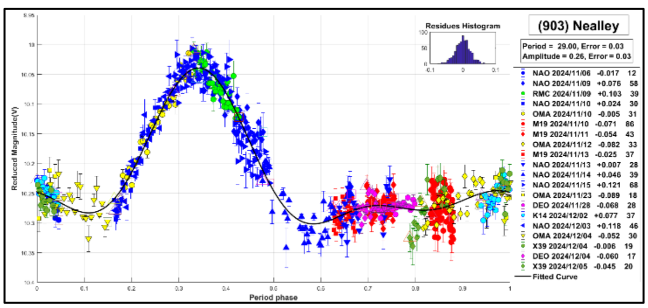
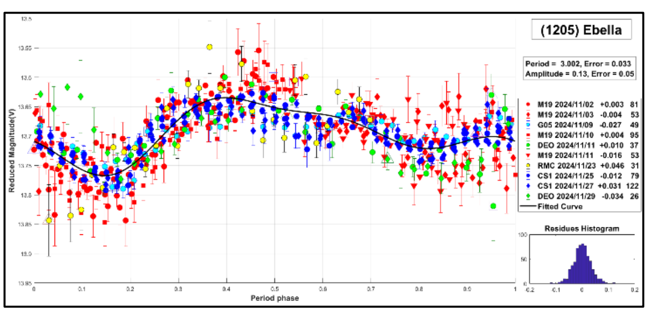


Figure 1b.

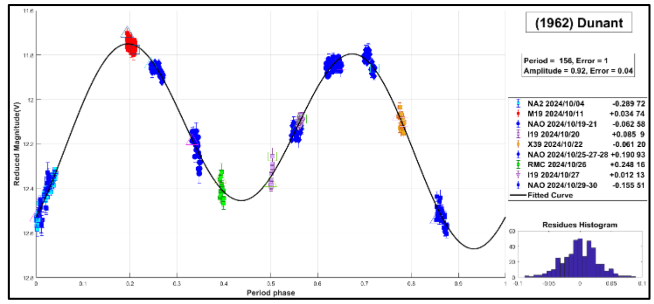
903 Nealley. This outer main-belt asteroid has a diameter of 58.065 km, discovered in 1918 by J. Palisa. The reported rotational period for this asteroid is P = 19.72 h (based on less than full coverage; Warner, 2012). Our observations suggest a longer period, yielding a value of P = 29.00 ± 0.03 h with Δm = 0.26 ± 0.03.



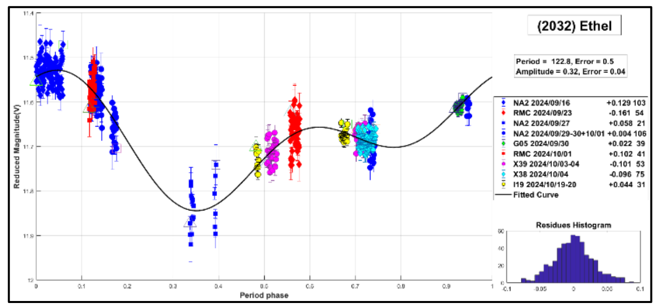
1205 Ebella. This main-belt asteroid has a diameter of 5.747 km, discovered in 1931 by K. Reinmuth. For this asteroid, we couldn't find published periods in the literature. In this work, we propose a short period of P = 3.002 ± 0.033 h with Δm = 0.13 ± 0.05 mag.



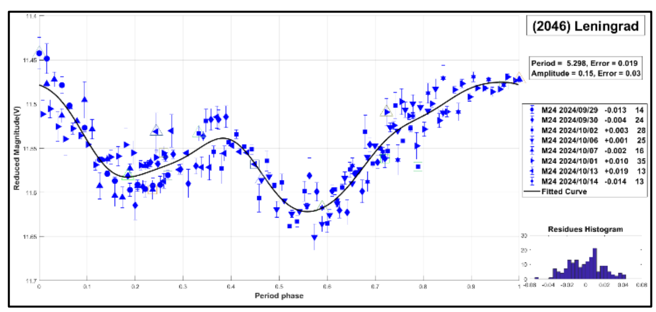
1962 Dunant. This main-belt asteroid was discovered in 1973 by P. Wild. It is classified as a C-type asteroid according to the SDSS-based Asteroid Taxonomy (Carvano et al., 2010), with a diameter of 18.927 km. For this asteroid, we could not find any published rotational periods in the literature. In this work, we propose a long period of P = 156 ± 1 h with Δm = 0.92 ± 0.04 mag.



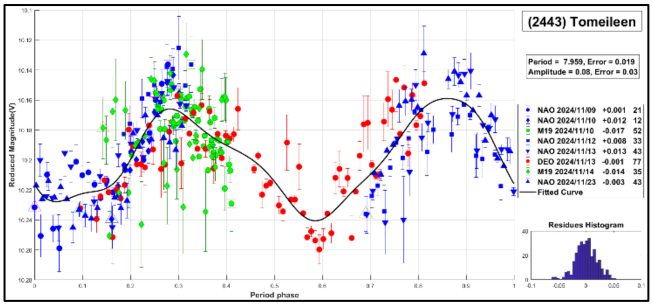
2032 Ethel. This main-belt asteroid has a diameter of 36.007 km, discovered in 1970 by T. Smirnova. For this asteroid, we could not find any published periods in the literature either. In this work, we propose a long period of P = 122.8 ± 0.5 h with Δm = 0.32 ± 0.04 mag.



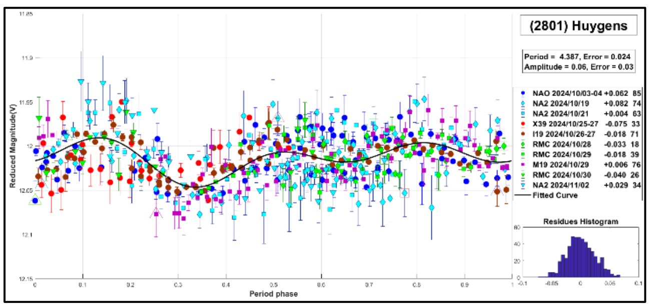
2046 Leningrad. This main-belt asteroid was discovered in 1968 by T. Smirnova. It is a member of the Themis family (Nesvorny et al., 2015), with a diameter of 23.968 km. The reported rotational period for this asteroid is P = 5.296 h (based on less than full coverage; Simpson et al., 2013). Our observations also support the short-period hypothesis, yielding a value of P = 5.298 ± 0.019 h with Δm = 0.15 ± 0.03.



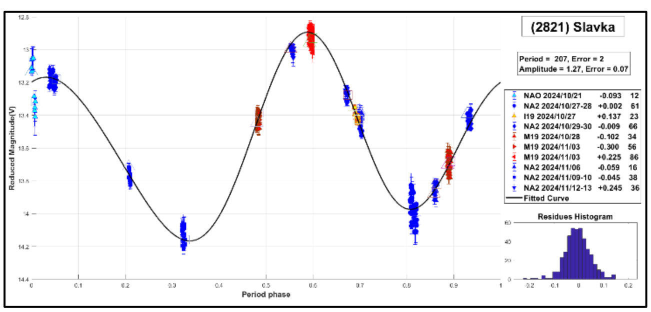
2443 Tomeileen. This main-belt asteroid was discovered in 1906 by M. Wolf. It is a member of the Eos family (Nesvorny et al., 2015), with a diameter of 31.878 km. The reported rotational period for this asteroid is P = 7.954 h (based on less than full coverage; Bonamico, 2020). Our measurement of the period, P = 7.959 ± 0.019 h, with Δm = 0.08 ± 0.03, agrees well with the value reported by the author.



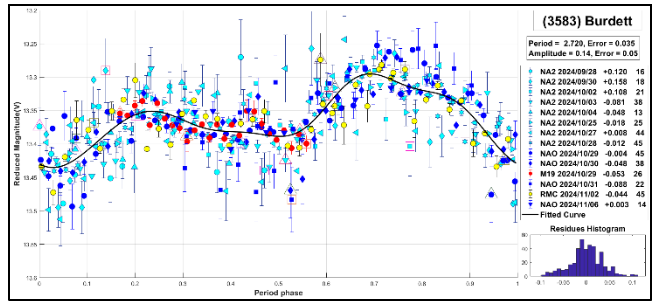
2801 Huygens. This main-belt asteroid was discovered in 1935 by H. Van Gent. It is a member of the Gefion family (Nesvorny et al., 2015), with a diameter of 11.525 km. It is an S-type asteroid in the SMASSII spectral type scheme (Xu et al., 1995; Bus and Binzel, 2002). Interestingly, we could not find a reported rotational period for this object in the literature. Based on our observations and thorough analysis, we propose a period of P = 4.387 ± 0.024 h and Δm = 0.06 ± 0.03 mag.



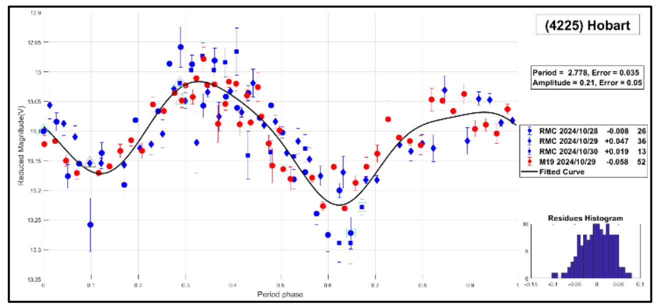
2821 Slavka. This main-belt asteroid has a diameter of 3.935 km, discovered in 1978 by Z. Vavrova. For this asteroid, we could not find published periods in the literature either. In this work, we propose a long period of P = 207 ± 2 h with Δm = 1.27 ± 0.07 mag.



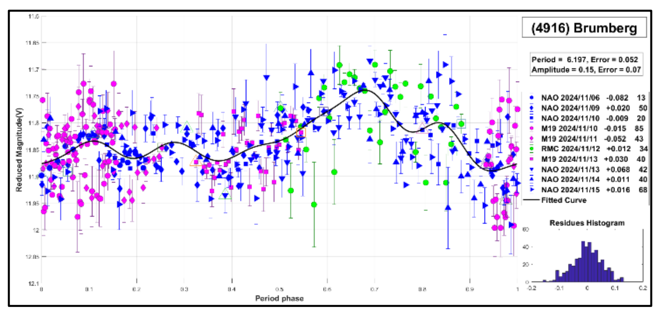
3583 Burdett. This main-belt asteroid was discovered in 1929 by C.W. Tombaugh. It is a member of the Nysa-Polana family (Nesvorny et al., 2015), with a diameter of 6.598 km. It is classified as an LS-type asteroid according to the SDSS-based Asteroid Taxonomy (Carvano et al., 2010). For this asteroid, we could not find any published rotational periods in the literature. In this work, we propose a period of P = 2.720 ± 0.035 h with Δm = 0.14 ± 0.05 mag.



4225 Hobart. This main-belt asteroid has a diameter of 6.397 km, discovered in 1989 by T. Hioki and N. Kawasato. For this asteroid, we couldn't find published periods in the literature either. In this work, we propose a short period of P = 2.778 ± 0.035 h with Δm = 0.21 ± 0.05 mag.



4916 Brumberg. This main-belt asteroid was discovered in 1970 by Crim. Astroph. Obs. The diameter is 16.507 km. The reported rotational period for this asteroid is 6.683 h (based on less than full coverage; Behrend, 2010web). Our measurement of the period, P = 6.197 ± 0.052 h, with Δm = 0.15 ± 0.07, agrees well with the value reported by the author.



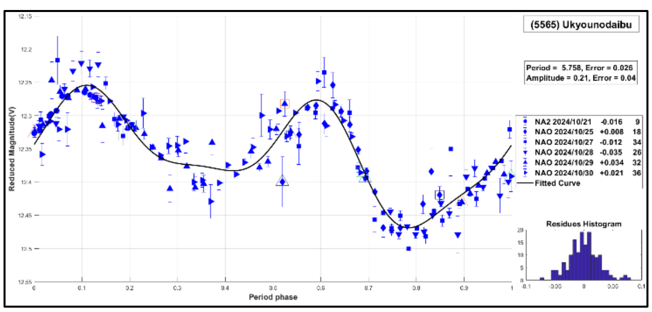
5565 Ukyounodaibu. This main-belt asteroid has a diameter of 12.286 km, discovered in 1970 by Natori and Urata. It is classified as an LS-type asteroid according to the SDSS-based Asteroid Taxonomy (Carvano et al., 2010) and as an S-type in the SMASSII spectral type scheme (Xu et al., 1995; Bus and Binzel, 2002). For this asteroid, we couldn't find published periods in the literature either. Based on our observations and thorough analysis, we propose a period of P = 5.758 ± 0.026 h and Δm = 0.21 ± 0.04 mag.

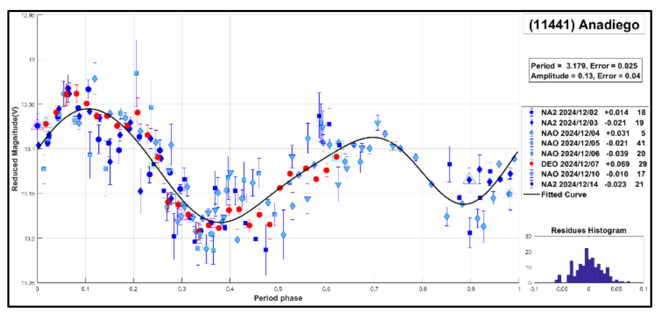
Number	Name	yy/ mm/dd- yy/ mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
617	Patroclus	24/08/10-24/10/28	*10.7,07.6	5	-17	102.9	0.2	0.08	0.03	HUN
903	Nealley	24/11/06-24/12/05	*07.8,07.1	60	-14	29.00	0.03	0.26	0.03	MB-O
1205	Ebella	24/11/02-24/11/29	*11.6,07.8	57	7	3.002	0.033	0.13	0.05	MB-I
1962	Dunant	24/10/04-24/10/30	01.2,12.8	9	0	156	1	0.92	0.04	MB-O
2032	Ethel	24/09/16-24/10/20	00.9,13.7	352	-1	122.8	0.5	0.32	0.04	MB-O
2046	Leningrad	24/09/29-24/10/14	13.4,07.7	37	-2	5.298	0.019	0.15	0.03	THM
2443	Tomeileen	24/11/06-24/11/15	07.9,05.6	62	-12	7.959	0.019	0.08	0.03	EOS
2801	Huygens	24/10/03-24/11/02	*02.9,13.6	11	-4	4.387	0.024	0.06	0.03	MB-O
2821	Slavka	24/10/21-24/11/13	19.6,07.7	61	-1	207	2	1.27	0.07	MB-I
3583	Burdett	24/09/28-24/11/06	*17.4,03.7	37	0	2.720	0.035	0.14	0.05	HER
4225	Hobart	24/10/28-24/10/30	13.3,14.2	13	-3	2.778	0.035	0.21	0.05	MB-I
4916	Brumberg	24/11/06-24/11/15	08.9,06.6	60	-14	6.197	0.052	0.15	0.07	EOS
5565	Ukyounodaibu	24/10/21-24/10/30	19.7,16.7	64	-13	5.758	0.026	0.21	0.04	MB-O
11441	Anadiego	24/12/02-24/12/14	12.4,09.3	84	-13	3.179	0.025	0.13	0.04	MB-I
13441	Janmerlin	24/09/29-24/11/16	*09.2,17.4	22	-3	23.082	0.049	0.58	0.07	MB-M
47834	2000 EN114	24/11/02-24/12/15	*17.8,28.2	53	25	29.087	0.046	0.40	0.07	PHO

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 extremum 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). MB-O: main-belt outer; MB-I: main-belt inner; HUN: Hungaria; HER: Hertha; EOS: 221 Eos; THM: Themis; MB-M: main-belt middle; PHO: Phocaea.

Observatory	Telescope	Camera
G05 Obs.Astr.Giordano Bruno	SCT (D=203mm; f=6.3)	CCD Atik 420 m
I19 Obs.Astr.El Gato Gris	SCT (D=355mm; f=10.6)	CCD SBIG STF-8300M
K14 Obs.Astr.de Sencelles	Newtonian (D=250mm; f=4.0)	CCD SBIG ST-7XME
M19 Osservatorio Explorer	Newtonian (D=254mm; f=3.8)	CCD Atik 414EX
M24 Oss.Astr.La Macchina del Tempo	RCT (D250mm; f=8.0)	CMOS ZWO ASI 1600MM
X38 Observatorio Pueyrredón	Newtonian (D=300mm; f=4.5)	CCD Apogee U8300
X39 Obs.Astr.Antares	Newtonian (D=250mm; f=4.72)	CCD QHY9 Mono
CS1 CapoSudObservatory	RCT (D=400mm; f=5.7)	CCD Atik 383L+Mono
DEO Dark Energy Observatory	Refractor (D=115mm; f=7.0)	CMOS QHY 294M pro
NAO Obs.Astr.Naos	Newtonian (D=250mm; f=4.0)	CMOS QHY 163M
NA2 Obs.Astr.Naos 2	Newtonian (D=200mm; f=5.0)	CMOS ZWO ASI 174
OAO Obs.Astr.Aficionado Omega	Newtonian (D=150mm; f=5.0)	CMOS QHY 174M
ODS Obs.Astr.de Damián Scotta 1	Newtonian (D=300mm; f=4.0)	CMOS QHY 174M
OMA Obs.Astr.Vuelta por el Universo	Newtonian (D=150mm; f=5.0)	CMOS POA Neptune-M
RMC Obs.Astr.de Raúl Melia Carlos Paz	Newtonian (D=254mm; f=4.7)	CMOS QHY 174M

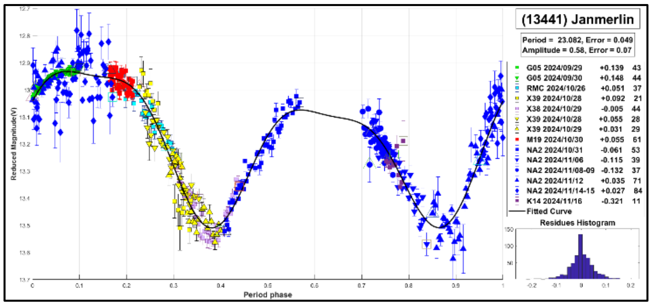
Table II. List of observatories and equipment.



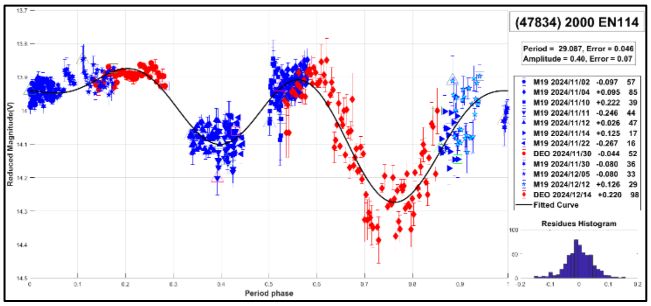


11441 Anadiego. This main-belt asteroid has a diameter of 6.833 km, discovered in 1975 by M.R. Cesco. It is classified as an S-type asteroid according to the SDSS-based Asteroid Taxonomy (Carvano et al., 2010). The reported rotational period for this asteroid is 3.179 h (based on less than full coverage; Hills, 2014). Our measurement of the period, P = 3.179 ± 0.025 h, with Δm = 0.13 ± 0.04, agrees well with the value reported by the author.

13441 Janmerlin. This main-belt asteroid was a diameter of 6.351 km, discovered in 1960 by C.J. Van Houten and I. Van Houten-Groeneveld on Palomar Schmidt plates taken by T. Gehrels. No published rotational periods for this asteroid were found in the literature. In this work, we propose a period of P = 23.082 ± 0.049 h with Δm = 0.58 ± 0.07 mag.



<u>(47834) 2000 EN114</u>. This Mars-crossing asteroid has a diameter of 4.398 km, discovered in 2000 by LINEAR. No published rotational periods for this asteroid were found in the literature. In this work, we propose a period of P = 29.087 ± 0.046 h with $\Delta m = 0.4 \pm 0.07$ mag.



Acknowledgements

We want to thank Julio Castellano as we used his *FotoDif* program for preliminary analyses, Fernando Mazzone for his *Periods* program, which was used in final analyses, and Matías Martini for his CalculadorMDE_v0.2 used for generating ephemerides used in the planning stage of the observations. This research has made use of the Small Bodies Data Ferret (*https://sbnapps.psi.edu/ferret/*), supported by the NASA Planetary System. This research has made use of data and/or services provided by the International Astronomical Union's Minor Planet Center.

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ADDITIONAL OBSERVATIONS OF (617) PATROCLUS-MENOETIUS MUTUAL EVENTS

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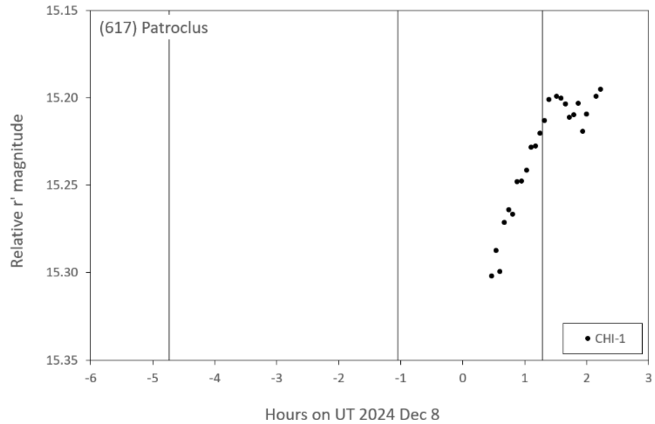
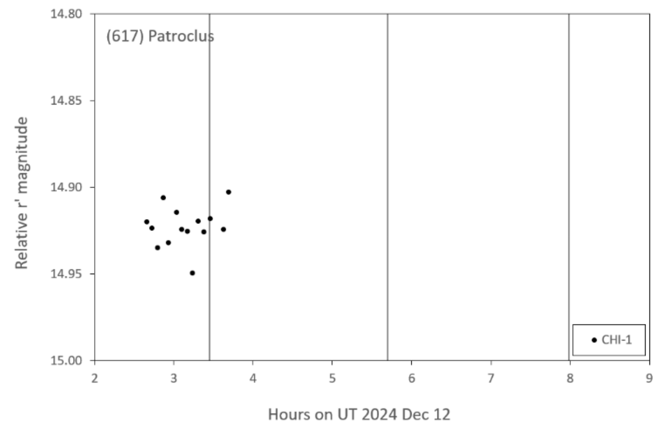
We present lightcurves of mutual events of the L5 binary trojan (617) Patroclus and its companion Menoetius on three nights in Dec 2024.

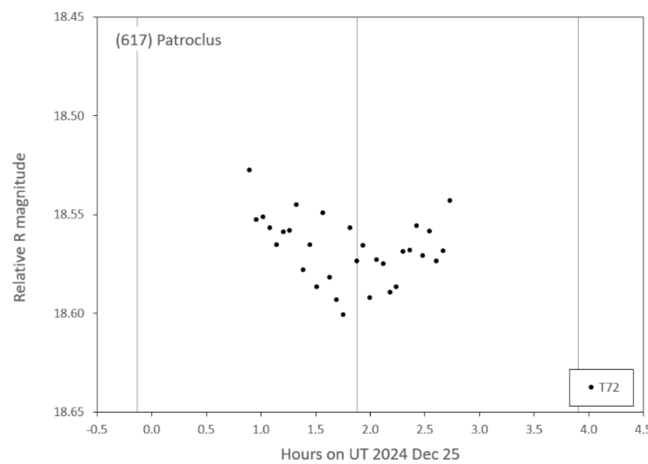
The binary trojan asteroid pair (617) Patroclus and its slightly smaller satellite Menoetius are the principal targets of study of NASA's Lucy Mission when it arrives at Jupiter's L_5 swarm in 2033. Both the spacecraft trajectory and the pointing of its instruments must be precisely programmed in advance, which requires an accurate dynamical model of the binary system. In response to an observing call (Binzel, 2024) we observed several mutual events of the Patroclus-Menoetius binary near their opposition (Wilkin et al., 2024). Although the observing geometry near opposition was more favorable for long observing sessions, the mutual events predicted by Brozović et al. (2024) continued until mid-January 2025, and the later, partial events may provide tight constraints on the binary's geometry despite the less favorable viewing geometry late in the season.

Observational planning used predicted start, maximum, and end times made available by Brozović et al. (2024), and we have reproduced their predictions in Table I for the three nights on which we obtained usable images. Telescopes and cameras are described in Table II. The telescopes CHI-1 and T72 are operated by Telescope.Live and iTelescope.net, respectively. Filters and telescopes used for individual nights are given in the lightcurve figures. All images were processed for bias, dark, and flat field corrections. We extracted photometric measurements from the images using *AstroImageJ* (Collins et al., 2017). The predicted ingress, maximum depth, and egress times are indicated in the lightcurve figures by vertical lines. No light travel time corrections were applied.

On Dec 8 we captured the egress of the event that began on Dec 7. The Dec 12 observation ended at about the predicted ingress time, and appears to be pre-ingress baseline only. Finally, our Dec 25 observation apparently captured the maximum occultation for the event that began on Dec 24. All three of the events were inferior, when the disk or shadow of Menoetius is partially contained within the visible disk of Patroclus. Further analysis of our results will be done in combination with additional observations contributed by other observers to obtain updated solutions for the physical parameters of the Patroclus-Menoetius system.







Start Date (UTC)	Start	Event Max	Stop	Events	Observation coverage
2024 12 07	19:16	22:57	25:17	PE, PO	Egress
2024 12 12	03:27	05:42	07:59	PO	Pre-Ingress Baseline
2024 12 24	23:52	25:53	27:54	PO	Maximum depth, In-transit-only

Table I. Mutual Events Season 2024. The first column indicates inferior (I) or superior (S) event and sequence number. Columns 3-5 give the predictions of Brozović et al. (2024). In column 6, possible events include: PO--Partial Occultation, PE--Partial Eclipse.

Name	Site	Telescope	Camera	Array	Filter	FOV (′)	Scale (″/pix)
CHI-1	Rio Hurtado, Chile	0.61-m f/6.8	QHY 600M Pro	9576×6382×3.8µm	r′	31×21	0.395
T72	Rio Hurtado, Chile	0.50-m f/6.8	FLI ML16200	4500×3600 ×6µm	R	27×22	0.359

Table II. Telescopes and Cameras. Filters: R: Cousins R; r': Sloan r'.

Acknowledgements

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TWO MUTUAL EVENTS OBSERVED FOR PATROCLUS-MENOETIUS BINARY SYSTEM

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Two mutual events were observed for 617 Patroclus-Menoetius synchronous binary system in 2024 October in order to contribute to refine the physical parameters of the system, in view of the NASA's Lucy fly-by mission, expected in year 2033.

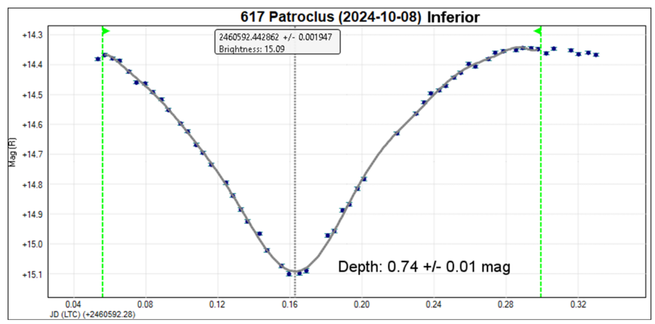
To respond to the "Call for Observations" by Binzel (2024), CCD observations of the Trojan binary asteroid 617 Patroclus-Menoetius were carried out in 2024 October 8 and 23 at the Schiaparelli Southern Observatory (Hakos Farm, Namibia, MPC code M21). We used a 0.36-m f/8.8 Ritchey-Chretien telescope, CCD Finger Lakes ProLine KAF16803 (bin 3×3), 300 second exposure time, clear filter.

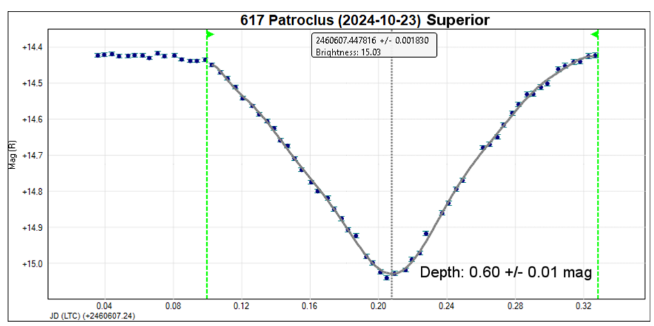
Photometric data reduction was performed with *MPO Canopus* (Warner, 2023). All data were converted to R band, using solar colored field star from CMC15 catalogue. These data are being archived to the asteroid lightcurve data base (LCDB). Time of the minima at the mid-eclipse were measured with Peranso (Paunzen and Vanmunster 2016) applying the correction for light time and using the "Lightcurve Workbench" function with a polynomial fit of order 15. The magnitude depth of the minima events were evaluated as the difference from the flat portion of the lightcurve and the fit minimum.

#	Time of Minimum JD (LTC) Date (UTC)	Depth Mag	Event Type
1	2460592.4429 ± 0.0019 2024-10-08 22:38	0.74 ± 0.01	Inferior
2	2460607.4478 ± 0.0018 2024-10-23 22:45	0.60 ± 0.01	Superior

Table 1. Measured time (LTC) of minima at the mid-eclipse for the observed mutual events.

We found the time of minima at the mid-eclipse for two mutual events, as reported on Table 1. The drop of the secondary eclipse, 0.60 ± 0.01, gives a lower limit on the secondary-to-primary mean diameter ratio Ds/Dp of 0.86 ± 0.02.





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LIGHTCURVES FROM THREE MUTUAL EVENTS OF TROJAN BINARY 617 PATROCLUS IN OCTOBER 2024

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(Received: 2024 December 18 Revised: 2025 January 4)

We present three raw lightcurves of Trojan binary 617 Patroclus on 2024 October 2, 6, and 21 during mutual events of the binary system.

The Lucy Mission is a NASA Discovery-class mission set to probe the Trojan asteroids around the L4 and L5 points of Jupiter (Levinson et al., 2021a). Named after a primitive *Australopithecus* human fossil, Lucy symbolizes the call to understanding the evolution of the Solar System. Lucy was launched on 2021 October 16 and will do a series of flybys near the following eight Trojan asteroids until 2033: 52246 Donaldjohanson, 3548 Eurybates + Queta, 15094 Polymele, 11351 Leucus, 21900 Orus, and 617 Patroclus + Menoetius. The mission will examine the geology of the surface, bulk properties (such as bulk density), and any potential satellites and/or rings associated with each asteroid (Levinson et al., 2021b).

Patroclus, officially titled 617 Patroclus, is a C-type binary Trojan asteroid (Smith et al., 1981). Previous observations have determined that Patroclus has a semimajor axis of 5.207 AU and an orbital period of 11.89 years (JPL, 2024). Its rotation period is notably long at 103.02 ± 0.40 hours (Mueller et al., 2010). 617 Patroclus is a binary system consisting of Patroclus and its companion Menoetius, which is similar in size and separated from the main body by a distance of 692.5 km. These asteroids are tidally locked such that their orbital period around each other is also 102.8 hours (Brozović et al., 2024). The binary nature of the system allows for mutual events such as transits and occultations to occur. These events can provide more information on Patroclus's characteristics, including its shape and surface features, which currently lack thorough documentation. Observing these characteristics will provide insight into the gravity field surrounding Patroclus, impacting how research endeavors including NASA's Lucy mission will approach flyby observations.

Images were taken using two different telescopes. All images were taken at Siding Spring Observatory (MPC Q62) in New South Wales, Australia. The images from October 2 were taken using a 0.50-m f/6.8 reflector telescope with a FLI-PL6303E CCD camera with an array of 3072×2048 pixels (iTelescope, 2024a). The images from October 6 and 21 were taken using a 0.43-m f/6.8 Corrected Dall-Kirkham telescope with a Moravian G4 16000 CCD camera with an array of 4096 x 4096 pixels (iTelescope, 2024b). All images were taken through an Astrodon E-Series Luminance filter with an exposure time of 300 seconds.

On 2024 October 2, a series of software and equipment issues severely impacted the images taken. After the first nine images, a software glitch caused the following 21 images to be mislabeled and prevented us from accessing them (access was restored days later). Additionally, starting with the 24th image, all subsequent images in the first sequence were very out of focus. Sometime later, another software glitch caused all of the images taken to be labeled under another iTelescope username, once again preventing access to acquire them (restored later). After the requisite meridian flip, the images were in focus until the 11th frame, where the telescope once again lost focus for the last 30-odd images of the night. After this, the iTelescope website repeatedly revoked access to the telescope and then restarted itself until the observatory closed at 17:57 UTC, preventing further imaging.

On 2024 October 6, the weather conditions were clear and there were no obstructions, and 36 images were taken. 617 Patroclus set below the horizon at approximately 18:30 UTC, so no more images were taken after this time.

2024 October 21 was the final night for observations by this campaign. The weather conditions were also clear with no main obstructions. 617 Patroclus dipped below the telescope's viewing range as the event was beginning, so the 13 images were taken before it began.

iTelescope automatically calibrates the images produced with a standard bias, dark, and flat field calibration procedure. Aperture photometry was conducted using the R magnitudes of several stars in the ATLAS catalog (Tonry et al., 2018), the MPOSC3 catalogue (Warner, 2018), or the APASS catalog (Henden et al., 2009) in *MPO Canopus* (Warner, 2018). Some of the images collected were out of focus, so observing data were split into various groups based on whether the images were in focus or before/after a meridian flip, with aperture sizes adjusted accordingly. In *MPO Canopus*, we chose five known non-variable comparison stars to determine the brightness of the asteroid. *MPO Canopus* automatically cycled through each image and determined the magnitude of 617 Patroclus based on the magnitudes of the comparison stars. This process was repeated several times on the various sets of in-focus and out-of-focus images in order to achieve the lightcurves below. For the October 2 session with some out-of-focus images, the same comparison stars were used throughout the photometry analysis for all images.

Fig. 1 is a raw lightcurve created using observations from October 2. These took place over the course of approximately 9.5 hours starting at 10:30 UTC and ending at 19:55 UTC when the observatory closed for the night. Some of the images from the end of the night were discarded due to being highly out of focus and because they were taken after the partial occultation/eclipse had ended. Each session of data indicated on Fig. 1 corresponds to the first images that were in focus (session 12), then a sequence of images that were out of focus (session 13), then a sequence of images that were in focus (session 14), then in-focus images after a meridian flip (session 15), and finally images that were out of focus (session 16).

The three vertical lines present in Fig. 1 correspond to the beginning, peak, and end times of the superior event as predicted by Brozović et al. (2024) and listed in Table I. Interestingly, these lines do not align with the beginning, peak, and end of the event according to the images taken. We are confident in our time calculations and placement of these lines, so it is unclear why this discrepancy exists. It could potentially be the result of an unknown aspect of the binary asteroid system, but more observations are needed to confirm this.

TABLE OF EVENTS:

Event Date	Event Start	Event Peak	Event End	Event Type (Superior/Inferior)
2024 10 02	09:14	21:51	00:51	Superior
2024 10 06	16:12	18:48	21:20	Superior
2024 10 21	16:14	19:20	21:58	Inferior

Table I. Event times (in UTC) for the observations in this paper (Brozović et al., 2024).

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
617	Patroclus	2024 10/02	4.1	5	-16.2					
617	Patroclus	2024 10/06	4.3	4.9	-16					
617	Patroclus	2024 10/21	6.4	4.7	-15.3					

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

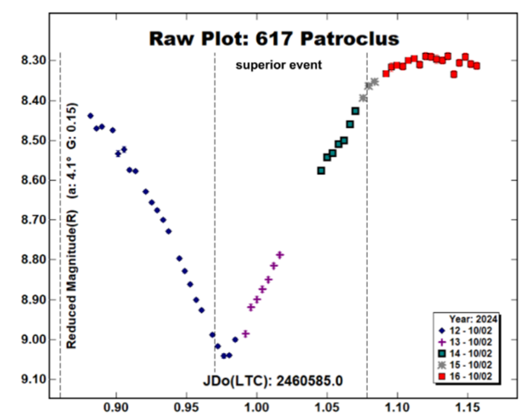

Fig. 1. Raw lightcurve of 617 Patroclus on 2024 Oct. 2 for superior event.

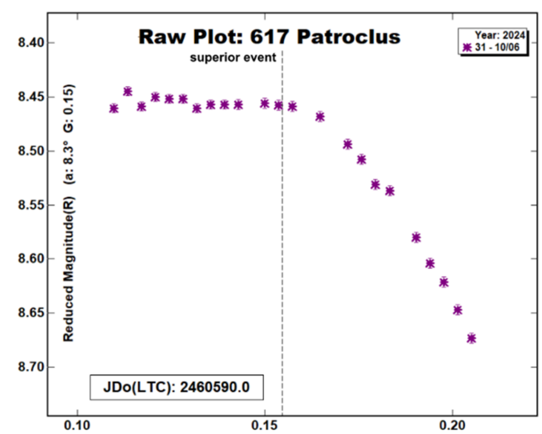

Fig. 2. Raw lightcurve of 617 Patroclus on 2024 Oct. 6 for superior event.

Observations resulting in the lightcurve shown in Fig. 2 were done on 2024 October 6. Data were collected over a period of 2.5 hours, from 15:00 to 17:30 UTC. Though the event was projected to peak at 18:48 UTC (Table I), we were unable to observe 617 Patroclus past 17:30 UTC due to it being out of the telescope's viewing range.

The raw lightcurve from the event on October 6 aligns with the timeline provided by Brozović et al. (2024). The vertical line in the plot represents the predicted start time for the event. To the left of this vertical line, the brightness does not appear to fluctuate immensely. However, the brightness drops significantly after the predicted start time for the event, further reinforcing the accuracy of the event timing given by Brozović et al. This was a superior event, and the lightcurve captured from our observations demonstrates a combination of an occultation and eclipse.

The lightcurve shown in Fig. 3 is from observations taken on 2024 October 21. Brozović et al. (2024) predicted the combined inferior eclipse and occultation event to start at 16:14 UTC (Table I). The vertical line represents when the event was supposed to start. The line is on the far right due to the event starting just before Patroclus went below the telescope's observing capabilities.

All data will be loaded into the Asteroid Lightcurve Photometry Database (ALCDEF; Warner et al., 2009) following publication.

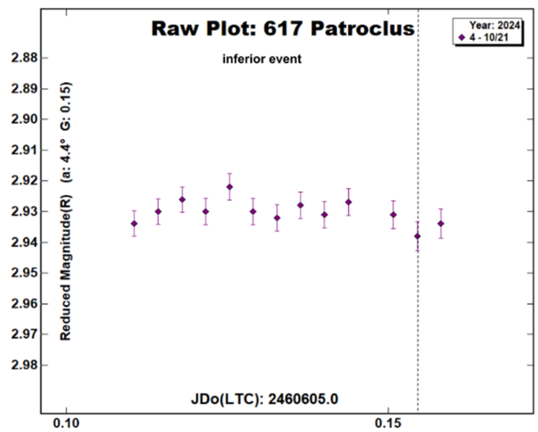

Fig. 3. Raw lightcurve of 617 Patroclus on 2024 Oct. 21 for inferior event.

Acknowledgements

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FOLLOW-UP OBSERVATIONS OF 617 PATROCLUS-MENOETIUS MUTUAL EVENTS: 2024 NOVEMBER TO 2025 JANUARY

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(Received: 2025 January 17)

We report on additional observations made and analysis following (Warner et al., 2025), continuing the effort to provide data prior to for NASA's Lucy fly-by mission in 2033 March. The additional data led to the same period, 102.873 h, but the formal precision was reduced by half to 0.003 h. Data for 2024 October 10-11 received after submission of our previous work filled in the missing part of the event, and we were able to refine the date and time for the start and minimum of the event. Other observations in late 2024 October through 2025 January 11 were either outside an event or covered only part of one. As before, we offer no interpretation regarding the parameters of the system beyond the rotation/orbital period. We also report H-G values of H_{PR} = 8.032 ± 0.042, G_{PR} = 0.075 ± 0.066. The value for H_{PR} was converted to H = 0.82 ± 0.06. The MPC reports H = 8.25 using G = 0.15.

In 2033 March, NASA's Lucy mission will fly by the Jupiter trojan 617 Patroclus and its moon, Menoetius. Mission planning requires having an accurate determination of the orbital period, the rotation period of the system (slightly different if excluding events from analysis), and the orbital parameters. A call was put out for photometric observations of the system during the mutual events season in mid-2024 to mid-2025 (e.g., Binzel, 2024). The timing, depths, and shapes of the events would provide critical information needed for mission planning.

In response to this call, we observed the pair from 2024 September to mid-October. The details of our observations, data measurement, and analysis can be found in Warner et al. (2025; referenced from here on as WEA) and are not repeated here.

Our additional observations cover the period from 2024 November 8 through 2025 January 11. Table I gives the dates and observers for the new observations.

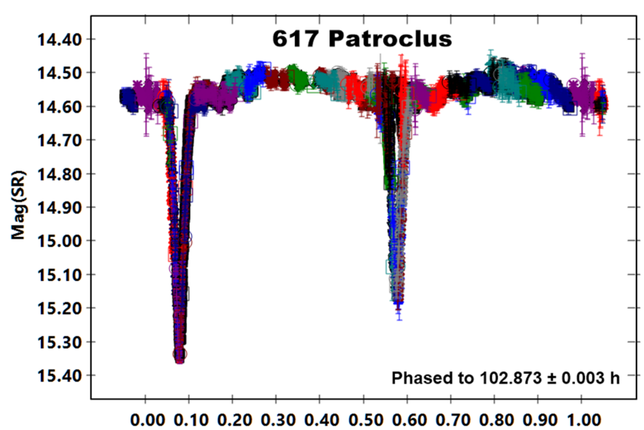
Lead	Observatory	Tel	MPC	Dates (mm/dd)
Gebauer	McCarthy	0.43	932	2024 10/10-11 2024 12/22 2025 01/09
Nastasi	Galhassin Robotic Telescope	0.40	L34	2024 10/10 2024 10/24
Sioulas	NOAK	0.25	L02	2024 10/23
Warner	CS3-U82	0.25	U82	2024 10/24-26 2024 11/08 2024 11/11-12 2025 11/08 2025 01/11

Table I. List of observers and dates of contributed data. The "Tel" column gives the telescope aperture, in meters.

Orbital Period Analysis

The phased plot is fit to the adopted period of 102.873 ± 0.003 h. The period is the same as in WEA, but the formal precision is half that of the previous result. As noted in WEA, this is the formal error reported by the FALC algorithm. A better estimate is the error in the period that would shift the data from the initial match by 0.01 to 0.10 phase (the latter being the so-called *2% rule*). Using 0.02 phase for the gauge, a more reasonable error is 0.04 h. Brozovic et al. (2024) reported 102.876 ± 0.005 h, so our result agrees with the margin of errors.

Given the shape of the lightcurve and depth of minimums along with the known nature of the asteroid, no attempt was made to search for shorter or longer alias periods.



Year: 2024-2025							
1 - 09/13	2 - 09/14	3 - 09/15	4 - 09/12	5 - 09/16	7 - 09/17	8 - 09/15	10 - 09/19
11 - 09/20	13 - 09/20	14 - 09/22	15 - 09/23	16 - 09/24	17 - 09/25	18 - 09/24	19 - 09/26
20 - 09/27	21 - 09/26	22 - 09/24	23 - 09/28	24 - 09/29	25 - 09/30	26 - 09/30	27 - 09/30
28 - 10/01	29 - 10/02	30 - 10/03	31 - 10/04	32 - 10/05	33 - 10/06	34 - 10/07	35 - 10/08
36 - 10/09	37 - 10/10	38 - 10/11	39 - 10/12	40 - 10/13	41 - 10/15	43 - 10/19	44 - 10/18
45 - 10/20	46 - 10/09	47 - 10/15	48 - 10/21	49 - 10/22	50 - 10/23	51 - 10/10	52 - 10/24
53 - 10/23	54 - 10/23	55 - 10/23	56 - 10/25	57 - 10/26	58 - 11/08	59 - 11/11	60 - 11/12
61 - 11/23	62 - 12/22	63 - 10/11	64 - 01/09	65 - 01/09	66 - 01/11	67 - 01/11	

JDo(LTC): 2460578.461589 Period: 102.873 ± 0.003 h

Table II. The legend, JD zero-point, and derived period for the phased plot. The raw plots are based on a subset of the full data set and have their own legends, JD zero-point. Session numbers are mostly, but not always, in date order. A symbol size/color combination can appear more than once due to the limited number of solid colors and symbol shapes.

To save space and repetition, the legend, zero-point JD, and period are included in the common plot above, which applies to ***all*** *but the two plots where the period was found when excluding events.*

Additional Observations: Updated/New/Out of Events

The superior event occurs when the secondary, Menoetius, *goes behind the primary*, Patroclus. The inferior event occurs when Menoetius *passes in front* of Patroclus. The depth of about 0.60 mag for the inferior event (the same as is in WEA) leads to an estimated effective diameter ratio between Menoetius and Patroclus of at least 0.86 ± 0.03. This is close to the 0.92 based on the published effective diameters of the two bodies (LCDB; Warner et al., 2009).

The X-axis of the plots use light-time corrected JD, which is required for proper period analysis. The program reports the UTC and LTC UTC when clicking on a point in the plot.

The Individual Events

For each event, the date and type are given. Use Table II to interpret the event types. An event in bold text is the one that causes the greatest magnitude drop. Since the full individual events were not observed in their entirety, only some of the mutual circumstances of an event were covered.

Superior Events

PO	Partial Occultation
PE	Partial Eclipse
PO+PE	Partial Occultation and Partial Eclipse with overlap
PO_PE	Partial Occultation and Partial Eclipse without overlap
TO	Total Occultation
TE	Total Eclipse

Inferior Events

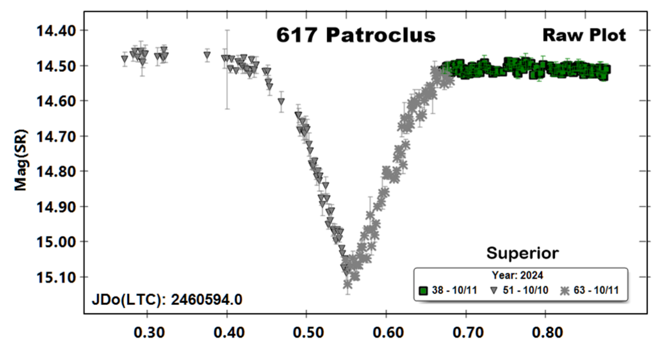
PO	Partial Occultation
PE	Partial Eclipse
PO+PE	Partial Occultation and Partial Eclipse with overlap
PO_PE	Partial Occultation and Partial Eclipse without overlap
AO	Annular Occultation
AO+PE	Annular Occultation and Partial Eclipse with overlap
AE	Annular Eclipse

Table III. List of abbreviations for superior and inferior mutual events as defined by Brozovic et al. (2024).

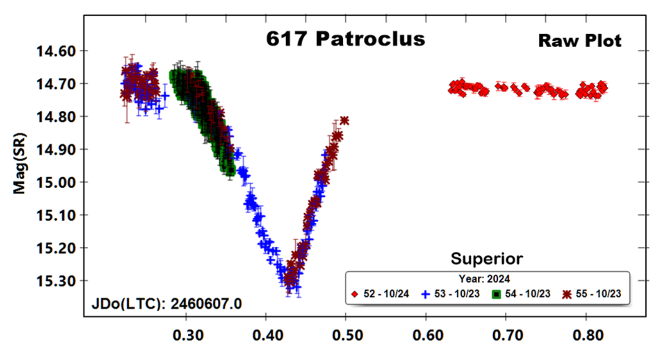
2024 October 10-11 (Superior - **PE** PO+PE, TO, PO+PE, PO). The start and apparent minimum of this event were observed by Nastasi (L34). Because of occasional periods of diminished transparency, the estimate for the start time is more uncertain than in other cases.

Gebauer and Cloutier provided additional data after WEA publication that completed the ascending branch of the lightcurve, allowing us to find a better estimate for the minimum and event end.

For the start of the event, our best estimate is on Oct 10 at 22:50 UT (0.431 d on the plot). Brozovic at al. predicted 23:08 UT (0.442 d). Our estimate for the time of minimum is Oct 11 at 01:56 UT (0.554 d on the plot). Brozovic et al. (2024) predicted 01:45 UT (0.552 d). The predicted time of event end was Oct 11 at 04:18 UT. We estimate the time to be 04:35 UT.

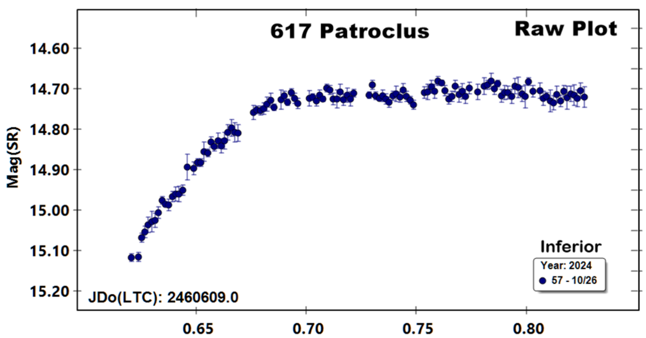


2024 October 23-24 (Superior - **PE,** PO+PE, PO). Overlapping observations were made Nastasi and Sioulas. Observations by Warner were post-event, as shown on the right side of the plot.



Since the minimum was well-covered, it was possible to find a reasonably accurate time of minimum: 2024 Oct 10 at 22:39 UT. The prediction by Brozovic et al. (2024) was 22:37 UT on the same date. As noted in WEA, estimating the exact time of the start or end time for an event was not possible but, instead, only a best guess "fuzzy" estimate. Our estimate is 2024 Oct 23 at 19:21 UT.

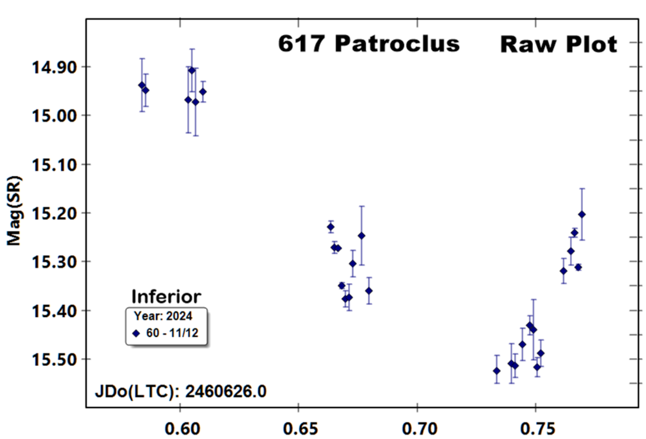
2024 October 25-26 (Inferior - **PE,** PO+PE, PO). Observations were made by Warner. The data covered the end of the event, but missed the start. The question of whether or not the minimum was caught left room for doubt.



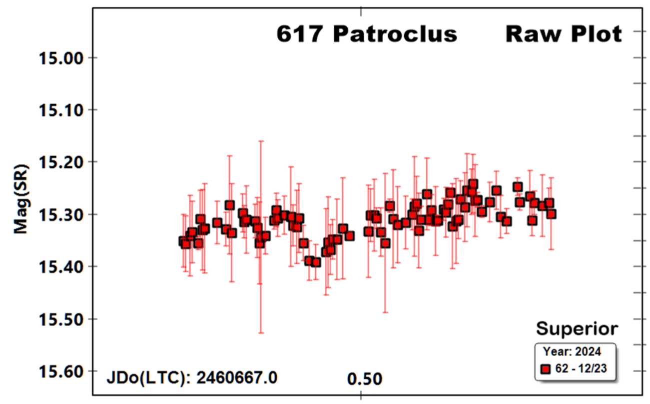
We took the liberty of using the magnitude drop of 0.4 mag to be 0.67 times the estimated full drop of 0.6 mag based on our analysis (see Table III). From the plot and Brozovic et al. (2024) times, the event was estimated to be about 300 minutes long and so the time from minimum to event end, assuming a symmetrical event, would be 150 minutes. Assuming that the rise from minimum to our first data point would take about 50 minutes, then we estimate the time of minimum to be 2024 Oct 26 at 02:34 UT. Brozovic et al. (2024) predicted a time of 02:18 UT.

2024 November 12 (Inferior - **PE,** PO_PE, PO). Observations were made by Warner. The data appear to begin near event start and only partially cover the minimum. Using the method by Hertzsprung (1928) as described by Henden and Kaitchuck (1990) and explained in WEA, we tried to extrapolate a time of minimum, which depended on which data point at the left-side of the plot we chose to be the start of the event; we used the first.

This eventually led to 2024 November 12 at 06:00 UT, ± 15 minutes. The mid-time is only one minute away from Brozovic et al. (2024).

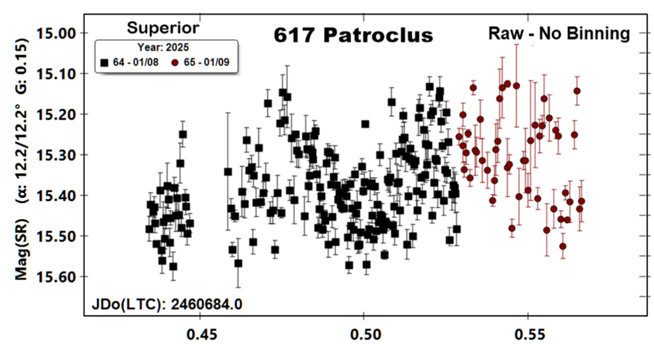


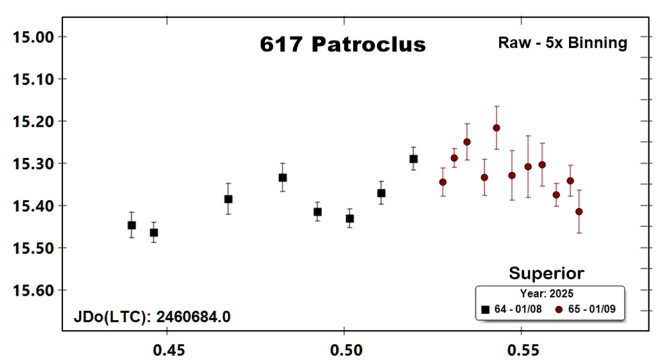
2024 December 22-23 (Superior - **PO**). Observations were made by Gebauer and Cloutier. It may not seem that any part of the event was captured. However, a close inspection of the phased plot shows that the lightcurve falls very briefly at the end of an event before slowing rising to a maximum half-way between the superior and inferior events.



The data seem to do something like that, and so we took the data point just before the small dip in the lightcurve to be the approximate end of the event (End 1), which was 2024 December 23 at 00:15 UT. On the other hand, the estimated time of minimum in that small dip (End 2) is 00:23 UT, or 2 minutes ahead of Brozovic et al.

2025 January 8-9 (Superior - **PO**). Observations were by Gebauer and Cloutier. Unfortunately, their observing run was hampered by the altitude approaching the preferred minimum of 30° and deteriorating conditions. Session 64 is based on the first two of three splits, the majority of the exposures being 30 seconds, with SNR ~ 40. By the time of the last of the three splits, SNR ~ 25.





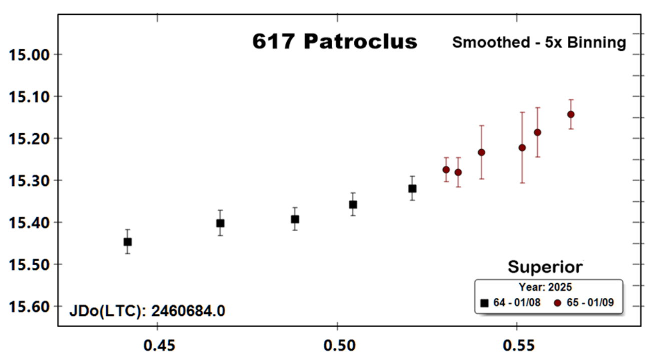
Parameters	This Paper	Brozovic et al.	Difference
Rotational Period with Events (h)	102.873 ± 0.006	102.876 ± 0.005	0.003 h
Minimum Depth (Superior, mag)	0.79 ± 0.03	0.76	0.03 mag
Maximum Depth (Inferior, mag)	0.60 ± 0.03	0.61	0.01 mag
Effective Diameter Ratio (Menoetius/Patroclus)	0.86 ± 0.03	0.92	0.06 ± 0.06

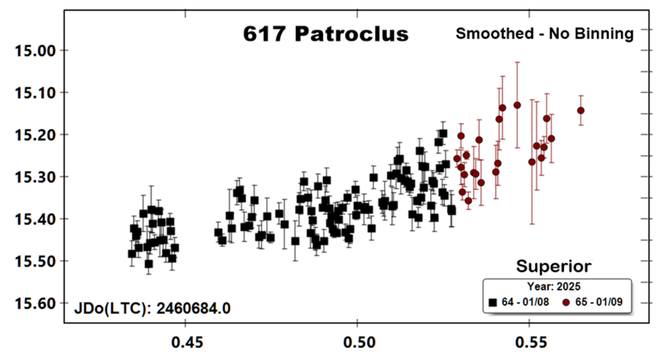
Observed Events	This Paper UT	Brozovic et al. UT	UT-Brozovic minutes
Oct 10 – Superior (start)	22:50	23:08	-18
(minimum – Oct 11)	01:56	01:45	+11
(end – Oct 11)	04:35	04:18	+17
Oct 23-24 – Superior (start)	19:21	19:22	-1
(minimum)	22:39	22:37	+2
Oct 25-26 – Inferior (minimum – see text)	02:34	02:18	+16
(end)	04:57	04:55	+2
Nov 12 – Inferior (minimum – see text)	05:45-06:15	05:59	+1
Dec 22-23 – Superior (end 1 – see text)	00:15	00:21	-6
(end 2 – see text)	00:23	00:21	+1
Jan 8-9 – Superior (minimum)	00:34	00:59	-25

Table IV. A listing of the observed events, giving the estimated UT from this paper, the UT predicted by Brozovic et al. (2024), and the difference between our estimate and Brozovic et al. (2024). The results for 2024 October 10-11 are based additional observations from Gebauer and Cloutier.

The "Raw - No Binning" plot shows the raw data as measured. From this, it's hard to say if the data were steadily increasing or covered a minimum with the initial data being "bad." The data were smoothed by binning them 5×10, meaning five successive data points, each no more than 10 minutes after the previous one, were averaged and used as a single data point. If two successive data points were more than 10 minutes apart, a new bin was started.

The result is shown in the "Raw - 5× Binning" plot, which, started to show a trend that steadily grew brighter. Going back to the unbinned raw plot, data points were excluded that, subjectively, strayed too far from the trend. The result is shown in the "Smoothed - 5× Binning" plot. When satisfied, the plot was reset to with no binning, as shown in "Smoothed - No Binning."

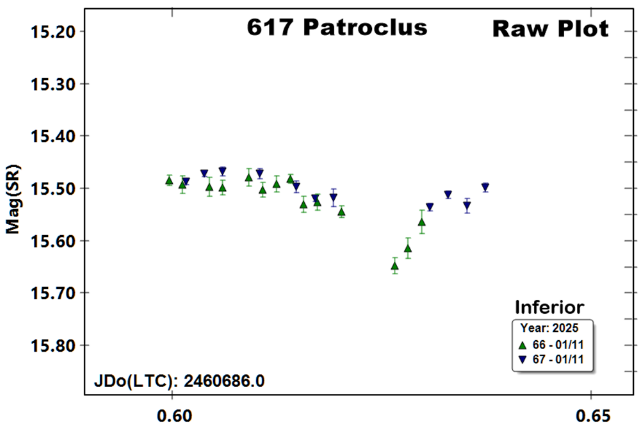




On the broad assumption that we were working with valid filtered data set, we hoped to use the Hertzsprung method to find a minimum. However, that method requires a minimum of three data points on either side of the proposed minimum. This condition could not be met. Therefore, we estimated the time of the minimum based on the earliest data point that seemed close to the trend line. This gave 2025 January 8 at 23:06 UT. Brozovic et al. (2024) predicted the minimum to occur on 2025 January 9 at 00:59 UT. The difference is almost two hours, or about 0.083 day.

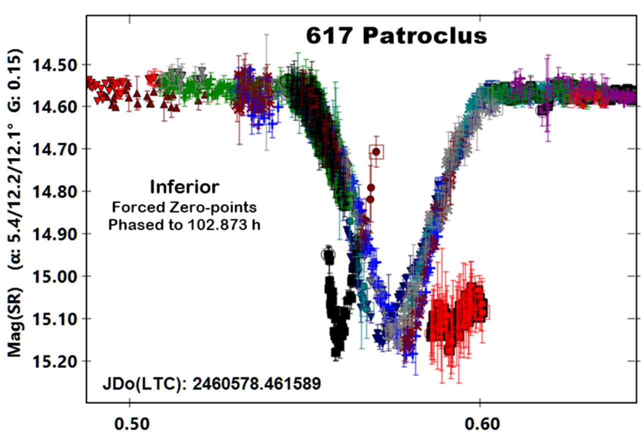
However, that time is almost the same as the predicted start of the event (2025 January 8 at 23:30). The data should be decreasing in brightness, but they are going in the opposition direction! There's yet one more, very intriguing problem. That is detailed in the "Square Pegs into a Round Hole" section below.

2025 January 11 (Inferior - **PO**). By the time Warner made these observations, Patroclus was above the 30° minimum altitude for only about two hours. These would be the last observations of the campaign.



The time of the apparent minimum (2025 January 11 at 03:41 UT) is almost an hour before the 04:34 predicted by Brozovic et al. The data likely represent some sort of local minimum. On the other hand, if presuming that the data show the start of the event, an estimate of the start time is about 2025 January 11 at 03:18 UT. Brozovic et al. (2024) predicted 03:11 UT.

Square Pegs into a Round Hole



A magnified section of the phased plot, forced to a period of 102.873 h, shows the data from 2024 December 23 and 2025 January 9, both obtained by Gebauer and Cloutier. Several things stand out. We'll save the most interesting one for last.

Assuming that the location in the phased plot for these two data sets is correct, both required a nearly +0.5 mag zero-point adjustment to get an approximate match to the other inferior event minimums. Setting the zero-point offsets to 0.0 raised the January 9 data such that it was 0.1 mag brighter than any other part of the curve. Gebauer and Cloutier used an SR filter, which might have explained the issue, but the measurements were made using the ATLAS refcat2 (Tonry et al., 2018) r´ magnitudes, as were all others - Clear and SR filters alike. Such an offset should not be required since all the other sessions required no more than ±0.05 mag zero-point adjustment.

No amount of orbital period refinement and/or zero-point offsets could get either of those two sessions to match the rest of the data at the inferior event. Even if the two sessions are not included, there was no single-period solution that allowed all the inferior events to overlap perfectly. The data for all the observed superior events, fit tightly about the same minimum.

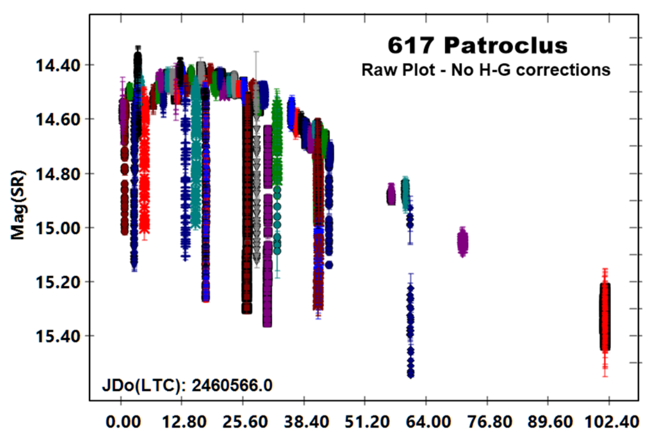
Now comes the most confusing result. The January 8-9 data are for a *superior* event. This means that they should be on the phased plot at about 0.08. Instead, they are near the inferior event phase near 0.60. Again, no combination of reasonable period changes or zero-point adjustments could resolve the issue. What's just as confounding is that the UT times of the data points are close to what they should be for the superior event, *not* inferior.

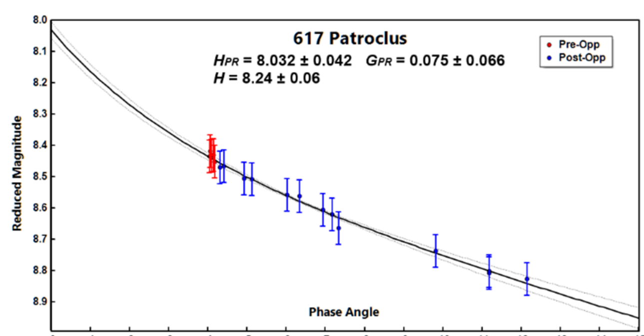
Any explanation of these issues, assuming valid data, is beyond the scope of this paper.

H-G Parameters

The complete data set covered phase angles from 4°, the minimum over the range of dates, to 12°. This allowed trying to find the absolute magnitude (*H*) and phase slope parameter (G) for the asteroid.

The "No H-G Corrections" plot shows the raw data set without correcting for changing Earth-Sun distances and phase angle. In other words, these are the raw "sky" (catalog) magnitudes plotted against Julian Date. The curve shows the expected behavior as the asteroid went from peak brightness near or at minimum phase angle (presumably also the closest Earth and Sun distances) and descended down and to right as the distances and phase angle increased.





The standard method to find H is to use the mean value of the amplitude of the lightcurve *at the time of the observation*. In cases where the period exceeds the maximum length of any observing run, there are several methods to interpolate that value based on the partial and full, phased lightcurve. In this case, Warner just “eyeballed” values after zooming tight on the curve and following the curve along the way. This is crude, but it was successful - *this time*.

The H-G plot shows the derived reduced magnitudes, i.e., the raw sky magnitudes assuming Earth and Sun distances of 1 au, and the phase angle. It shows a tight fit to the line that extrapolates to H_{PR} = 8.032 ± 0.042 using G_{PR} = 0.075 ± 0.066. The low albedo is consistent with darker asteroids, e.g., taxonomic type C, which - along with P - is the dominant type among the Jupiter Trojans.

By definition, *H* is a V magnitude. To get this required using some conversion formulae that started with V-R = 0.42 (Chatelain et al., 2016) and B-V = 1.12 (Chatelain, 2017) and used these in formulae from Kostov and Bonev (2018), who converted *griz* magnitudes to BVRI based on formulae from Stetson (2000). The net result was a correction of +0.21 mag, which gives *H* = 8.24 ± 0.06. The MPC uses *H* = 8.25, *G* = 0.15. Note that the difference between H_{PR} and *H* is dependent on the color index of an object and so is not a constant.

Remarks

All the data used in the analysis will be uploaded to the Asteroid Lightcurve Data Exchange Format (ALCDEF) web site at *https://alcdef.org* after publication of the follow-up paper.

Acknowledgements

This research has made use of the Astrophysics Data System, funded by NASA under Cooperative Agreement 80NSSC21M00561. This work has made use of 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. We thank *Minor Planet Bulletin* editor, Richard Binzel, and producer, Pedro A. Valdés Sada, for extending the usual submission deadline for this issue so that we could observe and report on as many events as possible. Warner and Stephens thank the Planetary Society for 2007 and 2013 Shoemaker NEO grants which helped purchase some of the equipment used in this effort. In addition, Warner thanks Robert D. (“Bob”) Stephens, his long-time observing cohort and occasional on-site maintenance engineer, for his help throughout the years. Tedesco thanks the Wilson Picler Foundation for their support. Durkee thanks the Planetary Society for the Shoemaker NEO grant in 2019 which funded the camera used in these observations.

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LIGHTCURVE PHOTOMETRY OPPORTUNITIES: 2025 APRIL-JULY

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We present lists of asteroid photometry opportunities for 2025 April-July. The extended four-month listing continues the changes announced in MPB 51-4 (Warner et al., 2024). Extending to the month beyond the usual quarter-year allows better observation planning, especially for those working in wide-spread collaborations. With the massive input of survey photometry, even if mostly sparse data, the small telescope researcher's role is moving away generic studies to those concentrating on specific needs and targets and so, we hope, leading to even more fulfilling and fruitful efforts.

We refer the reader to the lightcurve photometry opportunities article in *Minor Planet Bulletin* 51-4 (Warner et al., 2024) for a detailed discussion on the evolution of the lists presented here and the purpose behind each one. In addition, we refer the reader to other prior releases of this paper (e.g., Warner et al., 2023) for more detailed discussions about the requirements and considerations for the targets in the lists and to Warner et al. (2021a; 2021b).

On-Line Planning Tool

The ephemeris generator on the *https://MinorPlanet.info* web site allows creating custom lists for numbered objects reaching V ≤ 18.0 during a given month from 2020 through 2035 by setting search parameters based on a number of parameters.

https://www.minorplanet.info/php/callopplcdbquery.php

The updated page added data for the minimum phase angle of any object included in the search: the date (0.001 d), the minimum phase angle (0.1°), and the declination. Searches can limit results to a phase angle range between 0-120°. Also new is limiting the results to a range of rotation periods and so, for example, one can look for only long, or especially short, period objects.

Important and Useful Web Sites

The dates and values given on the MinorPlanet.info site are very good estimates in most cases. NEAs are sometimes an important exception. Use the site for preliminary planning for objects and then confirm those plans using the Minor Planet Center or JPL Horizons web sites.

MPC: *http://www.minorplanetcenter.net/iau/MPEph/MPEph.html*
JPL: *https://ssd.jpl.nasa.gov/sb/orbits.html*

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.

https://astro.troja.mff.cuni.cz/projects/damit/

to see what, if any, information it has on a chosen target.

For near-Earth asteroids in particular, check the list found on the Goldstone planned targets schedule at

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

and keep in touch with Lance Benner at the email above. The radar team often needs updated astrometry and photometry (rotation period) prior to observing. Keep in mind as well that the *MinorPlanet.info* site opposition database includes only numbered objects. Keep a close eye on the MPC NEA pages.

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

The database contains about 10.69 million observations for 24,454 objects (as of 2024 May 27), making it one of the more useful sources for raw data of *dense* time-series asteroid photometry.

The Planning Lists

The lists, excluding the one for NEAs, are usually restricted to objects reaching V ≤ 15.5 during the covered months. To include every object within a list that met this criterium alone resulted in far too many targets than the known community of asteroid photometrists could possibly handle, so only the "better" candidates are included. This is entirely subjective and the reader is encouraged to visit the *https://MinorPlanet.info* web site and use all the planning tools available there should our preferences not match yours.

Don't presume that something rated U ≥ 3– doesn't need more work nor, at the other end, that something not rated at all or 1– < U < 2+ or has a long period should be skipped in lieu of an "easier" project. The often-heard saying, "Past performance is not a guarantee of future results" should be part of your work ethic. Someone's "certain" result may not be so certain after all, especially if it's based on data that are minimal in quantity and/or quality.

Favorable Apparitions includes objects reaching one of the five brighter (favorable) apparitions from 1995 and 2050 and rated U < 3- in the LCDB.

No Pole Solutions includes objects rated U > 2+ but do not have a pole indicated on the LCDB summary line. This is list is the most likely needing further confirmation by checking the DAMIT web site, which grows in spurts large and small quite frequently and so the LCDB can lag considerably.

Poor Pole Solutions includes objects rated U < 3– that have a pole solution on the summary line. In this case, the period is often based on using sparse survey data, with or without support of dense lightcurve data. An additional set of dense data may help elevate both the U rating and the quality of the pole solution.

Low Phase Angles includes objects, regardless of U rating or even having a period, that reach a solar phase angle < 1°. You should refer to Warner et al. (2023) to review important information about low solar phase angle work.

Long Periods includes objects with $P \geq \sim 24$ hours. These are often overlooked because they are very difficult for a single-station campaign. However, they are ideal for collaborations, especially those with stations well-separated in longitude.

NEAs (aka Radar Target) is limited to *known* near-Earth asteroids that might be on the radar team's radar (pun intended). It is common for newly discovered objects to move into or out of the list. We recommend that you keep up with the latest discoveries by using the Minor Planet Center observing tools.

The List Data

If the list includes the "Fam" column, this is the orbital group (> 9000) using criteria from the LCDB or the collisional family (< 9000) based on Nesvorny et al. (2015) and Nesvorny (2015). To convert the number to a name, see the LCDB documentation on the LCDB web site or use the One Asteroid Lookup page on the site:

https://www.minorplanet.info/php/lcdb.php
https://minorplanet.info/php/oneasteroidinfo.php

Table Columns

Num	Asteroid number, if any.
Name	Name (or designation) assigned by the MPC.
Fam	Orbital group or collisional family.
BMD	Date of maximum brightness (to 0.1 d precision).
BMg	Approximate V magnitude at brightest.
BDC	Approximate declination at brightest.
PD	Date of minimum phase angle (to 0.001 d precision).
PMn	Phase angle at minimum (solar elongation > 90°).
PDC	Approximate declination at minimum phase angle.
P (h)	Synodic rotation period from summary line in the LCDB summary table. An * indicates a sidereal period.
U	LCDB solution quality (U) from 1 (probably wrong) to 3 (secure).
Notes	Comments about the object.

Some asteroids may appear in more than one list. The reader is referred to the latest LCDB release (Warner et al., 2009) and, where and when necessary, the original reference source should be used. The Notes column is rarely used, for now, except for the NEAs list.

All periods are taken from the summary line of the LCDB. If needed, the LCDB should be checked to find the source of the summary line period.

Favorable Apparitions (U < 3-)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
1287	Lorcia	606	04 02.4	15.0	-7	04 02.576	0.9	-7	8.878	2	
1841	Masaryk	9106	04 04.4	15.0	-5	04 05.675	0.6	-4	7.53	2+	
85953	1999 FK21	9101	04 05.0	14.6	34	03 31.001	30.1	11	28.08	2	
1512	Oulu	9107	04 08.5	14.3	-8	04 06.829	0.3	-8	132.3	2+	
1101	Clematis	2012	04 15.5	14.9	-8	04 13.453	0.3	-8	34.3	2	
1155	Aenna	9104	04 16.1	14.0	-7	04 15.971	1.4	-7	8.07	2+	
992	Swasey	9106	04 17.4	14.0	-12	04 16.987	0.6	-12	13.305	2+	
6372	Walker	604	05 15.5	14.9	-15	05 15.378	1.7	-15	44.25	2	
1905	Ambartsumian	9104	05 16.8	14.1	-16	05 16.674	1.7	-16	92.153	2	
2120	Tyumenia	9106	05 31.5	14.9	-9	05 30.689	4.8	-9	17.507	2	
3507	Vilas	602	06 01.5	14.8	-20	05 31.330	0.6	-20	3.959	2+	
1457	Ankara	9105	06 09.5	13.5	-30	06 09.831	2.9	-30	35.54	2	
2660	Wasserman	502	06 14.0	14.9	-4	06 12.481	8.7	-4	527.991	2	
2324	Janice	602	06 24.4	14.5	-24	06 25.835	0.2	-24	23.2	2-	
7747	Michalowski	9103	06 27.9	14.7	-26	06 27.556	1.6	-26	4.5	2	
896	Sphinx	9104	07 11.3	13.5	-12	07 12.270	5.2	-12	21.038	2+	
2898	Neuvo	9104	07 15.5	14.8	-20	07 15.431	0.7	-20	13.83	2	
4826	Wilhelms	701	07 16.0	14.8	-39	07 14.779	9.8	-39	15.004	2	
1728	Goethe Link	9104	07 22.2	14.2	-10	07 22.169	4.7	-10	81	2	
6422	Akagi	502	07 25.4	14.8	-18	07 25.748	0.9	-18	7.74	2	
2865	Laurel	506	07 30.9	14.3	-24	07 31.204	2.5	-24	21.5	2	

Table I. A partial list of numbered asteroids reaching a favorable apparition and with an LCDB rating U < 3-.

Spin Axis and Modeling (Favorable Apparition, U > 2+, No LCDB pole, not in DAMIT)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
1093	Freda	9106	05 18.5	12.3	-20	05 16.999	0.1	-20	19.670	3	
4185	Phystech	9104	05 24.0	14.9	-22	05 24.169	0.9	-22	4.669	3	
4223	Shikoku	606	06 21.5	14.7	-23	06 20.297	0.1	-24	9.137	3	
5386	Bajaja	9104	06 23.5	14.5	-24	06 23.080	0.2	-24	16.841	3	

Table II. A partial list of numbered asteroids reaching a favorable apparition that have high-quality periods solutions but do not have a pole solution in the LCDB or DAMIT databases.

Spin Axis and Modeling (Any Apparition, U < 3–, Pole in LCDB/DAMIT)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
1287	Lorcia	606	04 02.4	15.0	-7	04 02.576	0.9	-7	8.878	2	
1841	Masaryk	9106	04 04.4	15.0	-5	04 05.675	0.6	-4	7.530	2+	
1365	Henyey	2009	04 06.5	13.9	-14	04 05.840	4.4	-14	18.986	2	
1244	Deira	9104	04 09.9	14.1	-22	04 10.217	7.4	-22	210.600	2	
2115	Irakli	606	04 24.8	15.0	-19	04 24.806	2.2	-19	29.765	2	
818	Kapteynia	9106	05 16.3	14.0	-13	05 16.062	1.9	-13	16.350	2	
1905	Ambartsumian	9104	05 16.8	14.1	-16	05 16.674	1.7	-16	*92.153	2	
5518	Mariobotta	9104	05 18.8	14.8	-4	05 16.998	8.2	-4	108.600	2+	
2091	Sampo	606	05 27.5	15.0	-9	05 27.575	4.0	-9	71.340	2	
2120	Tyumenia	9106	05 31.5	14.9	-9	05 30.689	4.8	-9	17.507	2	
3507	Vilas	602	06 01.5	14.8	-20	05 31.330	0.6	-20	3.959	2+	
1236	Thais	9104	06 01.2	14.9	-30	05 30.808	3.4	-30	*47.989	2	
1457	Ankara	9105	06 09.5	13.5	-30	06 09.831	2.9	-30	35.540	2	
1326	Losaka	9105	06 12.8	14.9	-14	06 11.669	3.3	-14	6.900	2	
7747	Michalowski	9103	06 27.9	14.7	-26	06 27.556	1.6	-26	4.500	2	
3702	Trubetskaya	9105	07 05.0	14.9	-15	07 03.609	3.5	-14	*8.291	2	
896	Sphinx	9104	07 11.3	13.5	-12	07 12.270	5.2	-12	21.038	2+	
4826	Wilhelms	701	07 16.0	14.8	-39	07 14.779	9.8	-39	15.004	2	
1728	Goethe Link	9104	07 22.2	14.2	-10	07 22.169	4.7	-10	81.000	2	
6422	Akagi	502	07 25.4	14.8	-18	07 25.748	0.9	-18	7.740	2	
2865	Laurel	506	07 30.9	14.3	-24	07 31.204	2.5	-24	21.500	2	

Table III. A partial list of numbered asteroids reaching brightest magnitude that have a reported pole position but the LCDB rating is U < 3-. A period with an asterisk is sidereal.

Low Phase Angle (V ≤ 15.0, phase angle $\alpha \leq 1.0°$)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
175	Andromache	9106	04 03.5	13.7	-3	03 31.940	0.2	-4	8.324	3	
1512	Oulu	9107	04 08.5	14.3	-8	04 06.829	0.3	-8	132.3	2+	
1101	Clematis	2012	04 15.5	14.9	-8	04 13.453	0.3	-8	34.3	2	
510	Mabella	9105	04 16.5	12.6	-9	04 15.233	0.3	-9	19.4	3	
2052	Tamriko	606	04 18.5	14.9	-12	04 19.714	0.3	-12	7.469	3	
1675	Simonida	402	04 23.4	14.6	-14	04 24.056	0.3	-14	5.289	3	
468	Lina	602	04 26.5	14.6	-13	04 24.059	0.1	-13	16.33	3	
1060	Magnolia	402	04 28.5	14.5	-15	04 28.055	0.3	-15	2.911	3	
419	Aurelia	9104	05 09.5	10.2	-17	05 08.532	0.2	-17	16.784	3	
1093	Freda	9106	05 18.5	12.3	-20	05 16.999	0.1	-20	19.67	3	
2957	Tatsuo	606	05 28.5	14.7	-22	05 27.179	0.3	-22	6.819	3	
1716	Peter	9106	05 27.4	15	-21	05 28.711	0.3	-21	11.514	3	
690	Wratislavia	9106	06 04.5	12.5	-22	06 02.179	0.2	-23	8.64	3	
552	Sigelinde	9106	06 14.2	13.3	-24	06 14.897	0.2	-24	17.156	3	
4223	Shikoku	606	06 21.5	14.7	-23	06 20.297	0.1	-24	9.137	3	
5386	Bajaja	9104	06 23.5	14.5	-24	06 23.080	0.2	-24	16.841	3	
2324	Janice	602	06 24.4	14.5	-24	06 25.835	0.2	-24	23.2	2-	
551	Ortrud	9106	07 06.5	14.1	-23	07 04.323	0.2	-23	17.416	3	
295	Theresia	9106	07 08.5	14.1	-22	07 06.639	0.2	-22	10.702	3	
891	Gunhild	9106	07 11.5	13.6	-23	07 10.298	0.3	-23	11.892	3-	
1853	McElroy	9106	07 23.5	14.9	-20	07 21.728	0.1	-20	8.016	3-	
522	Helga	9106	07 28.5	13.7	-20	07 26.068	0.2	-20	8.129	3	
3478	Fanale	9104	07 27.5	14.9	-19	07 27.092	0.2	-19	3.245	3	
390	Alma	9105	07 26.5	14.1	-19	07 28.418	0.2	-19	3.741	3	

Table IV. A partial list of numbered asteroids reaching a minimum phase angle $\alpha \leq 1.0°$.

Long Period (Favorable Apparition, *P* ≥ 24 h, U < 3)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
85953	1999 FK21	9101	04 05.0	14.6	34	03 31.001	30.1	11	28.08	2	
1512	Oulu	9107	04 08.5	14.3	-8	04 06.829	0.3	-8	132.30	2+	
1101	Clematis	2012	04 15.5	14.9	-8	04 13.453	0.3	-8	34.30	2	
6372	Walker	604	05 15.5	14.9	-15	05 15.378	1.7	-15	44.25	2	
1905	Ambartsumian	9104	05 16.8	14.1	-16	05 16.674	1.7	-16	*92.153	2	
1457	Ankara	9105	06 09.5	13.5	-30	06 09.831	2.9	-30	35.54	2	
2660	Wasserman	502	06 14.0	14.9	-4	06 12.481	8.7	-4	527.99	2	
1728	Goethe Link	9104	07 22.2	14.2	-10	07 22.169	4.7	-10	81.00	2	

Table V. A partial list of numbered asteroids reaching a favorable apparition and with a reported period *P* ≥ 24 hours. A period with an asterisk is sidereal.

NEAs (aka Radar) Reaching Brightest for Year (Any Apparition, V ≤ 17.0, α ≤ 90°)

Num	Name	Fam	BMD	BMg	BDC	PD	PMn	PDC	P (h)	U	Notes
85953	1999 FK21	9101	04 05.0	14.6	34	03 31.001	30.1	11	28.08	2	
152754	1999 GS6	9101	04 09.6	16.9	-32	04 24.276	8.3	-22	8.021	2	
223456	2003 UB10	9101	04 10.2	16.8	8	08 11.472	2.1	-18			
462959	2011 DU	9101	04 21.2	16.0	35	12 29.403	5.4	15	10.290	3	PHA
436030	2009 JO2	9101	04 25.8	16.7	67	06 04.873	50.0	29			
9058	1992 JB	9101	04 26.3	14.7	-15	05 05.449	30.5	1			
433992	2000 HD74	9101	05 15.8	17.0	-44	05 12.689	21.5	-35	9.360	2	
390725	2003 HB	9101	05 20.1	16.7	61	04 14.120	55.9	19			PHA
4957	Brucemurray	9101	05 24.5	16.7	-44	05 15.842	20.9	-50	2.892	3	
163696	2003 EB50	9101	05 27.4	14.2	-20	05 26.664	1.8	-20	62.060	3-	Last radar: 2015
424482	2008 DG5	9101	06 01.9	13.8	13	11 19.765	2.1	22			PHA
85839	1998 YO4	9101	06 03.5	16.0	-53	07 01.968	25.0	-57	2.450	1	
4953	1990 MU	9101	06 09.1	15.1	-37	07 05.480	18.4	-52	14.218	3	Next radar: 2027
65733	1993 PC	9101	06 14.5	16.7	-44	06 29.433	13.2	-40	4.185	3	
138205	2000 EZ148	9101	06 17.1	14.3	-86	10 28.843	10.3	28			
7889	1994 LX	9101	06 25.3	16.8	13	06 28.840	21.1	10	2.741	3	
263976	2009 KD5	9101	06 30.2	15.9	-4	06 18.948	24.0	4	2.664	2+	
348400	2005 JF21	9101	07 13.5	16.5	9	12 07.061	14.2	-1	2.415	3	
437844	1999 MN	9101	07 02.4	16.4	-32	07 01.890	8.6	-32	5.495	3	Next radar: 2030
442609	2012 KU42	9101	07 29.1	16.7	5	12 20.839	23.4	-14			

Table VI. A list of near-Earth asteroids known as of 2024 Oct 10. Green bar lines are on the Goldstone list of planned targets. PHA: Potentially Hazardous Asteroid. NHATS: Near-Earth Object Human Space Flight Accessible Targets Study. BA: Binary asteroid. This is not necessarily a complete list of Goldstone targets. Check their web site.

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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 (52-3) is April 15, 2025. The deadline for issue 52-4 is July 15, 2025.

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